CHAMBRE DES DEPUTES

Session ordinaire 2012-2013

AT/vg

Commission de l'Enseignement supérieur, de la Recherche, des Media, des Communications et de l'Espace

Procès-verbal de la réunion du 05 novembre 2012

ORDRE DU JOUR :

1. Adoption des projets de procès-verbal des réunions des 15 et 18 octobre 2012
2. Présentation du rapport d'Euroconsult
3. Divers

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Présents : M. Claude Adam, M. Eugène Berger, Mme Claudia Dall'Agnol, Mme Christine Doerner, M. Ben Fayot, M. Norbert Haupert, M. Fernand Kartheiser remplaçant M. Jean Colombera, M. Marcel Oberweis, M. Gilles Roth remplaçant Mme Diane Adehm, M. Serge Wilmes

M. François Biltgen, Ministre de l'Enseignement supérieur et de la Recherche, Ministre des Communications et des Médias

M. Pierre Decker, M. Claude Lagoda, M. Marc Serres, Mme Asmira Skrijelj, du Ministère de l'Enseignement supérieur et de la Recherche

M. Pacôme Revillon, Mme Rachel Villain, d'Euroconsult
M. Per Tegner, Expert

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Présidence : M. Marcel Oberweis, Président de la Commission

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1. Adoption des projets de procès-verbal des réunions des 15 et 18 octobre 2012

Les projets de procès-verbal sous rubrique sont adoptés.

2. Présentation du rapport d'Euroconsult

a) Introduction par M. le Ministre

M. le Ministre a jugé opportun de réaliser une première évaluation de la politique menée en matière de sciences et technologies spatiales. Les objectifs de cette étude sont de tirer le bilan des activités effectuées depuis 2005, donc depuis l'adhésion du Luxembourg à l'Agence spatiale européenne (ESA), de déterminer les forces et faiblesses du système luxembourgeois, de mesurer les premiers impacts du plan d'action national en cette matière et d'identifier les opportunités d'avenir pour le Luxembourg. Cette étude débouche sur une série de recommandations permettant un positionnement optimal pour les prochaines 5 à 10 années. A noter que le Gouvernement devra encore se prononcer sur le suivi à accorder à ces recommandations d'Euroconsult.

M. le Ministre souligne que le Luxembourg assurera à partir du 22 novembre 2012 la coprésidence de l'ESA conjointement avec la Suisse pour une durée de trois ans. Rappelons dans ce contexte qu'une réunion de la commission parlementaire est prévue pour le 29 novembre 2012 à 14h30 où M. le Ministre présentera les dernières évolutions dans le dossier ESA et notamment l'avancement des travaux dans le domaine du nouveau plan d'action spatial du Gouvernement.

b) Présentation de l'étude par les représentants d'Euroconsult

L'expert gouvernemental explique que l'étude a été menée par la société Euroconsult, spécialisée pour l'analyse et le conseil dans le domaine spatial. Un groupe d'experts indépendants a été chargé d'encadrer cette étude dont M. Per Tegner, ancien directeur de l'agence spatiale suédoise et président du Conseil de l'ESA à deux reprises, qui en est le porte-parole.

Pour les détails de l'étude il est renvoyé à la présentation Powerpoint et au rapport « Preparing Lunxembourg's future in Space » repris en annexe du présent procès-verbal. De la présentation des experts d'Euroconsult il y a lieu de retenir succinctement les éléments suivants :

Dans le cadre de l'étude, Euroconsult a consulté 3 catégories d'acteurs, à savoir les acteurs de l'industrie spatiale, les Centres de recherche publics et plusieurs départements de l'Université du Luxembourg ainsi que différents ministères concernés par la politique spatiale.

Plan d'action national en matière de sciences et technologies spatiales

C'est en 1985 que le Luxembourg a initié ses activités sans le secteur spatial par la création de la SES. En 2000, le Luxembourg signe un accord de coopération avec l'ESA est devient officiellement membre de l'ESA en 2005. Le Gouvernement s'est doté depuis 2005 d'un plan d'action national en matière de sciences et technologies spatiales lequel a été révisé en 2008. Ce plan d'action national fixe 4 objectifs :

1. Contribuer à la diversification et à la pérennisation des activités économiques au Luxembourg ;

2. Consolider et valoriser les compétences existantes dans le domaine des médias et des télécommunications ;
3. Contribuer à renforcer la position compétitive des entreprises et des organisations de recherche publique dans le secteur spatial ;
4. Développer les compétences dans le secteur et amplifier l'intégration des acteurs luxembourgeois dans les réseaux internationaux.

Ces objectifs sont mis en œuvre par le biais des 3 piliers suivants :
- la participation du Luxembourg aux programmes ESA ;
- des activités nationales qui sont mises en œuvre à partir de deux instruments nationaux à savoir LuxLAUNCH géré au niveau national et le « 3rd party programme » géré par l'ESA ;
- la coopération internationale.

Le secteur spatial au Luxembourg

Le Luxembourg consacre 0,03% de son PIB aux investissements dans la politique spatiale, ce qui le classe en quatrième position au niveau européen, derrière la France, l'Allemagne et l'Italie.

Euroconsult recommande au Luxembourg de dégager un consensus national au sujet de sa politique spatiale nationale et de se doter d'une gouvernance adéquate afin de définir et de mettre en œuvre une nouvelle phase de ses activités spatiales.

L'industrie spatiale est représentée au Luxembourg aujourd'hui par une vingtaine d'entreprises et sept départements de recherche et emploie plus de 500 personnes (75% de ces emplois sont chez la SES). Les revenus générés par ce secteur en 2011 s'élèvent à 1,8 milliard d'euros dont 96% proviennent de la SES.

Alors que la moyenne européenne des retombées économiques du secteur spatial s'élève à 0,1% du PIB, ce taux est de 4% au Luxembourg. Ce taux élevé s'explique notamment par le poids économique de la SES.

Euroconsult constate que des capacités se sont développées dans plusieurs domaines au Luxembourg : en ce qui concerne les systèmes satellitaires il y a lieu de relever les microsatellites, les récepteurs AIS (Automatic ship Identification System) et la petite plateforme géostationnaire SGEO. Il y a également des systèmes et des services au sol notamment des antennes en bande Ka. En troisième lieu, citons des services satellitaires en matière de communications à large bande ou des applications d'observation de la terre. Euroconsult souligne qu'il n'y a pas d'activités au Luxembourg dans deux domaines qui ont cependant un potentiel commercial considérable : la propulsion électrique des satellites et la *Next generation platform*.

Ainsi, en termes de priorités thématiques pour le futur, Euroconsult propose au Gouvernement d'inclure dans ses axes de développement les microsatellites, les équipements de satellites, les équipements au sol et les services à valeur ajoutée utilisant des données satellitaires, incluant deux nouveaux domaines technologiques, la propulsion électrique et le développement de charges utiles.

Euroconsult conclut que le plan d'action national en matière de sciences et technologies spatiales a obtenu de bons résultats si l'on considère cette courte période depuis l'adhésion à l'ESA et l'inexistence d'activités spatiales préalables en dehors de celles de la SES il y a dix ans. Les activités spatiales nationales se sont prioritairement développées dans le

domaine des médias et télécommunications. La présence de la SES est évidemment un facteur important pour ce développement. L'impact économique est jugé positif puisque plus de 120 nouveaux emplois ont été créés sur les 7 dernières années.

Euroconsult recommande fortement que le Luxembourg se dote d'une nouvelle gouvernance renforcée en matière de politique spatiale. Voilà pourquoi Euroconsult propose de transformer le groupe de travail existant en un comité permanent de l'espace qui assumerait un rôle consultatif pour le Gouvernement. Ce comité se composerait à la fois de représentants gouvernementaux, de représentants des départements de recherche publique ainsi que d'acteurs de l'industrie spatiale et serait présidé par le Ministère ayant dans ses attributions la politique spatiale, en l'occurrence le Ministère de l'Enseignement supérieur et de la Recherche. En second lieu, Euroconsult conclut qu'il faudrait mettre en place une structure dédiée au sein du Ministère l'Enseignement supérieur et de la Recherche une sorte de « Luxembourg Space Office » qui aurait un rôle de représentation, de décision et de gestion.

A noter que le groupe d'experts indépendants chargé d'encadrer l'étude soutient pleinement les recommandations émises par Euroconsult et insiste également sur la nécessité de faire évoluer la gouvernance du dossier spatial.

c) Echange de vues

De l'échange de vues subséquent, il y a lieu de retenir succinctement les éléments suivants :

- Répondant à une question afférente, l'experte d'Euroconsult souligne que la coopération entre tous les acteurs concernés par le dossier spatial, notamment le monde académique ainsi que les entreprises privées, fonctionne effectivement. L'expert gouvernemental renvoie dans ce contexte au Groupement luxembourgeois de l'aéronautique et de l'espace (GLAE) qui a été crée en 2005 lors de l'adhésion du Luxembourg à l'ESA. Le GLAE est composé d'une vingtaine d'entreprises opérant dans le secteur spatial.

- L'économie satellitaire au Luxembourg émane d'une initiative publique avec la création de la SES. Les recommandations d'Euroconsult, notamment celle de la création d'un *Space Office,* vont également dans la direction de l'encouragement de l'économie spatiale par des fonds publics. C'est dans ce contexte qu'un membre de la Commission s'interroge si le secteur spatial pourrait se transformer à l'avenir en une économie dynamique de par sa propre initiative sans appui financier de l'Etat, d'autant plus que le Luxembourg ne dispose pas d'une industrie de défense contrairement à d'autres pays. L'experte d'Euroconsult estime qu'il y a de réelles opportunités au Luxembourg pour le développement d'une dynamique commerciale dans le domaine spatial. Même si ce sont les gouvernements qui sont en premier lieu demandeurs du développement des systèmes satellitaires, il y a également un bon nombre de prestataires de services commerciaux qui interviennent dans le secteur spatial. Les recommandations de l'étude d'Euroconsult concernent en particulier des perspectives de marchés commerciaux dans le secteur spatial. L'expert gouvernemental souligne dans ce contexte qu'il y a des projets spatiaux, notamment des programmes de l'ESA, qui sont cofinancés par des fonds publics et privés.

- Un membre de la Commission suggère à ce que le Luxembourg s'implique davantage dans l'ESA en participant et en contribuant à tous les programmes et à toutes les activités de l'Agence. L'orateur estime en outre qu'au vu d'un certain savoir-faire en matière de sécurité des communications satellitaires, et notamment le cryptage, au Luxembourg, il serait opportun de développer ces activités. L'experte d'Euroconsult explique que ce domaine est en train de se développer au sein de l'ESA et sera éventuellement renforcé au sein de l'UE dans le contexte du programme Horizon 2020.

- Les experts d'Euroconsult mettent en évidence la réactivité du Luxembourg dans la mesure où le Gouvernement a pris l'initiative de développer en 2011 emergency.lu, un système de communication à réaction rapide en cas de catastrophes et de missions humanitaires, alors que les discussions au sujet de la nécessité d'un tel instrument ont été menées depuis des années au sein des Nations Unies sans résultats concrets. Emergency.lu est désormais un outil important de la politique luxembourgeoise de coopération au développement.

- Une chaire de droit de l'espace, des télécommunications et des médias existe d'ores et déjà à l'Université du Luxembourg.

- Répondant à une question au sujet de la création éventuelle d'un *Space Office,* l'experte d'Euroconsult suggère de renforcer graduellement l'équipe en charge de la politique spatiale, en estimant que l'effectif d'un tel organe au Luxembourg pourrait s'élever à environ dix personnes.

Luxembourg, le 13 novembre 2012

La secrétaire, Anne Tescher	Le Président, Marcel Oberweis

Annexes :

- Présentation Powerpoint
- Rapport « Preparing Luxembourg's Future in Space »

"Per aspera ad astra"

Preparing Luxembourg's Future in Space

Presentation to Stakeholders

November 5, 2012

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA RECHERCHE
Grand-Duché de Luxembourg

AGENDA

1. Objective & method for the study
2. Space policy & governance in Luxembourg
3. Space capabilities in Luxembourg
4. Achievements of the national space plan
5. Recommendations to the Government of Luxembourg

1
Objective & method for the study

STUDY OBJECTIVE

- To support the Government of Luxembourg in reviewing its investment strategy in space and defining an optimized strategy for the coming years taking into account

  - the evolving market environment of the space sector
  - the national specificities

- The Statement of Work from the MESR identified three primary objectives:

  ✓ Provide an independent and comparative assessment of the strengths and weaknesses of the ecosystem of Luxembourg activities in space

  ✓ Provide an independent assessment of the impacts of the national space programme

  ✓ Formulate recommendations for optimizing the setup of Luxembourg space activities

STAKEHOLDER CONSULTATION

- Face-to-face interviews (+ telephone interviews) in February 2012 based on a list of interviewees defined by the MESR
- To collect primary information from government and industry stakeholders on their experience, lessons learned and perspectives regarding space and the national space programme
- Three categories of stakeholders consulted through detailed questionnaires

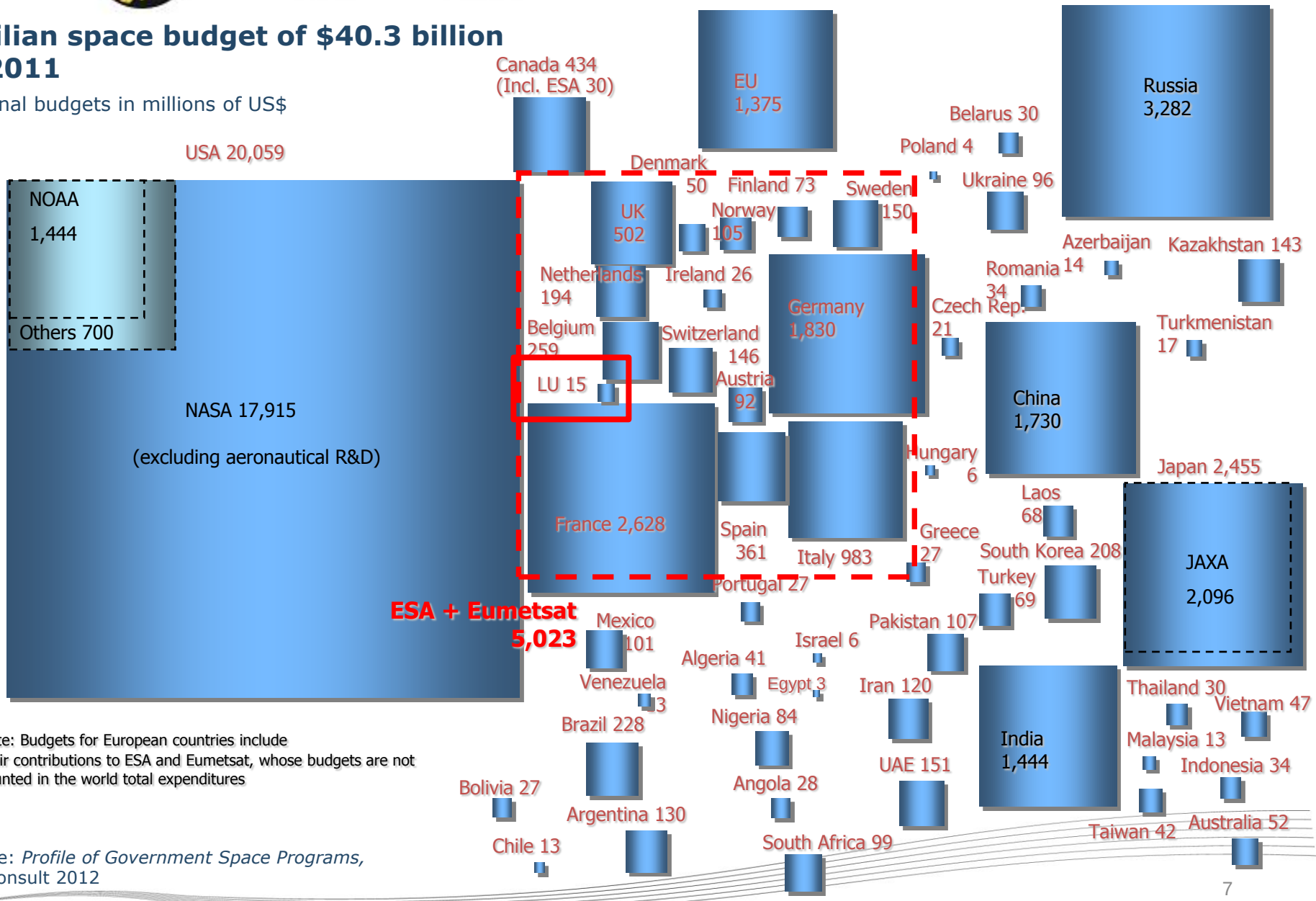
Industry	Research	Government
Cybercultus	CRP Gabriel Lippmann EVA	MESR
EmTronix	CRP Gabriel Lippmann SAM	ESA
Euro-Composites	CRP Henri Tudor (AMS+SSI)	Luxinnovation/Space Cluster
e-Xstream	Uni.lu P&M Geophysics	MAE – Coopération & Développement
GeoVille	Uni.lu RUES	MAE – Défense
Gradel	Uni.lu SnT	Ministère d'Etat - ANS
HITEC		Ministère de l'Economie
iPaymo		Ministère d'Etat - SMC
Lion Systems		
LuxSpace		
P&T		
SES Broadband Services		
SES Government Services		
SES TechCom		
Smalux		
Solelec		
Telindus		

2
Space policy and governance in Luxembourg

GOVERNMENTS DRIVE SPACE CAPABILITY DEVELOPMENT WORLDWIDE

Civilian space budget of $40.3 billion in 2011

National budgets in millions of US$



Note: Budgets for European countries include their contributions to ESA and Eumetsat, whose budgets are not counted in the world total expenditures

Source: *Profile of Government Space Programs*, Euroconsult 2012

THE FOUNDATIONS OF LUXEMBOURG'S SPACE POLICY

Several Milestones

- **1985**: Creation of SES
- **2000**: ESA Cooperating State
- **2005**: ESA Member State – 1st national space plan
- **2008**: Revised space plan
- **2009**: ESA/Luxembourg Agreement on the 3rd Party Programme

Three Pillars

- ESA programmes as a Member State
- National activities through 2 instruments
  - LuxLAUNCH (2006)
  - 3rd Party Programme (2009)
- International cooperation

Four Objectives

- **Contribute** to the diversification and sustainability of economic activities
- **Consolidate and valorize** the existing competencies in the domain of medias and telecommunications
- **Contribute** to reinforce the competitive position of industry and public research organizations in the space sector
- **Develop** Luxembourg's space sector skills and join international networks

LUXEMBOURG's SPACE GOVERNANCE VS. OTHER EUROPEAN COUNTRIES

- The space **governance and ecosystem** that developed in Luxembourg are unique
  creation of SES in 1985, ESA membership 20 years later
- Luxembourg's **space effort ranks 4th** in Europe at 0.03% of its GDP
  after the three largest Member States of ESA (France, Germany and Italy)
- **R&D activities of Luxembourg outside of ESA are quite significant**
  13% of the €74.5 million of public budget for space over 2005-2011 managed through the two instruments
- **Space traditionally under the mandate of Research/Education Ministries**
  In recent years, some countries decided to shift to Economy/Industry (Norway, Finland and soon Switzerland)
- **Only 6 countries have set up a Space Agency** to manage a significant national programme outside of ESA
  Space Office chosen as a lower cost structure dedicated to the management of space
- Several countries have set up a **permanent inter-ministerial working group**
  Finland, Switzerland, UK, Denmark including also other national stakeholders (industry & public research)

THE CHANGING CONTEXT FOR SPACE IN EUROPE

ISSUES ON SPACE POLICY

- **ESA enlargement** to new Member States : more complexity in the Agency's industry policy
- Increasing cooperation between ESA and the EU: **increasing application of EU competition rules** to the programmes managed by ESA
- **Long term evolution of ESA-EU relationship** ?
- Tough economic context for the 2012 Ministerial Council: **Budget tensions** on ESA and difficult funding decisions

IMPACTS FOR LUXEMBOURG

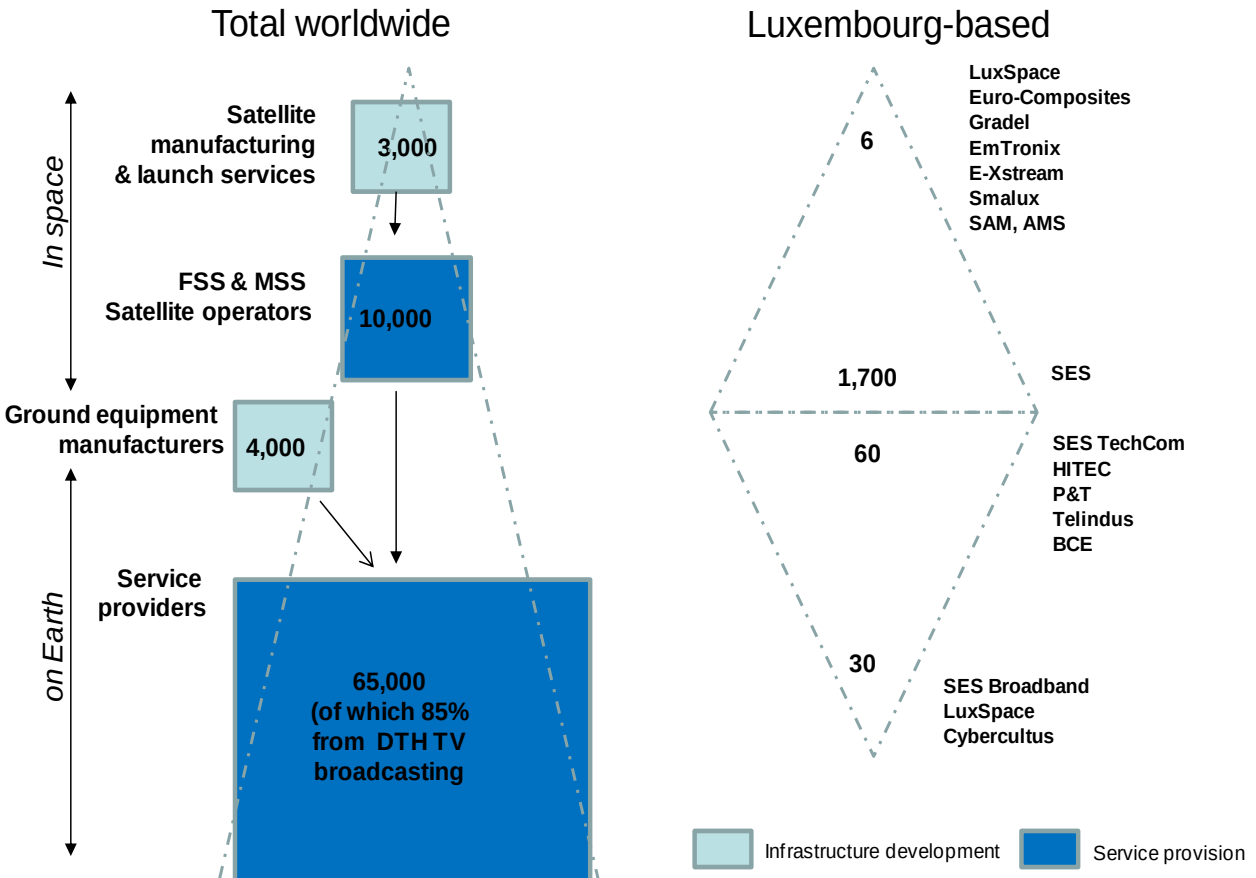
- Increasing competition from **lower cost countries** in some capability areas (ground equipment typically an entry point)
- More exceptions to the **GEO return** principle of ESA that has been instrumental to build up national capabilities in space
- Long-term applicability of the **3rd party model ?**
- **Uncertain funding decisions** for key programmes of strategic interest for Luxembourg (e.g. SAT-AIS)

Luxembourg should **build a consensus nationally** on its space development plan and **endow itself with the adequate governance** to define and implement a new phase of its national space plan

3
Space capabilities in Luxembourg

A VALUE CHAIN DRIVEN BY SATELLITE COMMUNICATIONS

- Satcom dominates the 4 levels of the value chain
  - Legacy from SES & ARTES
  - No space industry upstream
  - Academic sector less satcom
- About 10 organizations usptream, including research
- SES, one of the two world's largest commercial satellite operators
- 5 companies in ground equipment & services
  - SES is a client
- Satellite services providers based on SES satellites
  - exception: AIS data from LuxSpace



estimate in M€ for the year 2011

GROWTH IN SPACE R&D CONTRACT

- **€40M placed with the national industry & public research over 2000-2011**

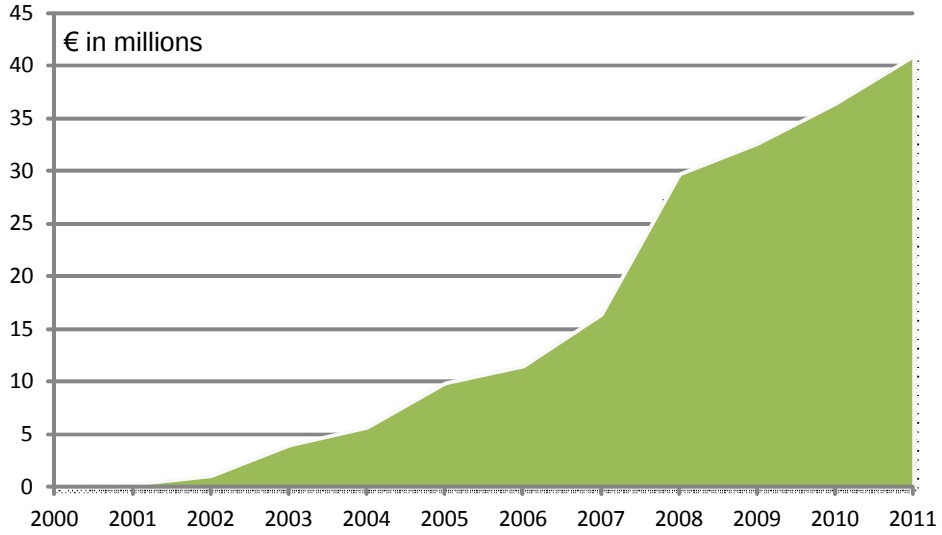
90% with entities still active today. Some organizations currently not involved, either definitively or temporarily

Two companies concentrate two-thirds of contracts: SES and LuxSpace

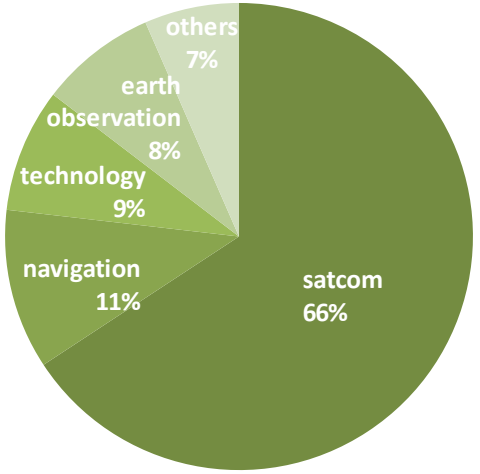
Satcom dominates with two applications: *SmallGEO* and *Satmode*. Other applications are navigation, technology development and earth observation

Academic sector is low (<5%) but it shares satellite activities with companies

Cumulative contract value from MESR



Total contract value by application



LUXEMBOURG'S SPACE SECTOR

- About **20 companies plus 7 research departments** (two CRPs and Uni.lu) **active at the 4 levels of the value chain**
  - revenues of €1.8 billion in 2011, of which 96% derived from SES
  - space staff of about 500 persons, of which 75% from SES
- Space sales at a **high level of the GDP** because of SES
  - over 4% vs. 0.1% for the European average
- **National capabilities** at each level of the value chain driven by satcom
  - satellite systems upstream: integration (for microsatellite and AIS receivers) and platform equipment development (*SmallGEO*)
  - ground systems & services: Ka-band antenna and satellite mission operation
  - satellite services downstream: broadband communications and earth observation
- National capabilities for satellite systems **in 15 technological areas**
  - but large differences between them in technology maturity and relatively to European standards

SPECIALIZATION ONATIONAL SPACE SECTOR

Existing capabilities to be adapted to capture growth potential

Two new domains of interest with high commercial potential: electric propulsion and Next Generation Platform

	Capability domains	Luxembourg existing capabilities
Satellite systems	Microsatellite	LuxSpace, EmTronix, Gradel, Euro-Composites
	AIS receiver	LuxSpace, EmTronix
	SmallGEO platform (SGEO)	LuxSpace, Gradel, Euro-Composites, Smalux
	Electric propulsion	*None (targeted domain)*
	Next generation platform (NGP)	*None (targeted domain)*
Ground systems & services	Ka-band antenna	HITEC, Uni.lu. RUES
	Mission operation	SES TechCom, P&T, Telindus, BCE, Uni.lu SnT
Downstream satellite services	Broadband communications	SES Broadband, SES Techcom, Cybercultus, Uni.lu SnT
	Earth observation	Geoville, CRP Tudor/Lippmann

OPPORTUNITY FOR NATIONAL SPACE SECTOR

	Existing capabilities in Luxembourg	Opportunity for Luxembourg players
Satellite systems	Equipment & integration for microsatellite with flight experience Industry has experience with composite structural parts, not with electric propulsion	1) Performance improvement of the existing microsatellite platform to enlarge its market 2) Payload development to give more value to the microsatellite platform: communications and earth observation payloads Two domains with a large commercial potential with geostationary satellites
Ground systems	Initial capability in large Ka-band antenna for communications with satellite missions	European Governments increasingly use Ka-band for their communications, earth observation and meteorology missions
Satellite services	Established in satellite communications / Emergent in earth observation, satellite navigation and integrated services	Growth with the development, integration and delivery of satellite services Companies involved in systems development could provide more value added services making use of national satellites

4
Achievements of the national space plan

ACHIEVEMENTS OF THE SPACE PLAN

- Achievements to date per criteria judged from the information collected during the consultation of national stakeholders
- The plan defined in 2005 and revised in 2008 did not associate a time schedule for completion of the objectives which are ultimate targets

Objective	Strategic objectives of the space plan	Criteria used to review the achievements
1	Contribute to the diversification and sustainability of economic activities in Luxembourg by a proactive approach (of identification of new market opportunities)	1. Economic value of the space sector 2. Revenues derived from the space programme 3. Profitability of space activities 4. Space revenue perspectives
2	Consolidate and valorise the competencies existing in the domain of media and communications services	1. Leverage effect from existing competencies 2. R&D efficiency (satcom mainly) 3. National partnerships
3	Contribute to reinforce the competitive position of the companies and public research organizations in the space domain	1. Market position of national players 2. Foreign investment in space
4	Develop skills in the space sector in Luxembourg and amplify the integration of Luxembourg players in international networks	1. Space employment 2. Education and training of space professionals 3. Visibility of the space programme 4. International partnerships

OVERALL ACHIEVEMENT IS EFFECTIVE

- **Luxembourg's space programme has performed well** with respect to the four objectives when considering

  - its time scale of development with less than ten years of satellite R&D

  - the lack of a pre-existing capability in aircraft construction, a capability that is common to most of ESA Member States

- **Highest achievements observed in two domains:**

  - valorisation of existing satcom capabilities: legacy allowed local suppliers to launch new services (e.g. SES Broadband Services) and the Government to develop international cooperation (*emergency.lu* initiative of the MAE)

  - support to the development of national players in the European space sector and to the attraction of strong players in Luxembourg (namely OHB)

- **The economic impact is also positive** considering the absence of space-related revenues and employment outside SES less than 10 years ago

  - about €65 million and 120 persons today

- **More limited impacts** observed in two domains

  - national development of skills

  - overall visibility of the sector (outside of SES)

5
Recommendations to the Government of Luxembourg

THEMATIC RECOMMENDATIONS

- The Government has **to remain selective in its investment decisions** to
  - prepare future expansion of local players in a growing sector at long cycle with today's investment
  - maximize the return on investment in space R&D for the country

- **Four areas have been identified as investment opportunity** because they offer accessible business growth to the different stakeholders
  - Microsatellite, both for platform and payload
  - Satellite equipment, in particular electric propulsion
  - Ground equipment, in particular Ka-band antenna
  - Value added services using satellite data, of which those produced by Luxembourg satellites

- These four investment areas represent a total of **10 capability domains**
  - 8 are evolutions of existing capabilities that will require evolution efforts of different intensity
  - 2 are new for Luxembourg: microsatellite payload and satellite electric propulsion

- **Concentration of Government's support** in the four areas will
  - align with the policy objectives of the Government for R&D, economic and industrial developments
  - enlarge the commercial potential for local players in the next decade
  - strengthen the existing local base and selectively attract new players
  - be in continuity with past budget effort for space development
  - represent a development effort that is at the same time ambitious in strategic intend and realistic to implement

IMPLEMENTATION RECOMMENDATIONS AT 4 LEVELS: ESA

- **Continue to invest in the 3 categories of programmes of ESA to maximize benefits of the contribution**

  - R&D purpose: e.g. ARTES 3-4, GSTP

  - System procurement for other government organizations: e.g. EDRS, METOP

  - Initial study of future applications: e.g. ARTES 1, EOPP

  Profit should continue to be taken of the funding flexibility ("pay-as-go") of ARTES (e.g. IAP)

- **Benefit from the future co-chair of ESA at ministerial level to take an active role in the European space policy**

- **Evolve bilateral relations with ESA in 3 directions as a result of the thematic priorities**

  - Increase the 3rd Party Programme to continue to develop national capabilities outside ESA

  - Invest significantly in ARTES 21 (SAT-AIS) and seek to obtain an observer status in this programme of strategic importance for the country

  - Offer services to ESA under different formula (PPP, facility management, in-kind contribution): hosted payloads, satellite bandwidth, testing facility

IMPLEMENTATION RECOMMENDATIONS AT 4 LEVELS: NATIONAL

- **Reinforce in the medium-term the 3rd Party programme and LuxLAUNCH**

  - the two instruments have proved relevant with respect to their objective & complementary in their missions
  - their adaptation to the new context of space investment shall be assessed at a later stage

- **Leverage on SES' experience/engineering capabilities in satellite communications**

  - SES could initially assist the MESR with expertise support, possibly evolving towards the management of satcom R&D
  - Large benefits to a strong and coherent approach to R&D in satellite communications as they are transversal to the 4 investment domains

- **Reinforce the visibility of the space programme through better integration into promotion actions abroad**

  - to attract investment, promote exportation and accelerate international cooperation

IMPLEMENTATION RECOMMENDATIONS AT 4 LEVELS

BILATERAL

- **Bilateral cooperation with other European countries should be further encouraged**

  - national stakeholders can benefit from the strengths of the partners in satellite systems and prepare better for more complex cooperation activities within ESA

  - excellent bilateral cooperation with Germany to date in satellite systems

EU

- **Participate to future space-related R&D initiatives of Horizon 2020**
  - in the domains of interest for the country

TWO GOVERNANCE RECOMMENDATIONS

- **A new governance of space is required as a result of major changes:**

  - the adequate financial resources need to be available to implement space development
  - the management tools of space development have to be further strengthened
  - the national space policy shall become more visible to be successfully implemented

- **The existing consultative working group should evolve into a permanent Space Committee with an advisory role to the Government**

  - As in other European countries, its role is to prepare consensually the space policy and to monitor its execution
  - Its composition shall reflect the diversity of stakeholders, i.e. the State administration and the public research and private sectors
  - It is chaired by the Ministry in charge of space R&D, i.e. the MESR

- **A Space Office should be created as a dedicated structure within the MESR with political recognition to implement efficiently the space policy**

  - the LSO will give political recognition to a dedicated structure with 3 roles for the space policy: representation, decision and management
  - As the LSO will have to cover a broad variety of missions, its operating budget will have to grow according to the volume and nature of its activities

"PER ASPERA AD ASTRA"

PREPARING LUXEMBOURG'S FUTURE IN SPACE

Euroconsult for

Ministère de l'Enseignement Supérieur

et de la Recherche du Luxembourg (MESR)

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA RECHERCHE
Grand-Duché de Luxembourg

FINAL REPORT

November 5, 2012

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Any opinions, findings, and conclusions or recommendations expressed in this report are those of Euroconsult that prepared the report under commissioning of the Ministère de l'Enseignement Supérieur et de la Recherche (MESR) du Grand-Duché de Luxembourg. They do not necessarily reflect the views of the MESR.

OVERALL ASSESSMENT AND RECOMMENDATIONS

Assessing the achievements of space development in Luxembourg to prepare for the future

After six years of implementation of the national space plan, the Ministère de l'Enseignement Supérieur et de la Recherche (MESR) of the Government of Luxembourg wished to have an independent assessment of Luxembourg-based activities in the space domain in order to prepare for future development. At year-end 2011, MESR commissioned Euroconsult as a specialized consultancy company to carry out the assessment on the basis of its expertise and of an extensive consultation of national stakeholders.

The study is aimed at supporting the Government of Luxembourg in reviewing its investment strategy in space and defining an optimized national strategy for the coming years taking into account 1) the evolving market environment of the space sector and 2) the national specificities. It has three major objectives:

- To provide an independent and comparative assessment of the strengths and weaknesses of the ecosystem of Luxembourg activities in space;
- To provide an independent assessment of the achievements of the national space programme;
- To formulate recommendations for optimizing the setup of future Luxembourg space activities.

A unique development model of space activities in Luxembourg

From the analysis and the comparison with other countries, it appears that the Luxembourg space sector is **unique in terms of governance of its activities and of the ecosystem** that developed pursuant to the creation of SES in 1985 and to the membership to the European Space Agency (ESA) 20 years after. Luxembourg has been at the forefront of the deregulation move in the broadcasting sector with the creation of SES that was instrumental in the development of satellite TV in Europe. From this legacy, the Government of Luxembourg committed to the ARTES (Advanced Research in Telecommunications Systems) programme of the European Space Agency in 2000 before joining the Agency as a full member in 2005.

Still today, regarding space activities in Luxembourg**,** the **value chain is very much driven by satellite communications** with the unique situation that SES developed into one of the world largest commercial satellite operators despite the lack of technology capabilities for satellite systems in the country. Satellite communications dominate in all stages of the value chain in Luxembourg, from research and technology development upstream to service provision downstream going through ground systems development and operation. The only segment of the value chain that is less satellite communications-centred is the academic sector working on technology development (materials, nanotech, security,..) which is nonetheless applicable to satellite systems for various applications.

Luxembourg's space budget is essentially directed towards ESA which has constituted 87% of the country's investment in space R&D since 2005 (i.e. a total of €65 million over 2005-2011), the remaining 13% being dedicated to national activities pursued through the Third Party programme managed by ESA (€6.4 million) and through LuxLAUNCH (€3.3 million) managed nationally. With its

space budget at 0.03% of its GDP, Luxembourg ranks fourth in terms of space effort in Europe, just behind the three largest Member States of ESA (France, Germany and Italy).

The national space effort aligns with the general policy objective of the Government aiming at improving conditions for innovation and R&D and for industrializing the country. It is also in line with other policy areas of the country, in particular Information and Communication Technologies, foreign affairs and maritime affairs.

Luxembourg's space sector is made of about 20 companies plus 7 research departments (in two public research centres and the University of Luxembourg) active in the four levels of the value chain, from satellite systems upstream to satellite services downstream going through satellite operation and ground networks. This is quite unique for a country the size of Luxembourg to have such a diversity of players with satellite communications being the driving force all along the value chain. These players are in position to benefit from the growth prospects existing at each level of the value chain in the coming years.

The total space revenues of these companies including commercial and Governmental contracts amounted to almost €1.8 billion in 2011, of which 96% derived from SES, the world's second largest commercial satellite operator. As a result, the sales of the space sector contributed to over 4% of the national economy in 2011. This is far much higher than the European average for which the ratio of space sales to GDP is 0.1%. Obviously, this high proportion of space sales in the GDP of Luxembourg is the result of SES's sales and stresses the importance of this company for Luxembourg's economy.

To date, the **technological capabilities of the Luxembourg space sector are concentrated in three domains** along the value chain of the sector:

- **Satellite systems upstream**, with 1) system integration capability for microsatellite and for receiver dedicated to Automatic Identification Systems (AIS) and 2) equipment development capability for the platform of the future small geostationary satellite of the European space industry;
- **Ground systems & services** with Ka-band antenna and satellite mission operation;
- **Satellite services downstream** for broadband communications and earth observation.

For the satellite systems designed to operate in orbit, Luxembourg has technological capabilities in 15 domains but with large differences between the domains in terms of maturity of the technologies and also relatively to the European standards.

Overall achievement of the Luxembourg space programme is effective after less than 10 years of satellite R&D

Luxembourg's space programme has performed well with respect to the four objectives defined in the national space plan in 2005 and confirmed in 2008; this is particularly obvious when considering 1) its time scale of development with less than ten years of satellite R&D and technology development and 2) the lack of a pre-existing capability in aircraft construction, a capability that is common to most of ESA Member States.

Highest achievements of the Luxembourg space programme **have been observed in its ability to 1) valorise existing capabilities in satellite communications and 2) support the market positioning of national players in the European space sector**. The legacy of the country in satellite communications has allowed local suppliers to launch new services and allows the Government to develop international cooperation as illustrated by the *emergency.lu* initiative of the Ministère des Affaires Etrangères. Besides, the support of the Luxembourg Government helped national players to reinforce their satellite-related activities or to enter the domain.

The economic impact is also positive considering the absence of space-related revenues and employment outside SES less than ten years ago. Space staff growth in Luxembourg companies outside of SES Headquarters has been strong since the mid-2000s (from about 20 persons in 2007 to 120 today) as several companies developed their satellite activities during the period either as newcomers following Luxembourg's adhesion to ESA or in continuation of a pre-existing activity related to satellite communications. Similarly to space staff growth, space sales outside SES grew from €26 million to €65 million over the same period.

More limited impacts have been observed for the national development of skills and the overall visibility of the sector as both require a long time effort to materialize. Still, space employment grew in the country in the past ten years despite limited local space skills; the integration of Luxembourg players in international networks is in good progress.

Considering the result of the assessment of the four objectives of the national space plan, and in view of the general and thematic policy objectives of the Luxembourg Government and notably the National Reform Program for the Grand-Duchy of Luxembourg under the Europe 2020 Strategy, **it is highly recommended to confirm these objectives as strategic for further development of space activities in the country.**

Four thematic recommendations for future space development in Luxembourg

The satellite sector will grow in all its dimensions in the decade to come but, as it is a long cycle investment sector, new entrants need to prepare their expansion in the sector with today's investment in order to be in position to reap fruit in the future. **To maximize the return on investment in space R&D for the country, the Government of Luxembourg has to sustain investment in space activities while remaining selective in its investment decisions.**

Four investment areas have been identified as priorities for the future development of Luxembourg in space as they offer opportunities at different levels of capabilities and for different stakeholders:

- Microsatellite, both for platform and payloads
- Satellite equipment, in a first instance electric propulsion
- Ground equipment, in a first instance Ka-band antenna
- Value added services using satellite data, particularly those produced by Luxembourg-built satellites.

