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Agile Space Living Lab – The Emergence of a New High-Tech Innovation Paradigm

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Abstract

The global space industry has recently seen a structural transformation through the emergence of "New Space", i.e. a significant expansion of the development of smaller, cheaper and more modular space-related products in services. One example of this expansion is the emergence of a world-leading cluster of New Space industry in Scotland (UK). Critically, this development is being pitched as a new approach to innovation ecosystem, which the players refer to as "Agile Space", based on a consolidation of cross-sector competences within a loose value chain integration. However, I argue in particular, that the emergence of the Scottish New Space Sector is crucially linked to the Living Laboratories (Living Lab) conceptualisation of the innovation practices and processes within the Agile Space approach. Hence, this paper maps the key features of the emergence and development of the New Space Industry in Scotland and analyses the key feature of the Agile Space Living Lab paradigm, before proposing a critical further research agenda suggesting several much-needed strands of enquiry.

Introduction – "Living Labs" and "Agile Space"

Over the past 10 years (2008-2018), Scotland has emerged as a global leader in the New Space Industry [1,2], in particular in nano-sat platform development and space-data driven applications [3]. The way in which such advantage was attained is of significant interest in understanding socio-economic and scientific context, which, coupled with changes to innovation practices and specific policy interventions, can bring about a transformational change within the sectoral and regional business ecosystem. This is of broad interest in theorising the factors influencing economic development, as well as proposing a structural framework supporting SMEs in high-tech innovation.

Hence, this paper is outlining the current state of the Scottish Space Sector in the context of the crucial development of the Space Industry in the UK and globally – the transition into the 3rd generation or "New Space" era [4]. In particular, I am examining the way in which the Scottish Space Sector SMEs are interacting with the environment, which is enabling them to co-develop the emerging technologies and markets. This