Together, **the four investment areas represent a total of ten capability domains**, of which eight are evolutions of existing capabilities that will require evolution efforts of different intensity. The two capability domains that are new for Luxembourg are microsatellite payloads and satellite electric propulsion.

Development efforts in these four areas reinforce the objectives of the national space policy that aligns itself with the policy of the Government of Luxembourg for the country's R&D and economic developments. They are at the same time **ambitious** in their strategic intent and **realistic to implement**. **The support of the Government of Luxembourg to national capability development in these four areas will help to establish local players sustainably in the European space sector with possibly large commercial benefits in the next decade.**

The concentration of the Government's support in the four areas will enlarge the commercial potential for local players ultimately even if the number of players may not be significantly enlarged as satellite systems suppliers develop vertically into service provision and as local players may consolidate.

The recommended development priorities will allow strengthening the existing local industrial base while attracting selectively new players into the country to develop a viable activity. Together they make a natural development scenario for Luxembourg because it allows an organic growth of the national space capabilities by adapting them to the changing context of European and international demand and by developing new capabilities in two areas that are central to future satellite missions (electric propulsion and mission instrumentation/payloads). Also, the public R&D funding effort required to undertake the development of these capabilities in the country is in continuity with the past effort of the Government for space.

Recommendations at four levels to implement space development in Luxembourg

The means, actions, resources and missions that are required to implement the scenario of satellite development in Luxembourg are presented below according to the three pillars of the national space policy (ESA, national and bilateral) complemented by that of the European Union.

European Space Agency

- To maximize the benefits of its contribution to the European Space Agency, the Government shall **continue to invest in the three categories of programmes of the Agency**: 1) those for R&D purpose (e.g. ARTES 3-4, GSTP), 2) those for system procurement for other Government organizations (e.g. EDRS, METOP) and 3) those preparing the future applications of satellite technology through initial studies (e.g. EOEP, ARTES 1). Also the funding flexibility ("pay-as-go") of several programmes of ESA (e.g. IAP) is of interest for Luxembourg and shall be preferred in the investment decisions of the Government.
- Through its **future co-chair of the European Space Agency at ministerial level** for the coming years, Luxembourg will have to play an active role in forging the future European Space Policy involving both ESA and EU. This will be an occasion for Luxembourg to increase its influence and political standing in space. The communication and management tools of space activities of Luxembourg must be adapted to that new role.

- As a result of the thematic investment priorities of Luxembourg, **the bilateral relations with ESA should evolve in three directions**:
    - The **3rd Party Programme managed by ESA should be enlarged** with a view to contributing to develop national space activities, notably in areas relevant for Luxembourg but that do not match with ESA's present and future programme lines;
    - Because of its particular interest for the country, **the ARTES 21 programme of ESA for SAT-AIS should receive a large participation of the Luxembourg Government**. In order to have more technical and financial control on this optional programme of ESA that will be highly subscribed by Luxembourg, the Government should seek to obtain an observer status in the internal reviewing process of ESA, thus allowing it to participate closely to programme development;
    - **Luxembourg can offer different types of services to ESA under different formula** (public/private partnership, facilities management, in-kind contribution, commercial proposal). Services include hosted payloads on the microsatellites of LuxSpace and on the geostationary satellites of SES, satellite bandwidth on SES satellites (to stimulate the development of new applications within the Integrated Application Promotion (IAP) programme for example) and facility outsourcing with the testing infrastructure of the CRP Gabriel Lippmann for micro-electromechanical systems (MEMS) made available to ESTEC.

National

- **The two instruments that have been created** to develop Luxembourg's space activities outside of ESA participation, i.e. the Third Party programme and LuxLAUNCH, **should be continued and even boosted in the medium term**. While the two initiatives have proved to be relevant with respect to their objective and complementary in their mission, their short history does not allow a proper assessment of their effective impact. Furthermore, the implementation of the recommendations of this Report will induce important changes in the landscape for Luxembourg's space activities. It is therefore recommended to assess in a few years' time (2014-2015) the need of adapting both instruments to the requirements of the changed environment.
- As satellite communications is a key sector in Luxembourg that is transversal to the four investment domains, **the Government should leverage on SES's experience and engineering capabilities in this domain.** In a first phase SES could assist the MESR with expertise support for satellite communications R&D. This support could later evolve towards the management, on behalf of and in close coordination with MESR, of specific satellite communications R&D activities. It is evident that this approach should be designed to avoid conflicts of interest. Nonetheless, the benefits of a strong and coherent approach to satellite communications R&D are much higher than the risks of possible conflicts of interest (considering moreover that SES does not compete with other local players).
- **The visibility of the Luxembourg space programme should be reinforced** to attract investment, promote exportation and accelerate international cooperation. The national satellite capabilities should be better integrated in campaigns promoting Luxembourg's capabilities abroad.

Bilateral

- **Bilateral collaboration with other European countries should be further encouraged** to allow the national stakeholders to benefit from the strength of these partners in satellite systems and to be better prepared for more complex international programs implemented within ESA framework.

  The excellent bilateral experience to date with Germany in satellite systems at both institutional and industry levels gives an evidence of the benefits of such collaborations and underlines the fact that Luxembourg can be an attractive partner for collaborative projects with other countries, even large space countries.

European Union

- The European Union is increasingly involved in the European Space Policy with two satellite infrastructure programmes now in the deployment phase (Galileo and GMES). Luxembourg's space actors should seize the opportunity of participating, **through the European Commission's "Horizon 2020" programme**, to future space-related R&D initiatives in the domains of interest for the country.

Two governance recommendations to the Government of Luxembourg

The recommendations above on the thematic priorities of Luxembourg in space and on their implementation have for direct consequences that

- the adequate financial resources have to be available for space development;
- the management tools of space development have to be strengthened further;
- Luxembourg's space policy should become more visible to be successfully implemented.

- **Growth of the space budget has to be maintained** to develop satellite systems and services in the four priorities domains for Luxembourg, i.e. microsatellite, satellite equipment, ground equipment and value added services. Larger budgetary resources will allow securing the achievements from previous investments and benefiting from the development opportunities offered by existing and new ESA programme lines and by a larger national programme implemented both locally and through bilateral cooperation. Funding growth will allow keeping the momentum, building on existing assets and developing new ones with locally based organizations, both in the research and industrial sectors. The growth of space-related funding will also increase the overall visibility of Luxembourg space activities, a factor that can be of importance to attract industrial players from other space countries in Europe and beyond.

- As a consequence of the growing investment and activities of Luxembourg in the space domain, **the management tools of space development by the Government have to be strengthened**. This induces more structuring of daily operations, including the measure of the impact of Government's investment in the space domain. In order to support future

decisions, it is opportune for the Government to define key performance indicators (KPI) to monitor the development of the national landscape for space activities.

- As Luxembourg enters a new phase of its space development and becomes a larger actor in the European space scene with more political responsibilities in the domain, **it needs more recognition of its space policy both nationally and internationally**. Luxembourg's space policy should become more visible through the political recognition of its ambition in order to be implemented successfully.

Considering these factors, two recommendations on Luxembourg's space governance have been defined. They acknowledge the fact that the governance of space activities in Luxembourg needs to evolve as the Government increases its investment effort in parallel with growing stakeholders' interest in the sector. The two governance recommendations are coherent with respect to one another and relevant with respect to best practices in other European countries.

The consultative working group for space science and technologies should evolve into a permanent Space Committee with an advisory role for the Government

- The services, departments, and ministries of the State administration with direct interest in satellite matters as user, regulator or promoter of satellite systems should be given a permanent forum to contribute to the formulation of the space policy of the country and to monitor its execution. The consultative working group for space science and technologies should therefore become a permanent Space Committee with an advisory role for the Government on its space policy.
- Like in Finland and Switzerland, its role should be to prepare and monitor the execution of the national space plan. The composition of the Space Committee should reflect the diversity of stakeholders in the national space policy, i.e. the State administration, the private sector active in space and public research.
- Considering the strong impact of R&D and technology development on space activities and the liaising role of the MESR in space matters with regard to ESA and the European Union, the Space Committee should be chaired by that Ministry.

A Space Office should be created as a dedicated structure with political recognition to implement efficiently Luxembourg's space policy

- Luxembourg enters a new phase of its space development and it needs a dedicated structure with political recognition to manage efficiently that development. The creation of a Space Office within MESR is recommended to give political recognition to a structure with three roles for the space policy of the country: representation, decision and manaqement. Roles' centralization is required for an efficient coordination of the efforts nationally and for a stronger voice of Luxembourg internationally. Luxembourg is to date the sole country with such a high relative effort for space without a unified structure to implement that effort.

- Following the favourable experience of other European countries (Belgium, Netherlands, Switzerland, Czech Republic, Denmark, Poland, Portugal) that have created a Space Office or a similar dedicated structure as part of a supervisory Ministry, the Luxembourg Space Office would have for responsibility to coordinate and manage the implementation of all space R&D activities of the country, i.e. its membership to ESA and the national space programme (including all activities outside ESA, conducted either nationally or bilaterally). The mandate of the Luxembourg Space Office could evolve over time to an administration of its own according to the political agenda of the country with respect to its investment in space.
- The Luxembourg Space Office will have to cover a broad variety of missions:
    - national delegation to ESA and to the European Union;
    - multiple interfaces within Luxembourg (State administration and Government, industry and research sectors) and outside Luxembourg (ESA-managed Third Party, European Union, delegations from other countries);
    - monitoring of programme development;
    - technical consultation;
    - space-related specialized training programme;
    - institutional and public communication;
    - impact assessment of space investment and key performance indicators.
- The Luxembourg Space Office will be in charge of managing space R&D and technological development in the four domains that have been defined as priority for Luxembourg, i.e. microsatellite, satellite equipment, ground equipment and value added services. Therefore the human resources of the Space Office and its operating budget will have to grow in relation with the volume and nature of the activities it manages. As a comparison, the operating budget in other European countries range between 3% and 10% of their total space budget. The range results from different mandates and different organizations of the space offices or space agencies between the countries.
- Furthermore it has to be underlined that the responsibility of co-chair of the European Space Agency at ministerial level will entail for the two to three years to come a supplementary draw on the scarce specialized human resources now available at MESR.

INTRODUCTION

If the 1985 decision of the Government of Luxembourg to create the national satellite operator SES represented the first step of the country in space, satellite R&D activities started in 2000 when the country joined the European Space Agency as a cooperating State on the ARTES programme (dedicated to satellite communications). The adhesion to the European Space Agency (ESA) as a Member State in 2005 was the third major step in the country's development in space.

The national space plan, first adopted in 2005 at the occasion of ESA accession and renewed in 2008, defines four strategic objectives to the national space programme:

- To contribute to the diversification and sustainability of economic activities in Luxembourg;
- To consolidate and valorise the existing competencies in the domain of medias and telecommunications;
- To contribute to reinforce the competitive position of industry and public research organizations in the space sector;
- To develop Luxembourg's space sector skills and join international networks.

To pursue its objectives, the space programme of Luxembourg relies on three pillars: 1) the participation to ESA activities, 2) national activities carried out through LuxLAUNCH and the Third Party programme and 3) international cooperation.

After six years of implementation of the national space plan, the Ministère de l'Enseignement Supérieur et de la Recherche (MESR) of the Government of Luxembourg wished to have an independent assessment of the Luxembourg based activities in the space domain being conducted in order to prepare for future development in the domain. At year-end 2011, MESR commissioned Euroconsult as a specialized consultancy to carry out the assessment on the basis of its expertise and of an extensive consultation of national stakeholders.

The study is aimed at supporting the Government of Luxembourg in reviewing its investment strategy in space and defining an optimized national strategy for the coming years taking into account 1) the evolving market environment of the space sector and 2) the national specificities. It has three major objectives:

- To provide an **independent and comparative assessment of the strengths and weaknesses** of the ecosystem of Luxembourg activities in space;
- To provide an **independent assessment of the achievements** of the national space programme (including domestic and ESA activities);
- To **formulate recommendations** for optimizing the setup of future Luxembourg space activities.

The study was carried out through four tasks over a period of eight months:

- *Task 1*: Methodology & information collection, to get all the appropriate information needed to carry out the analysis, in particular through literature search and a consultation of national stakeholders;
- *Task 2*: Assessment of Luxembourg ecosystem in space, to analyze national space policy, strategy, governance, industry and capabilities;
- *Task 3*: Assessment of the Luxembourg space programme to identify the benefits derived from the country's investment in domestic and ESA programmes;

- *Task 4*: Recommendations on future Luxembourg activities in space, with the aim to propose a coherent scenario to improve the strategy of the country in the space domain.

The consultation of national stakeholders as part of Task 1 was carried out through face-to-face or telephone interviews in February 2012 based on a list of interviewees defined with MESR. The objective was to obtain primary information from Government and industry stakeholders on their experience, lessons learned and perspectives regarding space and the national space programme.

Participants to the consultation of stakeholders

Industry	Research	Government
Cybercultus	CRP Gabriel Lippmann EVA	MESR
EmTronix	CRP Gabriel Lippmann SAM	ESA
Euro-Composites	CRP Henri Tudor (AMS+SSI)	Luxinnovation/Space Cluster
e-Xstream	Uni.lu P&M Geophysics	MAE – Coopération & Développement
GeoVille	Uni.lu RUES	MAE – Défense
Gradel	Uni.lu SnT	Ministère d'Etat - ANS
HITEC		Ministère de l'Economie
iPaymo		Ministère d'Etat - SMC
Lion Systems		
LuxSpace		
P&T		
SES Broadband Services		
SES Government Services		
SES Techcom		
Smalux		
Solelec		
Telindus		

The present final report of the study has been organized in four parts that follow the logic of the analysis:

- *Part 1:* The institutional environment for space activities in Luxembourg;
- *Part 2:* The industry environment for space activities in Luxembourg;
- *Part 3:* The achievements of space activities in Luxembourg to date;
- *Part 4:* Future priorities and recommendations for space activities in Luxembourg.

The study report starts with a summary of the overall assessment of Luxembourg's space activities and of the recommendations formulated for the Government of Luxembourg.

PART 1.

INSTITUTIONAL ENVIRONMENT FOR SPACE ACTIVITIES IN LUXEMBOURG

1.1 NATIONAL GOVERNANCE OF SPACE ACTIVITIES

1.1.1 Institutional framework for space activities in Luxembourg

The space programme of Luxembourg is managed by the **Ministry for Higher Education and Research (MESR)** which is responsible for the participation to the European Space Agency (ESA) and for national activities pursued through the LuxLAUNCH programme. More precisely, the "Research and Innovation" department is responsible for Luxembourg's space policy at European and international levels (financial, political and programmatic aspects) and for the definition of action plans in space science and technology (S&T), including the definition of the national space policy. The department defines, coordinates and implements Luxembourg's policy on public research as a whole, including space. It is responsible for the coordination and implementation of scientific and technological collaborations. Therefore, it coordinates the multi-annual programme for public R&D actors. The same responsibilities apply for space activities as the department prepares the national space plan, national budgets allocated to space for Government and parliamentary approval, coordinates with other national departments and is in charge of international cooperation related to space.

Luxembourg has not set up a national Space Agency to implement its space programme. It has instead decided to delegate part of its role to the **European Space Agency** (ESA) which takes over technical and contractual responsibilities for a part of the national activities funded through the so-called Third Party programme[1]. The motivation for such a choice was to benefit from ESA scientific and technical competencies as well as to avoid time consuming and costly creation of a dedicated national structure. It was also considered that this solution enabled a rapid implementation of national space activities.

National space activities, including ESA participation and LuxLAUNCH, are further supported by **Luxinnovation**, which assists MESR in its day-to-day activities. Luxinnovation is the National Agency for Innovation and Research created in 1984 as a common initiative of the public and private sector. The Agency became an Economic Interest Grouping (EIG) in 1988 composed of three public-sector partners (the Ministry of Economy and Foreign Trade; the Ministry of Higher Education and Research; the Ministry for the Small and Medium-sized Businesses and Tourism) and three private-sector partners (the Business Federation Luxembourg -FEDIL-; the Luxembourg Chamber of Commerce; the Luxembourg Chamber of Skilled Crafts). Luxinnovation informs and supports companies and research organisations at each phase of their projects and assists the Government in the areas of research, development and innovation. It also organises technology transfer and raises public awareness on innovation. Luxinnovation works under a performance contract with MESR.

Regarding space activities, Luxinnovation acts as an implementing arm of MESR supporting industry players active in space, promoting the national space sector and coordinating national space activities. Luxinnovation is the national contact point for ESA programmes, assists MESR in representing the Luxembourg delegation in relevant ESA bodies and manages the interface between industry, the public research sector and ESA. It is also the contact point for the European Union R&D Framework Programme.

[1] See sections 1.2.1 and 1.2.3 for a description of the Third Party programme.

Furthermore Luxinnovation manages the **Luxembourg Cluster Initiative (LCI)**, which brings together various clusters and innovation networks established in the Grand-Duchy. The Agency manages five clusters, related to BioHealth, EcoInnovation, ICT, Materials and Space. Working groups are regularly set up as part of the different Luxembourg-based clusters (for example, the Infrastructure WG of the Cluster for Logistics, aimed at identifying the needs in the different transportation modes and proposing solutions). Luxinnovation launched a new WG on Location Based Services in 2011, gathering members of the Space and ICT Clusters.

Other bodies directly or indirectly involved in space matters include:

Service des Médias et des Communications (SMC), is a department of the State Ministry in charge of the national policy and strategy for media and communication. It was created in 1991 to promote Luxembourg as a European centre for media and communications. SMC assists the Minister for Communications and Media and is in charge of media, telecommunications, radio spectrum, postal services and data protection. SMC is also in charge of legislation and regulation of space activities, in particular with regard to SES which holds a concession from the Government and whose activities under the concession are supervised by a government commissioner. SMC represents the Government of Luxembourg (holding 5.8% of the shares) at the board of SES. SMC is now focusing on the national strategy for data management (creation, protection, distribution, archiving…), a domain where Luxembourg aims to be a world leader.

The **Meteorological Service**, part of the Ministry for Sustainable Development and Infrastructure, represents Luxembourg in the Eumetsat Council. Luxembourg joined the European meteorological organisation in 2001 and now contributes for 0.21% of the organisation's budget (i.e. €0.64 million in 2011).

The Defence Department, part of the Ministry of Foreign Affairs, has had until now limited needs for space based solutions considering its limited involvement in overseas operations. More recently, the Defence Department revised its strategy with the objective to raise its position with respect to its international partners through the acquisition of new capabilities and the offer of innovative contributions to partners at the European Union and NATO. This led to the signature of a Memorandum of Understanding with the United States Air Force (USAF) to access satellite communications capacity in exchange of a percentage funding contribution to the WGS-9 satellite of the USAF. With this agreement the Defence Department clearly increases its action range regarding space matters both at international and domestic levels. Until now the Defence Department has not exercised an active role regarding national space policy matters but may be called for further participation in the future if its space-related projects become prevalent for the national space sector.

The Ministry of Economy and Foreign Trade implements the national policy of economic competitiveness which includes private sector research and development (R&D), technology transfer and innovation. The Ministry closely cooperates with the Ministry of Higher Education and Research, e.g. in the context of the Higher Committee for Research and Innovation. The Directorate of Research and Innovation manages support programme for R&D and innovation for the Luxembourg private sector. The Ministry is one of the supervisory authorities of Luxinnovation.

Further departments with potential direct or indirect interest in space activities include: the **National Security Authority** (ANS) for regulatory and information clearance aspects, the **Department of Cooperation and Development** for international cooperation issues, the **Department of**

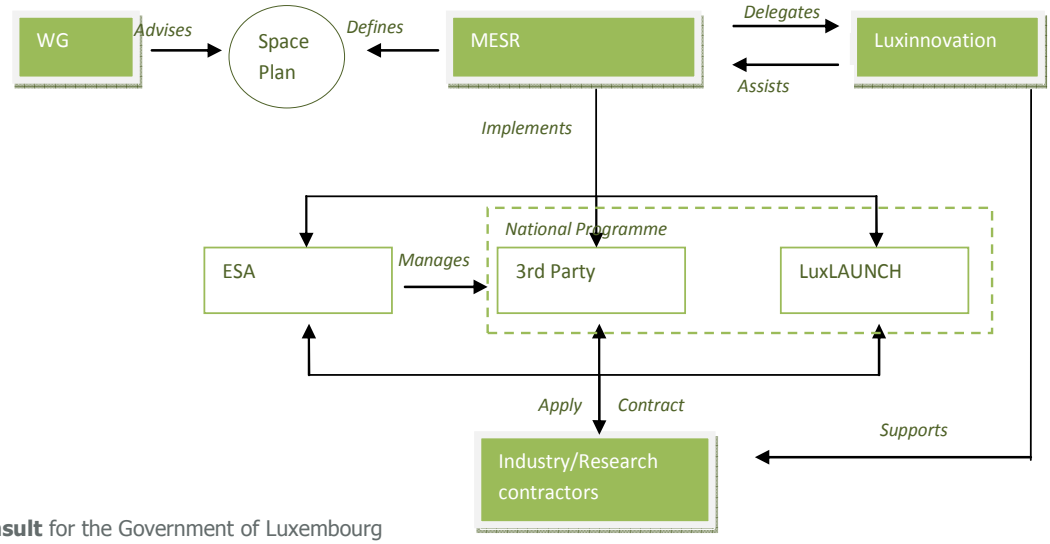
Transports of the Ministry for Sustainable Development and Infrastructure coordinating national contributions to the GALILEO programme and the **Commissariat du Gouvernement aux Affaires Maritimes** (CAM) attached to the Ministry of Economy and Foreign Trade. CAM is the leading body regarding maritime regulation and represents Luxembourg at the European Maritime Security Agency (EMSA). CAM is a key user/regulator regarding any future involvement of Luxembourg in ESA's Automatic Identification System (AIS) programme.

In 2007, a **Consultative Working Group** was created at the initiative of MESR in view of drawing up a "National Action Plan for Space and Aeronautics Science & Technology" and preparing decisions regarding Luxembourg's programme subscriptions at ESA 2008 Ministerial Council. This Working Group was composed of five members from the State administration, three representatives of the industrial sector and two representatives from the public research sector. This Working Group is not a permanent body and meets irregularly.

Administrative Organization of Luxembourg Space Activities

Organization	Place in Government	Major Activities
Ministry for Higher Education & Research (MESR)	Reports to the Prime Minister	Oversees all financial, political and programmatic aspects related to ESA activities and the national space programme.
Luxinnovation (National Agency for Innovation & Research)	Economic Interest Group with 6 members including 3 Ministries	Contact point for ESA activities, providing information & support to the national space sector. Manages the Space Cluster.
Service des Médias et des Communications (SMC)	A department of the State Ministry	In charge of media and communications policy, legislation and regulation (e.g. management of the frequency spectrum).
Meteorological Service	A department of the Ministry for Sustainable Development and Infrastructure	Represents Luxembourg in the Eumetsat Council.
Defense Department	A department of the Ministry of Foreign Affairs	Procures satellite capacity to support operations within multinational frameworks.
Ministry of Economy and Foreign Trade	Reports to the Prime Minister	Implements the technological research and development programme. Supervises Luxinnovation.

Framework of space activities in Luxembourg



1.1.2 Governance of space activities in four European countries

In order to assess the governance scheme adopted for Luxembourg space activities in a comparative approach, it has been compared against four European countries: Austria, Finland, Norway and Switzerland.

Beforehand it has to be underlined that none of these countries has implemented a framework similar to that of Luxembourg for their space activities.

Moreover the governance schemes implemented are very diverse. Two of the four countries, Norway and Austria, have national Space Agencies but with different responsibilities. Norway set up its Space Agency simultaneously with its ESA membership, while Austria had created its Space Agency 15 years before its ESA accession. Space activities in Switzerland are managed by an office under Ministerial supervision. Finland has delegated the management of its space programme to an R&D Agency.

1.1.2.1 The Austrian Space Agency is part of the national research promotion Agency (FFG)

The Austrian Space Agency (ASA) was created in 1972 under the auspices of the Federal Ministry of Science, Research and Arts. It aimed at coordinating projects in space research and technology, advising the Austrian Government on space related matters of interest for the country and conducting public relation activities. In 1976, the Austrian Government started a research programme on renewable energy sources and the Agency was transformed into the Austrian Solar and Space Agency (ASSA). After Austria had joined ESA in 1987 these new activities were transferred to a research centre and ASSA was re-transformed again into ASA, concentrating its activities fully on space related subjects. In 2002, the Agency again took over additional tasks, with responsibility for technological developments in the field of aeronautics and development of the nano-technology sector. In 2005 ASA was integrated into the Austrian Research Promotion Agency (FFG) as part of its Aeronautics and Space Agency (FFG-ALR).

Administrative Organization of Austrian Space Activities

Organization	Place in Government	Major Activities
Aeronautics and Space Agency (ALR) within Austrian Research Promotion Agency (FFG)	Reports to the BMVIT and the BMWFJ	Implements the Austrian aerospace policy, represents Austria in European and international institutions, and coordinates the participation of Austria to international programme. 13 staff members.
Space Research Institute (SRI)	Reports to the Austrian Academy of Sciences	Conducts scientific space research missions. Participates to several international scientific missions. Founded in 1970. Around 80 staff members.

FFG centralizes the promotion of research and innovation in the fields of Life Sciences, Information Technology, Materials and Manufacturing, Energy and Environment, Mobility, and Space. FFG is the national funding institution for applied R&D supervised by the Federal Ministry for Transport, Innovation and Technology (BMVIT) and the Federal Ministry of Economics, Family and Youth (BMWFJ). The Austrian Science Fund (FWF) is responsible for basic research funding. Some "bridge" initiatives have been launched to fund projects between basic and applied research. They are

implemented by the FFG and the FWF. The FFG offers services to Austrian companies and research institutions comprising: management of public funding programme, consulting services in technology development and innovation, support for integration into European research programme and networks, promotion of Austria's interests at European and international level. Its funding for 2010 was €554 million. R&D programmes are initiated and "owned" by the Ministries; their management and execution is carried out by the FFG.

1.1.2.2 The Norwegian Space Centre acts as a Space Agency

Norway set up a national Agency fully dedicated to space activities in 1987 when it became an ESA Member State. The Norwegian Space Centre (NSC) took over responsibility of space activities from the Royal Norwegian Council for Scientific and Industrial Research (NTNF) created in 1946 as an independent body. NSC was established first as an independent body rather than a Government Agency with the objective to increase programme management efficiency. NSC was given from the beginning a wide responsibility in the national space effort, with a focus towards ESA membership.

Administrative Organization of Norwegian Space Activities

Organization	Place in Government	Major Activities
Norwegian Space Centre (NSC)	Reports to the Ministry of Trade and Industry	Supports Norwegian interests in ESA, by participating in the ESA Board and Council, and coordinates national space activities. It also represents Norwegian space interests in EU programme. Staff of 32 in 2010.
Research Council of Norway (RCN)	Advisory body, reports to the Ministry of Education & Research	Research funding Agency established in 1993, in charge of the National Space Research Programme. Part of its funds comes from the Ministry of Trade and Industry. It employs around 400 persons. The RCN has funding authority for the national space science programme while the Norwegian contribution to the ESA science programme is paid by the NSC.
Norwegian Space Centre Properties (NSCP)	Reports to the NSC	Established in 1995 to own and maintain space infrastructure at the Tromso and Svalbard stations.
Andoya Rocket Range	Reports to the NSC	Launch facility for sounding rockets, established in 1960. It was privatized in 1997 with NSC holding 90% of its shares.
Norwegian Meteorological Institute	Reports to the Research Council	Executes Norway's membership in Eumetsat.

In 2004 NSC became a public administrative body under the responsibility of the Ministry of Trade and Industry. This change was caused by a new Norwegian legislation regulating foundations but had minor impact on the NSC. The choice of the ministry of industry for administrative supervision reflects the Norwegian Government's will to make the NSC an instrument for industry policy.

NSC not only implements but also defines the national space policy as its responsibilities include the compilation of the National Long-Term Plan for Space Activities, which relies on input from ministries, industry, research entities and other stakeholders of the space sector. Public and private actors jointly revise the plan regularly.

1.1.2.3 Short term changes expected for the Swiss Space Office

Switzerland is a founding member of ESA, but national institutions were implemented before accession to the Agency's Convention in 1975. An Advisory Committee on Space Affairs was created in 1963 to advise the Federal Council on all issues relating to the exploration and utilization of space. Following

institutions comprised the "Interdepartmental Coordinating Committee for Space Questions" (IKAR) created in 1992 and the Swiss Space Office (SSO), created in 1998, within the Swiss Science Agency of the Department of Home Affairs. In 2000, the Federal Government was given competence for space matters (instead of the Cantons) under the revised Swiss constitution.

Since 2004, SSO has been part of the State Secretariat for Education and Research (SER), which also includes the Federal Office for Education and Science and the State Secretariat for Science and Research. SSO implements the space policy defined by the IKAR on the basis of recommendations from the Federal Space Affairs Commission composed of representatives from space research institutes and industry. Its core function is to manage national participation to ESA as no significant space activities are implemented at national level. The Space Office is the core of the Swiss delegation to the ESA Council and its sub-committees. For this mission, it relies on specialists from the Federal Department of Economic Affairs (FDEA), the Federal Department of Defence, Civil Protection and Sport (DDPS) as well as members of the scientific community and organizations of users of space data.

In 2013, the SSO will be attached to a new Ministry in charge of Economy, Research and Education. While this should not change its overall mandate, the SSO envisages conducting more R&D activities nationally in order to better prepare its industry to ESA programme.

Administrative Organization of Swiss Space Activities

Organization	Place in Government	Major Activities
State Secretariat for Education and Research (SER)	Reports to the Federal Department of Home Affairs (FDHA)	Implements and manages the space programme through the Space Office. 100 staff members.
Swiss Space Office (SSO)	Reports to the SER	Implements the space policy and conducts space research in selected areas. 10 staff members.
Federal Space Affairs Commission (CFAS)	Reports to the Federal Council	Advises the Federal Council, which determines the space policy. The CFAS also commands two sub-committees: The PRODEX committee and the technology policy committee. It is composed of one president and 14 members, nominated by the Federal Council.
Interdepartmental Coordination Committee for Space Affairs (IKAR)	Reports to the SER	Prepares the official positions of Switzerland regarding space matters and ensures the coordination between the different departments in charge of space.
Swiss Academy of Sciences	Reports to the SER	The Committee on Space Research coordinates and stimulates space research.

1.1.2.4 Finland manages space activities as part of a global R&D approach

Finland got full membership of ESA in 1995 after being an associate member since 1987. TEKES, the Finnish Funding Agency for Technology and Innovation, has been responsible for coordinating and financing the country's participation in ESA, including scientific instruments developed in national projects for ESA programmes. Space activities are linked to other technology areas of TEKES. The Agency has a central role in technology and innovation policy making, promoting the technological competitiveness of the Finnish industry and the service sector. Its funding comes from the Ministry of Employment and Economy. TEKES defines its own strategy and operates in autonomy. In 2010, for example, it decided that funding will increasingly be allocated to start-ups that seek growth in internationalization. However, it follows the guidelines of the Government's policy (a strong focus on SMEs and moderate funding for projects of large companies; further investment in start-up

companies) and consults with the business and research communities to define R&D areas to support. TEKES' mandate is to fund risky projects that create know-how and innovations. It selects itself the projects to be financed and identifies strategically important areas of R&D together with the business community and researchers. In 2010 TEKES gave funding decisions regarding 1 896 projects for an amount totalling €633 million.

The Finnish Space Committee, also attached to the Ministry of Economy, is responsible for formulating the national space policy, which is then submitted to the Ministry for approval and financing. It operates as an advisory body that combines the views of the various administrative branches. The Committee makes propositions on matters related to space research, education and industrial development, exploitation of knowledge derived from space activities, and national and international cooperation.

Administrative Organization of Finnish Space Activities

Organization	Place in Government	Major Activities
Technology Development Center of Finland (TEKES)	Reports to the Ministry of Employment and the Economy	TEKES is the Finnish R&D Agency, established in 1983. It finances most of the Finnish space programme, and coordinates activities within the ESA. TEKES is also responsible for the coordination of bilateral activities and EU Space Policy in Finland. 400 staff members, including 15 for space.
Finnish Space Committee	Reports to the Ministry of Employment and the Economy	The Finnish Space Committee, established in 1985, prepares and monitors the execution of the National Space Strategy.
Academy of Finland	Reports to the Ministry of Education and Culture	The Academy of Finland finances space research programme in coordination with TEKES.
Finnish Meteorological Institute	Reports to the Ministry of Transport & Communications	Represents Finland in Eumetsat.

1.1.3 Governance of space activities in Luxembourg

1.1.3.1 Supervision of the national space programme

Space is usually managed in Europe by the Research/Education ministries as part of their wider science and research mandate. This is the case of leading national space programmes (such as France, Italy, Spain…) and of the majority of ESA Member States including two of the comparison countries (Austria and Switzerland). This is also the case of Luxembourg.

When space began generating increasing market related opportunities and became an important economic sector, several European Governments decided to shift the overall supervision of space activities to Ministries of Economies/Industry affairs to support the economic development of their space sector. This has been the case of Germany, the Netherlands and the UK. Three of the four countries of the comparison are in this case: Norway, Finland and soon Switzerland.

Many European countries still keep the supervision of space-related affairs to Education & Research but with increasing links with Economic & Trade departments as part of joint task forces or committees.

Such links are already well established in Luxembourg, either directly through the Ministry of Economy's participation in the Consultative Working Group or indirectly via Luxinnovation's participation in the implementation of the National Action Plan in Space Science & Technology.

Administrative Organization of Space Activities in ESA's Member States

Country	Implementing organization	Space Agency	Ministry(ies) of Supervision
Austria	FFG-ALR	Yes	Transport, Innovation & Technology; Economics, Family & Youth
Belgium	BELSPO	No	Prime Minister
Czech Republic	CSO	No	Education, Youth & Sports
Denmark	DTU Space	No	Science, Technology & Innovation
Finland	TEKES	No	Employment & the Economy
France	CNES	Yes	Higher Education & Research; Defence
Germany	DLR	Yes	Economics & Technology
Greece	GSRT	No	Education
Ireland	EI	No	Jobs, Enterprise & Innovation
Italy	ASI	Yes	Education, Universities & Research
Luxembourg	Luxinnovation	No	Higher Education & Research
Netherlands	NSO	Yes	Economic Affairs, Agriculture & Innovation
Norway	NSC	Yes	Trade & Industry
Portugal	FCT Space Office	No	Science & Higher Education
Spain	CDTI	No	Science & Innovation
Switzerland	SSO	No	now Education & Research, soon Economy, Education & Research
Sweden	SNSB	Yes	Education & Research
United Kingdom	UKSA	Yes	Trade & Industry

1.1.3.2 Consultation with other national stakeholders

The contribution of public and private stakeholders to the national space policy is common practice. The recent French national strategy (March 2012) and the UK national space plan (2010) have all been completed through extensive consultation with Government and private sectors directly or indirectly involved in space activities. This has been also the case of the Norwegian Long Term Space Plan.

Luxembourg is in line with this practice: MESR has initiated the setting up of a Working Group composed of representatives of the State administration, industry and public research to draw up the National Action Plan in 2005 and to prepare decisions regarding Luxembourg's programme subscriptions at the ESA 2008 Ministerial Council. However, the Working Group did not meet on a regular basis and is currently not active.

Thus no permanent working group is currently in place to collect Government departments' inputs regarding space matters. Discussions are reported to be undertaken on a rather informal basis. While benefitting from a certain flexibility this process lacks transparency and accountability. In particular, considering the growth of the public funds invested in space activities to date and in view of the perspective of increasing this budget in the years to come, it is considered opportune to give this Working Group a more formal status. To this respect, Luxembourg may inspire from Finland's Space Committee which acts as the advisory body for coordinating space activities.

1.1.3.3 Implementation of the national space programme

Only a limited number of European countries have set up a dedicated Space Agency to implement national space activities. Considering that for most of them, space activities are undertaken through ESA, there has been limited need to create an Agency with operational and programmatic

responsibilities. In many cases, it has been decided instead to create lower cost structures such as space offices or departments in charge of the administrative coordination of the national participation to ESA. This is the case of Switzerland and Finland, but also of the majority of European countries. Of the four countries of the comparison, only the Norwegian Space Centre acts as a true Space Agency, while the Austrian Space Agency acts more as a space office within the Austrian Research Promotion Agency (FFG).

Share of national expenditures in countries with a space agency (2011)

Country	Civil national budget/total budget
Austria	10%
France	59%
Germany	43%
Italy	43%
Netherlands	33%
Norway	9%
Sweden	22%
United Kingdom	21%

For the implementation of national activities in space in Luxembourg, MESR is assisted by Luxinnovation, a multi-disciplinary agency for the promotion of innovation and research, thus not focusing only on space-related matters.

A few other European countries have chosen to delegate this task to national agencies in charge of innovation and R&D and not space specifically. For the countries of the comparison, this is the case of Finland with TEKES and more recently with Austria with FFG. This is also the case of Spain with the Centre for the Development of Industrial Technology (CDTI). It has however to be underlined that these agencies have broader mandates not comparable to Luxinnovation's mission.

1.1.3.4 ESA Delegation

Nine persons participate to Luxembourg's delegation to ESA: four from the MESR, two from Luxinnovation and three from other Government departments. In terms of full time equivalence this amounts to four persons.

Austria has 6 delegates to ESA, all from the FFG. A member of the FFG Management Board and the Head of the Space Agency (ASA) are representatives to the ESA Council. All other delegates come from the ASA and represent Austria at the various ESA Boards and Programme Committees according to their fields of competences.

The Swiss delegation is larger and more diversified. If the SER's Swiss Space Office is the core, the delegation also relies on specialists from the Federal Department of Economic Affairs (FDEA), the Federal Department of Defence, Civil Protection and Sport (DDPS) as well as members of the scientific community and organisations of users of space data. In all, Switzerland has 17 delegates to ESA, of which 9 from the SER, participating to 20 ESA specific committees and councils.

1.2 LUXEMBOURG'S NATIONAL SPACE PROGRAMME

1.2.1 The national space policy

If the Government decision to create in 1985 the national satellite operator SES represents the first step of Luxembourg in space, the true development of satellite R&D activities started in 2000 when the country joined ESA as a cooperating State on the ARTES programme (dedicated to satellite communications), followed by full ESA membership in 2005.

The decision to develop the media and communications sector in the 1980s with the creation of SES was clearly motivated by the ambition to reduce the economic dependency on the iron and steel industry. Very similar objectives now drive the development of space-based capabilities, i.e. diversifying the national economy now dominated by financial services.

The national space plan, first adopted in 2005 at the occasion of ESA accession, and renewed in 2008, lays out Luxembourg's space policy. It highlights the national objectives, strategy and priorities in space taking into account SES' legacy and the national research, technological and industry capabilities. The four strategic objectives assigned to the national space programme are:

- to contribute to the diversification and sustainability of economic activities in Luxembourg;
- to consolidate and valorise the existing competencies in the domain of medias & communications;
- to contribute to reinforce the competitive position of industry and public research organizations in the space sector;
- to develop Luxembourg's space sector skills and join international networks.

To pursue its objectives, Luxembourg's space programme relies on three key pillars: 1) the national participation to ESA, 2) national activities and 3) international cooperation. Priorities and nature of activities have evolved over time as the national industry gained experience with space activities.

ESA programmes have been the main vehicle used to develop space capabilities in Luxembourg since it became a full member in 2005.

Beyond the participation in ESA's mandatory and optional programmes, Luxembourg's collaboration with ESA has relied on specific measures. An Industry Incentive Scheme was put in place between 2005 and 2011 to support Luxembourg's entry into ESA. The Incentive Scheme is a transitional measure defined in the Treaty for the Accession of new Member States to the ESA Convention. The Incentive Scheme had as its objective to prepare Luxembourg entities to integrate ESA regular programmes through dedicated preparatory activities initiated through calls for ideas.

National activities have been set up to support Luxembourg entities in the development of their space capabilities. It relies on two instruments:

- In 2006, the Government decided to set up LuxLAUNCH, a support programme aimed at preparing national actors for their future space activities. LuxLAUNCH consists in small scale preparatory studies (6 months, maximum of €150,000) helping industry and research organizations to identify market opportunities in space based applications. Studies are performed in collaboration between national players. Up to 6 studies are funded per year selected through calls for ideas.

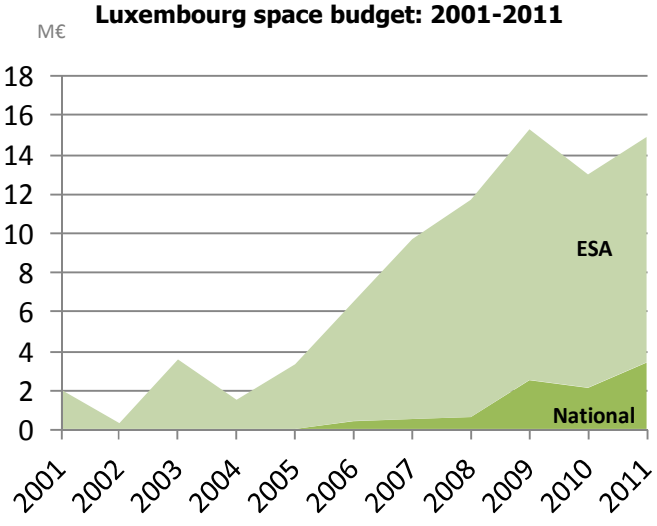
- In 2009, the Grand Duchy and ESA signed an agreement under which ESA supports and hosts, on behalf of the Luxembourg Governement, a national space programme (the so-called Third Party programme). The objective of the programme is to complement already existing activities (the Incentive Scheme, LuxLAUNCH) through additional resources to reinforce the competitiveness and space capabilities of Luxembourg based companies. Considering the technical and management skills associated to the setup of a national space programme, it was considered more efficient to delegate this role to ESA and to tap its extensive expertise. As such, ESA plays the role of Luxembourg's Space Agency managing funds and activities of the national space programme.

Finally, **international partnerships** are also intended to complement ESA and national activities. Agreements have been signed with France, furthermore Luxembourg companies and research entities have developed partnerships with DLR, JAXA and the Canadian Space Agency. Particularly strong relationships have developed with Germany which seems a natural partner due to existing partnerships in other sectors and relationships between Luxembourg and German space industries. Smaller European countries (such as Belgium, Switzerland) also offer interesting partnership opportunities.

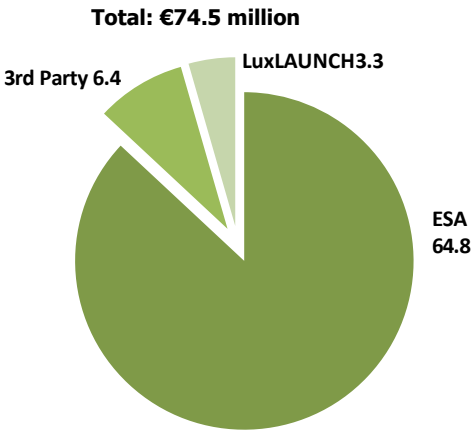
1.2.2 Luxembourg's space budget

Between 2001 and 2011, the Luxembourg Government space budget (i.e. funding to ESA and national civil activities) totalled €74.5 million. Annual funding increased from €3.3 million in 2005, the year of accession to ESA, to just below €15 million in 2011. Luxembourg space budget is planned to pass the €15 million level in 2012. Spending is essentially directed towards the ESA programmes which concentrate 87% of Luxembourg's space investment since 2005 (€65 million), the remaining 13% being dedicated to national activities pursued through the Third Party programme (€6.4 million) and LuxLAUNCH (€3.3 million).

Luxembourg space budget: 2001-2011



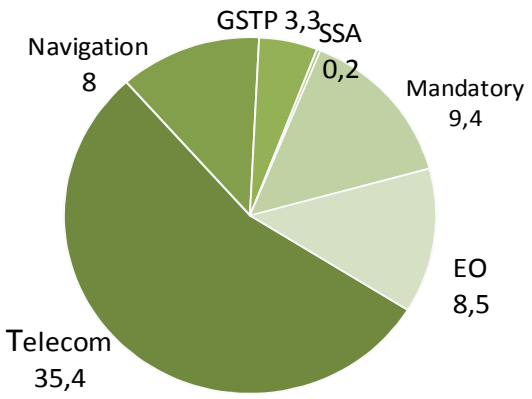
Breakdown of space budget: 2005-2011



90% of Luxembourg's contributions to ESA have been directed to optional programmes, a ratio higher than the average of other new ESA Member States. In line with the national priorities and industry capabilities the investments have been essentially directed towards application programmes and more particularly the ARTES (Telecom) programme. Earth observation and navigation follow with respectively 13% and 12%.

Luxembourg's commitments to ESA: 2005-2011

Total: €64.8 million



Luxembourg's Main Commitments to ESA Programmes

Programme	Application domain	Value in millions of €
ARTES 7 (EDRS)	Satellite communications	16.2
ARTES 11 (Small GEO)	Satellite communications	12
ARTES 3, 4 and 3-4	Satellite communications	10.4
ARTES 5	Satellite communications	5.8
Galileo	Satellite navigation	5
EOEP 2 & 3	Earth observation	5
GSTP 4 & 5	Technology development	5
ARTES 20 (IAP)	Integrated applications	4
ARTES 21 (SAT-AIS)	Satellite communications	3.9
GMES (GSE & GSC)	Earth observation	3.7
Science	Space science	3.7

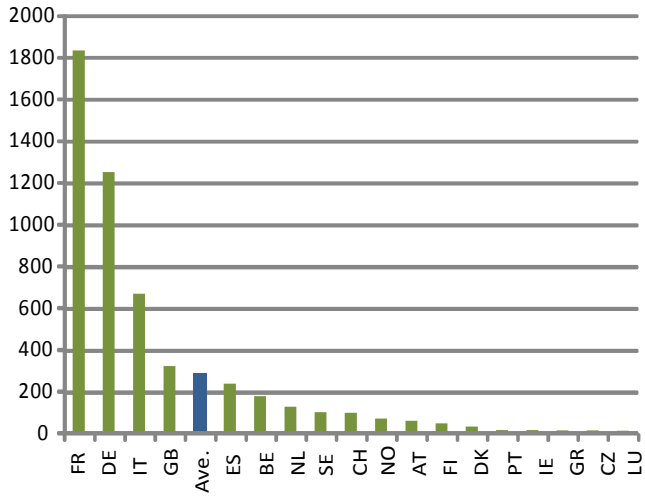
1.2.3 Luxembourg's positioning with respect to ESA Member States

1.2.3.1 Overall funding level for space activities

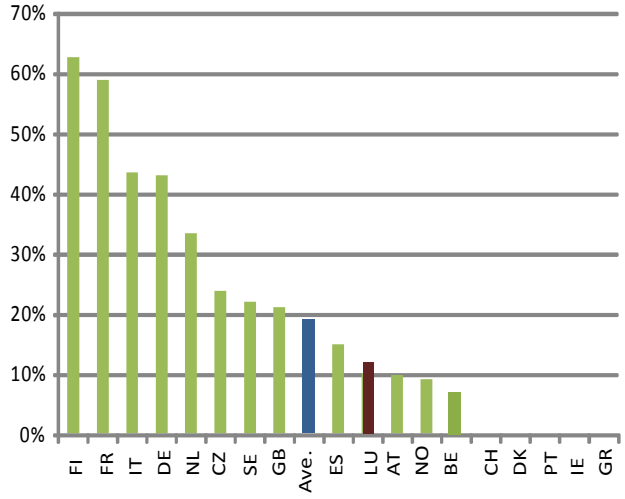
Luxembourg space budget is aligned with those of Member States which recently joined ESA (i.e. Portugal, Greece, and the Czech Republic) varying between €11 million to €16 million. If its budget is far below the average of ESA Member States in absolute terms (€283 million), Luxembourg positions itself at the higher end of the scale when considering the economy and population of the country, thus underlining the already significant financial effort committed by the Grand Duchy.

- It ranks 4th among ESA Member States regarding space budgets as of GDP (0.03%), just behind the three largest ESA contributors that also dedicate the largest share of their GDP (France, Germany and Italy). The average European ratio is 0.025%.
- In addition, Luxembourg is the Member State who spends the most on its space programme per inhabitant (30€), before France and far ahead the European average (around 9€).

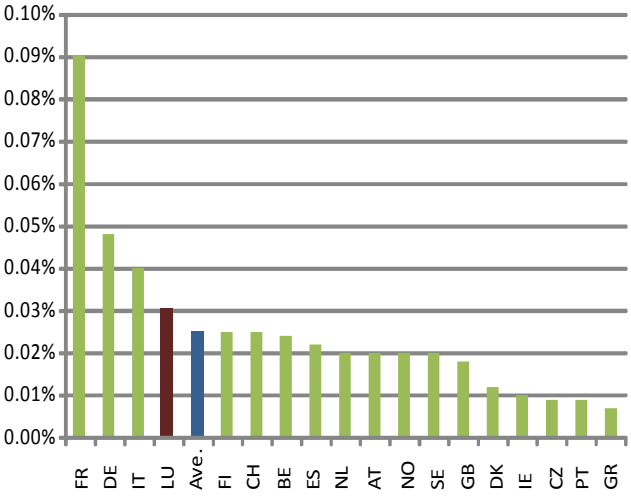
ESA Member States space budgets, 2011 (M€)



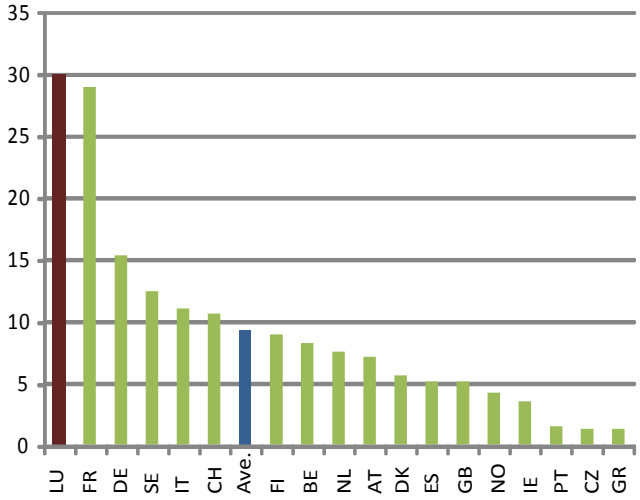
National programme as a % of total space, 2011



Space budget as a % of GDP, 2011



Space spending per inhabitant (€)



1.2.3.2 Funding of national space activities

The proportion of funding dedicated by Luxembourg to national activities is significant when compared to other Member States. New Member States, except the Czech Republic, do not undertake national activities and some older Members States dedicate less than 10% to non-ESA activities (Switzerland, Belgium and Norway). At 13%, the share of the national programme in Luxembourg is intermediate between Austria and Spain and not far from the European average (19%).

Only four of ESA Member States dedicate over 40% to their national programme, of which three are large historical space countries: France (59%), Italy (43%) and Germany (43%).

Finland is an exception in Europe with a strategy since 2005 to give priority to national activities (68%) with constant total funding for space (€50 million on average per year).

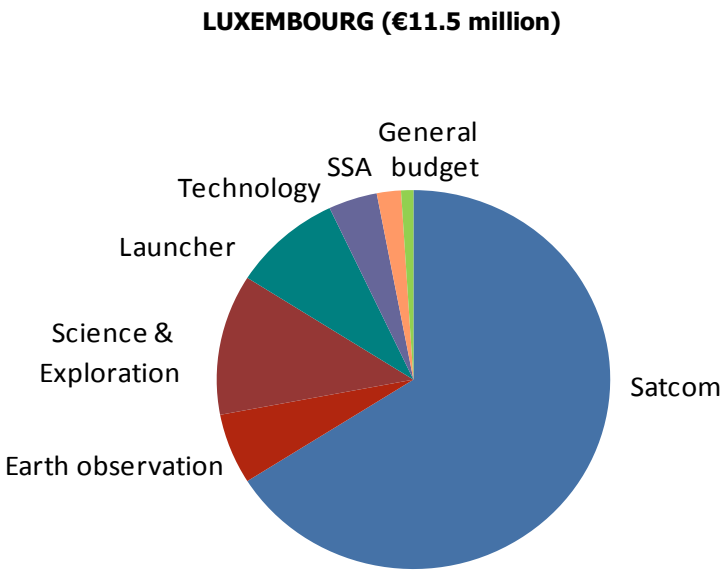
1.2.3.3 Funding of ESA activities

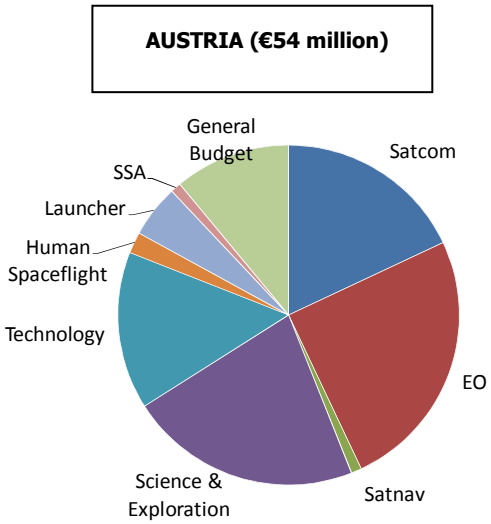
Luxembourg's funding of ESA activities is highly concentrated on three programmes realizing 85% of its contributions since 2011, all application-driven: satellite communications, earth observation and satellite navigation. Most ESA Member States have a wider spread distribution of funds within ESA programmes. As illustrated in the graphs next page, three of the four countries of the comparison spend their ESA allocation into more programmes - usually 6 to 7. Finland is an exception with similarities with Luxembourg as almost all of its funds to ESA are dedicated to three programmes.

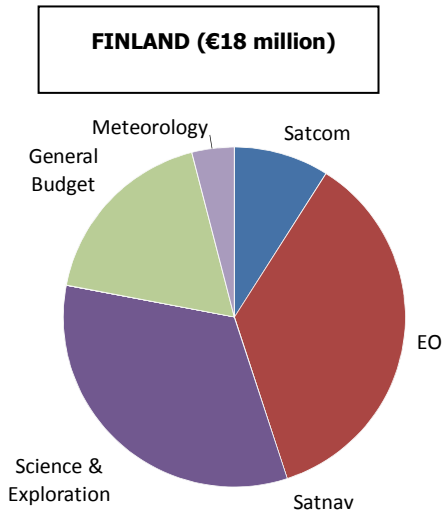
The predominance of satellite communications in Luxembourg funding is another particularity; it concentrates alone 58% of ESA funding. This is a unique case among ESA Member States. For the countries of the comparison the first programme in spending does not exceed 36% of overall allocations (the case of earth observation for Finland). Switzerland has the most spread spending amongst the four countries with the first application domain (science & exploration) representing 19% of its allocation to ESA.

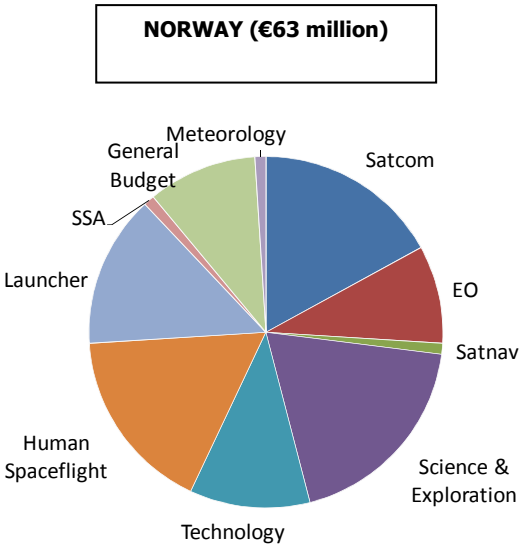
Luxembourg's spending focus on satellite communications obviously reflects the structure of its industry, the strategic importance of satellite communications for the country due to the presence of SES and the willingness to leverage on this company's leadership position in the satellite communications market to build additional national capabilities. It also reflects the predominance of two companies in ESA activities, SES and LuxSpace, as further shown in the Part 2 of this report.

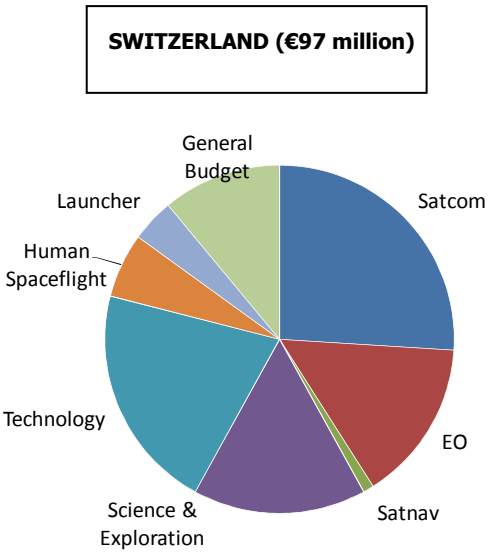
Contribution by country to ESA by application (2011)









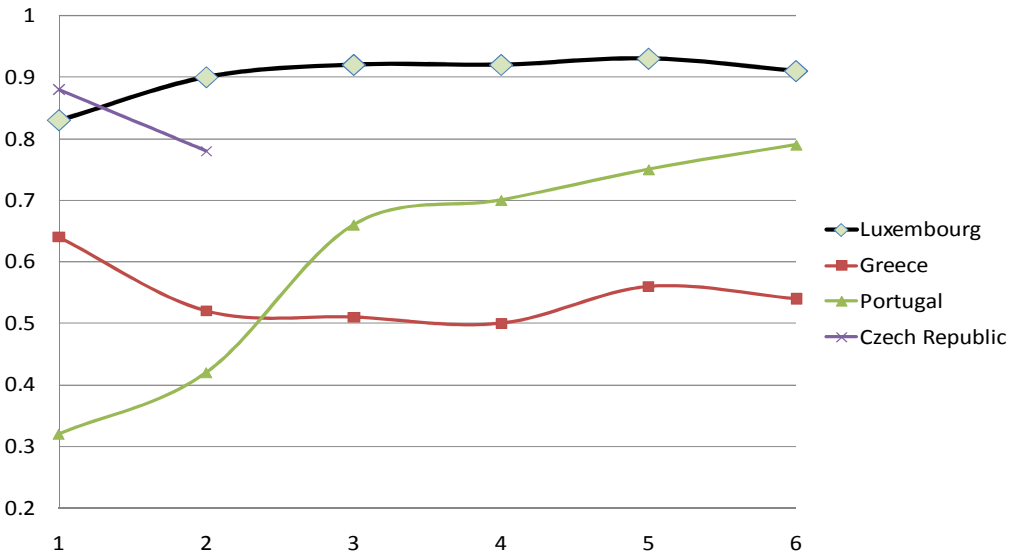


1.2.3.4 Geographical return rate

Luxembourg records a high geographical return rate from its funding to ESA: between 0.9 and 0.95 since 2007, thus topping the return rates of other new Member States. It should be noted however that this global return rates hide strong discrepancies according to funding areas: a high return rate for satellite communications programmes (over 1), a growing return rate for earth observation (now around 0.6) and return for science illustrating the difficulties to position national players in the large science programmes of ESA.

Luxembourg geo-return coefficient, 2005-2011

New Member State geo-return coefficients (years since ESA membership)



1.2.3.5 The Third Party programme

Luxembourg's Third Party programme with ESA is unique as there is no other example of a similar framework agreement between ESA and a Member State for the management of the national R&D programme. Some particular initiatives have been put in place for targeted projects including Spain's SEOSAT programme for which Spain signed with ESA a Third Party contract according to which ESA supports the development of the Spanish national EO satellite system. However, such initiatives remain focused on one specific mission and do not consist in the delegated management of national space activities.

Luxembourg's Third Party programme with ESA has allowed developing initial capabilities nationally with the technical support of an experienced Space Agency. It is suited to the R&D needs of Luxembourg in space, especially as national capabilities will have to mature to be increasingly part of the European space industry.

Third Party programme with ESA Member States (2000-2011)

Country	Programme	Description
Luxembourg	Support for national programme implementation	Agreement signed in June 2009 for ESA support to Luxembourg's national programme.
Spain	SEOSAT implementation	Assistance of ESA to the implementation phase of a Spanish national earth observation satellite and its ground segment, for which funding is provided by the CDTI. The contract was signed in Oct. 2006.
	2003 Taxi Flight	Commitment of Spain for the financing of a taxi flight to the ISS in Spring 2003.
Netherlands	Dutch subsidy for ESI (Embedded System Institute)	Funding provided by the Dutch Ministry of Economic Affairs under the frame of a subsidy agreement signed in Dec.2003.
	Dutch Soyuz mission	Financing of a taxi flight to the ISS as expressed in the agreement between ESA and the Government of the Netherlands signed in March 2003.
	Glovebox Technology Centre	Implementation of the Glovebox Technology Centre funded by the Dutch Ministry of Economic Affairs.
Italy	ASI Science Data Centre	Funding provided by ASI since 2000 for a science operation, data processing and data archiving centre located at the ESA site of ESRIN.
	2005 Soyuz mission	Soyuz flight in 2005 financed by the Italian Air Staff and the Region Lazio.
Germany	SDS activities (earth observation)	Funding providing by DLR under the terms of a bilateral contract signed in Oct. 2010.

1.3 LUXEMBOURG'S SPACE PROGRAMME IN THE NATIONAL POLICY CONTEXT

1.3.1 Alignment with general policy objectives

Luxembourg Government's current policy priorities must be seen in the wider context of the economic and financial crisis impacting the Euro zone. In 2010 the European Council adopted the Europe 2020 Strategy[2], successor of the Lisbon strategy, to help the EU and its Member States to respond to and emerge from the crisis. The Luxembourg Government has aligned with EU objectives and identified the following domains of national priority[3]:

- a well functioning and stable financial sector;
- improving conditions for innovation and R&D;
- achieving objectives in the area of climate change and energy;
- promoting employment and ensuring full utilisation of the economy's labour potential;
- improve the contribution of the education system to human capital building;
- reforming the pension system;
- promoting social inclusion, essentially by reducing poverty.

These global policy objectives present some connections with the national space programme, including:

- as an R&D intensive sector, space activities contribute to innovation and the emergence of new technologies. They also often act as a catalyst for boosting the development of R&D infrastructures. Luxembourg has to catch up in terms of R&D effort: 1.66% of the national GDP has been put into R&D in 2009 (€620 million)[4] compared to 2% for the average EU-27.
- when considering that most of space related funding is R&D focus, Government allocations to space represents 1.8% of total national R&D spending which is higher compared to the four countries of the comparison.

Space budget as a % of national R&D (2011)

Country	Space in %
Luxembourg	1.8%
Austria	0.7%
Finland	0.7%
Norway	1.2%
Switzerland	0.96%

- public research institutions (CRP-Gabriel Lippmann, CRP-Henri Tudor and the Uni.lu) have started space-related research activities aiming at stimulating synergies with other existing fields of research such as materials and nanotechnology.

[2] For more details see: http://ec.europa.eu/eu2020/index_fr.htm
[3] *Luxembourg 2020 – National Reform programme for the Grand-Duchy of Luxembourg under the Europe 2020 strategy*, Observatoire de la compétitivité du Grand-Duché de Luxembourg, 2011
[4] *Rapport d'Activité 2011*, MESR, 2012

Environment and climate change present interesting potential synergies as well. Established methods for the monitoring of environmental parameters such as remote sensing in various bands of the electromagnetic spectrum, earth observation and meteorological data collection heavily rely on satellite data. Both the public and the private sectors of Luxembourg have started activities in the fields of GIS and EO data services.

With regard to the country's plan to ensure full utilisation of the economy's labour potential, the Luxembourg space sector has grown to about 500 people despite difficulties in recruiting locally.

1.3.2 Alignment with thematic policy areas

1.3.2.1 Foreign Affairs – Defence

Luxembourg defence is structured as a land force of 1000 personnel. An air component has been created for the multinational operation of one A400M aircraft. The core capability of the army is represented by reconnaissance units equipped with protected vehicles and increasingly complex intelligence, surveillance and reconnaissance capabilities. There are plans to create a tactical UAV capability complementing the observation capabilities of reconnaissance units. The operation of current and future capabilities requires access to interoperable, wideband and long distance communication means.

Defence expenditure amounted to more than €200 million in 2011 (0.6% of the GDP). The share of investment in total defence expenditures averages 25% in recent years.

The Grand-Duchy is a founding member of the EU and NATO and adheres to the policies shaped in these frameworks. In addition to the deployment of forces for EU and NATO operations, Luxembourg has since 2009 started to provide telecommunications solutions in C- and Ku-bands procured through SES to partners within these frameworks or an a bilateral basis. Likewise, a multinational MOU has been signed in early 2012 between Canada, Denmark, Luxembourg, the Netherlands, New Zealand and the United States regarding access to X- and Ka-band capacity on the US DoD constellation of WGS satellites. Luxembourg's share in the programme is $37 million over the duration of the MOU (20 years).

1.3.2.2 Foreign Affairs - Cooperation and humanitarian development

Luxembourg has a long-standing history in humanitarian development. Under the auspices of the Ministry of Foreign Affairs, the Department of Cooperation and Humanitarian Development is a global player leading actions of development in Africa, Central America and South East Asia. Bilateral cooperation agreements exist with 10 countries (Burkina Faso, Cap Verde, El Salvador, Laos, Mali, Namibia, Nicaragua, Niger, Senegal, and Vietnam) and cover a wide range of domains including agriculture, education, environment, health, and water supply & management.

It is in this context that Luxembourg has launched in 2011 the *emergency.lu* platform, a rapid response communications solution for disaster relief and humanitarian operations. *emergency.lu* stands for an initiative in which the Luxembourg Government has reserved permanent satellite communications capacity from SES in order to be responsive to major disasters or humanitarian crises. In case of such an emergency, terminals procured by HITEC can be deployed anywhere on the planet within 12 hours to provide rapid communication capability. The total investment for *emergency.lu*

amounted to €17.2 million. Today the main user of *emergency.lu* is the UN. More advanced services to remote areas, like telemedicine, are planned for the future.

1.3.2.3 Information and Communications Technologies

In order to diversify further its industrial base, Luxembourg is currently fostering its capabilities in the domain of information and communications technologies (ICT). The country's strategy in the domain includes in particular the following 5 opportunities[5]:

- Media and entertainment: establishment of a digital media content platform in Luxembourg. As media content is digitised and new formats emerge, all media and entertainment businesses need to ensure that their content is readily real time. Making content available on immediate notice requires an efficient and secure platform and large data centres for content storage.
- Advanced financial services: pioneering the future of the financial asset management and e-fund industry through automated processes in order to secure productivity gains and tighten risk management. Accelerating the adoption and deployment of innovative payment methods such as e-money and m-payments (mobile payments).
- Energy and smart grid: promoting ICT embedded electricity distribution systems to manage the distribution and consumption of energy in a smart way.
- Cloud computing: providing transparent on-demand infrastructure, applications and services from a remote platform to be used by the customer on a pay-per-use basis.
- Digitised workflows: digitisation of the whole information management value chain for a very wide range of official, legal and administrative uses (e-Government, e-Commission).

Clearly, SES is in the position to play a significant role in the domain of media and entertainment. A very large amount of digital media content is broadcasted by this company. SES may therefore have the possibility to leverage content providers to store and distribute their data using a data centre situated in Luxembourg.

1.3.2.4 Maritime Affairs

Luxembourg is within less than 300km distance of three world-leading ports: Rotterdam, Antwerp and Zeebrugge. Rail, rivers and roads quickly link the country to the North Sea. Thanks to a strong political will to diversify the economy Luxembourg has become an attractive location for shipping businesses. A broad range of companies active in the maritime industry have established in the country: services range from shipping to dredging, yachting and ship management, consulting, legal, insurance, logistics and finance. About 240 merchant ships of 1.8 million of gross tonnage are registered today in Luxembourg. The Luxembourg Maritime Act of 1990 provides the general legal framework for all shipping matters in the country. Luxembourg is a full-fledged member of the European Maritime Safety Agency (EMSA) and the International Maritime Organization (IMO). Its maritime legislation adheres fully to international regulatory provisions and is set out in a way to encourage international ship owners to register their vessels in the country.

[5] *Luxembourg : an e-hub for Europe. Opportunities and actions on the horizon 2015*, PwC Luxembourg, 2011

The Ministry of Economy and Trade and the Commissariat aux Affaires Maritimes have been following with great interest the recent development of a satellite-based Automatic Identification System (AIS) allowing to considerably extend the range of coastal-based ship tracking systems. Although the actual tracking of Luxembourg-registered vessels is performed by EMSA, the Government and interested administrations have access to all relevant data in order to be compliant with regulatory obligations. It is in this context that the country currently aims to strengthen its industrial and technological competences regarding AIS. The Government has contacts with SES in the domain of ship communications and LuxSpace has recently built and launched two Vesselsat satellites, the first Luxembourg-built microsatellites carrying AIS receivers for use by Orbcomm.

1.4 LUXEMBOURG'S SPACE PROGRAMME IN THE INTERNATIONAL CONTEXT

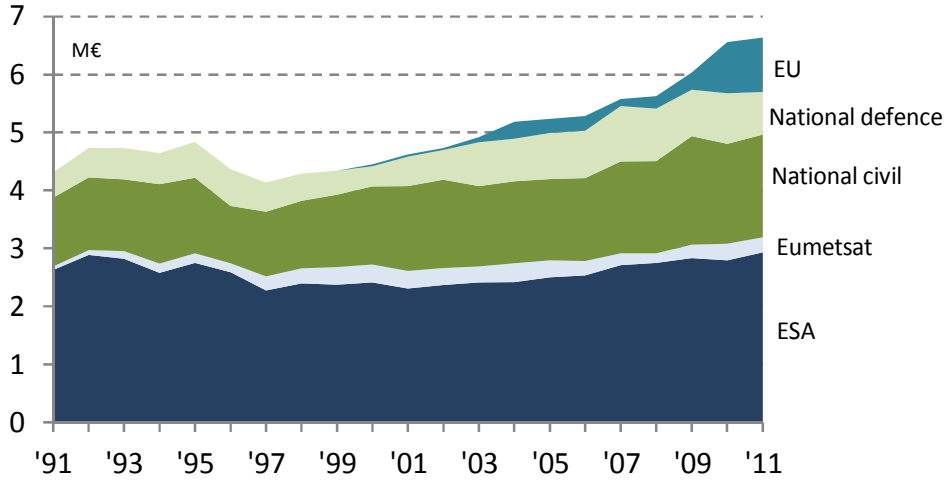
1.4.1 European context

1.4.1.1 Landscape of European space activities

For the last 20 years, the European space sector has had to deal with constant budget control from European Governments. From €5 billion in 1991, European Government funding for space activities (including defence) has increased to €6.8 billion in 2011. That is a 2% average growth per year in current Euro currency, meaning a flat investment after adjusting for inflation which was 1.9% during the same period in Europe[6]. Actually, net growth over the 20 year period has been generated only in the last 3 years with €1.2 billion of additional funding committed by European institutional stakeholders between 2008 and 2011. This increase has essentially come from the EU to fund Galileo deployment and national civil programmes.

While European investment in the early 1990s was made by only 14 Governments (i.e. ESA and Eumetsat Member States), the landscape has considerably enlarged in 2011 with 30 European Governments investing in civil and military space plus the European Union. However, the expansion of the number of countries/organisations involved in space activities in Europe has not been translated into a budget increase.

European Government budgets for space: 1991-2011



The European public debt crisis in 2011 has created unparalleled tensions over the Euro zone, its economy and public finances and has placed the European economic outlook in an unusual high uncertainty. While sustained investments may be maintained to execute commitments in certain areas (such as Galileo, GMES and Ariane-5), a decline in space budgets is anticipated until 2015 as all European countries have announced severe cuts in their public spending. Space expenditures should recover growth after 2015 with the stabilization of public finances, the launch of new procurement/R&D for next generation defence and civilian programmes. There is an opportunity for Luxembourg to behave in a counter-cyclic way and to increase its effort in the space domain.

[6] Source: European Central Bank, Harmonized Index of Consumer Price (HICP).

1.4.1.2 The European Space Agency

With 53% of European public investment for space in the last 20 years, ESA has been the cornerstone of the European space programme funding most of space R&D. This share has been decreasing over time due to a flat budgetary situation (basically no growth in allocations over 20 years when excluding EU's contributions) and increasing investments at national levels and from the EU.

Historically, Member States' contributions made at minimum 90% of ESA overall funding. This situation has changed recently with the increase of third party contributions, in particular those from the European Commission to fund GMES and Galileo. In 2011, third party contributions reached 18% of ESA's budget with a threefold increase since 2006.

ESA undertakes a diversified portfolio of programmes and invests in all applications areas. Earth observation has become the Agency's largest domain of investment ahead of launchers and science. Altogether, these three applications consume half of ESA budget.

In the years to come the European Space Agency will be confronted with new challenges of different kinds:

- Enlargement of its membership, getting closer to that of the European Union. This entails new challenges in terms of decision-making mechanisms and industrial policy (potential entry of countries with lower production costs).
- Increased cooperation with the European Union, posing major questions for mid- and long-term evolution, from changes in financial and procurement mechanisms to future positioning with regard to the European Union framework. ESA plays an increasing role in defining and implementing space systems to support the introduction of operational space-based services.
- The tough economic context in which the 2012 Ministerial Council will take place. It is expected that negotiations will be tight with strict objectives in terms of geographical return. The Council will define future priorities for ESA, and certainly for the European space sector as a whole, for the upcoming three years. The main stake should be launch vehicles, deciding on the Ariane 5 successor taking into account Member States' different requirements and views. Other topics to be discussed include the European strategy in space exploration, human spaceflight post-ISS and the definition of an optimal model for GMES and Galileo exploitation. Although marginal in funding, space security is a new area of interest for ESA, and the Agency has started cooperation with relevant players in the European civil security and defence communities.

These changes in environment directly impact Luxembourg long-term strategy in space:

- The enlargement of ESA creates more complexity in the Agency's industry policy with the obligation to integrate in its programmes suppliers of the recent entrants. For a country like Luxembourg building its capabilities within a 5-10 year horizon, this means potentially more competition from lower cost countries in some capability areas (especially at the satellite and ground equipment levels which are typical entry points for new ESA Member States). This creates the obligation for Luxembourg to adapt its ESA strategy with respect to the current/future newcomers.

Overview and status of current ESA programmes (2012)

Application	Budget 2011	Last 5 years CAGR	% as of 5 years' total budget	Key programmes and priorities
Earth Observation (including meteorology)	€757 million	13%	17%	ESA earth observation budget grew by 73% between 2007 and 2011. Funding for earth observation should be sustained until 2015 to support GMES, continue the roll-out of the Earth Explorer missions and the development of Meteosat satellites with Eumetsat. The meteorology budget (currently at 3% of ESA total budget) is rising, due to the Meteosat Third Generation (MTG). It reached €96 million in 2011. ESA Member States have agreed to pay about €790 million for the development of MTG, to be launched starting 2016.
Launcher	€613 million	3%	19%	Launcher represents ESA's second budget item with 18% of the Agency's budget in 2011. It had a 3% CAGR over the past five years. More than half of the budget is allocated to Ariane 5 (52% in 2011), but the Future Launcher Preparatory Programme (FLPP) accounts for a growing share (16% in 2011). It is expected that the launcher budget will remain relatively stable in the coming years as the Next-generation Launcher (NGL), intended to replace Ariane 5 by 2025, is only at the preparatory stage.
Science & Exploration	€654 million	6%	19%	Funding includes the mandatory science budget, whose progression was set at 3.5% per year (not adjusted for inflation) at the 2008 Ministerial Council, and the optional Aurora exploration programme. The latter, initiated in 2001, represented an investment of €100 million in 2011, mainly for the ExoMars robotic mission. Funding for science should stabilize in the coming years, while the exploration budget will continue to grow with the development of ExoMars.
Human Spaceflight	€321 million	-3%	10%	Budget for human spaceflight activities is on a downward trend, with -3% CAGR, as the investment is now focused on ISS exploitation (logistic supply with the ATV, Columbus operations, training, and support of astronauts). Funding amounted to €321 million in 2011, or 10% of ESA's budget. The Agency, under pressure from its Member States, has set a goal of reducing its annual expenditures for the space station's operations by 5% through 2015. These savings also intend to maximize the resources available to conduct experiments on the Columbus module. ESA will need €380 million annually to meet its commitments due to ISS lifetime prolongation.
Telecommunications	€339 million	10%	9%	Funding to the ESA Satellite Communications programme has been increasing since 2004 as the Agency entered into a cycle of investment in multiple Satellite Communications activities for both R&D and system development. Its Satellite Communications budget increased from €214 million (6% of total budget) in 2006 to €339 million (10% of total budget) in 2011. Funding is expected to stabilize to fund the completion of current programmes: ARTES 3-4 (products developments), ARTES 7 (EDRS), ARTES 8 (Alphabus-Alphasat) and ARTES 11 (Small GEO-AG1) which consume 75% of Satellite Communications expenditures.

Technology	€129 million	0%	3%	ESA budget for technology accounted for 4% of the total in 2011, at €129 million with no growth over the last five years. Essentially driven by contribution of Member states to GSTP and Prodex programmes. Since 2008, critical technologies have been identified by a task force with the European Commission, the European Defence Agency and industry stakeholders. Micro-electromechanical systems, advanced gyroscopes, small satellite on-board motors, mission-specific integrated circuits, and field-programmable gate arrays are among the featured technologies.
Navigation	€37 million	-36%	7%	Funding decreased significantly in 2011 (€37 million versus over €300 million during most of the previous years) as Galileo now enters into the deployment phase financed exclusively by the European Commission.
Security	€16 million	n./a.	0%	SSA is a new programme created during the 2008 Ministerial council. As for now, the SSA programme is limited to the creation of a coordinated acquisition network out of the existing ground-based radars existing in main European countries (France, Germany and UK). Full operational services will be implemented upon approval at the 2012 Ministerial Council but, due to budget restrictions in most of the European countries, the programme is threatened by lack of financial commitment.

- The increasing cooperation with the EU may lead in the long term to a different positioning of ESA with regard to the EU institutional framework, which poses among others the question of the long term viability of the geo-return model as it is applied today. These potential evolutions impact Luxembourg's strategy with respect to ESA due to a likely more competitive environment and the long-term applicability of the 3rd Party programme as it is implemented today.
- Budget tensions on ESA programmes and likely difficult decisions to be taken at the next Ministerial Council create both challenges and opportunities for Luxembourg. Key programmes with potential vital interest for Luxembourg's space strategy (e.g. AIS, IAP, and SSA) may face uncertain funding decisions that could impede or delay their implementation with significant consequence for the Luxembourg industry. On the other hand, it is also giving Luxembourg the opportunity to take a stronger involvement, or even leadership, in some programmes as other Member States may revise their ambitions downward.

1.4.1.3 The European Union

The EU has been the only public stakeholder in Europe to have significantly increased its financial contribution to the European space sector from almost nothing in 2001 to nearly €1 billion in 2011 driven by GMES and Galileo. Since 2001, EU's cumulative investment in space is estimated at €2.5 billion, which represents 5% of total European funding for space.

The European Commission, through its DG Enterprise and Industry (DG ENTR), has the lead role as regards the policy and regulatory thrust of the European space programme. With the adoption of the Lisbon Treaty the Commission has been vested with the mandate to handle space-related issues as a shared competence with its Member States.

The EU objectives and involvement in space are closely related to the European Space Policy (ESP) as elaborated jointly by the European Commission and ESA[7]. The Commission Communication of April 2011[8] sets out the most recent policy objectives of the EU for space, which is guided by three drivers:

- social: the needs of EU citizens, e.g. environment, humanitarian aid and transport,
- economic: space activities driving economic growth, e.g. knowledge generation, job creation and competitiveness,
- strategic: serving EU's position as a major world player.

Although Galileo and GMES already received significant funding at the development stage, uncertainties remain regarding their post deployment phase, i.e. regarding the funding of the operations. The Commission proposed GMES's operational costs, estimated at €1 billion over 2014-2020, to be funded outside of the Multiannual Financial Framework (MFF)[9]. Negotiations are underway to ensure that operational costs can be covered from 2014 onward.

[7] *European Space Policy*, Communication of the Commission to the Council and the European Parliament, COM(2007)212, April 24, 2007.
[8] *Towards a space strategy for the European Union that benefits to its citizens*, European Commission, April 2011, COM(2011) 152 final.
[9] Council of the European Union, *Multiannual Financial Framework- Interim report on duration, structure and flexibility*, October 2011, 15387/11

On the basis of the ESP, the European Commission investigates other potential areas of involvement in space such as security, space exploration and satellite communications. But securing successful implementation of Galileo and GMES is seen by Member States and other European stakeholders as a "must-have first", before launching new initiatives.

EU potential future areas of involvement in space

Application	Objectives
Space security	Strengthen EU security missions without depending on facilities and services of non-Member States. Develop a European capability for the monitoring and surveillance of its space infrastructure and of space debris. Unify SSA national initiatives into a single European project.
Space exploration	Achieve a common vision and long-term strategic planning for exploration. Potential EU exploration mission to be identified.
Satellite communications	Bridging the digital divide by providing basic broadband to all Europeans as part of the European digital agenda.

1.4.2 Space worldwide

Similarly to Europe, other Governments worldwide have been revising their spending policy in the context of the current economic crisis. While Governments across the world maintained their support investment in space programmes at the start of the crisis that translated into extra allocation of funds through stimulus packages during the last two years (in Europe, Canada, the US...), the growing pressure on public finances indicates that Governments may come back to much more stringent spending with direct consequence on space agencies allocations. This situation has already materialized in the US. In 2011, the US invested $42.5 billion in its space programme (civil and defence), $4 billion less than in 2010.

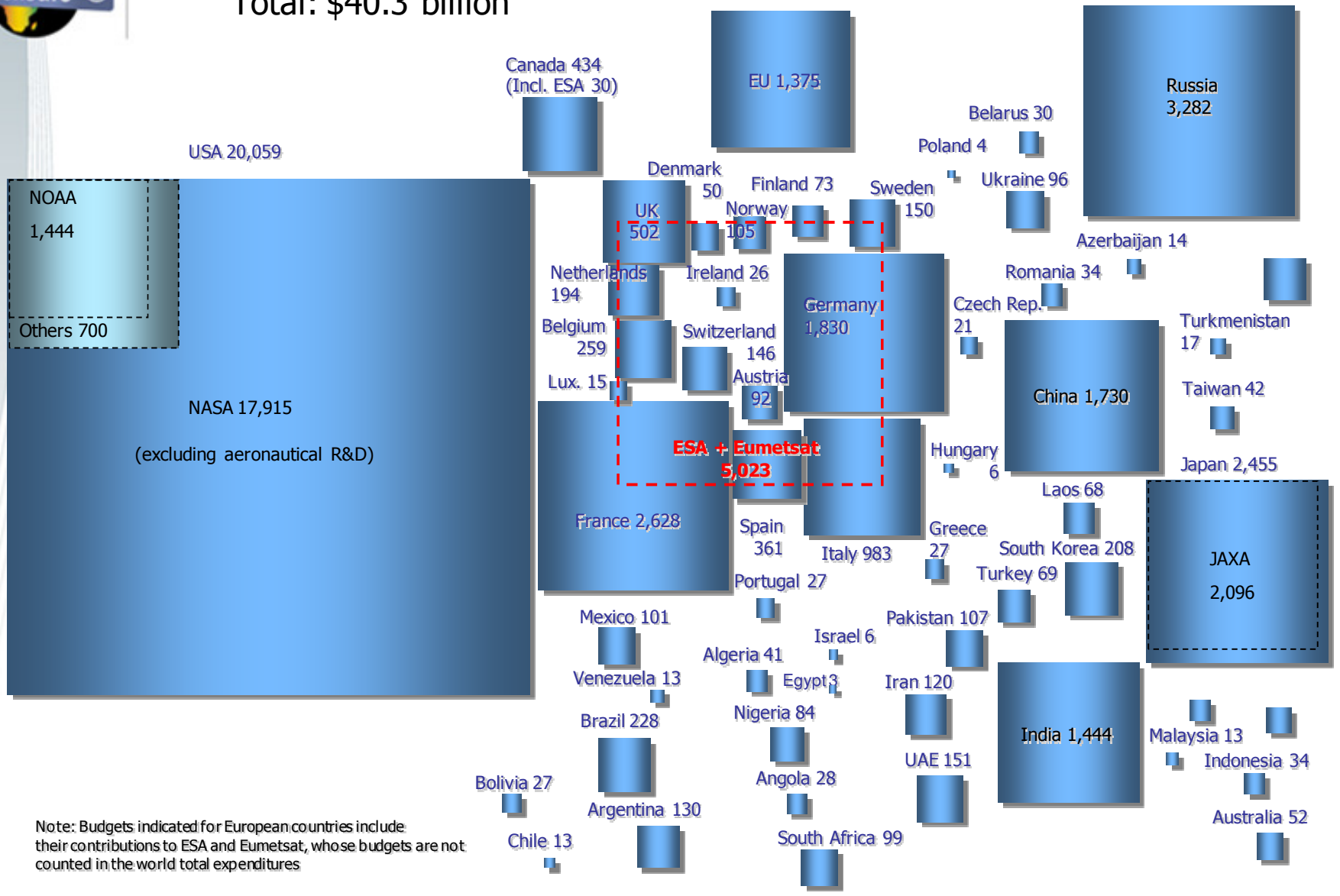
The US space programme now accounts for 60% of global space budgets, a record low (75% in the early 2000s) pulled down by a recent decrease in funding, the emergence of new regional leaders and more generally the multiplication of countries investing in space technologies. In 2011, 53 countries invested $10 million or more in space applications and technologies, compared to 42 countries in 2006 while they were 26 in 2001. The development of a global space programme in an increasing number of countries has been an obvious trend during the past decade as space has become a worthwhile investment for Governments willing to acquire independent assets to help their national social, economic and technological development as well as contributing to their national Defence and security programmes.

Upward investment trends can be observed in four space applications: earth observation (supported by a growing number of players), launchers, satellite navigation and space security. Spending in manned spaceflight and satellite communications is decreasing, while space science and exploration expenditures level off.

Review of key space applications worldwide (civil + defence)

Application	2011 Budget	Change from 2010	Last 5Y CAGR	European share	Main features
Manned Spaceflight	$10.9 B	-6%	1%	4%	Undergoes significant restructuring after termination of the Space Shuttle. The application tends to have very tight budgets, but China is expected to triple funding over the next 5 years.
Satellite Communications	$8.4 B	-10%	11%	17%	Cyclical investment, driven by defence agencies. Now in a downward trend following major procurements from the US DoD.
Earth Observation	$9 B	+16%	7%	21%	Increasing role of emerging nations across all continents. Overall, 50 countries invest in earth observation 74% of the investment is civil-oriented.
Science & Exploration	$6 B	-7%	0%	21%	Flat investment, partly due to budget pressure on NASA's programme. Other leading agencies have growing budgets.
Launchers	$5.8 B	+37%	11%	26%	Budgets continued to increase, fuelled by Russian and European developments.
Satellite Navigation	$3.2 B	+5%	14%	32%	Spending reached an all-time high in 2011 as several GNSS programmes, essentially from China and Europe, ramped up in their development cycle.
Space Security	$2.4 B	+26%	10%	8%	Predominantly a defence activity, largely dominated by the US. Civilian initiatives in Europe (SSA).

World Government Expenditures for Civil Space Programs (2011)
Total: $40.3 billion



Note: Budgets indicated for European countries include their contributions to ESA and Eumetsat, whose budgets are not counted in the world total expenditures

1.5 Observations on the institutional environment for space activities

The space effort developed in Luxembourg since its adhesion to ESA in 2005 is unique under two aspects:

- With a space budget at 0.03% of its GDP, Luxembourg ranks fourth in terms of relative space effort, just behind the three largest ESA Member States (France, Germany and Italy).
- Satellite-related sales of Luxembourg companies contributed to over 4% to the national economy in 2011 (far much higher than the European average of 0.1%). This high proportion of space sales in the GDP of Luxembourg stresses the importance of SES for the Luxembourg's economy.

The changes in the landscape of European space activities will impact Luxembourg's strategy in space:

- **Budget tensions on ESA programmes create both challenges and opportunities for Luxembourg**. Programmes with strategic interest for Luxembourg may face uncertain funding decisions that could impede or delay their implementation with significant consequence for the Luxembourg industry. On the other hand it is also giving Luxembourg the opportunity to take a stronger participation, or even leadership, in some programmes as other Member States may revise their ambitions downward. **The high participation or leadership in one ESA programme of strategic interest for Luxembourg can be considered as an objective of the national space policy**.
- The **enlargement of ESA** creates more complexity in the Agency's industry policy with the obligation to integrate suppliers from new entrant Member States. For Luxembourg that is now building capabilities within a 5-10 year horizon, this entails **potentially more competition from lower cost countries in some capability areas** (in particular satellite and ground equipment).
- The increasing cooperation with the EU may lead in the long term to a different positioning of ESA with regard to the EU institutional framework, which poses, among others, the **question of the long-term viability of the geo-return model and of the long-term applicability of the 3rd Party programme**, this latter issue being of particular relevance for Luxembourg.

In order to respond to these challenges, **Luxembourg should build its future space development plan on a broad consensus involving all stakeholders**. To this respect the consultative working group should evolve into a permanent working party with an advisory role for the Government.

Growth of the national space budget will allow positioning Luxembourg favourably with regard to a reinforced participation or possible leadership in ESA's programmes of strategic interest for Luxembourg thus giving Luxembourg space actors a level playing field for valorising their space capabilities.

With a growing space budget to be managed and more political and technical interfaces to be provided, **there is a need to create a central structure specifically dedicated to the coordination and management of the implementation of all space R&D activities of the country**.

PART 2.

INDUSTRY ENVIRONMENT FOR SPACE ACTIVITIES IN LUXEMBOURG

2.1 STRUCTURE OF LUXEMBOURG'S SPACE INDUSTRY

2.1.1 Satellite value chain in Luxembourg

2.1.1.1 A value chain driven by satellite communications

The value chain generated by satellite systems worldwide is driven by the Governments for all applications except satellite communications. In the case of satellite communications, the ultimate demand for telecom and broadcasting services using satellite systems is nowadays driven by commercial entities such as the incumbent national telecom operators, broadcasters have been privatized in most countries of the world and competing telecom operators and broadcasters have been licensed. This deregulation move in the telecom and broadcasting sectors has created a huge demand for transmission networks, from which satellite technology has been benefiting since the mid-1990s, especially for broadcasting free-to-air and pay-TV.

Luxembourg has been at the forefront of this move in the broadcasting sector with the creation of SES that was instrumental in the development of satellite TV in Europe. From this legacy, the Government of Luxembourg committed to the ARTES (Advanced Research in Telecommunications Systems) programme of ESA before joining as a full member.

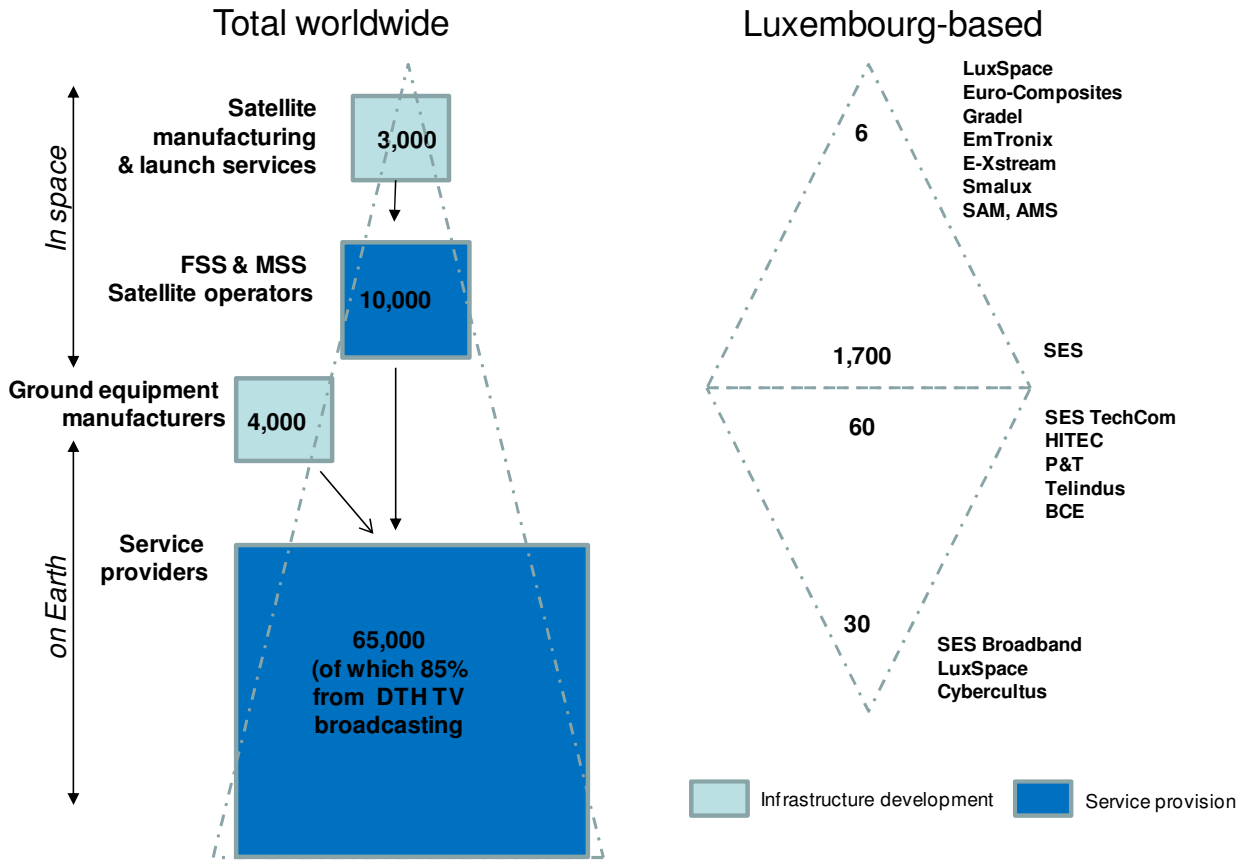
As a result, the satellite value chain in Luxembourg is very much driven by satellite communications with the unique situation that SES developed into one of the world largest commercial satellite operators despite the lack of technology capabilities for satellite systems in the country. This is not the case in the six other countries where large commercial operators have developed (USA, Russia, France, UK, Canada, and Japan), even if these operators do not always buy from the national satellite industry. The two other exceptions (beyond Luxembourg) in the top ten of the commercial satellite operators are Brazil and Australia; in these two countries no satellite industry has developed despite the numerous geostationary communications satellites that have been procured by the national satellite operator over the past 30 years (about 10 units each).

Satellite communications dominates in all stages of the value chain in Luxembourg, from research and technology development upstream to service provision downstream going through ground systems development and operation. The only segment of the value chain that is less satellite communications-centred is the academic sector upstream working on technology development (materials, nanotech, security,..) that is applicable to satellite systems for various applications.

Based on estimates of satellite communications related revenues or contracts for the upstream and downstream parts of the chain with SES in the centre, the study has quantified the value chain in satellite communications for Luxembourg-based entities. The upstream part has been quantified at €6 million in 2011 with less than 10 organizations involved, including public research organizations.

Below SES, five companies have developed an activity in ground equipment and ground service in relation with the operation of satellite systems, in particular a subsidiary of SES, called SES TechCom, the others four being HITEC, P&T, Telindus and BCE. SES is a major customer of most of these telecom service providers whose non-consolidated sales are estimated at €60 million in 2011. Further downstream in the chain, services are developed for users other than SES but based on SES satellites by SES Broadband and Cybercultus. LuxSpace's activity in AIS data sales is the only one independent of the satellite system of SES.

The value chain in satellite communications services
(estimate in M€ for the year 2011)



SES has a unique role in the satellite value chain in Luxembourg as the company is at the same time a global capacity provider and a satellite service provider with several service companies developed over time to address different types of clients:

- SES Government Solutions for government communications
- SES Platform Services for TV broadcasters
- SES Broadband Services for consumer broadband access
- SES Techcom Services for engineering services.

Outside of satellite communications, the four other domains of application of satellite technology that are not military-specific are earth observation, meteorology, navigation and science. They differ from satellite communications on two aspects:

- all four are driven (exclusively or predominantly) by the needs of Governments to fulfil their missions of protection of national assets, infrastructure and population;
- the satellite missions in earth observation, meteorology, navigation and science produces information while a satellite communications satellite is a relay of information in the sky and does not produce content by itself.

For the time being the Luxembourg national capabilities are extremely small in these four areas in both the academic and private sectors because they have not as yet raised enough interest, and correspondingly received a low volume of investment, that has not yet allowed achieving a critical size as it is the case in satellite communications.

2.1.1.2 Mapping of Luxembourg space industry players

About 40 Luxembourg-based entities have received financial support from the Government for satellite technology, systems and services over the past 12 years (2000-2011). Most of the contracts (81%) were placed through ESA as part of the optional programmes of the Agency to which Luxembourg participates. Another part of the contracts (14%) was placed in a national context through three programmes: the Industry Incentive Scheme and the 3rd Party Programme, both managed by ESA, and LuxLAUNCH. The remaining 5% of the contracts were placed through the mandatory programme of ESA.

About half of these 40 entities have been qualified as "active" in space today because they had recent contract activity (2009-2011), pending contract activity or because they have not claimed to be exiting the space business. These 20 active participants to satellite-related activities are very different in size, capabilities and position in the satellite value chain. Only three of them are "pure" players in space (SES, SES TechCom and LuxSpace), meaning that all of their revenues derive from satellite; only one has satellite integration capability for microsatellites in low earth orbit (LuxSpace). Excluding SES and the public research institutes, SES TechCom and LuxSpace do most of the consolidated sales of the space industry in Luxembourg[10]. These two companies are also the only two to have developed a commercial activity related to satellite in the sense that they have customers that are not directly related to Luxembourg Government funding (other satellite operators for SES TechCom, AIS data users (i.e. EMSA and NATO) and Orbcomm for LuxSpace).

There is a strong annual variability in satellite-related revenues, budgets and contracts of Luxembourg-based entities. This is logical for a country with a space technology investment that is quite recent and still limited in volume. As a result, some companies appear as non-active but there is uncertainty whether this non-activity is definitive. Euro-Composites had stopped its space activity in 2011 but has recently revised that decision to exit the space business. It seems that entities are not active anymore in satellite-related activities for two main reasons:

- their parent company located outside of Luxembourg has changed its strategy of presence in Luxembourg and/or its strategy with respect to satellite activities in Luxembourg (e.g. GIM, Altran, ESRI, GFI)
- they entered into bankruptcy or merged with another entity (Plastics Electronics, Satlynx,..).

a) Public research institutes in space

Three public research institutes are involved in satellite-related technology development with industry partners through seven departments, of which two specialize in material engineering (SAM and AMS),

[10] P&T is selling to SES TechCom

and two in ICT and networks (SSI and SnT). Two others are involved in specific research domains (EVA and P&M) while RUES within Uni.lu is in charge of applied engineering sciences.

Public research institutes involved in satellite R&D activities

Institute	Department	Space-related activity
CRP Gabriel Lippman	Sciences & materials Analysis Department (SAM)	Characterization of materials, MEMS, sensors for monitoring surface contamination, solarsails materials
	Environment & Agro-Biotechnologies Department (EVA)	Environment, agro- and biotechnology, geo- and biosciences
CRP Henri Tudor	Advanced Materials & Structures Department (AMS)	Materials, solar sails materials, honey-comb Kevlar structures, test facilities
	Service Science & Innovation Department (SSI)	Networks, security, media, ITV, Internet content sharing
University of Luxembourg	Physics & Material Sciences Research Unit (P&M)	Ground and space gravity, geodesy
	Research Unit in engineering Sciences (RUES)	Dynamic modeling of ground antennas
	Interdisciplinary Centre for Security Reliability and Trust (SnT)	Communications, software, networks, data protection, data policy

CRP Henri Tudor/SSI was the first institute to get involved in satellite-related research in 2003 under the impulsion of SES for an ARTES contract. CRP Henri Tudor/AMS entered later with a sub-contract on solar sail materials. The first department of Uni.lu to start space R&D was P&M Geophysics with geodesy and gravity measurements in 2006. This was followed in 2007 by Uni.lu/RUES and the modelling of ground antennas for the Galileo programme. In a similar manner to CRP Henri Tudor/AMS, CRP Gabriel Lippmann/SAM began working on solar sails materials in 2008 in partnership with LuxSpace. CRP Gabriel Lippmann/EVA started working on flood monitoring using radar sensors and in 2010 Uni.lu/SnT took part in the ARTES programme with SES.

The space-related budget of the academic sector is estimated at €3 million in 2011 i.e. a tenfold increase with respect to 2006, this increase being related to the growing number of departments collaborating with Luxembourg industry partners. The decision to merge taken by CRP-Gabriel Lippmann and CRP-Henri Tudor in order to create a stronger entity for applied and focused research will gather four departments with space-related activities under the same umbrella, thus creating new opportunities.

b) Satellite System

Six companies have developed or are developing hardware, software and system engineering for satellite systems: LuxSpace, GRADEL, Euro-Composites, EmTronix, e-Xstream and Smalux. Furthermore three public research departments (CRP Henri Tudor SSI & AMS and CRP Gabriel Lippmann SAM) have relevant capabilities (in materials, electronics).

In 2011, the non-consolidated space-related revenues of the 6 companies were estimated at €6 million, i.e. 6.5% of their total revenue of €92 million (of which Euro-Composites represents 80%).

Their space revenues have been 6 times smaller in 2006, i.e. €1 million. Altogether, the 6 companies have a workforce of 750 people[11], of which 40 are working on space projects exclusively.

LuxSpace is concentrating most of the activity (90%) because of its role of system integrator (Vesselsat and AIS) in addition to software development (SmallGEO).

Companies on the satellite system segment of the value chain

Company	Satellite-related capabilities	Flight model
LuxSpace	AIT, software	Vesselsat 1&2, Lux-AIS
Euro-Composites	Composite structure	Solar panels, heat pipes
Gradel	MGSE, materials welding, mechanical parts	SmallGEO, microsatellite
EmTronix	Onboard electronics	Lux-AIS
e-Xstream	3D composite satellite antenna modelling	None
Smalux	Steel machining	SmallGEO

c) Satellite Operation

The two world leading commercial satellite operators are legally established in Luxembourg: Intelsat and SES. While Intelsat has established its corporate office in the country, SES is conducting a significant part of its operations in Luxembourg.

Companies on the satellite operation segment of the value chain

Company	2011 worldwide sales	Total staff
SES	€1.7 billion	1,578
Intelsat	$2.6 billion	1,110

SES is the world's second largest commercial satellite operator in sales and satellite fleet after Intelsat. Only the US DoD operates a larger number of satellites located in different orbits. SES has been established in 1985 as *Société Européenne des Satellites* and has expanded since in geographical coverage and service capability. While focusing originally on bandwidth retail for broadcasting in Europe, SES has developed a geostationary satellite infrastructure along the geo arc through mergers and acquisitions and the opening of new orbital slots. Its portfolio of customers has diversified to include now telecom service providers for private networks and broadband access by satellite, including for Government users. The attempt to go further downstream in the value chain has stopped with the sale of subsidiaries that were serving the ultimate users of SES satellite bandwidth (i.e. Satlynx and ND Satellite Communications) in order to preserve the profitability of the core business (bandwidth retail) and not to enter in competition with customers.

[11] Of which Euro-Composites alone is 85%.

With worldwide revenues of €1.7 billion in 2011, SES concentrates most of the non-consolidated revenues that Luxembourg derives from space (95%). With 375 employees based in Luxembourg, SES's share of Luxembourg-based space employment is almost 70%. The largest Luxembourg customers of SES are RTL, the M7 Group and the Ministry of Foreign Affairs.

SES has been a driving force for Luxembourg SMEs and public research institutes to commit to satellite-related technology development as another area in their portfolio. It also created SES TechCom Services, a 100%-owned SES company, which provides operational services, technical consultancy and high-tech products as well as integrated solutions to the satellite industry around the world. Furthermore it is a founding member of SnT and an important customer of HITEC and P&T. However it has not yet played the role of an anchor actor furthering new company creations in Luxembourg even if business cases in satellite terminal development have been studied (as it happened in Belgium with Newtec).

d) Ground Equipment & Services

This segment includes the hardware, software and engineering services related to the development and operation of satellite ground networks in relation to satellites when they are in orbit. It includes professional stations for satellite operations (LEOP, IOT, and TT&C) and traffic uplink but excludes user premise equipment for TV reception (TVRO and STB) and for two-way communications (VSAT). It includes the provision of equipment and manpower for satellite mission control and operation.

Five companies are mainly active in the domain: SES TechCom, HITEC, P&T, Telindus and BCE. Together, they had non-consolidated sales of about €60 million in 2011 vs. €25 million in 2006. These sales are entirely satellite communications-related (including data relay and navigation). SES TechCom and P&T concentrate most of current revenues (95%) in this segment, SES TechCom being a significant customer of P&T and of HITEC, a company that has been created at the same time than SES.

Only SES TechCom is a pure player as the three other companies have significant business outside satellite communications. HITEC is 25% satellite communications related while P&T and Telindus have their main business in terrestrial telecom networks and services. BCE operates a teleport to provide engineering and technical services to broadcasters. The staff related to the ground satellite communications activity of these five companies is 65 people (vs. 15 in 2006) which corresponds to 5% of the overall workforce of 1 230 of the companies.

Companies on the ground equipment & service segment of the value chain

Company	Satellite ground networks capabilities
BCE	Operation of ground infrastructure for broadcasters
SES-TechCom	Operation of ground infrastructure for satellite missions
HITEC	Ground station integration (traffic uplink, TT&C Galileo)
Itrust	Localisation assurance & authentication software for Galileo
Lionsystems	Thermal measurements of temperature homogeneity of ground station antennas
P&T	Operation of traffic uplink stations, terrestrial network connectivity, data centre
Telindus	IT for satellite ground network, terrestrial network connectivity, data centre

From the public research side, Uni.lu RUES has performed dynamic modeling of Galileo TT&C antennas for HITEC. Likewise, the two small companies Itrust and Lionsystems are also involved in Galileo. Itrust provides localization assurance and authentication software for Galileo users. Lionsystems has performed thermal measurements of HITEC's TT&C antennas.

e) Satellite-based Services

There are a limited number of Luxembourg-based companies and organizations that deliver services based on the use of satellite systems. The two dominant service providers are pure players that have been created in the second part of the 2000s: SES Broadband Services, a business unit of SES, and LuxSpace, a 100% subsidiary of OHB. Together they had combined revenues of €27 million in 2011, made up principally by SES Broadband Services that offers a technical platform for broadband access by satellite in Europe. LuxSpace markets AIS data and provides land use/cover analysis studies to the European Commission (Eurostat).

The other entities involved in satellite-based services divide into two categories:

- ICT-related with less than 10 SMEs or public research institutes that develop a service or service technology in relation with satellite communications (including data relay and navigation): Cybercultus, Itrust, HITEC, iPAYMO, M-PLIFY, CRP Henri Tudor SSI, and Uni.lu SnT
- Environment-related: Geoville and CRP Gabriel Lippmann EVA.

Excluding SES and the research institutes, the sales of service providers are estimated at €1 million in 2011.

Companies on the satellite services segment of the value chain

Company	Satellite applications	Service capabilities
Cybercultus	Satellite communications	Social & immersive media, collaborative TV
DKE Aerospace	all	Engineering & consulting services
Geoville	Earth observation	Generic geo-information services & products
HITEC	Satellite communications	Satellite-based communications solutions
iPAYMO	Navigation	Payment authentication of mobile devices
Itrust	Navigation	Localisation assurance & authentication software
LuxSpace	Satellite communications/Earth observation	AIS data, satellite imagery services (agriculture, forestry, steel, banking)
M-PLIFY	Navigation	Bidirectional alerting applications for mobile devices
SES Broadband Services	Satellite communications	Broadband communications by satellite
CRP Gabriel Lippmann EVA	Earth observation	Satellite imagery services (flood, agriculture, forestry, nature management)
CRP Henri Tudor	Satellite communications	Networks, security, media, interactive TV, internet content sharing
Uni.lu SnT	Satellite communications	Networks, communications, data protection, data policy, data impact on communities

2.1.2 Government contracts to industry

2.1.2.1 Contract distribution by entity

Over the past 12 years (2000-2011), a total of €40.4 million of contracts has been placed with the national industry and with national public research organizations to develop satellite-related technologies or to acquire services in relation with space facilities. Over 90% of that total (i.e. €37 million) has been placed with entities that have been qualified as active today in satellite technology and satellite services development. About €3 million have been placed with entities that are currently not involved with satellite activities, either definitively or temporarily. Euro-Composites (€2.1 million) concentrates most of the contract to non-active companies.

Contract distribution by entity is highly concentrated as two companies received about 70% of the total: LuxSpace and SES. This concentration decreases to 65% when the non active entities are included in the total. If SES TechCom is considered together with SES, then SES becomes the number one recipient with a total of €15 million (i.e. 37% of the total).

2.1.2.2 Contract distribution by application

Altogether, telecommunications related applications concentrate 78% of the €40 million of contract value. The rest went essentially to technology development and earth observation with over €3 million each and to two transversal subjects (security and support & maintenance) that received about €1 million each.

The SmallGEO platform dominates inside the telecommunications with €12.2 million while two other subjects are also important: *Satmode* and navigation. Other telecom-related subjects received around €1 million each (AIS, data relay, broadcasting). Various other telecommunication contracts that could not be classified received a total of €7.4 million.

2.1.3 Mapping of Luxembourg's capabilities

2.1.3.1 ESA tools for capability assessment

Luxembourg space technology capabilities have been reviewed according to the Technology Tree and the Technology Readiness Level (TRL) defined by ESA to assess and compare European space capabilities.

ESA Technology Tree (ETT) has three levels with the first level made of 26 domains that represent satellite systems or services associated with the spacecraft, its ground segment or its mission (see table below). Each domain is then split in sub-domains corresponding to on-board functionalities. Sub-domains themselves divide into groups that represent different types of capabilities.

Luxembourg's capabilities according to ESA Technology Tree have been mapped in Appendix A with a differentiation in three categories:

- existence of a local capability (in either a technology domain, a subdomain or a group)
- no significant local capability
- technologies for which it is difficult to be conclusive (due to a lack of information about the maturity of the local technology in that area).

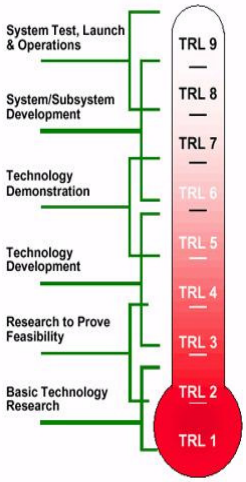
ESA Technology Tree

#	ETT Domain	#	ETT Domain
1	On-Board Data Systems	**14**	Life & Physical Sciences
2	Space System Software	**15**	Mechanisms & Tribology
3	Spacecraft Electrical Power	**16**	Optics
4	Spacecraft Environment & Effects	**17**	Optoelectronics
5	Space System Control	**18**	Aerothermodynamics
6	RF Payload and Systems	**19**	Propulsion
7	Electromagnetic Technologies and Techniques	**20**	Structures & Pyrotechnics
8	System Design & Verification	**21**	Thermal
9	Mission Operation and Ground Data systems	**22**	Environmental Control
10	Flight Dynamics and GNSS	**23**	EEE Components
11	Space Debris	**24**	Materials & Processes
12	Ground Station System and Networks	**25**	Quality, Dependability
13	Automation, Telepresence & Robotics	**26**	Others

ESA "Technology Readiness Level" scales from 1 to 9 the maturity of the technologies for satellite subsystems and instruments developed in Europe. Levels 1 to 4 relate to creative, innovative technologies before or during mission assessment phase. Levels 5 to 9 relate to existing technologies and to missions in definition phase.

ESA Technology Readiness Levels (TRL)

TRL Level	Level description
1	Basic principles observed and reported
2	Technology concept and/or application formulated
3	Analytical & experimental critical function and/or characteristic proof-of-concept
4	Component and/or breadboard validation in laboratory environment
5	Component and/or breadboard validation in relevant environment
6	System/subsystem model or prototype demonstration in a relevant environment
7	System prototype demonstration in a space environment
8	Basic principles observed and reported
9	Technology concept and/or application formulated



A simplified TRL matrix has been defined for Luxembourg in three levels (instead of nine for ESA): 1 for research and technology, 2 for development project that ultimately led to a product or services and 3 for flight proven hardware or operational services.

TRL scale for Luxembourg

TRL	Level	Level description
1	**Research & Technology**	**Basic principles**: Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. **Technology concept and/or application formulated**: Once basic principles are observed, practical applications can be invented and R&D started. Applications are speculative and may be unproven. **Analytical and experimental critical function and/or characteristic proof-of-concept**: Active research and development is initiated, including analytical / laboratory studies to validate predictions regarding the technology.
2	**Development & Validation**	**Component and/or breadboard validation in laboratory environment**: Basic technological components are integrated to establish that they will work together. **Component and/or breadboard validation in relevant environment** (ground or space): The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. **System/subsystem model or prototype demonstration in a relevant environment** (ground or space): A representative model or prototype system is tested in a relevant environment.
3	**Flight proven hardware & Operational services**	**System prototype demonstration in a space environment**: A prototype system that is near, or at, the planned operational system. **Actual system completed and "flight qualified" through test and demonstration (ground or space)**: In an actual system, the technology has been proven to work in its final form and under expected conditions. **Actual system "flight proven" through successful mission operations**: The system incorporating the new technology in its final form has been used under actual mission conditions.

2.1.3.2 Review of Luxembourg's capabilities

Simplified TRLs have been defined for each of the 15 Technology Domains and 29 Technology Subdomains where Luxembourg has a capability (see also the ESA Technology Tree provided in Appendix A).

On-Board Data Systems

- LuxSpace has developed skills in payload data processing and onboard data management through the development of LUX-AIS, the AIS receiver on the ISS (through an ESA GSTP contract), and of two Vesselsat microsats under a commercial contract with OHB (for Orbcomm).
- EmTroniX has also developed skills in the domain as it has been subcontractor of LuxSpace for Vesselsat and LUX-AIS receivers. It provided 50% of the analogue components for Vesselsat (AIS & TC receivers, GPS & OBC interface) and was involved in the design of the FPGA of the LUX-AIS on the ISS.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
1	**On-Board Data Systems**	A	Payload Data Processing			
		C	Microelectronics for digital and analogue applications			

Space System Software

- SES possesses a significant expertise in ground segment software and ground data processing acquired during more than 25 years of commercial activity as a geostationary satellite operator.
- Uni.lu RUES has expertise in the numerical modeling of the dynamics of ground station antennas obtained through the participation in the ESA optional programme (Navigation: Galileo).
- Uni.lu SnT is involved in a number of ground segment software projects, mostly in the domain of authentication, security and reliability (ESA mandatory and ESA optional ARTES).
- Geoville handles a set of EO payload data exploitation software. The company has acquired capabilities in the field through 2 LuxLAUNCH contracts and a 4-year framework contract with the European Environment Agency (EEA) for the provision of data services.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
2	**Space System Software**	C	Ground Segment Software			
		D	Ground Data Processing			
		E	Earth Observation Payload Data Exploitation			

Spacecraft Environment & Effects

- SES has experience in Space Environment. The company performs numerical modelling of space environment and conducts operational in-flight monitoring of different space environmental parameters.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
4	**Spacecraft Environment & Effects**	A	Space Environment:			

RF Payload and Systems

- SES has extensive capabilities in the domain of telecommunication satellites system engineering acquired during more than 25 years of commercial activity as a geostationary satellite operator. These capabilities include the following technology groups: Telecom System Engineering Tools, Telecom Signal Processing Networking Techniques, Telecom Equipments, Telecom Security Techniques and Technologies and TT&C System Tools Telecommunication payloads.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
6	**RF Payload and Systems**	A	Telecommunication (sub-)Systems			

System Design & Verification

- The core business of LuxSpace is satellite system integration, a domain in which it has gained experience through ESA and commercial contracts (AIS receiver and microsat). The company also develops the software for the simulator of SmallGEO.
- Gradel has proven capability in manufacturing MGSE for SmallGEO of OHB. The company plans to start a business line in the manufacturing of satellite containers.
- SES TechCom supplies electrical ground support equipment (EGSE) for ESA satellites.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
8	**System Design & verification**	A	Mission and System Specification			
		C	System Analysis and Design			
		D	Verification and AIT			

Mission Operation and Ground Data systems

- SES has extensive experience in Mission Operations including Distributed and Decentralized Operations, Mission Planning, Operations Support. The company has become one of the world's largest commercial satellite operators over the past more than 25 years.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
9	**Mission Operation and Ground Data systems**	A	Advanced System Concepts			
		B	Mission Operations			
		C	Ground Data Systems			

Flight Dynamics and GNSS

- SES has extensive experience in Flight Dynamics, including Mission Analysis, Trajectory Design and Control, Attitude Determination, Analysis and Control. The company has developed its own in-house Flight Dynamics software suite since its beginning and is well recognized for its expertise. SES TechCom provides this capability to third party customers.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
10	**Flight Dynamics and GNSS**	A	Flight Dynamics			

Ground Station System and Networks

- One of the business lines of HITEC is the design of Ground Station Systems. The company has acquired this expertise mostly through commercial contracts with SES in the 1980s on ground segment engineering. The domains of activity of HITEC include Advanced Ground Station Design concepts and Ground TT&C Antenna Systems. The company builds limited-motion and full-motio n antennas. The latter antennas have been used successfully during the IOT phase of Galileo.
- SES has sound experience in Ground Communications Networks.

- Uni.lu SnT is involved in a number of satellite communications and networking activities mostly in the domain of authentication, security and reliability (ESA mandatory and ESA optional ARTES).
- P&T and to a lesser extent Telindus and BCE have experience of operating satellite networks for connectivity with data centres.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
12	**Ground Station System and Networks**	A	Ground Station System			
		B	Ground Communications Networks			

Mechanisms & Tribology

- CRP Gabriel Lippmann (SAM) is a centre of expertise in materials and in the characterisation of material surfaces. It has capabilities in tribology technologies and MEMS. The most prominent space projects in which the centre has acquired these skills is ESA's Solar Sails Materials project (ESA mandatory programme), EASYMECA (MEMS and nanomaterials) and a partnership with CNES (study of micro-traction platines for MEMS).

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
15	**Mechanism & Tribology**	A	Mechanism core technologies			
		E	MEMS technologies			
		F	Tribology technologies			

Optics

- Lionsystems has expertise in optical & thermal cameras, illumination devices and displays. So far, the company has had only one minor contract in the space sector which involved the study of ground antenna heating with a thermal camera (commercial contract with HITEC).
- CRP Gabriel Lippmann owns instruments and infrastructure for R&D in optics.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
16	**Optics**	A	Optical system engineering			
		C	Optical equipment and instrument technology			

Propulsion

- LuxSpace and the CRPs Lippman and Tudor have been involved in ESA studies on solar sailing propulsion systems.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
19	**Propulsion**	C	Advanced Propulsion			

Structures & Pyrotechnics

- Euro-Composites is a specialist of advanced composites for structural parts, especially for the aviation market. It diversified into space in 2005, when Luxembourg joined

ESA, with panels provided to systems' integrators for solar array substrates, heat exchangers and embedded heat pipes.

- In recent years, Gradel has been involved in the furnishing of burnwire actuators and interface rings to LuxSpace (under an ESA ARTES 11 contract). The company also has experience in the welding of advanced materials gained through the Luxembourg 3rd Party Programme.
- e-Xstream has developed an advanced nonlinear multi-scale software package (DIGIMAT) used in for micromechanical modeling of composite structures. The company has acquired competence in the modeling of space systems in the context of an ESA 3rd party contract involving the modeling of composite onboard antennas.
- CRP Gabriel Lippmann (SAM) is involved in the building of satellite sensors for the tracking and monitoring of materials surface contamination. The project is led in partnership with CNES.
- CRP Henri Tudor has also a number of capabilities in the domain.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
20	**Structure and Pyrotechnics**	A	Structural design and verification			
		E	Active/adaptive structures			
		J	Advanced structural concepts and materials			

Thermal

- CRP-Gabriel Lippmann (SAM) has an ongoing project regarding material studies on thermal components of heat pipes.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
21	**Thermal**	A	Heat Transport Technology			

EEE Components and quality

- CRP-Gabriel Lippmann (SAM) is a centre of expertise in MEMS and nanotechnology. The institute has acquired space-related experience in the domain through the EASYMECA project and a partnership with CNES (study of microtraction platines for MEMS).
- CRP-Henri Tudor has related capabilities in the field of nanotechnology.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
23	**EEE Components and Quality**	B	EEE Component technologies			

Materials & Processes

- CRP-Henri Tudor is involved in a number of projects that can be related to space and advanced materials technology. The research centre possesses technical means for

spectroscopy analysis, surface & bulk treatment, mechanical fatigue and accelerated ageing tests. It also has competences in process engineering and material joining.

- CRP-Gabriel Lippmann (SAM) has built experience in material assessment, material joining and material coating.

  Both actors have not yet demonstrated these capabilities in space projects.

- Gradel has joining and welding capabilities.
- Smalux has experience in joining, welding and coating.

#	Technology Domain	#	Technology Subdomain	TRL1	TRL2	TRL3
24	**Materials & Processes**	A	Novel Materials			
		B	Materials Processes			

2.1.4 Luxembourg's space industry in the national ecosystem

2.1.4.1 From a prosperous service-based economy to a knowledge-based economy

Over the last quarter of the 20th century, Luxembourg's productive structure has transformed from an industry-based (mainly steel) economy into an economy largely dominated by services and high technology. Whereas in 1970 the iron and steel industry accounted for 28% of the country's GDP, its share collapsed to less than 2% in 2010. Over the last 40 years Luxembourg has become one of the world's most prosperous countries and one of the leading financial centres, specialising in international finance, asset management and personal investment.

In 2010, the financial services (financial intermediation, insurance and financial auxiliaries) accounted for a quarter of the GDP and there are currently nearly 146 banks in the Grand-Duchy (37 in 1970). Thanks to its unique position at the heart of Europe, its multilingualism and openness, Luxembourg has become a fertile ground for investors from all over the world. Worth to be noted, economic growth has been accompanied by growth in employment of cross-border and foreign workers (French, Belgian and German people). Foreign population accounted for 38% of the total resident population in 2010 (18% in 1970).

Despite the favourable environment, the country was hit hard by the economic downturns of 2001 and 2008-2009. While economic growth averaged 8.4% during the booming years of 1999-2000, growth rate fell to 1.3% in 2002 and, after a short-lived recovery between 2004 and 2007, dropped again to 1.4% in 2008. The recession of 2009 translated by a negative growth rate (-3.6%). In the last decade the unemployment rate has tripled (from 2% in 2000 to 6.8% in 2010) although it remains at a very low level compared to other countries.

Today concerns have risen about the competitiveness of the pre-eminent economic sectors of Luxembourg, financial services and services other than finance, although the overall performance can still be considered as solid. There are about 40 banks less in the country than in 2000 and the number of resident insurance companies has also decreased since 2007. The growth of foreign direct investment in banking, equal to 200% in the time frame 1995-2000, has diminished by 25% between 2005 and 2009.

Key figures of Luxembourg: 2010 vs. 2000

	Unit	2000	2010
Demography			
Population	thousand	441.1	502.1
of which Luxembourgers	%	*62*	57
Population growth rate	%	1.29	1.02
Geography			
Surface area	thousand sq km	2586	2586
Economy			
GDP at constant prices	€ billions	22	29,6
GDP growth rate at constant prices	%	8.4	3.5
GDP per capita at current prices	€	50200	82100
Employment			
Domestic employment	thousand	263.8	357.8
Net borderers	thousand	79	138.7
Unemployment rate	%	2	6.8
Information & Communication Technology			
Households			
Household access to a computer	%	N/A	90
Households with Internet access	%	N/A	90
Households using Broadband connection	%	N/A	78
Enterprise equipment			
Enterprises using IT	%	N/A	98
Enterprises with Internet access	%	N/A	96
Enterprises using Broadband connection	%	N/A	90

Source: Luxembourg in Figures, STATEC, 2011

Market share of World exports in financial (left) and other than financial (right) services (2007; at current prices)

It is in this context of stagnant growth and competitiveness that the Luxembourg Government is seeking to diversify its economic base further. Today the country has started to focus on new, knowledge-based activities to develop high value products and services in domains such as health, biotechnology and environment. This strategy is in line with the creation of the three "Centres de Recherche Publics" at the end of the 1980s and the University of Luxembourg later on (2003). Likewise, Luxinnovation has been created to stimulate and support innovation, especially at SME level. In parallel to these efforts targeted towards industrial research & technology, a specialization in the media sector has been pursued on the basis of the existence of the CLT, now RTL Group.

The most obvious results in the domain have been the creation of SES and the development of economic activities around the ICT, focussing for the time being more on infrastructure than on content. Expertise has emerged in communications and networking security (with synergies from the banking sector) and Luxembourg has attracted foreign ICT and e-commerce companies by promoting itself as a European "hub" for advanced ICT solutions. Global brands such as Amazon, eBay, iTunes, PayPal and Skype have European headquarters or major operations in the country due to comparatively low VAT rates for the supply of their e-commerce services. The country seeks to take advantage of its small size and flexibility and seeks to implement a coherent legal and regulatory framework for the digital future in order to attract more foreign players in the sector (see section 1.3.2 for more detail on Luxembourg's ICT policy).

2.1.4.2 The national space industry in the national ecosystem

Most space companies of Luxembourg combine both space-related business with business that does not involve space assets. The non-space activities of these players fit well into the general economic environment mentioned above. The key non-space capability areas of the entities can always be associated to at least one of the traditional (or emerging) industry sectors of the country. Synergies in domains not related to space are abundant.

Background capabilities of Luxembourg entities involved in space activities

Capability area	Hardware related	Software related
Steelwork, machining, mechanical engineering	HITEC, Gradel, Smalux, Uni.lu (RUES)	Uni.lu (RUES)
Materials research & engineering	CRP Gabriel Lippmann (SAM), CRP Henri Tudor (AMS)	e-Xstream
Electrics, electronics, electromechanics	EmTronix, HITEC, Solelec, Uni.lu (RUES)	
Environmental research & applications	CRP Gabriel Lippmann (EVA)	Geoville, CRP Gabriel Lippmann (EVA)
Optics engineering & systems	Lionsystems, Uni.lu (RUES)	Lionsystem
Multimedia & entertainment		Cybercultus, CRP Henri Tudor (SSI)
ICT, networks & security		iTrust, CRP Henri Tudor (SSI), Telindus, Uni.lu (snT)

According to the information collected during consultation, two capability areas show a surprisingly small number of partnerships for the time being: materials engineering and optical engineering & systems. The development of cooperation between CRP-Gabriel Lippmann (SAM), CRP-Henri Tudor (AMS), Euro-Composites and e-Xstream could allow new and promising capabilities in materials engineering. In the optical domain, Lionsystems and Uni.lu (RUES) have expertise in camera hardware and software; they could team to assemble a camera meeting the technological requirements to fly on a microsatellite.

Non-space partnerships in Luxembourg of entities involved in satellite activity

Entity involved in satellite activity	National partner	Domain
Cybercultus	CRP Henri Tudor (SSI), BCE (RTL Group)	Interactive TV
EmTronix	Delphi Automotive Systems	
Geoville	CRP Gabriel Lippmann (EVA), Nokia-Siemens	
P&T	Uni.lu (SnT)	
Lionsystems	CRP Henri Tudor, CRP Santé	Medical technologies
Gradel	CRP Henri Tudor (AMS)	
Uni.lu P&M Geophysics	CRP Gabriel Lippmann	Meteorological prediction
CRP Gabriel Lippmann (SAM)	CRP Henri Tudor, CRP Santé, Uni.lu	

2.1.5 Luxembourg's space industry in the European ecosystem

2.1.5.1 Structure of the European space industry

The European space industry *stricto sensu* (upstream) employs almost 35,000 people for consolidated sales of €6 billion in 2010. It represents about 5% of the total aerospace & defence employment in Europe. Employment is highly qualified as about two thirds are engineers and PhD[12]. Sales and employment of the European space industry have evolved cyclically over the past two decades as a result of the structural cyclicality of the geostationary communications satellite (comsat) market while the institutional European market was more stable between €3 and 3.5 billion per year.

Revenues are concentrated in a limited number of companies: the two leading companies EADS Astrium and Thales generate about one third of the total revenues of the industry, the top six companies (Astrium, Thales Alenia Space, Finmeccanica, Safran, OHB and Ruag) generate over 80% of the revenues. The remaining is unevenly split between around 150 entities located throughout Europe.

Satellite manufacturing represents a growing proportion of the sales of the European space industry: from less than 50% in the early 1990s to over 60% today. Satellite sales of the European space industry have grown cyclically in relation with 1) the satellite demand of European institutional customers and 2) the export performance of European satellite manufacturers, both for communication and earth observation satellite systems.

[12] Source: ASD-Eurospace Facts & Figures.

There are now three satellite system integrators in Europe: EADS Astrium Satellites, Thales Alenia Space (TAS) and OHB. Because of their heritage, the first two companies cover all the spectrum of satellite activities (telecommunications, science, earth observation, navigation) plus infrastructure in space. OHB has emerged as the third satellite integrator as a result of the German Government's willingness to have such capability available domestically in addition to Astrium Germany. Astrium and TAS have developed and maintain key satellite equipment design and manufacturing capabilities[13]. They supply equipments to each other, and beside frontal competition, they occasionally collaborate for certain R&D programmes (e.g. Alphabus), for certain Government programmes (e.g. satellite communications for the Bundeswehr) and for certain commercial satellite projects (Arabsat, YahSat).

The development of a satellite prime contractor capability is attractive to many Governments and new medium/small satellite system integrators recently emerged in Germany (OHB), the UK (SSTL), and Belgium (Qinetiq). In order to enlarge its supplier base, OHB created LuxSpace in November 2004 in Luxembourg and has since acquired small companies in Sweden, Italy and Belgium.

In terms of employment, the European space staff base is estimated at 41 000 persons working at the three levels of the value chain in Europe:

- space industry (*upstream*): 35 300 persons in about 150 industrial companies based in Europe, concentrated at 80% in 6 large conglomerates[14] having divisions and subsidiaries in various European countries;
- satellite operators: 1 700 persons in 6 companies headquartered in Europe (SES, Eutelsat, Inmarsat, Telenor, Hispasat and Hellasat);
- satellite service providers: about 4 000 persons in less than 50 companies[15] manufacturing ground equipment and/or providing communications, broadcasting, and earth observation services.

The three European satellite integrators

	Astrium	Thales Alenia Space	OHB
Headquarters	Paris, France	Cannes, France	Bremen, Germany
Employees (2010°	15 000	7 200	2 200
Space products/services	Launch vehicle integration, satellite integration, satellite equipment, satellite payload, government satellite services	Satellite integration, satellite equipment, satellite payload,	Launch vehicle equipment, satellite integration
Geographic presence	Toulouse (France), Stevenage (UK), Friedrichshafen (Germany). Also Casa Espacio (Spain), Dutch Space (the Netherlands), SSTL (UK)	Toulouse (France), Turin and Rome (Italy). Subsidiaries in Spain and Germany	Germany, Belgium, Sweden, Luxembourg, Italy
Majority shareholders	Daimler, Lagardère, French, German and Spanish States	Thales (67%), Finmeccanica (33%)	Fuchs family, Frankfort Stock Exchange
Space revenues (M€, 2011)	5 000	2 000	555

[13] Satellite integrators maintain a strong control over the supply of critical equipment as a condition for risk mitigation, in particular on the commercial market.
[14] EADS Astrium, Thales, Finmeccanica, OHB, RUAG and Safran (exclusively space propulsion).
[15] Excluding European multichannel satellite TV platforms (e.g. Sky, CanalSat, ..) .

2.1.5.2 Emerging and advanced space countries in Europe

Luxembourg is one of the most recent members of ESA and belongs to a group of European countries that can be qualified as emerging in terms of space industry. However, Luxembourg differs from the three other European emerging space countries (Czech Republic, Greece, and Portugal) because of the existence of SES and the resulting legacy in satellite communications services. It also differs from these countries and from advanced countries with respect to military expenditures and the impact they have on the development of national technology and industrial capabilities.

The advanced group of space countries is made of 10 European countries that all started their space activities primarily from their technical and engineering background in the aerospace/defence sector[16]. From this starting point, they contributed to space missions with "soft" technologies or the supply of ground software & services as well as ground support equipment (EGSE, MGSE, facilities maintenance).

"Soft" technologies include contributions to science missions (which may include limited hardware/software development related to space instruments) and basic structural panels and mechanical parts for satellites.

Entry activities generally correspond to low entry barrier activities when compared to the delivery of flight-proven systems. As the building of industrial capabilities for flight systems is a long, costly and uncertain process and because flight capabilities are already established elsewhere in Europe or outside Europe, newcomer countries tend to stay at the lower border of the space industry (typically ground systems and services serving the space systems) and to seek growth in the downstream sector of satellite-based products and services. Of the 10 countries flagged as advanced space countries in Europe, Finland and Ireland appear to stay behind the 8 others in terms of capability growth of their national space industry.

Another aspect of the maturity of the national space industry is the capacity to sell commercially, i.e. on a competitive basis within or outside Europe. This capacity development generally goes along with a product specialization that has permitted companies such as Tesat, Sodern, Jena, Saft to become world reference for specific satellite equipment and subsystems.

In Spain and Norway this specialization of the capabilities of the national space industry has been helped by the good synergies between Government investment decisions in space R&D and the procurement strategy of the national commercial satellite operator. In these two countries, the offsets of the satellite integrator for Telenor and Hispasat satellites to the national industry have helped local companies to develop product specialization.

2.1.5.3 Structure of the European commercial satellite operators

Three of the world's four leading commercial operators (FSS and MSS) originated in Europe: SES, Eutelsat, Inmarsat, all three under Government initiative. Three other smaller operators are also based in Europe: Hispasat, Telenor and Hellasat. They were created to serve domestic communications and broadcasting needs and later enlarged their geographic service coverage.

Originally in a duopoly situation with Eutelsat in Europe for broadcasting capacity, SES is now in competition worldwide with Intelsat and Eutelsat and with regional satellite operators that generally

[16] Namely: Austria, Belgium, France, Germany, Italy, Norway, Spain, Switzerland, the Netherlands and UK.

have a strong local market hold. With its offering for broadband services in the EMEA region, SES is again in strong competition with Eutelsat in a new market segment whose future is uncertain in Europe. As other FSS operators, SES is increasingly in competition with Inmarsat for mobile broadband communications globally. For the introduction of S-band satellite services in Europe, SES claims to be ready for Solaris to enter into a satellite sharing agreement with Inmarsat.

	GEO satellites	Non-GEO satellites	2011 world sales
FSS operators	40 companies including 5 European	none	$9 billion
MSS operators	2 companies including Inmarsat	3 companies including Orbcomm	$1 billion

2.1.5.4 Structure of the European commercial satellite service providers

The commercial provision of satellite services developed unequally in Europe in three application domains:

- broadcasting including direct to home satellite TV (DTH), cable TV (CATV), IPTV, DTT,
- telecommunications for virtual private networks, cellular backhaul, emergency communications,
- environmental and geospatial information.

Europe being one of the world largest media markets, digital satellite TV developed strongly in the 1990s and 2000s to feed terrestrial broadcasting networks and for DTH services. Multichannel satellite TV platforms multiplied with capacity leased primarily to the five European satellite operators. As part of the development of this new market, technical service providers (backhaul, uplink, ...) multiplied, generally originating internally either from the telecom operators or from the broadcasters (Globecast, BCE, ..).

Telecommunications services (data, voice and video) that rely exclusively or partly on satellite systems are provided by the incumbent national telecom operators and by the alternative operators that have been licensed pursuant to the deregulation of the telecom markets in Europe. However, as the wired and wireless terrestrial infrastructure is well developed in Europe and national networks are well interconnected, the use of satellite networks in Europe is limited to specific usage (backup & restoration, gapfiller).

Environmental and geospatial information is a growing domain where satellite has an increasing market share as it provides complementary information to aerial and in-situ data. The demand is driven by Governments for operational services (e.g. intelligence-surveillance-reconnaissance, maritime security) and for research and scientific purposes. Commercial satellite imagery data distribution has concentrated over time in Europe and value added services start to develop for specific user communities (oil & gas, fishing, agriculture, insurance, ...).

2.1.5.5 Conclusive remark on Luxembourg's space industry in the European context

Luxembourg is in the unique situation of being the home country of the world's second largest commercial satellite operator while not having yet a satellite industry upstream in position to design and develop geostationary satellite equipment.

As the building of industrial capabilities for satellite systems is a long and costly process and because such capabilities are already established elsewhere in Europe or outside Europe, **Luxembourg has to be selective in its strategy of development of capabilities in satellite systems and equipment.**

The downstream sector of satellite-based products and services in Luxembourg is driven by the satellite communications legacy of the country. **The maturity of the local industry in this domain can allow it to expand to other countries in Europe and outside Europe**. In the other domains of satellite information which are less mature globally than satellite communications (i.e. navigation, environmental and geospatial), the Luxembourg industry can take benefits of a growing demand from both the Governmental and commercial sectors.

Maturity of the European space industry in technology areas where Luxembourg has a capability

#	Technology Domain	#	Technology Subdomain where Luxembourg has a capability	Number of EU Main players (TRL 3)	Commercial presence (Share of commercial turnover)	Export performance	Level of competition
1	**On-Board Data Systems**	A	Payload Data Processing	> 25	Medium	Inexistent	Depending on technology but overall, established players and high import (US)
		C	Microelectronics for digital and analogue applications				
2	**Space System Software**	B	Space Segment Software	>30	Low to Medium	Inexistent to Low	High due to established players (GMV)
		C	Ground Segment Software				
		D	Ground Data Processing				
		E	Earth Observation Payload Data Exploitation				
4	**Spacecraft Environment Effects**	A	Space Environment:	Few	Inexistent	Inexistent	Mainly institutional but specific players (SES)
6	**RF Payload and Systems**	A	Telecommunication (sub-)Systems	~30	High	High	High
8	**System Design and Verification**	D	Verification and AIT	> 35	Low to Medium	Inexistent	High for design / Low for AIT but established players
9	**Mission Operation and Ground Data Systems**	A	Advanced System Concepts	~20	High	High	High
		B	Mission Operations				
		C	Ground Data Systems				
10	**Flight Dynamics and GNSS**	A	Flight Dynamics	~20	High	Low	High, Established players operating their system and subcontracting to partners
12	**Ground Station System and Networks**	A	Ground Station System	~50	Low	Medium	Medium
		B	Ground Communications Networks				
15	**Mechanisms and Tribology**	A	Mechanism core technologies	~20	Low	Inexistent	?
		E	MEMS technologies				
		F	Tribology technologies				

16	**Optics**	A	Optical system engineering	~18	Very Low	Low to Medium	Medium
20	**Structure and Pyrotechnics**	E	Active/adaptive structures	~35	Low	Inexistent (but for Launcher)	High
		J	Advanced structural concepts and materials				
21	**Thermal**	A	Heat Transport Technology	~7	Low	Inexistent	Medium
23	**EEE Components and quality**	B	EEE Component technologies	~20	Medium	Low to Medium	Depending on technology but overall, established players
24	**Materials and Processes**	A	Novel Materials	n.a.	n.a.	n.a.	n.a.
		B	Materials Processes				

2.2 PERFORMANCE OF LUXEMBOURG'S SPACE INDUSTRY

2.2.1 Economic importance of satellite activities in Luxembourg

2.2.1.1 Revenues

The Luxembourg space sector is made of about 20 active (see section 2.1.1. for definition of the term "active") companies (excluding public research centres). The total space revenues of these companies including commercial and Governmental contracts amounted to €1777 million in 2011, of which 96% derived from SES, the world's 2nd largest commercial satellite operator.

The revenues of the other companies apart from SES amount to €65 million. They include among others Gradel, HITEC, LuxSpace, P&T, iTrust, DKE and SES TechCom but do not include Euro-Composites which had no space sales in 2011 as a result of a strategic decision to exit the sector[17].

These revenues are highly concentrated as two companies (P&T and TechCom) declare about €55 million related exclusively to satellite communications traffic (telecom and TV uplink). Two other important actors are HITEC, also in satellite communications, and LuxSpace, the sole pure player outside SES. Together these four companies represent 97% of the space sales outside of SES.

The remaining 3% (i.e. €2.2 million) of space revenues are made up by seven companies with space revenues ranging between €150,000 and €400,000. Part of them are large companies (Solelec, Telindus, Gradel) weakly involved in space activities while others (Geoville, Emtronix, ..) are more involved.

Revenues perspectives for space for the next five years are positive or even very positive for the largest companies and are exclusively satellite communications related. SMEs are more conservative declaring limited or no growth perspectives. This may result from single disappointing experiences in space business and the perception that growth opportunities are better outside of space or elsewhere geographically.

2011 industry data estimate for the Luxembourg space sector

	Sales (€ in millions)			Staff (full time)		
	total	of which space	In %	total	of which space	In %
SES*	1712	1712	100%	375	375	100%
other companies consulted	558	65	11%	1485	119	8%
Total	2270	1777	78%	1860	494	26%

* global sales of SES (including TechCom). SES sales are global while staff is Luxembourg-based only (source: GLAE). Total staff of SES at YE 2010 was 1,580.

2.2.1.2 Profitability

Perception of the profitability of space related activities is different between large and small companies. Larger companies usually report profitable business while SMEs view space as low profitability business. The low profitability of space for SMEs results from the combination of:

[17] This decision is currently being revised.

1) the specific constraints of that activity (high entry costs including quality requirements and specific equipment, limited recurrence of products/services, uncertain market dynamics, competition from strong established suppliers);

2) a few constraints specific to Luxembourg (high wages, better market opportunities in other activities). It also explains why several SMEs decided to exit the space business or consider it as a non-strategic business. All the companies declaring a positive evolution of space profitability in the future are relatively large companies (SES, LuxSpace, HITEC).

2.2.1.3 Staff

In 2011 the companies had a Luxembourg-based space staff of almost 500 people, of which over 75% is SES (excluding SES TechCom). SES TechCom and LuxSpace are the most staffed companies (40 and 30 persons, respectively) while the largest in sales apart from TechCom had only 10 persons (P&T). HITEC is the only company with more than 10 persons apart from LuxSpace, P&T, and SES TechCom.

Space staff represents about 8% of the total staff of all companies (excluding SES) translating the service orientation of the companies (as space sales represent 11% of the total sales).

Companies differ on the prospects for space staff growth in the next 5 years. The most positive on staff growth prospects are the largest space companies: SES TechCom, HITEC, LuxSpace and P&T.

2.2.2 Market positioning for the Luxembourg space sector in 8 domains

The specialization domains occupied to date by the Luxembourg space sector at the different levels of the value chain have been reviewed from the angle of their market accessibility and market dynamics for Luxembourg players in the future focussing on markets offering sustained business growth and where the Luxembourg industry may have a competitive advantage.

Within these domains eight areas have been reviewed with regard to their overall development perspectives for the Luxembourg space community. Five relate to satellite systems designed to operate in-orbit while the three others relate to the ground equipment and services, including the downstream satellite services. While overlapping the subjects of the microsatellites (microsats) in low earth orbit and of AIS receivers have been considered separately. The subject of electric propulsion has also been considered as a new area of specialization of potential interest for Luxembourg.

Overview of market opportunities considered for the Luxembourg space sector

	Opportunities	Luxembourg capabilities	Market dynamics	Competition
Satellite systems	Microsatellite	LuxSpace EmTronix Gradel Euro-Composites	Growing demand for more intelligent microsat that translates into more complex and heavier satellites	Increased competition from established suppliers and from new entrants

Satellite systems	AIS receiver	LuxSpace EmTronix	AIS data production capacity growing. Risk of overcapacity. Demand not just for AIS data but for maritime security information	Increased competition both in AIS data production and in value added services for maritime security information
	SmallGEO platform	Euro-Composites LuxSpace, Gradel, Smalux	Accessible Governments demand for low power GEO satellites (i.e. small satellites) is low	The SmallGEO bus now in development faces the competition of larger satellites and of more capex effective small satellites
	Electric propulsion	None to date	Increasingly cost effective technology for satellite operation (station-keeping) and for the orbital injection of satellites	Only a few companies in position to deliver cost effective systems pursuant to long technology development efforts
	Next Generation Platform		Potential for 150 platforms over product's lifetime driven by commercial GEO comsat demand	Strong because of the established European supply base of Astrium and TAS for Eurostar and Spacebus products
Ground systems & services	Ka-band antenna	HITEC RUES	Transition from S and X bands to Ka-band for mission operation (LEOP, TT&C, IOT) creates more demand	Three US companies dominate with qualified and amortized products
	Mission operation	SES TechCom P&T Telindus BCE SnT	Huge investments of European Governments in satellite infrastructure creates demand for PPP and facilities management	Competition in Europe squeezed by the PPP schemes and the principle of geo-return
Downstream satellite services	Broadband communication, earth observation	SES Broadband SES TechCom Cybercultus SnT Geoville CRP Tudor/Lippmann	Outside broadcasting, satellite service demand driven by the Governments, generally on a national basis and not relying exclusively on satellite systems	Large satellite service providers have developed initially in countries where Government demand was large and then expand to other clients

2.2.2.1 Microsatellites

Trend in the microsatellite market

A total of 50 microsatellites with a launch mass comprised between 30 kg and 200 kg have been launched worldwide over the past ten years (2002 to 2011), i.e. an average of 5 units per year. Most of the microsatellites (85%) were ordered by Government agencies for three applications: in-orbit technology demonstration, earth observation and science. The only significant commercial operator of

microsatellite is Orbcomm who has launched 6 satellites over the period of interest with an AIS capability[18].

Half of the 50 microsatellites launched had a launch mass comprised between 30 and 100 kg while the other half was between 100 and 200 kg.

Less than 10%, or 5 of the 50 microsatellites, can be defined as accessible to the European space industry in the sense that they were not captive of the national industry in the country that funded the satellite development.

Because of the development of the second generation of Orbcomm (18 units), a total of 38 microsatellites are currently under development for launch between 2012 and 2015, i.e. an average of 9.5 per year, significantly higher than the 5 unit average experienced in the past ten years. The launch mass category of 30 to 100 kg decreases significantly in relative importance because 1) Orbcomm 2G satellites are heavier than 1G and 2) replacement satellites get bigger as missions evolve from demonstration to operational purpose. The higher performance requirements in terms of orbit control, data storage and lifetime translate into higher mass. In addition, more stringent regulation on debris creation creates new obligation that make small satellites heavier (orbit control for de-orbiting).

	First satellite	Second satellite
ESA	Proba (94 kg)	Proba-2 (130 kg)
ASAL (Algeria)	Alsat 1 (90 kg)	Alsat 2 (130 kg)
NASRDA (Nigeria)	Nigeriasat 1 (100 kg)	Nigeriasat 2 (300 kg)
EIAST (Dubai Emirate)	Dubaisat 1 (200 kg)	Dubaisat 2 (250 kg)
Orbcomm	Orbcomm 1G (45 kg)	Orbcomm 2G (140 kg)

Around 30% of the satellites currently under development are defined as accessible, equally dividing between the two categories of launch mass (below and over 100 kg). This translates the fact that more and more Governments enter the space domain by acquiring microsatellites for earth observation and/or technology demonstration in order to develop their engineering capability and to be autonomous in data collection over the regions of interest for them (e.g. the multinational DMC constellation).

Characterization of the micro-satellite market (30 kg to 200 kg of launch mass)

	Launched 2002-2011	To be launched 2012-2016
Annual average with Orbcomm	5/year	9.5/year
Annual average without Orbcomm	4.4/year	5/year
Proportion 30kg to 100 kg of launch mass	50%	16%
Proportion accessible to European suppliers	6%	30%

[18] That capability is not operational as the 6 satellites failed shortly after launch.

In annual average this means 2 to 3 microsatellites per year accessible to European suppliers, of which half (i.e. about 1 to 1.5 units per year) would be between 30 and 100 kg of launch mass.

About 20 organizations are involved in microsatellite development worldwide, of which industrial companies, space agencies, public laboratories and universities. However, supply is quite concentrated with 10 organizations dominating, of which two are European (Astrium Satellites and OHB). Astrium Satellites is present directly and indirectly via SSTL, while OHB is involved through four subsidiaries: Kayser-Threde (Germany), Carlo Gavazzi (Italy), OHB Sweden (the former Space Systems division of SSC) and LuxSpace (Luxembourg). Like for larger satellites in low earth orbit, Government agencies take benefit of the standardization of multi-mission platforms that become available from manufacturers (e.g. Microsat of SSTL and Astrosat of Astrium).

Integration capability for microsatellites diversifies worldwide and competition increases as established players and new entrants (from South Korea, South Africa, and Canada) increasingly look outside their domestic Government market. Supply divides into two groups of players corresponding to different capabilities and clients:

- on one hand, the nanosatellite suppliers that specialize into providing more capable low-cost satellites generally below 30 kg of launch mass; this segment of the market includes Technical Universities (Berlin, Toronto,..) that develop their own platform, space agencies such as ISRO (India) and pure players such as SpaceQuest in the USA;
- on the other hand, the microsatellite suppliers that have platforms starting at 100kg. Such platforms have a mission range generally up to 300-350 kg. This is the case for SSTL and Qinetiq in Europe, Satrec Initiative in South Korea, and Sierra Nevada Corp. in the USA. Two countries have succeeded in accommodating high performance earth observation payload for military use on microsatellite (Topsat in the UK and TEC-SAR in Israel). Such satellites have high performance in terms of agility, power and resolution, at development costs that are unknown.

Leading suppliers of Nanosats and Microsats

	Europe	USA and Canada	Rest of the World
Nanosatellite	TUB Roma Univ. VKI ...	SpaceQuest UTIAS (Toronto) ...	ISRO ..
Microsatellite	Astrium SSTL OHB Qinetiq	OSC MSCI ComDev ATK	Satrec Initiative IAI SunSpace ATSB

The supply of microsatellites with launch mass between 30 kg and 100 kg is not developed as the accessible demand (in the sense that is not captive of a given supplier) is not. Projects for small constellations with satellites in that mass range have not materialized to date (e.g. Cosmic-2, Cicero) and AIS-dedicated satellites use smaller nanosatellites or are hosted on larger satellites.

Luxembourg positioning and future perspectives in microsatellites

LuxSpace has integrated two Vesselsats that are used for Orbcomm's AIS service and is supposed to have three more microsatellites in development. The two Vesselsats of 28 kg will be integrated into the Orbcomm 2G constellation of 18 AIS-enabled satellites now in construction in the USA by Sierra Nevada Corp (SNC). The UHF transceivers of Vesselsat were developed in Luxembourg.

The AIT experience gained by LuxSpace with Vesselsat pertains to microsatellites with limited capability as the platform of Vesselsat has been designed to embark an AIS receiver with no orbit control. Some of the 3 microsatellites now in development are understood to be also AIS platforms. Therefore, the growth of Vesselsat-type market for LuxSpace is highly related to the demand for AIS receivers (see next domain).

Most of the microsatellite developers have experienced product evolution towards more capability (accuracy, lifetime, data link ...) with impact on AOCS, power and propulsion technologies in order to make their satellites more cost competitive for operational use. As a result, LuxSpace's position as a microsatellite integrator is intermediate between the academic/research side of the microsatellite demand and more complex needs that generally go to larger microsatellites. In that sense, LuxSpace's position is a rather challenging position. As LuxSpace does not have the benefit of a domestic microsatellite demand, it has to look for customers in countries wishing to enter the satellite domain that are not captive of established microsatellite suppliers. This is a costly effort as illustrated by SSTL's (UK) and Satrec's (South Korea) history.

Based on its heritage and provided it receives adequate R&D support, **LuxSpace will be able to develop a more capable and versatile microsatellite platform that will enable it to access a larger market in the decade.**

Luxembourg SWOT for microsatellites

STRENGTHS	WEAKNESSES
• Proven systems' integration capability of LuxSpace with two Vesselsat in orbit + 3 more in development • Microsatellite experience within OHB group	• No domestic demand for microsatellites • Competition from both ends of the microsatellite market (nanosatellites and larger satellites in low earth orbit) • Low capability of the existing microsatellite platform (no orbit control, no redundancy) • Microsatellite subsystems technologies not mature from Luxembourg suppliers
OPPORTUNITIES	**THREATS**
• Capabilities of LuxSpace to develop an improved microsatellite platform locally under Government initiative • Market access opportunity offered by OHB • Government demand for microsatellites in countries that want to develop engineering capabilities in the domain	• Uncertain demand for AIS-dedicated microsatellites that would be accessible to LuxSpace • Strong competitors base in and outside of Europe preventing to achieve critical size locally • Competition from "microsatellite experienced" subsidiaries of the OHB group

2.2.2.2 AIS receivers

Trend in the AIS market

About 10 receivers for automatic identification systems by satellite (SAT-AIS) are now in orbit funded by commercial companies and by Governments. Commercial AIS receivers are loaded on dedicated or multi-mission microsatellites. About 25 additional AIS receivers will be launched in the coming two years, of which 18 for the second generation of Orbcomm satellites, for another commercial company (exactEarth) and for Government satellites (Italy, Germany, Spain, Norway, Latvia, Indonesia...).

Two commercial providers of commercial satellite AIS data have emerged to complement the UHF terrestrial AIS: Orbcomm and exactEarth (backed by Comdev and Hisdesat). A third one emerges backed by Norwegian interests (the Norwegian Defence Research Establishment, FFI, and three entities of Kongsberg, KDA, KSA and Seatex).

The revenues currently generated from SAT-AIS data sales are small but Orbcomm estimates its AIS business could represent about $10 to 15 million per year once it becomes an established business. By the end of 2011, exactEarth had booked more than $10 million in orders and delivered more than 3 billion vessel position reports during the year.

Leading AIS suppliers

	Orbcomm (USA)	exactEarth (Canada)	Kongsberg (Norway)
SAT-AIS fleet	2 Vessselsat in orbit + 18 Orbcomm 2G to be launched	4 ExactEarth/Aprizesat in orbit + 4 to be launched	AISSat-1 in orbit + AISSat 2 to be launched + AISSat 3 in planning
Satellite platform	LuxSpace, SNC	SpaceQuest, SSTL	UTIAS/SFL (Univ. Toronto)
AIS receiver	LuxSpace/EmTronix	SpaceQuest	KSeatex

The supply of UHF transceivers for SAT-AIS divides into two groups of companies and products:

- advanced space qualified equipment, itself dividing between high and low data rate, from US and European suppliers (e.g. L3, SSTL),
- lower cost equipment, either space qualified or not and with different performance, from US (SpaceQuest) and other electronic suppliers.

Luxembourg positioning and future perspectives in AIS

ESA GSTP program funded two AIS receivers hosted on the Columbus module of the ISS (COLAIS) sharing the same external antenna. One was provided by Luxembourg (LUXAIS) and the other by Norway (NORAIS). LUXAIS is a second-generation AIS receiver of LuxSpace and EmTronix while the 3 others made by LuxSpace are of first generation (AIS Pathfinder and 2 Vesselsat).

LuxSpace has developed its own UHF transceiver for the Vesselsat (analogue components) while LUXAIS for COLAIS is digital. As part of an ESA study, LuxSpace has analyzed the opportunity to develop a new transceiver that would be more flexible to needs with software defined radio (SDR). It

concluded that considering the number of existing products having amortized their non-recurring costs, only a strong increase in demand (from 2 to 6 per year) would justify the investment.

As a result of the growth in SAT-AIS data production capacity, data will become a commodity business and the service suppliers to the maritime security organizations will look for more value added services in order to develop their activity. This is already the approach of Norwegian suppliers that will benefit from the AIS receiver hosted on the PAZ radar satellite of Spain to offer more services. CLS of France, which is responsible for the SAT-AIS DPC study for ESA/EMSA, has extensive experience in satellite maritime services that combines navigation signal and radar observation.

For Luxembourg, and especially LuxSpace, there is an opportunity to go further than SAT-AIS data production by developing value added services geared to the needs of the operators of maritime security in Europe.

Luxembourg SWOT for SAT-AIS

STRENGTHS	WEAKNESSES
• Flight-proven capability of LuxSpace to develop 1st generation AIS receivers • Privileged relations of LuxSpace with one of the two main commercial AIS data providers (Orbcomm)	• 2nd generation AIS receiver of LuxSpace not demonstrated in-orbit (LUXAIS on the ISS) • Strong competition in both ends of AIS receivers' development with European, American and RoW suppliers
OPPORTUNITIES	**THREATS**
• LuxSpace contribution to the Blue Belt project for European SAT-AIS data provision (ARTES 20 then 21) • Stronger role of Luxembourg suppliers for the provision of value added services in relation to SAT-AIS for maritime security in Europe (satellite operation, data center, data broadcast)	• Growth of competition in Europe with KSeatex (Norway) having a captive domestic market and Carlo Gavazzi Space (Italy) developing AIS receiver technology • Uncertain evolution of AIS data demand (over capacity?)

2.2.2.3 Small GEO Satellites

Trend in the Small GEO satellites market

Over the past 10 years, a total of 22 satellites of less than 4kW of power were launched into geostationary orbit worldwide, of which 12 were for Government services (military satellite communications, data relay, technology demonstration, tele-education). Only two of the 10 non-Government satellites were integrated by Astrium and Thales Alenia Space, both using platforms provided by a third party for reason of cost competitiveness (the Indian Space Agency for Hylas 1 to Astrium and Orbital Science Corp. for Koreasat 6 to Thales Alenia Space). The other commercial

satellites predominantly used the smallest version of Lockheed Martin's satellite bus, as this was at that time the preferred supplier of SES Americom and SES Astra for their small satellites.

13% of the 54 civilian geostationary satellites currently in construction for launch in the next three years are below 4 kW of power, i.e. 7 units. All of them but AG1[19] are for Governments in countries with a local satellite industry (India, China, and Russia).

The SmallGEO project has been initiated by ESA to develop a new multipurpose satellite platform in Europe to complement those from Astrium Satellites and Thales Alenia Space (TAS) that do not cover the same capability range. The ARTES 11 programme dedicated to SmallGEO platform has been subscribed by 8 ESA countries (Austria, Denmark, Finland, Germany, Luxembourg, Spain, Sweden, and Switzerland) and OHB has been selected as prime contractor in 2007. It divides into three phases:

- Development of a platform supporting a payload with a mass up to 400 kg and a power up to 3.5 kW;
- Flight qualification and in-orbit demonstration of the platform and of payload elements through an operational mission implemented through a PPP between ESA and Hispasat (the AG1 satellite).
- Improvements of the cost competitiveness of the SmallGEO platform in order to enlarge its market reach with new technologies. This may include in particular electric propulsion in order to have an all electric satellite system that would be more capex effective for commercial missions.

In addition to AG1 planned for launch in 2013, OHB will integrate seven additional SmallGEO platforms: six for Eumetsat (Meteosat Third Generation) and one for Astrium Services (European Data Relay System). The German Government will likely approve the development of a technology mission in Ka-band (Heinrich Hertz or H2Sat) that will use the SmallGEO bus.

According to the contributions of ESA Member States the supply chain for the SmallGEO platform development has been organized with OHB, RUAG and their European subsidiaries concentrating most of the value:

- in Sweden: OHB Sweden (for AOCS and EPS) and RUAG Sweden (for data handling)
- in Luxembourg: LuxSpace (coding for the satellite simulation software)
- in Italy: Carlo Gavazzi Space

TESAT GmbH is the payload prime contractor with payload subsystems provided by TAS Spain and EADS Casa Espacio.

The procurement for MTG and EDRS is in progress. It is unknown how much of the supply chain created for the AG1 platform will be kept for these two other procurement programs as MTG is subject to a different geographic return rule, while EDRS is close to a commercial procurement from Astrium Services as part of a PPP with ESA.

[19] The AG1 mission for Hispasat will use the first flight model of the SmallGEO bus developed with ESA funding. SmallGEO is understood here not as a generic name but as that of the new European platform development project.

Luxembourg positioning and future perspectives for the SmallGEO platform

The demand for the SmallGEO platform is currently driven by European Governments and organisations (ESA, Eumetsat and DLR). When the platform will have acquired flight heritage, commercial satellite operators may consider it for specific mission requirements, especially as replacement of low capacity satellites, risk mitigation for capacity expansion and placeholder at a new orbital slot. However, its low power capability in relation to its cost limits its penetration of the commercial satellite communication market where demand is driven by broadcasting services and higher power satellites.

Luxembourg's participation to the SmallGEO platform development has to be seen in relation with the activities of three companies. In addition to LuxSpace development for OHB (see above), Gradel and Smalux provide low-tech equipment to RUAG (MGSE and steel-cutting, respectively).

Development perspectives for Luxembourg actors are highly tributary of the sustainability of these activities which, in turn, depend much on the procurement strategies of OHB for MTG and EDRS. The satellite simulation software to which LuxSpace is contributing for OHB is a critical item in satellite system development and operation which OHB may want to internalize in the future. Luxembourg's geo return requirement on MTG is very low (financial contribution represents 0.05%), while for EDRS OHB may decide to partner with established commercial equipment suppliers to safeguard its margin for its contract with Astrium. However, the opportunistic development of the MGSE by Gradel for the AG1 mission may allow the company to be recognized by European integrators even if RUAG is an established supplier of GSE (MGSE and EGSE) for ESA and commercial satellites.

Luxembourg SWOT for the SmallGEO platform

STRENGTHS	WEAKNESSES
• Three Luxembourg companies participate to the development of the SmallGEO platform • LuxSpace is one of the subsidiaries of OHB, now the third GEO satellite integrator in Europe	• Euro-Composites is not developing structure for the SmallGEO platform • Competition from European platform subsystems integrators (Ruag and Casa) in case of geo-return
OPPORTUNITIES	**THREATS**
• Gradel's experience with the MGSE of AG1 beneficial for other satellites' MGSE • Return of Euro-Composites in satellite structure development • Developing national capabilities in a new domain of satellite technology (electric propulsion for all electric satellites)	• European institutional demand for the SmallGEO platform not all accessible to Luxembourg suppliers (e.g. MTG, EDRS) • OHB's strategy of workload distribution between its European subsidiaries • Low cost competitiveness of the SmallGEO platform for the commercial market

2.2.2.4 Electric propulsion

Trend in satellite electric propulsion

Electric propulsion is potentially a game changer for the economics of satellite operation. As of today, electric propulsion is used only for the in-orbit station keeping of some large geostationary satellites as it is not yet cost-effective for all types of geostationary satellites. In a recent satellite proposal[20], it appears that the option of electric propulsion for station keeping increases the price by 5%. ESA has already experienced the advantages of using electric propulsion for Artemis and Smart 1 and has selected it for future science (BepiColombo), telecommunications (Alphabus and SmallGEO) and earth observation (GOCE) satellites.

The use of electric propulsion for orbital injection would allow significant mass saving that would permit lower cost launches or more capable satellites but at lower launch mass than today. Over 50% of the launch mass of a geostationary satellite today is for the propellant and the associated hardware. If the launch cost savings compensate for the cost of the electric propulsion system itself and for the operational unavailability of the satellite during the transfer time[21] it will be endorsed by commercial satellite operators as a cost-effective technology. The generalization of all electric satellites should be a long time process as illustrated by previous cases of new technologies introduction (e.g. electric propulsion for station keeping, lithium-ion batteries). As of today, Space Systems/Loral and Astrium have together a total of 20 satellites in orbit equipped with electric propulsion for station keeping even though the technology has been used for decades in Russia.

Satellite orbital transfer using electric propulsion has been tested in the few cases when the traditional chemical propulsion failed to achieve the geostationary orbit (Artemis satellite in Europe and AEHF-1 satellite in the USA[22]) and for deep space satellite missions that required high energy propulsion systems (Deep Space 1 in the US, Smart in Europe). To date, no civilian satellite has been injected purposely into the geostationary orbit with electric transfer. This should happen for the first time in 2015 when two commercial geostationary satellites built by Boeing with such capability will be launched together on a single launch of Falcon 9.

SES, which is rather conservative in new technology adoption on its satellite fleet, has expressed a strong interest for having all electric satellites in the future. If electric propulsion proves to be a reliable technology for the orbital transfer of geostationary satellites, then SES may consider adopting it for a more cost-effective satellite fleet.

Luxembourg positioning and future perspectives for satellite electric propulsion

Various thrusters have been developed and qualified in-orbit for electric propulsion in Russia (Fakel's SPT), USA (L-3 ETI's XIPS), and Europe (Snecma's PPS-1350 derived from the SPT). Others are in development in Europe (Qinetiq and Thales Electron Devices). Space Systems/Loral and Astrium

[20] For two Asiasat satellites (5 and 8) at 3,200 kg of unit launch mass by Space Systems/Loral with launch by SpaceX.

[21] Transfer time is estimated between 5 to 6 months during which the asset is unproductive.

[22] The 4.5kW HTPS engine of Aerojet for AEHF-1 allowed for a propellant mass saving of 900 kg compared to the use of all chemical propulsion. On AG1, the use of the HEMPT will allow for a mass saving of 220 kg. On the KaSat of Eutelsat, the use of electric propulsion hybrid with chemical propulsion for station-keeping allowed for a mass saving of about 1,000 kg. If KaSat had been a full EP satellite, the mass saving would have been 30%

Satellites, the two leading manufacturers of commercial geostationary satellites, have been using electric propulsion for station keeping since 2004 while Boeing and Lockheed Martin have longer experience with US Government satellites. Space Systems/Loral is currently developing an ion thruster to shorten the orbit-raising period to as low as three months, a time period it considers critical to improve the economic advantage of all electric satellites.

	Satellite integrator	Supplier of EP thrusters
AlphaBus	Astrium + TAS	Qinetiq (T6) and Snecma-F (SPT)
SmallGEO	OHB	TED-G (HEMPT) and Snecma-F (SPT)

To stimulate their domestic industry base, various Governments of ESA Member States have invested in electric propulsion technology development over the past decade, resulting in competing designs (France, UK, and Germany) with low flight heritage for geostationary satellites. Italy, Austria and Switzerland also work on other thrusters technologies for low earth orbit and scientific missions.

Various developments are under way in the USA and Europe to qualify new generation of ion thrusters and to experiment new technologies in the area. SES itself has two university partnerships on electric propulsion for transfer orbit with Princeton University and La Sapienza University of Rome.

Studies are in progress on devices that create thrust without electrodes or other erodible parts being immersed in the plasma. A start-up company (Elwing) recently entered into an agreement with OHB Sweden to develop electrodeless plasma propulsion technology that would allow for all electric geostationary satellites[23]. Elwing is looking for the opportunity to have its technology qualified in orbit at a development cost it estimates at $25 million over three years. Elwing has approached the Government of Luxembourg for that development to be carried out in Luxembourg. In comparison to Astrium Satellites and TAS, that have in-house technology development capabilities, partnering with OHB will bring for Elwing the advantage of technological complementarity. The mode of financing this technology development imposed by OHB will condition the viability of the option of developing electric propulsion in Luxembourg.

[23] Elwing claims to hold multiples patents on the technology in 20+ jurisdictions

Luxembourg SWOT for satellite electric propulsion

STRENGTHS	WEAKNESSES
• Availability of Government funds in Luxembourg to support the technology development effort of Elwing for a new technology for satellite electric propulsion (electrodeless) • Interest of SES for all electric satellites (i.e. orbital injection and station-keeping)	• Strong industry players have qualified electric propulsion devices with technology improvements efforts in progress in the USA, Europe and Japan • Commercial operators are slow to adopt new technologies for their satellites • Satellite integrators already have large interests in electric propulsion associated to traditional technology (i.e. using electrodes)
OPPORTUNITIES	**THREATS**
• The new technology for electric propulsion proposed by Elwing can proved to be cost-effective for all electric satellites (electrodeless and thrust scalability)	• All electric satellite technology will not prove its economic advantage before many years of R&D • Elwing may not succeed to compete with established European players to access public R&D fund to finance the qualification of its technology • Low R&D synergy of electric propulsion with the academic sector in Luxembourg

2.2.2.5 Next Generation Platform

Trend in the Next Generation Platform market

The European satellite industry, led by CNES and ESA, is embarking on the design of a new platform for missions of typically 3 to 6 tonnes in geostationary orbit. The research programme, commonly called Next Generation Platform (NGP), aims to launch a prototype of the platform by 2018. Considering that more than 80% of the geostationary communication satellite market addressable by the European industry concentrates on that segment, the opportunities are huge for the industry in the commercial market. A demand of up to 150 NGP platforms is estimated for the expected lifetime and desired market share (50%) of the product.

Astrium and Thales Alenia Space (TAS) currently serve that segment with the Eurostar and Spacebus platforms that will incrementally be improved (under ARTES 3&4) before NGP becomes available. Two new platforms are currently in development for the low end of the market (SmallGEO) and for the higher end (Alphabus) with a first flight in 2014 and 2013, respectively. The target of NGP is to improve cost competitiveness at satellite level by 30% with respect to legacy products. NGP is a joint initiative of Astrium and TAS in order to optimize the use of R&D funds and to maximize the return on investment for the suppliers participating to NGP development. Under the supervision of ESA and CNES, the goal is to develop a maximum of common building blocks on an agreed single set of requirements at European level.

European telecommunication satellite platforms

Platform		Satellite launch mass	Payload power consumption
Today	Future		
	SmallGEO	up to 3000 kg	up to 3.5 kW
Spacebus 4000 Eurostar 3000	NGP	3000 kg - 6000 kg	up to 12 kW
	Alphabus	6000 kg - 8000 kg	12 kW - 18 kW

In order to efficiently harmonise efforts from technology and equipment suppliers up to prime integrator level, a preliminary design of the system architecture and an initial top-down assessment of the procurement chain has been performed by CNES through its "Programme d'Investissement d'Avenir" (PIA) with a total investment of €42.5 million. Currently, NGP-related invitations to tender (ITT) are managed through ESA's GSP and ARTES 5.1 programmes. In 2013 a new ARTES element dedicated to NGP will be introduced that will divide into two sub-elements. Satellite and sub-system design activities will be carried out up to 2013 to be followed by technological development and qualification.

Luxembourg positioning and future perspectives regarding NGP

NGP development implementation rules will be decided at the ESA Ministerial Conference in November 2012 according to member States' contributions. An overview of the key technologies to be investigated by subsystems is given in the following table.

Key Technologies for Next Generation Platform (NGP)

Subsystem	Candidate Technologies
AOCS	Low-cost Gyro (MEMS technology) : development of the technology and the associated electronics
	Star tracker : concept with remote S/W in the Satellite Computer
Data Handling	New generation of computer with major improvement of memory and processing capacity
	Bus couplers such as wireless technology (for ground and/or flight?)
Electrical Power	High efficiency DC/DC Converter
	Solar Arrays: AsGa cells evolution, layer, flexible panels, concentrators,…
	Battery: new cells generation– opportunity of regenerative fuel cells?
	Need of battery bypass?
	New concept of cells balancing?
Harness / connectors	Development of a new high performance wire (mass, digital performance, …)
	Connectors : screw-less locking, industrialisation …
Pointing Mechanisms	Accurate Pointing : development of new high performance mechanisms
	Low-shock antenna & solar array hold down and release mechanism
Structure	New direct manufacturing processes
	Development of a new fibre
	Integration of new functions within the structure perimeter
	Specification, conception & qualification of damping system

Thermal	Thermal joints & glues, Scotch Secondary Surface Mirror , High Performance OSR
	Development of new paints & coatings (i.e. electro-chrome type)
	Development of a new source of heat-pipes
	Deployable Radiator , Fluid loop heat-pipes …
Propulsion (Chemical & Electrical)	New products with higher performance (Isp, life-time,…)
	Magnetic beam steering for Electric Propulsion

Potential niches for Luxembourg have been identified in the following areas:

AOCS: development of MEMS technology and electronics. The to-be-merged CRP-Gabriel Lippmann and CRP-Henri Tudor are acknowledged by ESA for their capabilities in these domains. **Synergies between the two institutes are likely to foster the capability of Luxembourg in the domain of electro-mechanical systems.**

Thermal: new sources of heat pipes / fluid loop heat pipes. CRP-Gabriel Lippmann SAM and TAS recently announced their intention to conduct joint R&D regarding the development of thermal components of heat pipes (the work being performed under CNES budget). It is likely that the outcome of this R&D be related to current NGP requirements for heat pipe technology innovation. **It could therefore be of interest for Luxembourg, and its public research centres in particular, to closely monitor the evolution of heat pipe technology and invest in the required infrastructure.**

Structure: new direct manufacturing processes. Novel manufacturing and joining techniques aim to reduce mass, volume, manufacturing & AIT complexity and quality control inspections in space systems design. Technologies used include screw-less joining, flange-less feed components and novel welding techniques. The additive manufacturing technique physically constructs 3D geometries directly from 3D CAD and allows spacecraft structures resulting from complex multi-materials assemblies to be manufactured in one shot. So far, Luxembourg does not have any major capability in the domain. However, **considering the significant legacy of the country in the field of structures and materials (CRPs, Euro-Composites, Gradel, X-Stream and other companies not yet engaged in space activities), direct manufacturing processes may be an area of interest for the country**. Such processes have been used extensively in other industries such as automotive, aviation and military using complex parts of small to medium size.

Electric propulsion: As of today, it is not clear what concept of propulsion system NGP will use. If electric propulsion is baselined for an all electric platform, the Luxembourg industry may take part to the development, provided it is well articulated with the decision to be made on the investment in a new thruster technology at national level (see dedicated section on electric propulsion above).

Luxembourg SWOT for Next Generation Platform

STRENGTHS	WEAKNESSES
• Existing basic capabilities in the national industrial and academic sectors	• Euro-Composites is not developing structure for the SmallGEO platform
OPPORTUNITIES	**THREATS**
• Participate from the early days to the design of a new European satellite product with strong commercial demand • Develop national capabilities in a new domain of satellite technology (electric propulsion for all electric satellites) • Develop national capabilities in niche techniques for future satellite technology (MEMS, heat pipe, structure manufacturing, welding)	• Cost competitiveness will drive supplier selection by the two integrators (Astrium and Thales Alenia Space) • Strong competition from more advanced suppliers of subsystems in new technology development

2.2.2.6 Ka-band ground antenna

Trend in Ka-band antenna market

Ka-band ground antennas are increasingly used for high rate communications for different types of satellite systems: scientific for deep space missions, communication, earth observation and meteorology. While communication satellites are predominantly commercial, the other applications are under the responsibility of Governments that procure satellite systems (including ground equipment) from national industries. The use of always higher frequency bands is a structural trend in the satellite communication industry where Ka-band is now an operational frequency band along with X-, C- and Ku-bands for civilian and military users.

Demand for Ka-band ground antennas for communication satellites is growing as more and more hybrid or dedicated Ka-band geostationary satellites are launched for fixed and mobile broadband communications and for high definition TV in the USA. In addition, the first commercial satellite system in Ka-band will be launched in medium earth orbit starting in 2013 for O3B. Commercial geostationary satellites use Ka-band frequencies to serve end user terminals but also for internal satellite operations (LEOP, TT&C, IOT and payload operation). Such functions are generally provided with large antennas (over 10m) capable of full motion.

The usage of Ka-band frequencies for earth observation and meteorology missions in low earth orbit is less mature. However, the increasing performance of such satellite systems results in an increasing volume of data that have to be transmitted to ground stations with growing requirements for real time transmission. In parallel, the traditional systems in S and X-band may either progressively get saturated or be insufficient considering the data rates required. Several space agencies use in-orbit

data relay systems in Ka-band (e.g. TDRSS and EDRS) and earth observation satellites are equipped with data downlink in Ka-band (e.g. the Sentinel satellites of the GMES program of the European Union).

Thanks to the support of its Government market, the US industry dominates the sector with a wide range of qualified products and capabilities (IOT, TT&C, gateway, uplink and data reception). Two US companies especially lead the global market:

- Viasat is the market leader with over 75 Ka-band gateways delivered to date (from 3 to 13.5 m) to commercial satellite operators and to the US Government (NASA and DoD)
- GD Satellite Communications Technologies (formerly Vertex RSI), a leader in X-band antennas, claims the sale of 50 Ka-band antennas of 9.2m and 13.2m for various uses (TT&C, IOT, broadband access and TV uplink).

The two companies sell directly to the US Government or through military communications integrators such as L-3 Communications Systems-West or Harris. The other main suppliers are American (Hughes Network System, Globecomm Systems Inc. and ASC Signal) and Israeli (Gilat Satellite Systems). Hughes and Gilat are active in the Ka-band market with both small user terminals and gateways. ASC develops very specific radar and satellite antenna systems for the USAF and the US Navy but it is increasingly present on the commercial market.

Luxembourg positioning and future perspectives in Ka band ground antennas

HITEC has developed full motion and limited motion antenna systems in different diameters and different frequency bands for TT&C and IOT. Its main client to date is SES, both for its own use and for SES TechCom's client use (e.g. for the Vinasat system of Vietnam). In partnership with SES TechCom, HITEC developed two large TT&C antennas in S-band installed at Kourou and Kiruna for Galileo In-Orbit Validation under contract of the DLR and Inmarsat for ESA (acting as technical procurement agent for the European Commission). Separately and pursuant to an inter-governmental agreement with Germany, HITEC has developed a large in-orbit testing antenna in Ka-band for the DLR that will enable it to have mission support and research in this frequency band. In April 2012, HITEC was selected by ESA (GSTP) with its Swiss partner Mirad to design an S/K-band full motion antenna (13 to 15 m) for earth observation (TT&C in S-band and payload data in K-band).

Luxembourg research entities have participated to these developments, especially SnT and RUES.

HITEC's future in the Ka-band antenna market is highly dependent on SES TechCom's capability to provide ground system engineering and operation services to European Government clients (as in the case of EDRS operation centre to be provided by Redu Satellite Services to Astrium). The acquisition by Luxembourg Defence of Ka-band capacity on WGS (and potentially on SES satellites) is an opportunity for SES TechCom and HITEC to develop their activity in Ka-band. Other future European missions with specific requirements (H2Sat, L2 and lunar missions) may allow HITEC to partner with SES TechCom for the DLR. The ARTES activities preparing the use of a new frequency band (Q/V) and of laser communications will be of interest to HITEC and SES TechCom. Under DLR guidance, the German industry is at the forefront of satellite laser communications worldwide.

Access to the commercial Ka-band antenna market seems difficult for HITEC as it will have to compete with US suppliers that benefit from a large captive domestic market (DoD and NASA). This

allows them to be present in the commercial marketplace with qualified and standardized products having amortized non-recurring costs. The niche positioning of HITEC implies it remains proactive with respect to the technology development needs of SES TechCom, DLR and ESA.

Luxembourg SWOT for Ka-band ground antennas

STRENGTHS	WEAKNESSES
• HITEC has developed a full motion large Ka-band ground antenna for in-orbit testing • Synergies with national applied research resources for antenna technology research	• HITEC's dependence from SES TechCom for market access • Not the critical size to achieve economies of scale for antenna development
OPPORTUNITIES	**THREATS**
• Growing commercial and institutional demand for large Ka-band ground antennas • Niche offering of HITEC for the needs of SES TechCom, DLR and ESA • Research on ground antenna technology evolving toward Q/V band and laser communications	• Strong competition of US suppliers offering qualified and standardized products at lower prices than European suppliers • Ka-band antenna procured competitively in case of PPP for satellite systems for European Governments

2.2.2.7 Mission operations

Trend in satellite mission operations

Mission operations are defined by all the equipment, software and manned engineering capabilities that are required to:

- operate a satellite system during its lifetime in-orbit (from launch and early orbit phase to end of life deorbitation)
- collect, store, process and distribute the information produced by the satellite mission to the users.

The operations of commercial geostationary satellites are generally provided internally by the satellite operator or by a third party operator (as it was the case initially for Hellasat by SES TechCom). Information relayed by commercial geostationary satellites is generally received, processed and distributed by the clients of the satellite bandwidth.

As European Governments are increasingly using low earth orbit satellite systems for operational missions in earth observation, meteorology and navigation, they tend to contract with commercial suppliers for mission operations through public-private partnerships (PPP) or facilities management contract. This creates business opportunities for ground network operators and specialized ICT providers. The data collection and dissemination of satellite missions has historically been under the

responsibility of the space agencies but as they now share the investment with operational agencies, they increasingly go to third parties for such activity.

Four large satellite infrastructure programs are currently deployed in Europe totalling an investment of about €20.78 billion. EDRS is the only one to be financed through a PPP between ESA and Astrium Services for a contract value of €275 million that includes a dedicated small geostationary satellite to be provided by OHB in addition to a data relay payload hosted on a commercial satellite of Eutelsat. The EDRS satellite will host a commercial payload for Avanti (Hylas 3) that will help to finance the satellite investment of about €150 million.

Four large satellite infrastructure programs in Europe

	Owner	Total investment (incl. operation)	Satellite system	Mission operation	Luxembourg commitment to date
GALILEO	EU/GSA	€11 billion	OHB + SSTL	RSS for IOT	€6 million ESA (e.c. 2001) + 0.21% EU
GMES	EU/?	€7 billion	Astrium + TAS	RSS for Sentinel data collection	€4 million (GSC + GSE)
MTG	Eumetsat	€2.5 billion	TAS + OHB	TBD	€500,000 (e.c. 2008)
EDRS	ESA PPP	€275 million	Astrium Services + OHB	RSS for 2 sites (Germany + backup at Redu)	€15.4 million (e.c. 2008)

(*) RSS is the joint venture between SES and Qinetiq to operate the Redu site of ESA

Four new large European Government-financed infrastructure programs are planned for meteorology, maritime security, air traffic management (ATM) and space situational awareness (SSA) that will include satellite systems. The user requirements are currently being defined for these programs with ATM and SSA requirements being the more complex to define as they involve different user communities internationally.

1. **Meteorology**: Eumetsat is the user of the meteorological satellites designed and developed with ESA. The second generation of METOP to be operational by 2020 should comprise up to three sets of satellite pairs at a total cost of €3.8 billion of which ESA would contribute for about €540 million.
2. **Maritime security**: EMSA is the user Agency of maritime surveillance information with ESA contributing for the development of the satellite component: SAT-AIS and the Sentinel satellites of GMES. The SafeSeaNet (SSN) service of EMSA for coastal AIS operates with five regional servers and a European Index Server (EIS) hosted by the DG DIGIT in its Luxembourg facilities. ESA contribution to SAT-AIS is organised through three ARTES elements that deal with technology development (antenna, receivers, … through ARTES 5), validation of a data processing centre with co-funding from EMSA (Blue Belt of ARTES 20), and the definition of an operational demonstration mission (ODEM) and of a PPP for an operational system (ARTES 21).

   Two European countries with strong interest for maritime security both as user and supplier are involved in SAT-AIS as a complement to other information sources:

- France: CLS manages the Blue Belt IAP project with SAT-AIS data provided by KSAT, exactEarth and LuxSpace. CLS has also experience in radar imagery that will be used complementarily to AIS information for future maritime security services.
- Norway: As part of bilateral agreement with Spain, Norway will have an AIS receiver added to the Spanish PAZ observation satellite in order to combine both capabilities on the same satellite.

3. **Air Traffic Management:** IRIS (ARTES 20) is the satellite contribution to the Single European Sky ATM Research (SESAR) programme of the EU. By 2020 it will contribute to the modernisation of air traffic management by providing digital datalinks to cockpit crews in continental and oceanic airspace. Architecture studies are in progress with Astrium and Thales involving satellite operators in order to have testing of satellite communications for ATM starting by 2015. As in the case of AIS, the business models studied as part of a PPP are not yet conclusive on a dedicated satellite infrastructure.
4. In 2009, ESA initiated the preparatory programme for **Space Situational Awareness** (SSA) with other European stakeholders (the European Commission and the European Defence Agency) on a SSA system that will have four main components for three segments of applications (Space Surveillance and Tracking, Space Weather and Near Earth Objects):
   - Sensors located on the ground and in space
   - Data centres (one per segment, see table below) to receive and correlate sensor data (plus a SSA Tasking Centre located at ESA/ESOC in Germany)
   - Management system (including a dedicated data centre) to conduct overall system control and data distribution
   - Service centres (one per Segment) - to deliver data products, warnings and alerts to SSA customers

SSA segment	Space Surveillance and Tracking (SST)	Space Weather (SWE)	Near Earth Objects (NEO)
Pilot data centre location	Space Surveillance Test and Validation Centre (SSTC), located at ESA/ESAC, Spain	Service Coordination Centre (SSCC), located at RSS in Belgium	Small Bodies Data Centre (SBDC), located at ESA/ESRIN, Italy

Luxembourg positioning and future perspectives for Mission Operations

European Governments' investments in satellite infrastructure have been beneficial to date principally to SES TechCom, either directly or through its joint venture with Qinetiq in Redu Satellite Services (RSS) and to a lesser extend to HITEC (for Galileo IOV) and Telindus (ESOC information security).

RSS was selected in 2007 by ESA to maintain its ground station facilities at Redu in Belgium and to operate satellite missions from there under a 10-year contract. In continuation of its role of serving ESA missions, Redu is the site of ESA's new space weather data centre for SSA. Through a concession agreement with ESA, RSS can offer commercial services from Redu. RSS was selected by ESA for the

IOT of the full Galileo constellation (in addition to the IOV satellites already tested from Redu) and by Astrium for the mission operation centre (MOC) of EDRS.

Separately of RSS, SES will create activities in Betzdorf in relation with its investment in the commercial Ka-band system of O3B. The fleet of 16 satellites in medium earth orbit will be controlled and operated from SES facilities in Luxembourg with a staff of over 20 people.

Luxembourg companies such as SES TechCom, P&T and Telindus have the capability to offer multiyear service contract for satellite mission operation, preferably in joint offers. However, the economic activity to be generated for Luxembourg by satellite mission operations is mainly conditional upon the decision of SES (and then of SES TechCom) to get involved in a PPP with European Governments at conditions that are satisfactory for its shareholders in terms of profitability and cost of opportunity.

As users of satellite systems, the decisions of European Governments and international entities will be critical for the future of the Luxembourg suppliers of ground equipment & services: ESA, the European Commission (and its operating agencies, e.g. EMSA), Eumetsat and the German Government (through DLR). Each of these four organizations has different policies and rules to procure the ground equipment and services associated to the satellite systems they financed. This heterogeneity requires that Luxembourg Government strategy be coordinated with that of SES as the company has to balance multiple and contradictory interests for its own strategy. **A better coordination of mutual interests could be achieved by involving SES more in the definition of the satellite R&D programme of Luxembourg.**

Luxembourg SWOT for Mission Operations

STRENGTHS	WEAKNESSES
• Existence of robust national infrastructures and capabilities in data centre and information technology security • Investment capacity of SES into new satellite ventures (TechCom, O3b, RSS, ...) • Complementarity of Luxembourg and Belgium investments in RSS	• Dependence of Luxembourg players from SES strategy
OPPORTUNITIES	**THREATS**
• Investment capacity of SES to participate to public-private partnerships with European Governments • Synergies with strategy of Luxembourg IT service providers looking for more internationalization • Leverage on SES TechCom market access for other national players	• SES's request for return on investment not favourable to public-private partnerships with European Governments

2.2.2.8 Downstream satellite services

Trend in downstream satellite services

The provision of communications, broadcasting, geospatial and navigation services using satellite systems has totally different business logic than that to develop satellite systems. From a technology neutral perspective users look for cost-effective solutions, therefore the satellite solution generally combines with terrestrial solutions. The satellite solution is unique when the terrestrial networks and systems are either not available physically or available but not at the right quality level.

Integrated applications is a concept that is being promoted by ESA to support the emergence of new satellite services (preferably by SMEs) that combine the capabilities of different satellite systems and/or terrestrial systems (e.g. satellite communications/3G with satellite images, GPS + satellite images).

Domains	Communication	Broadcasting	Geospatial information	Navigation information	Integrated applications
Satellite's role	Backup, complement and replace terrestrial networks	Primary network to feeds terrestrial networks	Combined with aerial and in-situ data collection	Primary solution for global coverage	Combination of capabilities of different satellite systems

For businesses to develop into satellite services provision the market has to be accessible and profitable. This is not the case when incumbent terrestrial operators still have a de facto monopoly (e.g. on teleport and VSAT networks) or when Government agencies compete with private suppliers (e.g. environmental research). Economies of scale are important in satellite service provision and start-ups generally have difficulties in expanding their satellite service capabilities over large geographical areas and to different clients' types.

Profitability in satellite service provision is allowed when the cost of the infrastructure (satellite bandwidth or observation time + ground equipment) and operational costs can be recouped with a price that values the quality or uniqueness of the service that is delivered.

Satellite services have developed very strongly in the past 20 years in the broadcasting industry because of the extraordinary cost efficiency of the satellite solution, while for the communications industry the satellite infrastructure remains marginal especially in regions well served by broadband wired and wireless terrestrial networks. In the geospatial domain the technology improvement of satellite observation of the earth has allowed for optical and radar imagery to become a commercial marketplace while the processing and interpretation of this imagery remains strongly internalized by Government agencies. This has as consequence that 1) the value added service providers that emerged have developed captive Government businesses and that 2) new entrants compete for a small accessible market with large established suppliers and sometimes even with Government structures.

Downstream services are highly developed in the satellite communications domain with an estimate of €65 billion of revenues worldwide, of which 85% derive from a single application: Direct-to-Home (DTH) TV broadcasting. The remainder is made of professional broadcasting services (backhaul of TV

content) and communication services (backhaul of fixed and mobile telephony, internet broadband access and private communication networking). Satellite TV growth is decelerating in mature digital media markets (i.e. North America, Europe, Japan) as the competition from alternative terrestrial broadcast networks is growing (cable TV, digital terrestrial TV, IPTV). This deceleration is offset by the growth of satellite TV in emerging markets (Asia, Middle East, Africa and South America) where the number of multichannel satellite TV platforms multiplies and where the number of TV channels increases. In several digital TV and entertainment markets the transition from standard broadcasting to high definition broadcasting has started with larger demand for satellite bandwidth. 3D-TV is still a technology demonstration market to which satellite broadcasting will have to adapt in the long term future.

In the domain of broadband communications by satellites, two applications emerged in the past ten years driven by the requirements of the North American market:

- Military satellite communications (milsat communications) with the multiplication of theatres of presence of the US forces outside the country. Commercial satellite bandwidth and service providers are used by the DoD[24] in addition to proprietary satellite systems of different capabilities[25];
- Internet broadband access by satellite with two systems in competition (Viasat and HNS) to serve the rural and remote areas in the USA and Canada not well served by ADSL and other broadband access solutions.

The business models that have developed in the USA for these two applications cannot be replicated as such in other geographic markets considering the specifics of that market. In Europe, the countries involved in peacekeeping and military operations outside their borders have contracted with commercial service providers for milsat communications services, either through PPP (Paradigm in the UK, Spainsat in Spain, Milsat Services in Germany) or through regular service procurement (e.g. ASTEL and PASTEL contracts in France). The large specialized satellite service providers such as Astrium Services and Telespazio generally partner with telecommunications operators (e.g. BT, Orange Business Services, Deutsche Telekom) to offer one-stop shopping solutions to their Government clients for satellite communications services.

Internet broadband access by satellite is new in Europe with the first two dedicated satellites using multispot beam Ka-band frequencies having been launched in 2011 (Hylas and KaSat) with a combined capacity for 1.3 million consumer subscribers. Skylogic, Eutelsat's subsidiary in charge of marketing the Tooway service, has started to sign distribution agreements with large and small IP service providers in Europe. The satellite user terminals are provided by US companies (HNS, Viasat).

In the earth observation and navigation domains, the downstream value-added services that can be attributed to satellite systems are much smaller than in satellite communications (estimated together at about €5 billion vs. €65 billion in satellite communications). This is because the information created by the satellite (i.e. scanning of the Earth and PNT signal, respectively) has not so much value per se if it is not combined with other information to provide geospatial and location-based services (LBS). This is typically the business of value-added service providers that design and deploy services that include satellite information for different categories of users (Governments, businesses, individuals) in

[24] 80% of the non-secured satellite bandwidth required by the US Government is supplied by commercial satellite operators.
[25] Of which the WGS satellite system to which Luxembourg will participate.

different economic sectors (e.g. homeland security, precision agriculture, fisheries, maritime transportation, leisure & travel).

Satellite-based value-added services will develop commercially outside the satellite communications domain upon two main conditions:

- Governments procure geospatial and LBS services from third parties at true service development costs;
- Businesses in various economic sectors perceive that the productivity gains of using satellite solutions justify the cost of the solution.

Luxembourg positioning and future perspectives in downstream satellite services

SES has been one of the few winners of the satellite broadcasting industry globally with the creation of SES Astra to serve European households and with external growth through the acquisition of other operators worldwide. However, this "infrastructure" success of SES has not been a driving force for the creation of content and media companies in Luxembourg nor for the development of a satellite TV terminal industry there.

SES's portfolio of clients is now diversifying with the provision of satellite capacity for Government communication services and internet broadband access in addition to legacy broadcasting capacity.

SES offers more than satellite capacity to Governments as illustrated by the engineering services or hosted payloads it is providing to NATO (Alliance Ground Surveillance project), the European Union (EGNOS L-band payloads on two satellites) and the USAF (CHIRP payload on SES-2)[26]. Increasingly, Governments look for services rather than just capacity lease.

For consumer and professional broadband access, SES has developed SES Broadband Services that was introduced on the European market in 2007 under the brand name of Astra2Connect. The service is available in Ku-band from two orbital slots through national resellers. It had 80 000 subscribers early 2012, ahead of Eutelsat's competing service. The Astra2Connect platform was developed by SES at a substantial cost with initial support provided by the ARTES programme (*Satmode* project). The transition to Ka-band will occur in 2013 with end-user equipment now developed by Newtec (Belgium) and Gilat Satellite Networks (Israel).

The SES Broadband platform is not only used to provide consumer broadband access. Its other uses include eSchools, internet kiosks, maritime communications, village connectivity, and tele-measurement (e.g. for smart grid networks).

The perspectives for these services are favourable, even if they will not achieve the economic value of satellite broadcasting because of a smaller addressable base combined with a lower penetration rate of satellite technology. User equipment is critical in the economic equation of broadband communication satellite services. User terminal manufacturers generally have a technology base that was developed through military communications R&D. The Newtec company is an exception as it was created *ex nihilo* 25 years ago in Belgium and developed into a pure player with now 300 employees, three product lines and over 50 different products. In its first ten years, Newtec worked exclusively on R&D and projects for ESA as part of ARTES. ESA and Belgium's support outside of ESA remain strong

[26] About 25% of SES business is now Government related (source: SES interview).

for Newtec. SES is a large client or prescriber of Newtec's products, both for satellite TV and broadband communications. **The business and technology relationship that is developing between the two companies as part of SES Broadband Ka-band terminal could expand in the future to the benefits of the two companies with co-development activities in Luxembourg**.

One way to prepare the satellite service market of the future is to combine satellite functionalities in order to maximize the benefits for the users. As part of the phase 1 of the IAP program of ESA (ARTES 20) about 25 projects have been financed by ESA Member States for both feasibility and demonstration studies. Three of them involve the EVA Department of the CRP-Gabriel Lippmann as a partner in European consortiums (BIOSCOPE, SAVEWATER and FAAPS). This department, which conducts applied research in environment and agro-biotechnologies, focuses on hyperspectral sensors (in the field and airborne). This specialization could prove synergetic with hyperspectral observation from space, a domain that is quite new. Hyperspectral observation is of high interest for specific research and application sectors (environment, agriculture, land use, water management and geology) that fit with EVA and Geoville's activities.

A limited number of spaceborne hyperspectral systems have flown to date in Europe, of which the Proba-1 technology demonstration satellite of ESA launched in 2001 equipped with the CHRIS sensor (14 kg)[27]. Germany and Italy have large national interest in spaceborne hyperspectral instrumentation with two satellites now under development (EnMAP and Prisma, respectively). It is worth noting that OHB is involved in the two projects through CGS in Italy (platform supplier and integrator for Prisma), Kayser Threde (hyperspectral imager of EnMAP) in Germany and the supply of the EnMAP platform.

	Prisma (Italy)	EnMAP (Germany)
Basic specifications	500 kg, 5 years lifetime	810 kg, 5 years lifetime
Launch date	2012 (Vega)	2013 (PSLV)
Partners	ASI, Carlo Gavazzi Space (CGS), Selex Galileo, Rheinmetall Italia	DLR, GFZ, Kayser Threde, OHB
Platform heritage	Agile, MITA	SAR-Lupe

[27] Proba-1 development was financed by GSTP with the platform developed by Verhaert (now Qinetiq Space of Belgium) and the CHRIS sensor funded by the UK (provided by Sira Electro-Optics, acquired since by SSTL).

Luxembourg SWOT for Downstream Satellite Services

STRENGTHS	WEAKNESSES
• SES's operational experience of Government services in the USA • Deployment of SES's Broadband service in incremental mode • Business relations existing between SES and Newtec of Belgium for satellite communications user terminal • EVA's experience in airborne hyperspectral observation	• SES is at disadvantage relatively to Eutelsat and Inmarsat at ESA in terms of MS contributions • Government demand for satellite earth observation services not large enough to allow for service providers to develop • Low capabilities existing locally for satellite communications user terminal development (electronic & RF)
OPPORTUNITIES	**THREATS**
• Luxembourg can leverage on SES' assets and capabilities for international cooperation in milsat communications • Synergies with strategy of Luxembourg IT service providers looking for more internationalization • Leverage on SES TechCom market access for other national players	▪ No single satellite service developing to the extent achieved by satellite broadcasting ▪ Costly transition of SES's Broadband service from Ku-band to Ka-band ▪ OHB's national strategy with respect to spaceborne hyperspectral systems ▪ SES's request for return on investment not favourable to PPP with European Governments

2.2.3 SWOT assessment of the satellite sector in Luxembourg

Considering the review by domains and the other structural factors of the Luxembourg space sector, a general SWOT assessment has been defined for satellite systems and services in the country.

STRENGTHS	WEAKNESSES
• **Existence of SES** with 1) a driving effect on national satellite communications technology development and 2) the capability to partner with European Governments for satellite service deployment and operation • **Relation to Germany** with local industry relation with OHB and with DLR • **ICT capabilities of local** companies (TechCom, Telindus, P&T, HITEC) to serve the satellite infrastructures of the national and other European Governments	• **No critical size in several** areas of satellite technology and engineering (science, microsat, structural parts, ground antenna) that slowdowns efforts to improve quality insurance • **No domestic satellite demand** (microsat, GEO comsat)
OPPORTUNITIES	**THREATS**
• **Participation to the diversification of the supply base** of the three European satellite integrators (TAS, Astrium, OHB) for specific satellite products (e.g. MGSE/EGSE, structural and mechanical parts) • **Enlargement of the domestic base of qualified suppliers** in satellite and ground equipment for systems and services integrators (LuxSpace, SES TechCom, SES Government services, SES Broadband) • **Niche specialization in new satellite technology development areas** (electric propulsion, nanotechnologies, laser communications) through NGP and/or specific developments • **Development of new capabilities in niche satellite services** (satellite communications user terminal, spaceborne hyperspectral observation)	• **Intra-European competition** for specific satellite products from established suppliers (in Spain, Swiss, Sweden, UK and Norway) • **US competition** for Ka-band ground antenna with amortized products • **Lack of coordination within OHB group of companies** may not be in favour of Luxembourg (geo-return for group's subsidiaries and cost competitiveness for commercial procurements) • **Low cost competitiveness** on markets governed by competitive procurements (i.e. commercial companies, EU agencies), both for services or systems

2.2.4 Conclusive remarks on the satellite domains of interest for Luxembourg

- **Microsatellite is a domain where the Luxembourg industry has developed equipment and integration capability with flight experience**. However, the performance of the existing microsatellite platform has to be improved to meet future requirements of the market.
- In order to increase the value of Luxembourg's offering for the microsatellite market mission payloads can be developed in the two domains of interest for Luxembourg's stakeholders: communications and earth observation. **Payload development is an opportunity for the national satellite industry** to expand its capability beyond the platform that tends to become a commodity.
- **Two capability domains will require a significant development investment, but they offer the opportunity of a large commercial market with geostationary satellites: composite structural parts and electric propulsion for satellite injection into orbit**. The Luxembourg industry has experience with structural parts, but not yet with electric propulsion.
- **The Luxembourg industry has developed initial capability in large Ka-band antennas for communications with the satellite missions.** Several opportunities exist with European Governments for their communications, earth observation and meteorology satellite missions working in Ka-band.
- **Four categories of satellite services have growth potential in the decade with opportunities for Luxembourg players to develop, integrate and operate in them: satellite communications, earth observation, satellite navigation and integrated services.** The Luxembourg companies involved in systems development will develop more value added services that will make use of national satellite assets.

PART 3.

REVIEW OF ACHIEVEMENTS OF THE NATIONAL SPACE PLAN

3.1. Methodology to review the achievements of the national space plan

The achievements of the national space plan defined in 2005 and revised in 2008 were assessed relatively to the four strategic objectives of the plan listed below. The national space plan did not associate a time schedule for the completion of the objectives which were considered as ultimate targets for the national space programme. As a result the assessment allows determining how the four objectives have been pursued and met to date.

Each objective is assessed through the analysis of specific criteria (between 2 and 4 criteria by objective). Achievement to date per criteria has been judged notionally on a scale for each criteria. The assessment has been pursued on the basis of the information collected during the consultation of national stakeholders. The space programme of the national space plan is understood in all its dimensions: ARTES participation since 2000, ESA membership since 2005, Luxembourg Industry Incentive Scheme then the 3rd Party Programme with ESA and LuxLAUNCH.

Objective	Stratxxegic objectives of the national space plan	Criteria to assess the national space programme
1	Contribute to the diversification and sustainability of economic activities in Luxembourg by a proactive approach (of identification of new market opportunities)	1. Economic value of the space sector 2. Revenues derived from the space programme 3. Profitability of space activities 4. Space revenue perspectives
2	Consolidate and valorise the competencies existing in the domain of media and communications services	1. Leverage effect from existing competencies 2. R&D efficiency (satellite communications mainly) 3. National partnerships
3	Contribute to reinforce the competitive position of the companies and public research organizations in the space domain	1. Market position of national players 2. Foreign investment in space
4	Develop skills in the space sector in Luxembourg and amplify the integration of Luxembourg players in international networks	1. Space related employment 2. Education and training of space professionals 3. Visibility of the space programme 4. International partnerships

3.2. Achievements per objective to date

3.2.1 Contribution to the diversification and sustainability of economic activities

The first objective of the 2008 national space plan is to "contribute to diversify and sustain economic activities in Luxembourg by a proactive approach (of identification of new market opportunities)". The contribution of the national space programme to this objective is assessed against four criteria:

- The economic value of the Luxembourg space sector in order to measure the importance of space activities with regard to Luxembourg's economy and identify key source of revenues;
- The space revenues Luxembourg companies derived from the national space programme in order to determine how influent the national programme was in generating these revenues;
- Profitability of space activities, in particular in the applications and technology domains where the Luxembourg Government invested;
- Space revenue perspectives, in particular in the applications and technology domains where the Luxembourg Government invested.

a) Economic value of the Luxembourg space sector

The total space revenues of the 20 Luxembourg companies active in the space sector in 2011 amounted to €1.77 billion in 2011[28], of which 96% derived from SES. Considering that Luxembourg GDP was €42.8 billion in 2011, the space sector contributed to over 4% to the national economy. This is much higher than the European average for which the ratio is 0.1%. Obviously this high ratio is induced by SES revenues and stresses the importance of the company for the Luxembourg economy. Without SES and the satellite communications service companies (P&T and Telindus), the ratio for Luxembourg is considerably smaller and even falls below the European average of 0.06%.

Space sales in proportion of GDP in Europe

	Luxembourg	European average
Space industry + satellite operators*	4.3%	0.1%
Space industry (upstream)°	0.02%	0.06%

(*) include SES in Luxembourg, Eutelsat in France, Inmarsat in UK, Telenor in Norway, Hispasat in Spain and Hellasat in Greece

(°) sale data from the European space industry association, Eurospace

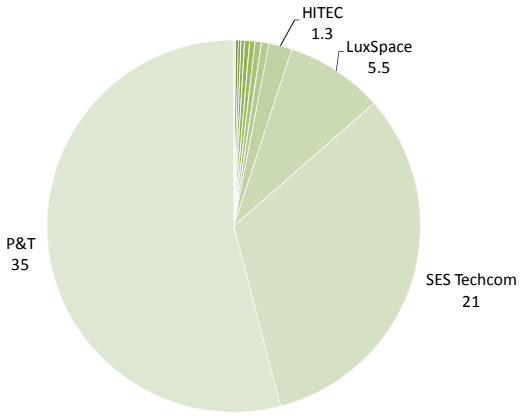
Revenues of the Luxembourg industry are extremely concentrated: even when is SES excluded, the other top four companies generate 97% of the national space revenues. This situation reflects a still fragile structure of the Luxembourg industry: very concentrated on the top and fragmented at the bottom where most industry players generate less than €400,000 in sales. For these players, space revenues are too marginal to make space either a true strategic business (in the case of a multinational company) or a sustainable activity to build on their business (in the case of a SME). It

[28] See section 2.2.1 (the total excludes an estimate of €3 million of budget and contract related to space activities within the academic sector).

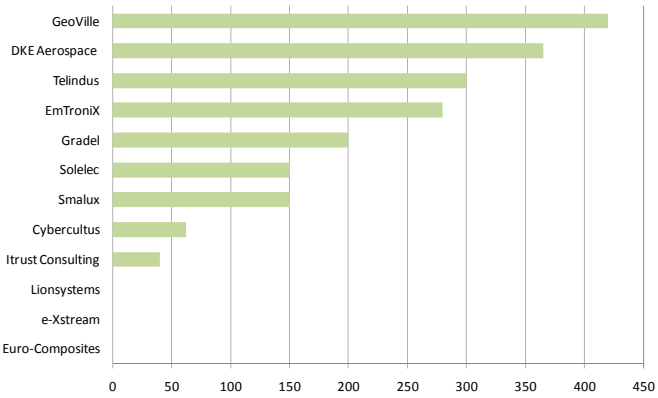
has to be underlined that this situation is quite common for smaller countries with an emerging space sector.

Revenues of Luxembourg space companies excluding SES in 2011

Four major companies (€ in millions)



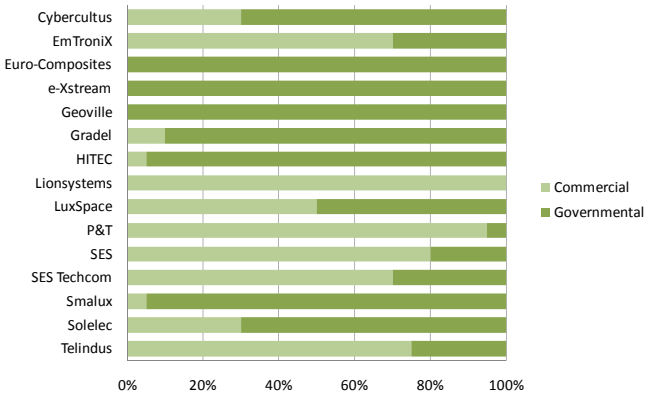
Other companies (€x100 000)



The ratio of Government contracts vs. commercial contracts changes significantly from one company to the other[29]. Whereas smaller companies mainly rely on business opportunities enabled through ESA's geo-return policy and national initiatives, the revenues generated by the larger companies tend to be more commercially driven (SES, P&T, SES TechCom). Out of the companies involved in commercial activities, SES and LuxSpace report the only significant non-European revenues[30].

Breakdown of companies' space revenues

by customer type



*Estimates for Cybercultus, EmTroniX, e-Xstream, Gradel and P&T

by customer origin

	Luxembourg	European	Non-European
Geoville	10%	90%	0%
Gradel	5%	95%	0%
Hitech	50%	50%	0%
LuxSpace	2%	48%	50%
P&T	95%	5%	0%
SES	marginal	56%	44%
Smalux	15%	85%	0%
Solelec	0%	100%	0%

*Estimates for HITEC, P&T and Solelec.

[29] Not only because the definition of Government and commercial contracts is appreciated differently by the companies (i.e. lower tier level suppliers may consider contracts with higher tier suppliers as commercial while the client of Tier 1 supplier is a Government).
[30] LuxSpace reports Vesselsat as a commercial contract for Orbcomm, a US company, while it may invoice OHB who holds the contract with Orbcomm.

Space revenues account for a larger proportion of Luxembourg's economy than the European average because of SES's sales. When excluding SES and the activity it generates for other companies (HITEC and P&T mainly), the structure of national revenues highlights a non-yet mature industry, both upstream and downstream, with risks for long-term sustainability especially for small players and new entrants.

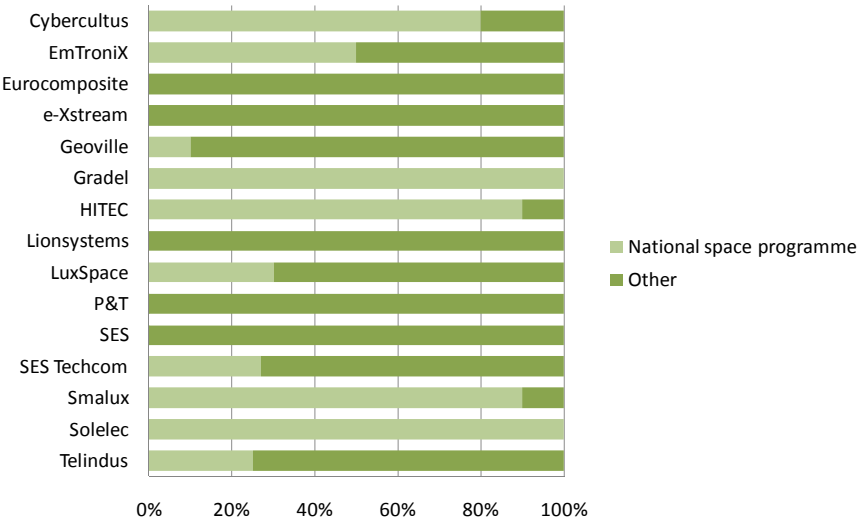
b) Revenues derived from the national programme

The Luxembourg space programme impacts the local industry to a different extent. The few companies that generate most of the industry's revenues report to derive a marginal fraction of their revenues and limited financial leverage from their participation to the national programme. This includes three multidisciplinary companies (P&T, Telindus and Solelec,) for which space activities are not considered to be a strategic business line. This also includes SES who has had until now limited leverage between its participation to the national space programme and its satellite business. SES TechCom certainly represents SES's business line with greatest interactions to the space programme, as Government funding into the *Satmode* project through ESA has supported the company to develop its consumer broadband service.

The companies who reported a marginal impact of the national space programme in their revenues concentrate 40% of Luxembourg's public funding contracts between 2000 and 2011 (of which 30% for SES alone).

Other industry players are in the opposite situation with a strong dependency of their space revenues from the national space programme. In fact, for most of them, contracts from the national space programme represent most, sometime all, of the revenues they generate in space. As these companies are essentially SMEs and sometimes pure players in niche markets, this support should be designed to encourage them to dedicate enough effort to access the commercial market, thus reducing their dependency on Government support.

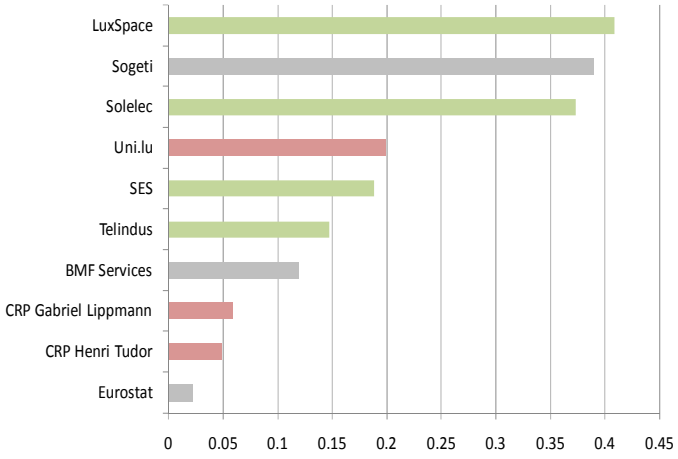
Revenues from the Luxembourg space programme as % of total revenues (2011)



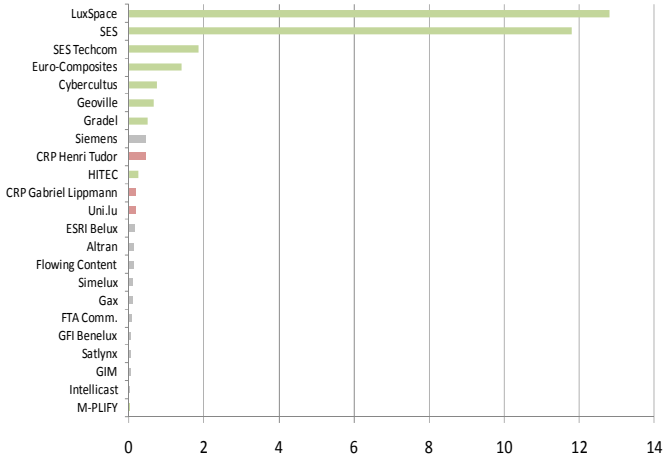
Contract value from the national space programme 2000-2011 (€ in millions)

ESA Membership

ESA mandatory programme

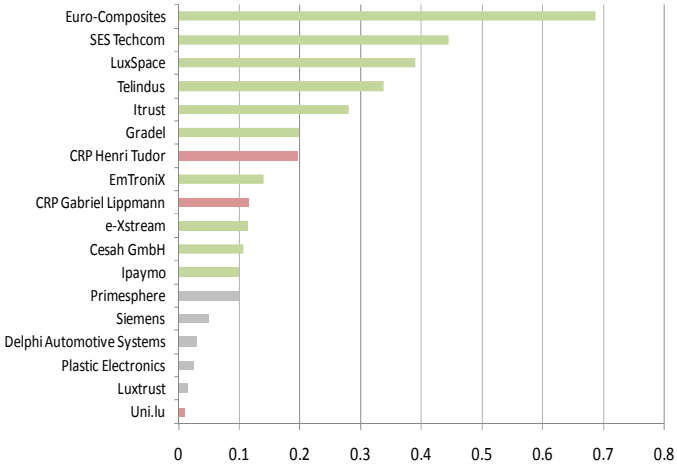


ESA optional programmes

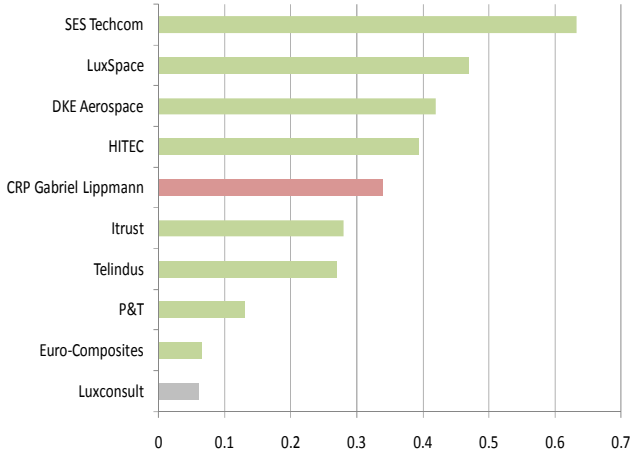


National programme

3rd Party Programme



LuxLAUNCH



* Red indicates academic institutes. Grey highlights companies not active in space in 2011.

The distribution of contracts from the national space programme by entity highlights a high concentration as two companies received about two thirds of the total: LuxSpace and SES. If SES TechCom is considered together with SES, then SES becomes the number one recipient with a total of €15 million (i.e. 37% of the total), just ahead of LuxSpace at €14 million. LuxSpace appears as the Luxembourg company who has leveraged the most on Government investment in space as the company developed a small satellite integration capability through ESA and national activities' support

and succeeded to start commercial activities through its shareholding relationship with OHB. On the other side, this investment has had limited impact on SES' business considering the already significant size of the company which has built a leadership in commercial satellite communication outside the remit of Government-sponsored R&D programmes. As an indication, the company reports that its internal R&D spending is not influenced by Government-funded programmes.

The companies generating most of the space revenues report a marginal impact of the national space programme in their revenues except LuxSpace. Space revenues of most of the SMEs are highly dependent on the national space funding. The limited translation into commercial business to date is due to the youth of the industry after less than 10 years of development. This is normal for an emerging space industry without aerospace/defence roots and with poor domestic Government demand for satellite services.

C) Profitability of space activities

Statements on the profitability of space activities are exclusively based on the perception of actors as expressed during the consultation. The majority of Luxembourg companies report limited or very limited profitability of their space business, often perceived as less profitable than other business lines. This perception results from the fact that many players are in the early development phase of their space capabilities with limited access to the commercial market. It also shows the dependency of most of the SMEs on ESA activities (including the national Third Party programme managed by ESA) for which several companies report limited/negative margin, difficulty to break-even and also time-consuming administrative management requirements to which they have to respond to. The low profitability of space for SMEs results from the specific constraints of that activity (high entry cost including quality requirements and specific equipment, being early in their learning curve, low recurrence of products/services) combined with a few constraints specific to Luxembourg (high wages, better market opportunities in other activities).

For the companies involved in multiple sectors, it turned out to be difficult to estimate whether their margin on non-space activities benefited from their investment in space. Of the companies that provided feedback (EmTroniX, Geoville, Gradel, HITEC, P&T, Smalux), Geoville and HITEC indicate a truly positive effect on their general margin, the other companies report only modest or no benefit.

On one hand, SES, the largest company of the national space sector, reports a high profitability which is however only marginally generated by the national space programme. On the other hand, most companies report a low profitability of their space activities, in any case lower than in the other activities they are traditionally involved in. In some cases, this could constitute a major concern for the continuation of their space activity, unless they come to consider it to be a strategic investment for their future business.

d) Space revenue perspectives

Revenues perspectives for the companies' space business for the next five years are positive or even very positive for the largest companies and essentially satellite communications related: all divisions of SES (Broadband services, Government services and SES Techcom), LuxSpace and HITEC. Geoville is the most positive non-satellite communications related company.

SES and LuxSpace concentrate most of Government funding (over 70% of contracts together), HITEC is a supplier to SES. The positive future revenue perception of these companies shows an efficient choice of funding from the national space programme. LuxSpace and HITEC have developed their products/services in close relation with the Luxembourg space programme. This is less true for SES's traditional bandwidth business and for its new consumer broadband services that are less related to the national space programme than SES TechCom and SES Government services.

SMEs are more conservative regarding their space revenues prospects with limited or no growth perspectives. This may result from a single disappointing experience in the space business and contrasts with their positive perception of growth opportunities in other, non-space, business lines or elsewhere geographically than in Luxembourg.

Future perspectives are essentially driven by commercial opportunities, but companies also acknowledge the central role of the national space programme and of the Government in general in stimulating/creating the business opportunities: AIS, data centres, SmallGEO, satellite and ground equipment. Most companies consider that their future business opportunities, including commercial prospects, will be positively impacted by the decisions of the Luxembourg Government with regard to investments in space related R&D.

Key space-related opportunities and risks anticipated by the companies

Company	Market opportunity	Market Risks
Cybercultus	High value adding services to dedicated sector	Future evolution of the HBBTV standard for ITV
EmTroniX	COTS products AIS with IP interface	ESA contract management and payment delays Non-recurrent business
e-Xstream	Commercial projects with large space integrators	
Geoville	GMES related services EO data dissemination End to end solutions for the commercial market IAP	Remaining competitive Data access within GMES Cost of EO satellite data
GRADEL	Specific MGSE	Loss of manpower and know-how Decrease of overall space activities
HITEC	System integration Defence and commercial markets	Public funding Access to public programmes and procurement
LuxSpace	AIS Microsatellite SmallGEO Satellite integration	ESA contract management and payment delays Euro-USD exchange rate Continuity in Government support Decisions of the German Government
P&T	International and commercial business National defence Data management: M2M, data centres	Network security
SES Broadband	Consumer broadband	
SES TechCom	Governmental services, Galileo dissemination for space operations	Change of shareholder structure with disinvestment of SES
Smalux	Product diversification More recurring products	Too much dependency on a single economic sector
Telindus	Data security: AIS, EDRS…	Profitability. Access to clients internationally

Revenue perspectives for the companies' space business are positive for the largest companies and essentially satellite communications-related. SMEs are more conservative for space revenues perspectives because of their immaturity in the sector.

3.2.2 Consolidation and valorisation of existing competencies

The second objective of the 2008 national space plan is to "consolidate and valorise the competencies existing in the domain of media and communications services". The contribution of the national space programme to this objective is assessed against three criteria:

- The leverage effect from existing competencies in media and communications;
- R&D efficiency, especially in satellite communications;
- Partnerships between local players, both companies and research organizations.

a) Leverage effect

Not surprisingly, telecom-related activities generate most of the revenues of the Luxembourg space industry, reflecting the importance of SES in the sector. Even after excluding SES, telecom still represents 94% of the national space sector revenues. This fact also explains the Government's preferential support for developing telecommunications R&D activities and capabilities, both through ESA and the national programme.[31]

However, Luxembourg media and communications companies have had limited interaction so far with the national space sector[32]. Two telecom network operators (P&T and Telindus) have been involved in satellite-related projects as providers of infrastructure services (to SES and ESA) but not really playing on potential synergies with other national space stakeholders. More importantly, the unique role of SES between the (global) satellite industry and the (global) media and communications industry has not brought tangible benefit to the development of new national competences in media and communications. Some partnerships have emerged on an opportunistic basis (for LuxLAUNCH studies for instance). More recently, the *emergency.lu* project has been launched as a new service for the restoration of communications in case of natural disasters and humanitarian emergency situations.

More leverage should be sought in the future to make the unique position of SES beneficial for the Luxembourg space actors and economy. The recognition of the central role of SES for developing telecommunications and broadcasting activities by satellite in Luxembourg prompts the idea of having the company playing a larger role in the implementation the national programme.

[31] 60% of Government funding is directed to telecom applications.
[32] With the exception of the national media and telecom companies that lease satellite bandwidth to SES (i.e. RTL, BCE and the M7 Group).

Satellite-related recent investment history in Luxembourg

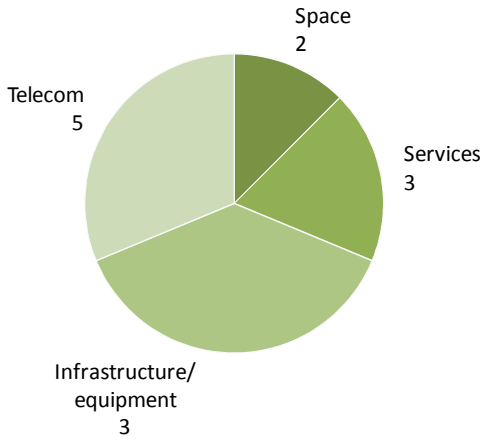
		Investment	Context for the investment
		Luxembourg Government	
MESR	Ministry of Higher Education & Research	About €70 million spent over 2005-2011 for space R&D of which 78% for ESA optional programme, 13.4% for ESA mandatory programme and 8.6% for the national programme (LIIS + 3rd Party Programme)	When Luxembourg became ESA's 17th member State in 2005, it started a national program (LIIS) that has been continued by the 3rd party program. Prior to ESA membership, Luxembourg had spent €7.3 million on ARTES, ESA's R&D program specific to satellite communications via a cooperation agreement with ESA
MAE	Ministry of Foreign Affairs	€17.2 million for the "emergency.lu" satellite-based platform over 3 years (bandwidth lease from SES, terminals from HITEC and middleware)	"emergency.lu" made available as a global public good to the humanitarian community (as part of the Emergency Telecom Cluster of the UN)
MAE	Defence Directorate	20 year commitment valued at $37 million for shared capacity on the WGS constellation in X- and Ka-bands Leased capacity in C- and Ku-bands through SES	Own requirements and additional capability offered to partners within multinational frameworks
		Private companies	
SES	Commercial satellite operator	€140 million since 2007 on the Betzdorf site (incl. the new business centre and technical building)	44 satellites in GEO orbit, of which 22 controlled from Betzdorf (+12 in MEO for O3b)
P&T	Government telecom operator	€87 million for the resilience data centre East located at Betzdorf and opened early 2012	The data centre at Betzdorf is the 5th of ebrc, the subsidiary of P&T created in 2000 for business resilience services
LuxSpace	Space system integrator	Creation of LuxSpace in 2004 on the Betzdorf site with support of the Ministry of Economy	As part of OHB strategy to enlarge its supply chain taking into account ESA geo return principles

The ability to leverage on existing expertise in other sectors can also be assessed through the synergies reported by industry and academic players. Almost all Luxembourg space industry players are not "pure players" in the sense that they have already developed products or services in another core business and aim at leveraging their expertise/capabilities in the space sector. The sectors of origin of the companies involved in space are essentially the infrastructure and industrial equipment industry (nuclear, automotive, and steel) and the telecom sector (network operation service provision).

The spin-in and spin-off effects represent interesting metrics for that purpose, spin-in measuring the integration, in space activities, of technologies developed outside the space sector, and spin-off relating to the use of space technologies in other sectors. Eight companies and six research organisations were able to comment on the synergies of their space activities with other domains.

Industry players generally report limited spin-in[33] and very limited spin-off effects of their space activities. The specific constraints associated to space mission, such as heritage and reliability requirements, have contributed to a certain disappointment of national players about their inability to leverage on their participation to space activity; strong initial expectations contrast with limited real opportunities at the end.

Primary sector of activity of Luxembourg space companies
(in number of companies)



Due to the short history of space activities in Luxembourg there have been limited opportunities so far to leverage on existing expertise in the satellite sector; new entrant companies report difficulties to fully exploit their capabilities for space projects in the short timeframe. **Telecom is a clear driver for revenues but still with limited leverage to date**. However more opportunities appear in the future that need specific encouragement to bear fruit.

b) Efficiency of the R&D effort

Over three-quarters of the €40 million of contracts funded to date relate to telecommunications satellite technology and applications. Considering these funds as R&D expenditures the way they have been spent is important as it determines a specialization of the local recipients in terms of resources (staff qualification and experience) and means (tooling, process, license) on different technologies, subsystems, software or capabilities relative to satellite systems.

The efficiency of the R&D expenditures can be appreciated by their contribution to the development of the space capabilities of the recipients themselves and of the local organisations that received work from the recipients.

Over three-quarters of the total contract funds (i.e. €30 million) went to three companies (SES, LuxSpace and Euro-Composites) with different development histories and strategies with respect to satellite systems. They moderately contracted with local organizations to develop the hardware,

[33] e.g. stainless steel welding for the nuclear industry at Gradel and numerical composite testing for heavy industries by X-Stream.

software or services defined by the contracts with ESA and LuxLAUNCH. The largest beneficiaries locally have been EmTronix, HITEC, Gradel, and SnT.

Each of the three largest contractors is in a unique situation with respect to its R&D needs in space:

- SES, a highly technically educated operator, procures satellite systems (both space and ground elements) on a competitive basis driven by the economics of its business, i.e.to maximize the spectrum efficiencies of the satellite systems it deploys. It is carrying out technology development activities, both privately and publicly funded, geared to operational purposes in order to ensure it can always 1) operate its satellite fleet more cost-effectively and 2) deploy new satellite communication solutions for its clients. The *Satmode* and *Pacora*[34] activities funded through ESA illustrate this double objective of technology development. *Satmode* was instrumental in triggering the development of the SES Broadband Service platform to which SES contributed also significantly by its own to transform it into an operational and cost-effective satellite solution. HITEC and SnT have been the most involved in the technology development efforts of SES.
- LuxSpace has developed capabilities for AIS receiver and microsat integration for which public R&D funding was instrumental. Government support was coherent with OHB investment in Luxembourg and helped LuxSpace to develop flight systems, a significant milestone for any new entrant in the space domain. EmTronix has been the most involved in the technology development efforts of LuxSpace.
- Euro-Composites started to develop satellite structural parts through the national space programme (LIIS and ARTES). On the verge of a new investment phase to develop product quality assurance for the commercial satellite market, the main shareholder of the company decided to stop efforts in the space domain. This decision is currently being revised (opportunities having meanwhile been lost that can hardly be recovered).

Considering the two levels of efficiency of space R&D expenditures, the Luxembourg Government contributed efficiently to the development of a national capability in space in the sense that Government-funded R&D supported the emergence of a technology intensive industry in the country in less than 10 years. It should be underlined that the development of commercial products by local suppliers other than SES still requires a sustained R&D effort in the few domains where initial capabilities have been gained.

c) National partnerships

Satellite communications drive most of the national partnerships both at companies and research levels. The main space companies of the country (SES, SES Techcom, HITEC, LuxSpace, Cybercultus, P&T and Gradel) have business relations between themselves and with the academic sector as part of the national space programme.

SES and the ARTES programme have allowed a sustained and robust relationship to develop between the research community and the companies involved in satellite systems and services. The specialized

[34] System for orbit determination and prediction.

departments of the three public research institutes have received contracts from the industry in relationship with ESA and LuxLAUNCH activities. Companies also occasionally procure test facilities and engineering services from research organizations (e.g. Gradel with Tudor for materials welding). Outside of satellite communications, materials engineering is in fact the second topic area of connection between research and industry in the country. Environmental research is another area of connection, involving mainly Geoville and the CRP-Gabriel Lippmann's EVA unit.

The recent decision of CRP-Gabriel Lippmann and CRP-Henri Tudor to merge in order to create a stronger entity for applied and focused research will gather four departments with space-related activities under the same umbrella. This should be beneficial to reinforcing space-related R&D activities in Luxembourg.

Most of the participants to the national space programme are members of the Space Cluster managed by Luxinnovation. Some companies are not part of the Space Cluster or belong to another cluster (materials, ICT). The benefits recognized to the participation to the Space cluster are networking and information collection, even if one company regrets its focus on satellite communications. Visibility on local capabilities through the Space cluster is appreciated, especially because systems and service integrators (i.e. LuxSpace, SES TechCom, SES Broadband) are looking for qualified suppliers[35].

National partnerships related to space

Entity	Partner in industry	Partner in academic
Academic entities		
CRP Gabriel Lippmann (EVA)	LuxSpace, Geoville, HITEC	
CRP Gabriel Lippmann (SAM)	LuxSpace	Uni.lu
CRP Henri Tudor	LuxSpace, CETREL, Euro-Composites, iTrust, P&T, HITEC, Gradel, EmTronix, Clearstream, Cybercultus, ACL, IEE, Telindus	Uni.lu SnT, CRP Gabriel Lippmann
Uni.lu P&M Geophysics	LuxSpace	CRP Gabriel Lippmann
Uni.lu RUES	SES	
Uni.lu SnT	SES, HITEC	
Industry entities		
Cybercultus	SES, BCE (RTL group)	CRP Henri Tudor (SSI)
EmTronix	LuxSpace, SES TechCom	Uni.lu SnT
Euro-Composites	LuxSpace, SES, HITEC	CRP Henri Tudor
e-Xstream	Euro-Composites	Uni.lu
Geoville	Nokia-Siemens, DKE	CRP Gabriel Lippmann (EVA), CEPS
HITEC	SES TechCom	CRP Gabriel Lippmann
Lionsystems	LuxSpace	
LuxSpace	EmTronix, Gradel, Smalux, SES TechCom	CRPs Lippmann & Tudor
P&T	SES, HITEC	
SES Broadband	FTA	
SES TechCom	HITEC, LuxSpace, Telindus	CRPs Lippmann & Tudor, SnT
Smalux	LuxSpace, HITEC	

[35] Geographic and cultural proximity with their suppliers is important for space integrators

Satellite communications drive most of the national partnerships and SES and the ARTES programme have greatly contributed to structure the relationship between the research community and the companies involved in satellite systems and services. The main benefits of participation to the Space cluster managed by Luxinnovation are networking with visibility on each member's capabilities and information collection.

3.2.3 Contribution to reinforce the competitive position of national players

The third objective of the 2008 national space plan is to "contribute to reinforce the competitive position of the companies and public research organisations in the space domain". The contribution of the national space programme to this objective is assessed against two criteria:

- Supporting market positioning of national industry players, especially in the applications and technology domains where the Luxembourg Government concentrated its support;
- Foreign investment in the Luxembourg space sector by attraction of foreign parties to develop their space activity in the country.

a) Market positioning of national space players

Only a limited number of companies have been able to determine their competitiveness level often showing a limited view of the industry structure of the space sector in Europe and worldwide. This is especially true, and not surprising, for small companies, and more particularly in a country with a short history of space activities. Only the largest players see themselves in international competition while other smaller players consider their positioning protected through the participation to ESA activities.

The respondents are rather positive on the competitiveness of their space products/services with respect to other European companies. For SES, this results from the company's domination in Europe in broadband services and from its unique service company (SES TechCom).

Participation to the Luxembourg space programme has been beneficial for the market positioning of most respondents who report direct positive or very positive impact on their competitiveness. Companies reporting highest impact are often SMEs who diversified into the space sector from a core expertise or new entrants developing a core business in a niche market (such as LuxSpace, HITEC Gradel and Geoville). On the other hand, the impact of the national space programme on the competitiveness of a company like SES is marginal considering that the company developed its business well before the initiation of the Luxembourg space programme. Nevertheless, it should be noted that *Satmode*, an ESA-driven development, helped the company to enter into a new market (consumer broadband).

Space actors rate Government support on average as positive or even very positive with regard to their market positioning. Nonetheless these actors generally ask for more support from the Government. Increased support does not necessarily mean financial support for technology or service development. For many companies who developed their capabilities in the last 5 to 10 years, the key

issue is to mature technology and increase quality insurance to enter the commercial market and limit their dependency on Government support. They look for:

- Better efficiency in program execution and management, especially with respect to ESA (optional and 3rd party) programmes where strong administrative constraints are highlighted.
- Long term visibility regarding future priorities and investment areas of the Luxembourg space programme, but also of the space sector in general and its business environment.
- Political and commercial support to favour access to clients (e.g. national and foreign defence), to projects (e.g. PPP for ESA) and to international export market (SES and LuxSpace).

Participation to the national space programme has been instrumental for developing/improving the market positioning of most companies. The industry recognizes the strong support received from the national space programme and generally desires increased and sustained support in the future to mature the capabilities that have started to be developed.

b) Foreign investment

The creation of LuxSpace by OHB is a testimony of a successful attraction of foreign investment to Luxembourg and into the Luxembourg space sector. OHB is a relatively new entrant in the European space industry, experiencing fast growth in recent years[36], both organic and from acquisitions. The acquisitions in Italy (Carlo Gavazzi Space), Belgium (Antwerp Space) and Sweden (part of Swedish Space Corp) add to the investment in Luxembourg. These investments reflect OHB's strategy to enlarge its supply chain while taking account of ESA's geographic return opportunities outside of Germany[37].

OHB's historical relationship with Orbcomm brought activity to LuxSpace for two Vesselsat satellites that were launched at the end of 2011 and in early 2012. Orbcomm pays OHB for exclusive use of the two small satellites built by LuxSpace that will allow the American operator to reconstruct its AIS service.

OHB's satellite backlog is made principally of three satellite development contracts for European Governments (Galileo, MTG and EDRS) for which the Luxembourg industry is a small supplier (AG1 and EDRS). This means that LuxSpace will have to develop an endogen growth based on the microsat AIT capabilities it has acquired since its creation.

Intelsat's change of domiciliation to Luxembourg in 2010 illustrates the attractiveness of the financial marketplace of Luxembourg but this move has not, as yet, further contributed to the growth of technology intensive industries in the country. It has to be noted that since it became a privately held company in the early 2000s, Intelsat stopped carrying out R&D on satellite systems' technology. Like SES, Intelsat procures its satellite systems on a competitive basis and is interested in benefiting from

[36] Total sales of €550 million in 2011 (+23% over 2010) with a employee headcount of 2,352 people at year-end (+40%).
[37] Maximizing access to the geo-return of ESA is not specific to OHB as it is part of the strategy of European space integrators.

the qualified products and technologies at satellite and ground segment levels that have been developed by its suppliers, either internally funded or by public R&D funding[38].

Despite the intrinsic limitation due to the low volume of activity available nationally in both satellite systems development and satellite services provision, **Luxembourg has been able to attract foreign investment in the space domain.** OHB created LuxSpace as this investment fitted with the strategic objectives of the mother company and brought to it commercial activity in relation with microsatellite and AIS.

3.2.4 National development of space skills and international integration of national players

The fourth and last objective of the 2008 national space plan is, in fact, a double objective as it aims at "developing skills in the space sector in Luxembourg and amplifying the integration of Luxembourg players in international networks". The contribution of the national space programme to this objective is assessed against three criteria:

- Creation of highly qualified jobs in the space sector, i.e. space employment
- Ability to educate and train space professionals
- International partnership for the integration of national players into the international industrial and research framework.

a) Space-related employment

The 20 companies active in space in Luxembourg in 2011 had a space staff of nearly 500 people, of which over 75% are SES (excluding SES-Techcom). Most of the 120 persons employed outside of SES HQ (i.e. 80%) are located in four companies (SES Techcom, LuxSpace, HITEC and P&T) with the remaining 25 persons distributed over 15 companies.

The two "pure" space companies (SES Techcom and LuxSpace) are the most staffed (40 and 30 persons, respectively) while the largest in space sales after SES Techcom has only 10 persons (P&T). HITEC is the only other company with more than 10 persons.

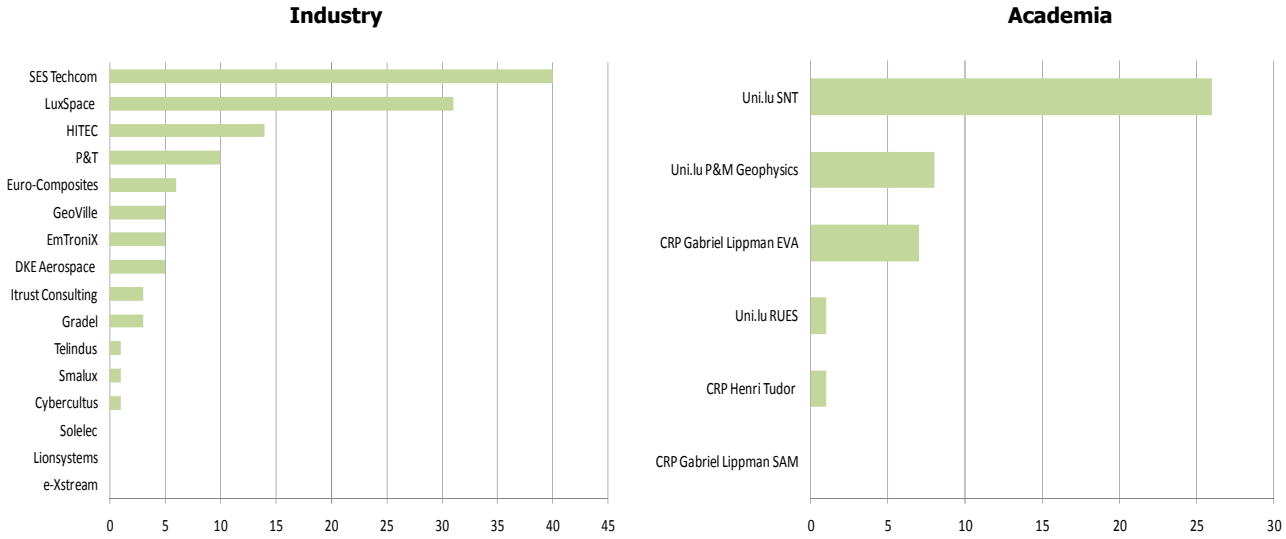
Space staff represents a small proportion for Luxembourg entities working in the space sector: about 8% of the total staff of all companies, except SES, illustrating the limited strategic importance of space activity for most of local players (except for the two pure players). Luxembourg-based space-related staff represents just over 1%[39] of the European space staff base, estimated at 41,000 persons working at the three levels of the value chain in Europe. In the academic sector, space-related researchers represent about 40 full-time equivalents, concentrating in three thematic departments, of which two belong to Uni.lu and the third to the CRP Gabriel Lippmann:

[38] Specifically for electric propulsion (EP) for in-orbit station keeping, Intelsat procured system from Astrium and SS/L, both using qualified Russian technology.

[39] This figure has to be compared to Luxembourg's overall GDP ratio of 0.22-0.23%, thus underlining the relative importance of Luxembourg-based space staff despite its small volume.

- SnT (Uni.lu) for applied research in three areas of the ICT (security, reliability and trust); SES is, as a contributing partner, on the board of SnT;
- EVA (CRP Gabriel Lippmann) for applied research in the management of natural resources and the valorisation of bioresources;
- P&M (part of RUES at Uni.lu) for geophysics research.

Full-time equivalent space-related staff (2011)



Space staff growth in Luxembourg companies outside of SES Headquarters has been strong since the mid-2000s (from about 20 persons in 2007 to 120 today) as several companies developed their space activities during the period either as newcomers following Luxembourg's adhesion to ESA (the case of LuxSpace, EmTronix, Euro-Composites, Gradel, Smalux, Itrust, DKE, Telindus, Solelec) or in continuation of a pre-existing activity related to satellite communications (the case of SES Techcom and HITEC).

Luxembourg companies equally divide on the prospects for space staff growth in the next 5 years. The most positive on staff growth prospects are the largest space companies: SES Techcom, HITEC, LuxSpace and P&T. This translates their trust in developing operational satellite products and services in the future.

Separately from SES Techcom, SES intends to create a team of 20 to 25 persons based in Luxembourg for the operation of the O3b constellation of 12 MEO satellites starting in 2013[40]. On the other hand SES' extension of services toward Government communications and consumer broadband is likely to be conducted with limited staff growth in Luxembourg.

[40] SES has invested $190 million in cash in O3b plus in-kind contributions to date.

The growth of space-related employment in Luxembourg outside of SES Headquarters has been strong since the mid-2000s as several companies and research organizations initiated space activities during this period or expanded the activities they already had in satellite communications. Prospects for space staff growth in the coming years are positive in the five largest space companies and two research organizations considering the capabilities they have developed and the future demand they anticipate for their capabilities.

b) Educated and trained space professionals

The Luxembourg Government initiated in 1996 a first reform of its higher education framework. This eventually led to the creation of the University of Luxembourg in 2003 taking benefit of the existing institutes. In order to meet the objectives of gaining visibility and strengthening ties with neighbouring universities, the University of Luxembourg has participated since its early beginnings in building the University of the Grande Région, a cross-border initiative with Belgium, France and Germany.

Today the Uni.lu has three faculties and two interdisciplinary centres:

- the Faculty of Sciences, Technology and Communication ;
- the Faculty of Law, Economy and Finance;
- the Faculty of Literature, Human Sciences, Arts and Educational Sciences;
- the Centre for Security, Reliability and Trust (SnT);
- the Luxembourg Centre for Systems Biomedicine.

No dedicated university programme on space studies is offered despite the vast majority of Luxembourg companies reporting difficulties, even significant difficulties, in recruiting relevant personnel with space qualification. Even if the proportion of space staff remains limited for most companies involved in space activities, these recruitment difficulties are viewed as a major issue with a high impact on the ability to develop skills, expertise and build successful competitive business.

Companies involved in downstream value adding activities report less difficulty as they do not require space engineers but software specialists. Companies active in the upstream part of the value chain (satellite/ground system and equipment manufacturing) are the most impacted by the lack of adequate local skills; the majority of companies have therefore decided to train their personnel internally. All companies involved in satellite/ground system engineering indicate that working in the space business is a key retainer for highly qualified personnel: it is technically attractive from an engineering standpoint, it creates opportunities to work in prestigious projects and helps the staff to improve in processes and standards.

A very marginal portion of the industry staff is native of Luxembourg, highlighting the lack of adequate training programmes and interest from native students to pursue an engineering career that is often perceived as non-appealing from a financial standpoint. In most cases, companies employ no or only a handful of native-born engineers. For instance, LuxSpace, which can be considered as a national flagship space start-up, employs one Luxembourger; only 20% of SES' employees are Luxembourgers, and these are primarily active in administration and operation, not in engineering.

The absence of local staff is not viewed as a problem for day-to-day business but makes the recruitment process more difficult. Even SES which recognizes its attraction for space engineers as a world leading satellite operator indicates that it needs to offer significant economic and social incentives to attract talents. Companies would favour to increase the proportion of their national staff as they recognise their social and educational role to support the development of space activities in the country.

Very few respondents were able to comment when asked on how to improve space engineering training in the country. It is recognised that the lack of critical mass of students and of industry needs render the creation of a Master in space engineering less realistic. Furthermore, the recruitment issue is considered to be more related to engineering training in general rather than to be specific to space. Collaboration with international training programmes such as the International Space University and ESA Young Graduate Trainee programme is therefore considered highly important.

In March 2010, SES and the University of Luxembourg entered into a multi-year partnership agreement to jointly develop Luxembourg as a European and international centre of excellence and innovation for advanced ICT in satellite systems and to create a globally unique chair encompassing all relevant aspects of space, telecom and media law in the field of satellite communications. The amount of SES' contribution over 6 years is €2 million. This contribution is being directed to the Interdisciplinary Centre for Security, Reliability and Trust (SnT) as well as to the creation of a university chair. Within the Faculty of Law, Economy and Finance, the SES Chair in Satellite Communications and Media Law has been installed in September 2011 with the mission to develop a highly competitive research and teaching programme with a particular focus on spectrum regulation and satellite communications.

The lack of adequate local engineering skills is an issue faced by the entire Luxembourg industry which needs to attract foreign talent to develop its activities and in particular its space activities. The issue is actually broader than space training, as **it is recognised that the country should strengthen its engineering academic programme as a whole**. However, the lack of critical mass of students and local employment opportunities makes the creation of a dedicate space engineering programme difficult to implement.

c) Visibility of the national space programme

The initiatives of the MESR together with Luxinnovation to develop awareness of the national programme are recognized by local players (e.g. the Catalogue of national space capabilities, the "Space Industry Days" events). Still, it is generally felt that more could be done to promote space activities in general and the national space programme in particular. Several respondents indicated that if SES was well-known by the Luxembourg population, there was a clear gap in the awareness regarding the national space sector in general. However limited concrete suggestions emerged from the consultations: suggestions essentially leverage on SES popularity, on organising national space days opened to the public and on schools' visits.

It has to be underlined that the fact that Luxembourg invests in space applications rather than in prestigious projects more visible to the public, such as space exploration, makes communication

around its achievements in space more challenging. If the launch of two Vesselsat microsatellites made in Luxembourg was quoted as poorly promoted, the *emergency.lu* initiative has been widely communicated on.

If SES is well-known by the Luxembourg population there is a clear gap in the awareness regarding the national space sector in general. The fact that Luxembourg invests in applications rather than in more prestigious/visible projects, such as space exploration, makes public communication on its achievements in space more challenging.

d) International integration

The Luxembourg-based entities involved in satellite activity reported a number of partnerships with European entities in relation with satellite operations while partnerships outside of Europe are more limited, partnerships being understood as having joint projects running or in definition or intended to have in the future. For some actors the supplier/customer relationship is also understood as partnership.

European partners divide into two categories:

- Satellite equipment and satellite systems integrators in France, Italy and Germany: the three European integrators of space systems were quoted (Astrium, TAS and OHB) and some subsystems suppliers (Selex Galileo, RUAG, Amos, SpaceTech, ABSL, and Mirad).
- Satellite-based service providers or users of satellite systems (e.g. TV channels, EIB, Eurostat).

P&T is the only Luxembourg company to be related to a satellite operator other than SES. As a former member of Eutelsat (at times when Eutelsat was an international Government organization), P&T continues uplinking traffic to Eutelsat satellites from its teleport[41].

The national research community is connected internationally in two domains in relation with satellite technology:

- Environmental research: CRP Gabriel Lippmann (EVA) in relation with European service companies (VITO and TerraSphere) and with non-European space agencies (CSA in Canada and JAXA in Japan)
- Geophysics: Uni.lu P&M in relation with European research organizations (GRGS Toulouse and the Observatory of Belgium) and the Jet Propulsion Laboratory (JPL) of NASA.

Entity involved in satellite activity	European partners	Non-European partners
CRP Gabriel Lippmann (EVA)	VITO (Belgium), TerraSphere (the Netherlands)	CSA, JAXA
CRP Gabriel Lippmann (SAM)	CNES, Thales Alenia Space (France)	
CRP Henri Tudor (AMS, SSI)	Deutsche Welle (Germany), EADS (France), GCS (Austria), INRIA/Loria	

[41] P&T recently won a contract from the European Commission for the transmission of two TV channels (EbS) with Eutelsat satellites

	(France), Newtec (Belgium), Politecnico di Torino (Italy) RBB (Germany) Thales Alenia Space (Italy), TW1 (Austria), Univ. of Salzburg (Austria)	
Cybercultus	ARD (Germany), ORF (Austria), TW1 (Austria)	Star One (Brazil)
e-Xstream	Astrium (France/Germany), Thales Alenia Space (France), CNES	
Geoville	GSAT (Czech Republic), Infoterra (France)	
Gradel	OHB (Germany)	
LuxSpace	OHB (Germany), EIB, Eurostat	JAXA (Japan)
HITEC	Mirad (Switzerland)	
Llonsystems	Selex Galileo (Italy), Univ. of Kaiserslautern (Germany)	
P&T	Eutelsat (France)	
SES Broadband	Astrium Services (France)	
Smalux	ABSL (UK), RUAG (Switzerland), Thales Alenia Space (France), AMOS (Belgium)	
Uni.lu (RUES)	DLR (Germany), CTTC (Spain), Astrium (France), SpaceTech (Italy)	
Uni.lu P&M Geophysics	GRGS Toulouse (France), Observatory of Belgium	NASA JPL

SES has research activities with three universities (Princeton, UCL, and La Sapienza) in areas not related to partnership projects with the national research community.

University	Country	Current projects	Duration
Princeton	USA	- Use of electric propulsion in transfer orbit and impacts on satellite bus architecture - Internet intelligent overlay network using satellite	2 years
UCL (Louvain)	Belgium	- Reconfigurable radio systems using non-exclusive frequency bands - High rate generic pre-distortion system demonstrator for automated optimized multicarrier operation of a transponder - Use of polarization as a signaling dimension	1 to 4 years
La Sapienza (Rome)	Italy	Mission design for electric propulsion transfer orbit	7 months

The national space programme has helped the Luxembourg space sector to get strongly connected to European entities while partnerships outside of Europe are more limited. European partners are either participants to the space industry upstream in the three largest space countries (France, Germany, Italy) plus Belgium and Switzerland or satellite-based service providers and users of satellite systems downstream in the value chain. The international connectivity of the national research community is well developed in two domains: environmental research and geophysics.

3.3 Overall achievements of Luxembourg's space programme

In the previous section the four strategic objectives defined for the national space plan have been assessed relatively to their individual state of completion to date. Overall, the achievements of the national space programme are:

- **Luxembourg's space programme has performed well with respect to the objectives of the national space plan considering** 1) its time scale of development with less than ten years of satellite R&D and technology development and 2) the lack of a pre-existing capability in aircraft construction, a capability that is common to most of ESA Member States .
- **Highest achievements of the Luxembourg space programme have been observed in its ability to 1) valorise existing capabilities in satellite communications and 2) support the market positioning of national players in the European space sector**. The satellite communications legacy of the country has allowed local suppliers to launch new services and allows the Government to contribute to international cooperation, as illustrated by the *emergency.lu* initiative of the Ministère des Affaires Etrangères. Besides, the support of the Luxembourg Government helped national players to reinforce their satellite-related activities or to enter that domain. Furthermore, it has contributed attracting strong European players (namely OHB) to Luxembourg.
- **The economic impact is also positive considering the absence of space-related revenues and employment outside SES less than ten years ago.** Space staff growth in Luxembourg companies outside of SES Headquarters has been strong since the mid-2000s (from about 20 persons in 2007 to 120 today) as several companies developed their space activities during the period either as newcomers following Luxembourg's adhesion to ESA or in continuation of a pre-existing activity related to satellite communications. Similarly to space staff growth, space sales outside SES grew from €26 million to €65 million over the same period.
- **More limited impacts have been observed for the national development of skills and the overall visibility of the sector** that both require a long term effort to materialize**. Space employment has developed** in the country in the past ten years despite difficulties in locally training specific space skills; the integration of Luxembourg players in international networks is in good progress.

Considering the result of the assessment of the four objectives of the national space plan, and in view of the general and thematic policy objectives of the Luxembourg Government and notably the National Reform Program for the Grand-Duchy of Luxembourg under the Europe 2020 Strategy, **it is highly recommended to confirm these objectives as strategic for further development of space activities in the country**.

This statement provides the basic concept for the next step, i.e. the definition of the priorities and recommendations for future space activities in Luxembourg (Part 4).

PART 4.

PRIORITIES AND RECOMMENDATIONS FOR FUTURE SPACE ACTIVITIES IN LUXEMBOURG

4.1 Future thematic investment priorities for Luxembourg

The satellite sector will grow in all its dimensions in the decade to come, but as it is a long cycle investment sector, new entrants need to prepare their expansion in the sector with today's investment to be in position to reap fruit in the future. **To maximize the return on investment in space R&D for the country, the Government of Luxembourg has to sustain investment in space while remaining selective in its investment decisions.**

Four investment areas have been identified as priorities for the future development of Luxembourg in space, as they offer opportunities at different levels of capabilities and for different stakeholders. Two of them relate to satellite systems, i.e. the satellite industry upstream, while the two others refer to the downstream part of the sector, i.e. ground equipment and satellite-based services. **Together, they represent a total of ten capability domains**, of which eight are evolutions of existing capabilities that will require evolution efforts of different intensity (see scale below). The two other capability domains (microsatellite payloads and satellite electric propulsion) are new for Luxembourg and therefore require particular investment efforts.

The identification of these four investment priority areas results from the consultation with national stakeholders combined with the independent analysis of market segments conducted in Part 2 and matched with the achievements to date of the national space plan (Part 3). These are areas with favourable market dynamics where the aggregate investment of Luxembourg to date could be valorised. They align with the achievements and with the objectives of the national space policy in order to be at the same time ambitious and realistic for the future of Luxembourg in space.

	Priority areas	**Capability domain**	**Capability type**	**Intensity of effort**
Satellite Systems	Microsatellite	Microsatellite platform	Evolution	+++
		Microsatellite payload	New	+++++
	Satellite equipment	Composite structure	Evolution	+++
		Electric propulsion	New	+++++
		Other equipment	Evolution	++
Ground Systems & Services	Ground equipment	Ground support equipment*	Evolution	+
		Ka-band antenna	Evolution	+
	Satellite service	Satellite communications services	Evolution	+
		earth observation & navigation services	Evolution	++
		Integrated applications	Evolution	++

(*) Mechanical and Electrical Ground Support Equipment (MGSE/EGSE)

4.2 Review of the four priority areas for investment

The four investment priority areas for Luxembourg in space have been reviewed individually in order to characterize them and to analyse how sensitive they are in terms of risk/opportunity at macro (country) and micro (company) levels. The key success factors are also presented.

4.2.1 Microsatellite

The microsatellite investment area includes two major capabilities to be developed in Luxembourg in order for the local stakeholders to be part of the European space industry with a full mission capability including the platform of the satellite and the mission payload (the instrumentation). Obviously the capability to assemble, integrate and test (AIT) the whole system will grow in complexity with that of the platform and of the payload and will require the satellite integrator to adapt to that complexity.

4.2.1.1 Platform

The flight-proven microsatellite platform of LuxSpace has been designed with a focus on mission payload dedicated to Automatic Identification Systems (AIS). Its future usefulness for purposes other than AIS receivers is however limited and there is a need to have it evolve into a multifunctional platform product capable of accommodating different types of payloads. The next generation microsatellite platform must include at least two major refinements: 1) an attitude and orbit control system (AOCS) in order for the satellite to maintain a constant pointing direction, a capability necessary for earth observation missions or more refined telecommunication payloads than AIS receivers, and 2) a propulsion system essential for mission operations, including de-orbiting at the end of the satellite's lifetime[42]. A standard payload interface and the compatibility with multiple launch vehicles would also maximize the flexibility of the Luxembourg microsatellite platform.

Three AIS microsatellites are under development at LuxSpace of which the third will require a more advanced platform as it will also accommodate an optical payload and possibly another instrument (for space situational awareness purposes or an ADS-B receiver[43]). The first two legacy microsatellites are scheduled for launch by 2016 while the third is anticipated by 2018 to allow for development time. It is an opportunity for the Luxembourg Government to contribute to the national development of a more versatile microsatellite platform through the ESA ARTES-21 programme that is dedicated to SAT-AIS. This programme will allow countries with interest in small satellites and in AIS to federate funding for the development of a dedicated advanced satellite.

4.2.1.2 Payloads

The availability of a more advanced and more versatile microsatellite platform will allow flying different types of mission payloads in low earth orbit for operational and demonstration purposes. These payloads will be in the domains of interest of Luxembourg stakeholders, i.e. satellite communications and earth observation. Payload development is an opportunity for the Luxembourg satellite industry to expand its capability beyond the platform domain which is tending to become a commodity. For LuxSpace specifically, it is an opportunity to offer complete satellite missions with more value offered to the mission's users, e.g. AIS-data augmentation for maritime surveillance.

[42] The non-binding space debris mitigation guidelines of the Inter-Agency Space Debris Coordination Committee (IADC) consider 25 years to be a reasonable and appropriate lifetime limit for low earth orbit satellites before atmospheric re-entry.
[43] Automatic Dependent Surveillance-Broadcast (ADS-B) is the equivalent of AIS for air navigation.

Two missions appear as key to settle Luxembourg's capabilities in satellite payloads:

- An AIS-derivative telecommunications payload for the detection of non-cooperative vessels. LuxSpace currently works on technical development of the payload as part of the 3rd Party Programme in order to identify and to track the vessels that do not provide AIS information with their VHF transmitter. Beyond the satellite payload, LuxSpace could then propose a data service to the institutions with interest in maritime surveillance.
- A space-borne hyperspectral imager that would be of interest to the CRP-Gabriel Lippmann which is already involved in this domain with ground instruments. The cooperation that exists between the EVA Department of the CRP-Gabriel Lippmann and the Israeli company Elbit, specialist of electro-optical equipment, would accelerate the learning process in Luxembourg for both imager technology and imagery applications of hyperspectral observation.

At a later stage, there are other instrument opportunities involving local technology development such as real time video from low earth orbit with a camera loaded on a microsatellite, spectrum analysis from the GEO orbit for frequency monitoring and scientific or space weather instrumentation.

	Platform	**Payload**
Opportunity	Develop a more capable multifunctional platform in order to maximize mission opportunities within the national and European contexts	Develop instruments for satellite missions in low Earth orbit that are in synergy with local interests in satellite communications and earth observation
Risk	Strong competition within ESA for microsatellite platform	Lack of know-how and/or insufficient technology transfer from other countries
Programme opportunity	ESA ARTES-21	ESA GSTP ESA EOEP ESA ARTES 4 and 5 National
Public funding need	Medium/High	High

4.2.2 Satellite Equipment

Investment priorities in satellite equipment include three capabilities to be developed in order for local stakeholders to be part of the European satellite manufacturing industry which is well established internationally. This industry has an obligation to be always more cost/technology effective and there is an opportunity for Luxembourg to be part of this change as the satellite integrators are looking for additional or new suppliers for the subsystems and parts they do not develop themselves[44].

[44] This has been quoted by ESA and by the integrators themselves.

Of these three capabilities, two are key for Luxembourg in the sense that they require a significant investment to develop a new capability for which there is a large recurring commercial market for geostationary satellites: composite structural parts (for platforms and solar panels) and electric propulsion (for orbital injection and in-orbit station keeping). The third capability is for equipment elements (satellite simulation software and Telecommand/Telemetry & Ranging equipment) for which initial capability has been developed at LuxSpace as part of the SmallGEO satellite programme of ESA (ARTES 11). These two equipments are generally developed internally by the satellite integrator. The good relationship between LuxSpace and its parent company OHB will be key to ensure that the initial capability developed within ARTES 11 can be maintained in Luxembourg for the other missions of the SmallGEO platform under the responsibility of OHB.

For composite satellite structure, the key success factor will be the recovery in production capacity of Euro-Composites before considering a strategic evolution toward more value-added production, i.e. a higher level of integration of structural parts. Electra (ARTES 33) and Proba-3 will be programmatic opportunities as part of ESA for Euro-Composites' return to space activities, especially as the satellite integrators of the missions (OHB in Germany and SENER in Spain, respectively) have a positive appreciation of the company[45]. The ARTES-14 element to develop a new generation platform (NGP) for medium-class geostationary satellites could also be an opportunity if Euro-Composites' capability is recognized by the two integrators during the concurrent engineering phase. This phase of NGP development is important for companies with no supply experience with Thales Alenia Space or Astrium Satellites. Alternatively, the Atlas initiative of ESA as part of ARTES 3-4 could be the right vehicle for the in-flight qualification of a more integrated equipment developed by Euro-Composites such as embedded heat pipes. However, for composite structure to develop as a space business in Luxembourg, the support of the Government of Luxembourg should be brought closely into line with Euro-Composites' own efforts.

In the same vein, for the electric propulsion technology proposed by Elwing to become a successful business in Luxembourg the support of the Government of Luxembourg should be brought closely into line with Elwing's efforts. The first phase of technology testing and cost estimate at ESTEC could be funded with seed money provided by the Luxembourg Government while thruster assembly is provided by Elwing for testing. Full technology development in the second phase will however require a higher commitment from both the Government and Elwing in order to prepare a thruster for in-flight qualification.

Different funding vehicles are possible to allow for electric propulsion technology development to be conducted in a phased approach.

	Composite structure	**Electric propulsion**	**Other equipment**
Opportunity	- Restart the space composite capacity of Euro-Composites and prepare it for commercial procurements ("print-to-build")	- Develop locally a new satellite technology with high commercial potential with Government & commercial satellite operators	- Ensure that the simulation software and TT&R development conducted for SmallGEO (ARTES 11) are used by OHB in other SmallGEO

[45] This has been quoted by ESA.

	- Develop Euro-Composites engineering capability for more integrated assembly ("design-to-build")	- Allow SES to procure a satellite technology developed locally by a new company	missions (e.g. EDRS in ARTES 7)
Risk	- With more design & integration capability, Euro-Composites enters in competition with its clients	- In-flight technology qualification could be more costly than anticipated because of limited cost-sharing opportunity - Criticality of the technology for the satellite industry favours in-house procurement by the integrators	- IPRs and fierce competition in TT&R equipment may limit market opportunity with OHB
Programme opportunity	- Electra (ARTES 33) for the SmallGEO platform - Proba 3 formation flying mission - Next Generation Platform (ARTES 14)	- Proof of concept and cost estimate by ESTEC (3rd Party) in 1st phase with national funding - Next Generation Platform (ARTES 14) - Atlas (ARTES 3-4) for in-flight qualification on an operational satellite	- Electra (ARTES 33) for the SmallGEO platform
Public funding need	Medium to high	High to very high	Low

4.2.3 Ground Equipment

The ground equipment area includes two niche capabilities to be developed in Luxembourg in order for the local stakeholders to benefit from changes in the acquisition process of such equipment by:

- Satellite integrators for ground support equipment (mechanical and electrical).
- Satellite operators for ground antennas in Ka-band frequency.

For the mechanical ground support equipment (MGSE) provided to satellite integrators during the satellite construction and operation phases, the key success factor will be the capability of Gradel to offer an evolution of the product developed as part of ARTES 11 (SmallGEO). Evolutions of the existing product include its automation and its adaptation to non-contamination constraints and to transportable container. Then the evolution towards engineering services such as thermal simulation and electro-mechanical simulation would add value to the offering of Gradel in the future. Synergies can be activated between local companies (Gradel, LuxSpace, SES TechCom[46] and HITEC) in order to enlarge the Luxembourg's capabilities in this niche domain of satellite manufacturing.

ARTES and GSTP would be the right programmatic opportunities as part of ESA to support MGSE product evolution.

[46] SES TechCom supplies electrical ground support equipment (EGSE) for ESA satellites.

	Ground support equipment	Ka-band antenna
Opportunity	Access to a larger market in satellite communications, earth observation, science with more advanced MGSE product and more engineering capability	Enlarge product portfolio for satellite communications, satellite navigation and earth observation applications Serve better local and foreign clients
Risk	Fierce competition reduces accessible commercial market	Commercial dependency of HITEC on SES TechCom
Programme opportunity	Electra (ARTES 33) GSTP	Satellite communications (ARTES 3-4, ARTES 5) Meteorology (MTG, METOP) GSTP
Public funding need	Medium	Medium

Initial capability development of HITEC in large Ka-band antennas has been funded in three ways (nationally, via ESA and commercially through SES Techcom). There is an opportunity to develop, adapt and enlarge the product portfolio of Ka-band antennas integrated in Luxembourg for different satellite applications (satellite communications, satellite navigation, earth observation and meteorology) and for different uses (in-orbit testing, tracking/telemetry & control, traffic uplink and payload data).

While it is difficult for a newcomer to compete for commercial Ka-band antennas, there are business opportunities for the Luxembourg industry with European Government organizations. They can be seized through ESA in its role of a "R&D Agency" for product evolution but also as a "procurement agent" for other European organizations operating satellite systems (Eumetsat and the European Commission). In the meteorology domain, the MTG and METOP-2G systems are designed by ESA for Eumetsat, the multilateral European organization in charge of space meteorology.

As part of the *emergency.lu* initiative of the Ministère des Affaires Etrangères (MAE), HITEC developed a nomadic terminal for emergency communications that is used with an inflatable antenna and Ku-band satellite spectrum. As the technical platform has been designed for multi-service purposes by the partners in the project, there is an opportunity for HITEC to adapt this transportable terminal to different users (e.g. military, humanitarian, scientific). R&D efforts with regard to the customization of the nomadic terminal could be supported to some extent by the Government.

4.2.4 Satellite Services

In addition to its core capacity business SES has developed broadband communications services that are now operational in Europe. A few local players have just begun to be involved in the development of value-added services using satellite systems for communications, broadcasting, navigation, and earth observation applications.

These services add value in the sense that they take the signal or information provided by the satellite and develop from it services that are geared towards specific communities of users (transportation industry, homeland security, agriculture, fisheries, environmental researchers, ..). Value-added services can use a single satellite functionality (communications, broadcasting, navigation and earth observation separately) or a combination of them for integrated applications. ESA has launched an ARTES programme element dedicated to the promotion of integrated applications (IAP or ARTES 20) to which Luxembourg is contributing.

In the coming decade, four categories of satellite services have growth potential with opportunities for Luxembourg players to develop, integrate and operate them: satellite communications, earth observation, satellite navigation and integrated services. SES and companies involved in systems' development (i.e. LuxSpace, HITEC) will have the possibility to develop value added services that will make use of national satellite assets.

Communications and broadcasting services are currently better developed in Luxembourg than the other two categories of services because of the legacy of SES and of ARTES. Still, several new communications and broadcasting services will be developed in the coming years on the basis of the existing national satellite infrastructure (microsatellites, geostationary satellites, and the *emergency.lu* platform). Locally-generated ideas for new services will require Government support at different stages of their development (concept and feasibility study, technical development, support to deployment and implementation)[47]. To illustrate: satellite data for the detection of vessels not cooperating for automatic identification can be combined with terrestrial data and processed according to the interests of maritime surveillance agencies. Similarly, the tracking of hazardous materials by satellite can evolve into an operational service that Luxembourg suppliers prepare to offer. In case of emergency humanitarian situations, the combination of satellite imagery with satellite communications permitted by *emergency.lu* can improve the action of rescue organizations. Situation awareness can also be improved by combining the use of *emergency.lu* with small UAVs flying over the territory of interest.

Success factors for the development of satellite services in Luxembourg include national and intra-European cooperation and the existence of national service providers in a position to take commercial risks.

	Satellite communications services	**Satellite navigation & earth observation services**	**Integrated services**
Opportunity	Mature the development of the services that has been initiated nationally and through ARTES Develop new services that will use the national satellite infrastructure (bandwidth and hosted payloads)	Mature the development of the services that has been initiated through ESA dedicated program lines (Galileo, GMES, EOEP) Develop new services that will use the national satellite infrastructure (mission payload and data processing)	Understand better the needs of potential user communities and educate them to satellite solutions Increase the lead role of Luxembourg in the consortiums managing the IAP projects

[47] As illustrated by the PACORA system and the SAT-IP converter developments of SES recently.

Risk	Too few national service providers in position to take commercial risks Not finding the right selectivity in proposals and ideas		Demonstration projects of integrated applications failing to evolve into operational services as the cost of the satellite solution remains too high for potential users
Programme opportunity	All ARTES elements National	GSTP 6, EOEP, GMES, EGNOS, Galileo National	ARTES 20 National
Public funding need	Low to medium	Medium	Medium

Matching of the four investment priority areas with the four objectives of the national space policy

	Microsatellite	**Satellite Equipment**	**Ground Equipment**	**Satellite Service**
Contribute to diversify and sustain economic activities	The development of the instrumentation to be hosted on the national microsatellite platform will diversify and increase the economic value of Luxembourg's space sector The development of a more advanced national microsatellite platform will sustain existing economic activities and to pave the way to future revenues	Electric propulsion development will diversify and increase the economic value of Luxembourg's space sector Further involvement in composite structures, satellite simulators and TT&R sustains existing economic activities	The evolution of ground support equipment towards engineering services will diversify and increase the economic value of Luxembourg's space sector The development of advanced MGSE and Ka-band antennas for new applications sustains existing economic capabilities	The evolution toward more value added services will diversify and increase the economic value of Luxembourg's space assets (microsatellites, geostationary satellites, *emergency.lu*)
Consolidate and valorise existing competencies	Commitment to ARTES-21 will foster existing national AIS competencies, R&D efficiency and national partnerships The collection, storing, processing, and distribution of mission data from national instrumentation can benefit from national capabilities in ICT and data centres	Further involvement in composite structures, satellite simulators and TT&R consolidates and valorises existing competencies	The development of advanced Ka-band antennas and MGSE largely relies on existing competencies in the field	The experience of SES in satellite service development and implementation is a driver for other national service providers
Contribute to reinforce the competitive position of national players	AIS has the potential to become a niche market for Luxembourg satellite companies	Evolving from "print-to-build" to "design-to-print" in composite structure will increase the interest of satellite integrators Developing an electric propulsion capability nationally through risk sharing will attract foreign investment to the country	The development in Luxembourg of special materials welding technologies for future space propulsion technologies	The development of satellite services using Luxembourg's satellite assets (microsatellites, geostationary satellites, *emergency.lu*) will augment the competitive position of national players in Europe & internationally

	Microsatellite	**Satellite Equipment**	**Ground Equipment**	**Satellite Service**
Develop space skills nationally and integrate national players internationally	Microsatellite platform and payload development drives LuxSpace's plans to increase qualified staffing The microsatellite platform and instrumentation will increase cooperation internationally with both equipment suppliers and researchers (the case of hyperspectral imagery)	The development of electric propulsion will require new and highly-skilled workforce in the country It will also require international cooperation for access to testing facilities (with ESA and bilaterally)	Unique skills in material welding technologies for space systems Ka-band ground antenna development for new applications (earth observation, meteorology) will allow to connect with new communities of users internationally	The worldwide user communities for satellite services based on Luxembourg's satellite assets will increase the integration of national players in international consortia

4.3 Recommendations to the Government of Luxembourg

The recommendations to the Government of Luxembourg on its space policy for the decade have been developed in three steps to define:

- the optimal scenario of space development for the country;
- the implementation of the space development scenario;
- the governance required to implement the space development scenario.

4.3.1 A natural scenario for space development in Luxembourg based on four thematic objectives

All four domains of investment priorities previously analysed are recommended to be part of the Luxembourg space programme for the decade to come:

- Microsatellite, both for platform and payload
- Satellite equipment, in a first instance electric propulsion
- Ground equipment, in a first instance Ka-band antenna
- Value added services using satellite data, of which those produced by Luxembourg-built satellites.

Development efforts in these four domains reinforce the objectives of the national space policy that aligns itself with the policy of the Government of Luxembourg for the country's R&D and economic developments. They are at the same time ambitious in their strategic intent and realistic to implement.

The support of the Government of Luxembourg to national capability development in these four areas will help to

- establish local players sustainably in the European space sector with possibly large commercial benefits in the next decade;
- enlarge the commercial potential for local players ultimately;
- strengthen the existing local industrial base while attracting selectively new players into the country to develop a viable activity.

The scenario to implement the four investment priorities can be defined as natural in the sense that it is built upon achievements to date and the capabilities existing in the country in order to both

- maximize the strengths of Luxembourg in space: i.e. the valuable heritage in satellite communications, the attractiveness of SES, the flexibility and synergies of national space stakeholders;
- avoid the risks associated with the weaknesses of the country in space, i.e. entering too late in new technology development and discouraging local and foreign investment (because of the small size of the investment and its resulting selectivity).

It is a natural scenario also because it allows an organic growth of the national space capabilities by adapting them to the changing context of European and international demand and by developing new capabilities in two areas that are critical for future satellite missions (electric propulsion and payload). The public R&D funding effort required to undertake the development of these capabilities in the country is in continuity with the past effort of the Government for space.

4.3.2 The implementation of the scenario of space development in Luxembourg at four levels

The means, actions, resources and missions that are required to implement the scenario of satellite development in Luxembourg are presented below according to the three pillars of the national space policy (ESA, national and bilateral) complemented by that of the European Union.

European Space Agency

- To maximize the benefits of its contribution to the European Space Agency, the Government shall **continue to invest in the three categories of programmes of the Agency**: 1) those for R&D purpose (e.g. ARTES 3-4, GSTP), 2) those for system procurement for other Government organizations (e.g. EDRS, METOP) and 3) those preparing the future applications of satellite technology through initial studies (e.g. EOEP, ARTES 1). Also the funding flexibility ("pay-as-go") of the ARTES programme of ESA (e.g. IAP) is of interest for Luxembourg and shall be preferred in the investment decisions of the Government.
- Through its **future co-chair of the European Space Agency at ministerial level** for the coming years, Luxembourg will have to play an active role in forging the future European Space Policy involving both ESA and EU. This will be an occasion for Luxembourg to increase its influence and political standing in space. The communication and management tools of space activities of Luxembourg must be adapted to that new role.
- As a result of the thematic investment priorities of Luxembourg, **the bilateral relations with ESA should evolve in three directions**:
    - The **3rd Party Programme managed by ESA should be enlarged** with a view to contributing to develop national space activities, notably in areas relevant for Luxembourg but that do not match with ESA's present and future programme lines;
    - Because of its particular interest for the country, **the ARTES 21 programme of ESA for SAT-AIS should receive a large participation of the Luxembourg Government**. In order to have more technical and financial control on this optional programme of ESA that will be highly subscribed by Luxembourg, the Government should seek to obtain an observer status in the internal reviewing process of ESA, thus allowing it to participate closely to programme development;
    - **Luxembourg can offer different types of services to ESA under different formula** (public/private partnership, facilities management, in-kind contribution, commercial proposal). Services include hosted payloads on the microsatellites of LuxSpace and on the geostationary satellites of SES, satellite bandwidth on SES

satellites (to stimulate the development of new applications within the IAP programme for example) and facility outsourcing with the MEMS testing infrastructure of the CRP Gabriel Lippmann made available to ESTEC.

National

- **The two instruments that have been created** to develop Luxembourg's space activities outside of ESA participation, i.e. the Third Party programme and LuxLAUNCH, **should be continued and even boosted in the medium term**. While the two initiatives have proved to be relevant with respect to their objective and complementary in their mission, their short history does not allow a proper assessment of their effective impact. Furthermore, the implementation of the recommendations of this Report will induce important changes in the landscape for Luxembourg's space activities. It is therefore recommended to assess in a few years' time (2014-2015) the need of adapting both instruments to the requirements of the changed environment.
- As satellite communications is a key sector in Luxembourg that is transversal to the four investment domains, **the Government should leverage on SES's experience and engineering capabilities in this domain.** In a first phase SES could assist the MESR with expertise support for satellite communications R&D. This support could later evolve towards the management, on behalf of and in close coordination with MESR, of specific satellite communications R&D activities. It is evident that this approach should be designed to avoid conflicts of interest. Nonetheless, the benefits of a strong and coherent approach to satellite communications R&D are much higher than the risks of possible conflicts of interest (considering moreover that SES does not compete with other local players).
- **The visibility of the Luxembourg space programme should be reinforced** to attract investment, promote exportation and accelerate international cooperation. The national satellite capabilities should be better integrated in campaigns promoting Luxembourg's capabilities abroad.

Bilateral

- **Bilateral collaboration with other European countries should be further encouraged** to allow the national stakeholders to benefit from the strength of these partners in satellite systems and to be better prepared for more complex international programs implemented within ESA framework.

  The excellent bilateral experience to date with Germany in satellite systems at both institutional and industry levels gives an evidence of the benefits of such collaborations and underlines the fact that Luxembourg can be an attractive partner for collaborative projects with other countries, even large space countries.

European Union

- The European Union is increasingly involved in the European Space Policy with two satellite infrastructure programmes now in the deployment phase (Galileo and GMES). Luxembourg's space actors should seize the opportunity of participating, **through the European Commission's "Horizon 2020" programme**, to future space-related R&D initiatives in the domains of interest for the country.

4.3.3. A new governance is required for space development in Luxembourg

The recommendations above on the thematic priorities for space in Luxembourg and on their implementation have for direct consequences that

- the adequate financial resources have to be available for space development;
- the management tools of space development have to be strengthened;
- the Luxembourg's space policy should become more visible to be successfully implemented.

- **Growth of the space budget has to be maintained** to develop satellite systems and services in the four priorities domains for Luxembourg, i.e. microsatellite, satellite equipment, ground equipment and value added services. Larger budgetary resources will allow securing the achievements from previous investments and benefiting from the development opportunities offered by existing and new ESA programme lines and by a larger national programme implemented both locally and through bilateral cooperation. Funding growth will allow keeping the momentum, building on existing assets and developing new ones with locally based organizations, both in the research and industrial sectors. The growth of space-related funding will also increase the overall visibility of Luxembourg space activities, a factor that can be of importance to attract industrial players from other space countries in Europe and beyond.

- As a consequence of the growing investment and activities of Luxembourg in the space domain, **the management tools of space development by the Government have to be strengthened**. This induces more structuring of daily operations, including the measure of the impact of Government's investment in the space domain. In order to support future decisions, it is opportune for the Government to define key performance indicators (KPI) to monitor the development of the national landscape for space activities.

- As Luxembourg enters a new phase of its space development and becomes a larger actor in the European space scene with more political responsibilities in the domain, **it needs more recognition of its space policy both nationally and internationally**. Luxembourg's space policy should become more visible through the political recognition of its ambition in order to be implemented successfully.

Considering these factors, two recommendations on Luxembourg's space governance have been defined. They acknowledge the fact that the governance of space activities in Luxembourg needs to evolve as the Government increases its investment effort in parallel with growing stakeholders' interest in the sector. The two governance recommendations are coherent with respect to one another and relevant with respect to best practices in other European countries.

The consultative working group for space science and technologies should evolve into a permanent Space Committee with an advisory role for the Government

- The services, departments, and ministries of the State administration with direct interest in satellite matters as user, regulator or promoter of satellite systems should be given a permanent forum to contribute to the formulation of the space policy of the country and to monitor its execution. The consultative working group for space science and technologies should therefore become a permanent Space Committee with an advisory role for the Government on its space policy.
- Like in Finland and Switzerland, its role should be to prepare and monitor the execution of the national space plan. The composition of the Space Committee should reflect the diversity of stakeholders in the national space policy, i.e. the State administration, the private sector active in space and public research.
- Considering the strong impact of R&D and technology development on space activities and the liaising role of the MESR in space matters with regard to ESA and the European Union, the Space Committee should be chaired by that Ministry.

A Space Office should be created as a dedicated structure with political recognition to implement efficiently Luxembourg's space policy

- Luxembourg enters a new phase of its space development and it needs a dedicated structure with political recognition to manage efficiently that development. The creation of a Space Office within MESR is recommended to give political recognition to a structure with three roles for the space policy of the country: representation, decision and manaqement. Roles' centralization is required for an efficient coordination of the efforts nationally and for a stronger voice of Luxembourg internationally. Luxembourg is to date the sole country with such a high relative effort for space without a unified structure to implement that effort.

- Following the favourable experience of other European countries (Belgium, Netherlands, Switzerland, Czech Republic, Denmark, Poland, Portugal) that have created a Space Office or a similar dedicated structure as part of a supervisory Ministry, the Luxembourg Space Office would have for responsibility to coordinate and manage the implementation of all space R&D activities of the country, i.e. its membership to ESA and the national space programme (including all activities outside ESA, conducted either nationally or bilaterally). The mandate of the Luxembourg Space Office could evolve over time to an administration of its own according to the political agenda of the country with respect to its investment in space.

- The Luxembourg Space Office will have to cover a broad variety of missions:

  - national delegation to ESA and to the European Union;
  - multiple interfaces within Luxembourg (State administration and Government, industry and research sectors) and outside Luxembourg (ESA-managed Third Party, European Union, delegations from other countries);
  - monitoring of programme development;
  - technical consultation;
  - space-related specialized training programme;
  - institutional and public communication;
  - impact assessment of space investment and key performance indicators.

- The Luxembourg Space Office will be in charge of managing space R&D and technological development in the four domains that have been defined as priority for Luxembourg, i.e. microsatellite, satellite equipment, ground equipment and value added services. Therefore the human resources of the Space Office and its operating budget will have to grow in relation with the volume and nature of the activities it manages. As a comparison, the operating budget in other European countries range between 3% and 10% of their total space budget. The range results from different mandates and different organizations of the space offices or space agencies between the countries.
- Furthermore it has to be underlined that the responsibility of co-chair of the European Space Agency at ministerial level will entail for the two to three years to come a supplementary draw on the scarce specialized human resources now available at MESR.

APPENDICES

Luxembourg space capabilities according to ESA Technology Tree

Light grey indicates that Luxembourg has a capability either in a Technology Domain, a Subdomain or a Group.

Dark grey indicates no significant capability of Luxembourg

White refers to areas for which it is difficult to be conclusive due to a lack of information about the maturity of the Luxembourg technology in that area.

#	DOMAINS	#	SUBDOMAINS	#	GROUPS
1	**On-Board Data Systems**	A	Payload Data Processing	I	System Technologies for Payload Data Processing
				II	Hardware Technologies for Payload Data Processing
				III	Software Technologies for Payload Data Processing
		B	On Board Data Management	I	System
				II	On board computers
				III	Data Storage
				IV	On board networks and control/monitoring
		C	Microelectronics for digital and analogue applications	I	Methodologies
				II	Digital and analogue devices and technologies
2	**Space System Software**	A	Advanced Software technologies	I	Advanced software development methods and tools
				II	Advanced software functions
		B	Space Segment Software	I	Methods and tools for the On Board software Engineering Processes
				II	Innovative Software Management Process
				III	Software architectures
		C	Ground Segment Software		
		D	Ground Data Processing	I	Data Archiving Systems
				II	Analytical Processing
		E	Earth Observation Payload Data Exploitation	I	Data and Information Processing
				II	Application and Services
				III	Information Systems and User Interfaces
				IV	Core Infrastructure and Architectures
3	**Spacecraft Electrical Power**	A	Power system architecture		
		B	Power generation technologies	I	Photovoltaic generator technology
				II	Fuel cell technology

				III	Nuclear and thermo-electric power generator technologies.
		C	Energy storage technologies	I	Electro-chemical technologies for energy storage
				II	Mechanical technology for energy storage
		D	Power conditioning and distribution	I	Power conditioning
				II	Specific Power Supplies
				III	Power Distribution
4	**Spacecraft Environment & Effects**	A	Space Environment:	I	Numerical modelling of environments
				II	In-flight monitoring
		B	Environment effects	I	Effects analysis tools
				II	Experimental investigations
		C	Space Weather	I	Modelling development and IT infrastructure
				II	Space Weather Monitoring Technology
5	**Space System Control**	A	Space system architecture and autonomy	I	Space System Architecture
				II	Autonomy and Automated Operations
		B	Space segment Guidance Navigation and Control (GNC)	I	GNC Systems
				II	GNC Technology
				III	High accuracy pointing systems
6	**RF Payload and Systems**	A	Telecommunication (sub-)Systems	I	Telecom System Engineering Tools.
				II	Telecom Signal Processing
				III	Networking Techniques
				IV	Telecom Equipments
				V	Telecom Security Techniques and Technologies
		B	Radio Navigation (sub-)Systems	I	Navigation System Tools
				II	Ground receivers
				III	On-board receivers
				IV	Formation flying RF metrology
		C	TT&C (sub-)Systems	I	TT&C System Tools
				II	Deep Space Transponders
				III	Near Earth Transponders
				IV	Proximity Link
				V	High-speed Telemetry Downlink Modulators
		D	RF Payloads	I	Payload Tools
				II	Telecommunication payloads

				III	EO instruments
				IV	Navigation payloads
		E	Microwave and millimeter wave technologies and equipments	I	RF Modelling and Design tools
				II	RF Equipments
				III	RF Devices
				IV	Vacuum electronics
				V	Time and frequency references
				VI	Measurement, characterisation and calibration techniques
7	**Electromagnetic Technologies and Techniques**	A	Antennas	I	Antenna design tools
				II	Reflector and lens antennas and feeds
				III	Array antennas
				IV	Millimetre-wave and sub-millimetre wave antenna front-ends
				V	Measurement, characterisation and calibration techniques for radiative payloads and antennas
		B	Wave Interaction and Propagation	I	Wave interaction
				II	Wave Propagation
		C	EMC/RFC/ESD	I	EMC modelling
				II	EMC test techniques
8	**System Design & verification**	A	Mission and System Specification	I	Specification Methods and Tools
				II	Requirements Engineering
		B	Collaborative and Concurrent Engineering	I	Concurrent Design
				II	Product Data Exchange
				III	Distributed Collaborative Engineering
		C	System Analysis and Design	I	System Design and Simulation
				II	Multidisciplinary Analysis
		D	Verification and AIT	I	Advanced AIT Methods
				II	Ground Support Equipment
9	**Mission Operation and Ground Data systems**	A	Advanced System Concepts		
		B	Mission Operations	I	Distributed and Decentralised Operations
				II	Automation and Mission Planning Concepts
				III	Operation Support Processes

		C	Ground Data Systems (MCS)	I	Mission Control System, Automation, Mission Planning, Simulators and Station M&C Architecture and Technologies
				II	Preparation and Procedure Tools
				III	Human Computer Interfaces and Technologies
10	**Flight Dynamics and GNSS**	A	Flight Dynamics	I	Mission Analysis, Trajectory Design and Control
				II	Attitude Determination, Analysis and Control
				III	Flight Dynamics Modelling
				IV	Advanced Flight Dynamics Concepts
		B	GNSS systems and ground-related technologies	I	Ground Tracking Networks
				II	GNSS and LEO Data Processing
11	**Space Debris**	A	Measurements		
		B	Modelling, Databases and Risk Analysis		
		C	Hyper-Velocity Impact (HVI) and Protection		
12	**Ground Station System and Networks**	A	Ground Station System	I	Advanced ground station design concepts
				II	Ground TT&C Antenna Systems
				III	Microwave Active/Passive Systems
				IV	TT&C Signal & Data Processing
				V	Frequency & Time generation and distribution
		B	Ground Communications Networks	I	Advanced ground communication networking concepts
				II	Communication Network technologies and protocols
13	**Automation, Telepresence & Robotics**	A	Applications and Concepts	I	Planetary Exploration
				II	Orbital Systems
		B	Automation & Robotics Systems	I	Manipulation systems
				II	Mobility Systems
				III	Payload Automation Systems
		C	Automation & Robotics components and Technologies	I	Perception
				II	Control, Autonomy and Intelligence
				III	Motion and Actuation
				IV	Robot-User Interfacing
				V	Robot Ground Testing
14	**Life & Physical Sciences**	A	Instrumentation in support of Life Sciences	I	Sensors and Analytical Instrumentation
				II	Imaging Diagnostics and Image Treatment Technologies

				III	Cultivation and (Bio) Processing
		B	Instrumentation in support of Physical Sciences	I	Sensors and Analytical Instrumentation
				II	Imaging Diagnostics and Image Treatment Technologies
				III	Processing and production
		C	Applied Life Science Technology	I	Application of Human Physiology Technologies:
				II	Bioburden/Biodiversity Monitoring
				III	Biobarriers
				IV	Dry Heat Sterilisation
				V	Low Temperature Sterilisation
				VI	Precision Cleaning to achieve sterility
		D	Applied physical Science Technology	I	Processing and production
15	**Mechanisms & Tribology**	A	Mechanism core technologies	I	Actuator technologies
				II	Dampers & speed regulator technologies
				III	Motion transformer technologies
				IV	Motion & force sensor technologies
				V	Guiding Technologies
				VI	Sealing technologies
				VII	Electrical transfer technologies
		B	Non explosive release technologies		
		C	Exploration tool technologies		
		D	Control electronics technologies		
		E	MEMS technologies		
		F	Tribology technologies	I	Lubrication technologies
				II	Material surface technologies
		G	Mechanism engineering	I	Engineering Disciplines
					Engineering tools
16	**Optics**	A	Optical system engineering	I	Overall optical system definition, design and engineering

				II	Optical design performance evaluation and analysis (incl. straylight)
		B	Optical component technology and materials	I	Optical components
				II	Micro-optics components, MOEMS, optical fibers and passive integrated optics
				III	Mirror and telescope technologies
				IV	Optical bench and mounting technologies
		C	Optical equipment and instrument technology	I	Spectrometers, imaging spectrometers, radiometers
				II	Cameras, Illumination devices, displays
				III	Laser ranging and imaging, lidars and altimeters
				IV	Interferometry, aperture synthesis and optical phased arrays
				V	High Precision Optical Metrology
				VI	Optical communications
17	**Optoelectronics**	A	Laser Technologies	I	Laser sources (oscillators)
				II	Laser pumping
				III	Laser amplifiers
				IV	Laser frequency control and stabilisation
				V	Non-linear optics
		B	Detector Technologies	I	Visible (Si-based) Detectors
				II	NIR-FIR Detectors
				III	UV, X-ray Detectors
				IV	Super-conducting Detectors
				V	Superconducting devices
				VI	Focal-Plane Technologies
		C	Photonics	I	RF Photonics
				II	Micro & nano-photonics
				III	Fibre-optic sensors
				IV	Optical atomic clocks
				V	Quantum devices
18	**Aerothermodynamics**	A	Computational Tools	I	Computational Fluid Dynamics (CFD)
				II	Advanced Numerical Methods
				III	Physical Models
				IV	Engineering and ATD Design Tools
		B	Ground Based Facilities	I	Perfect Gas Facilities

				II	High Enthalpy Facilities
				III	Plasma Facilities
				IV	Rocket Nozzle Test Stands
		C	Flight Testing	I	In-Flight Research
				II	In-Flight Measurements (intrusive and non-intrusive)
		D	Multi-Disciplinary Tools	I	Multi-Disciplinary Tool Development
				II	Multi-Disciplinary Optimisation
19	**Propulsion**	A	Chemical Propulsion Technologies	I	Liquid Propulsion Systems
				II	Solid Propulsion Systems
				III	Air-Breathing and Hybrid Propulsion Systems
		B	Electric Propulsion Technologies	I	Electrostatic Systems
				II	Electrothermal Systems
				III	Electromagnetic Systems
		C	Advanced Propulsion	I	Solar Thermal Propulsion Systems
				II	Nuclear Propulsion Systems
				III	Solar Sailing Propulsion Systems
				IV	Tethered Propulsion Systems
				V	New concepts
		D	Supporting Propulsion Technologies and Tools	I	Modelling
				II	Testing and Diagnostics
				III	Propellants
				IV	Ground Support Equipment (GSE)
20	**Structures & Pyrotechnics**	A	Structural design and verification methods and tools	I	S/C Design and Design Tools
				II	Analysis Tools and Methodologies
				III	Testing Tools and Methodologies
				IV	In flight/In orbit loads and vibration measurement techniques
		B	High stability and high precision S/C structures	I	Advanced stable structures materials technologies
				II	Joining and mounting technologies
				III	Thermo-elastic stability verification technologies
		C	Inflatable and deployable structures	I	Design and verification technologies
				II	Structural material concepts
				III	Joining technologies
		D	Hot structures	I	Ceramic structures design and verification technologies

				II	Metallic structures design and verification technologies
				III	New advanced hot structures materials
				IV	Joining technologies
				V	Health Monitoring Technologies
		E	Active/adaptive structures	I	Sensor/actuator technologies
				II	Technologies for structural integration
				III	Data acquisition and control logic technologies related to structural dynamics
				IV	Design and verification tools and methodologies
		F	Damage tolerance and health monitoring	I	Non Destructive Inspection Technologies (NDI)
				II	Structural health monitoring Sensor technologies
				III	Fracture Control tools and methodologies
		G	Launchers, re-entry vehicles, planetary vehicles	I	Technologies for design and verification of advanced primary structures
				II	Advanced Tank design and verification technologies
				III	Landing attenuation technologies
				IV	Control surfaces, design an verification technologies
		H	Crew Habitation, Safe Haven and EVA suits	I	Habitation primary and secondary structures technologies
				II	EVA suits, mechanical aspects
		I	Meteoroid and Debris shield design and analysis	I	Tools and methodologies for design and verification of M&D shields
		J	Advanced structural concepts and materials	I	Design and verification technologies
		K	Pyrotechnics technologies	I	Explosive composition technologies
				II	Thermite technologies
				III	Shape memory alloy technologies
				IV	Optical ignition technologies
				V	Miniaturization technologies
				VI	Development of new devices for future exploration and exploitation missions
				VII	Reliability determination for non-repeating functions
21	**Thermal**	A	Heat Transport Technology	I	Heat Pipes
				II	Capillary Driven Loops
				III	Mechanically Pumped 2-Phase Loops

				IV	Mechanically Pumped Single-Phase Loops
		B	Cryogenics and Refrigeration	I	Refrigeration and Heat Pumps
				II	Cryo-coolers
				III	Passive Coolers and Stored Cryogens
				IV	Sub-Kelvin Coolers
		C	Thermal Protection	I	Ablative Systems
				II	Reusable Systems
		D	Heat Storage and Rejection	I	Coatings and Insulations
				II	Heat Storage
				III	Radiators
		E	Thermal Analysis Tools	I	Thermal & ECLS Software Tools
				II	Thermal Data Exchange
				III	Thermal & ECLS Analysis Methods
22	**Environmental Control Life Support (ECLS) and In-Situ Resource Utilisation (ISRU)**	A	Environmental Control & Life Support (ECLS)	I	Environmental Control and Monitoring
				II	Regenerative Life Support
				III	Habitability
				IV	Integrated ECLS
		B	In-Situ Resource Utilisation (ISRU	I	ECLS Consumables
				II	Fuels
				III	Storage and Distribution
23	**EEE Components and Quality**	A	Methods and Processes for Radiation Hardness Assurance	I	Evaluation and Testing
				II	Radiation Hardening
				III	Design and Development
		B	EEE Component technologies	I	Passive Components
				II	Silicon based components
				III	RF Microwave and Milimetre Wave Components
				IV	Optoelectronic active and passive components
				V	Hybrids and Micropackaging
				VI	Power Components
				VII	Wide Band Gap Technologies
				VIII	Micro Electro Mechanical Systems (MEMS)
				IX	Nano Technology
24	Materials & Processes	A	Novel Materials	I	Material assessment
		B	Materials Processes	I	Joining

				II	Coating
				III	Characterisation & Feedback
				IV	Advanced Materials Manufacturing
		C	Cleanliness and Sterilisation	I	Sterilisation of materials
				II	Molecular contamination
				III	Particulate contamination
				IV	Bio-corrosion, biocites, plasma corrosion etc
25	**Quality, Dependability and Safety**	A	System Dependability and Safety	I	Dependability and Safety methods & tools
				II	Technical Risk Management techniques
		B	Software Quality	I	SW process quality techniques
				II	SW product quality techniques

List of Acronyms

AIS	Automatic Identification System
AMS	CRP Henri Tudor Advanced Materials and Structures Department
ANS	Autorité Nationale de Sécurité
AOCS	Attitude and Orbit Control System
ARTES	Advanced Research in Telecommunications Systems
ASA	Austrian Space Agency
BMVIT	Austrian Federal Ministry of Transport, Innovation and Technology
BMWFJ	Austrian Federal Ministry of Economics, Family and Youth
CAM	Commissariat du Gouvernement aux Affaires Maritimes
Capex	Capital expenditure
CDTI	Spanish Centre for the Development of Industrial Technology
CFAS	Swiss Federal Space Affairs Commission
CNES	Centre National d'Etudes Spatiales (French Space Agency)
CSDP	Common Security and Defence Policy of the EU
DDPS	Swiss Federal Department of Defence, Civil Protection and Sport
DG ENT	Directorate-General of Enterprise and Industry of the EU
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DoD	Department of Defence of the US
DTH	Direct-To-Home
EC	European Commission
EDRS	European Data Relay System
EEA	European Environment Agency
EGSE	Electrical Ground Support Equipment
EIB	European Investment Bank
EIG	Economic Interest Group
EMEA	Europe, Middle East & Asia
EMSA	European Maritime Security Agency
EO	Earth Observation
ESA	European Space Agency
ESP	European Space Policy
EU	European Union
EVA	CRP Gabriel Lippmann Environment and Agro-Biotechnologies Department
FDEA	Swiss Federal Department of Economic Affairs
FDHA	Swiss Federal Department of Home Affairs
FEDIL	Business Federation Luxembourg
FFG	Austrian Research Promotion Agency
FP	Framework Programme of the European Union
FSS	Fixed Satellite Services
FTE	Full time equivalent
FWF	Austrain Science Fund
GDP	Gross Domestic Product
GEO	Geosynchronous Orbit
GLAE	Groupement Luxembourgeois de l'Aeronautique et de l'Espace
GSE	Ground Support Equipment
IAP	Integrated Applications Promotion
ICT	Information and Communication Technologies

IKAR	Swiss Interdepartmental Coordinating Committee for Space Questions
IOT	In-Orbit Testing
IOV	In-Orbit Validation
ISRO	Indian Space Research Organisation
ITV	Interactive TV
JAXA	Space Agency of Japan
LBS	Location Based Services
LCI	Luxembourg Cluster Initiative
LEO	Low Earth Orbit
LEOP	Launch and Early Operations
LIIS	Luxembourg Industry Incentive Scheme
M2M	Machine to Machine
MEMS	Microelectromechanical Systems
MEO	Medium Earth Orbit
MESR	Ministère de l'Education Supérieure et de la Recherche
METOP	Meteorological Operational satellite
MFF	Multiannual Financial Framework
MGSE	Mechanical Ground Support Equipment
MSS	Mobile Satellite Services
MTG	Meteosat Third Generation
NASA	National Aeronautics and Space Administration
NSC	Norwegian Space Centre
NSCP	Norwegian Space Centre Properties
NTNF	Royal NorwegianCouncil for Scientific and Industrial Research
Opex	operational expenditure
P&M	Uni.lu Physics and Material Sciences Research Unit
PNT	Positioning, Navigation and Timing
PPP	Public-Private Partnership
R&D	Research and Development
R&T	Research and Technology
RCN	Research Council of Norway
RUES	Uni.lu Research unit in Engineering Science
S&T	Science and Technology
SAM	CRP Gabriel Lippmann Science and Materials Analysis Department
Satcom	Satellite communications
Satnav	Satellite navigation
SDR	Software-Defined Radio
SER	Swiss State Secretariat for Education and Research
SES	Société Européenne de Satellites
SMC	Service des Médias et des Communications
SME	Small and Medium Enterprises
SnT	Uni.lu Interdisciplinary Centre for Security, Reliability and Trust
SSA	Space Situational Awareness
SSI	CRP Henri Tudor Service Science and Innovation Department
SSO	Swiss Space Office
TDRSS	Tracking and Data Relay Satellite System
TEKES	Finnish Funding Agency for Technology and Innovation
Telcom	Telecommunications

TRL	Technology Readiness Level
TT&C	Telemetry, Tracking and Command
UAV	Unmanned Aerial Vehicle
VSAT	Very Small Aperture Terminal
WG	Working Group
WGS	Wideband Global Satellite System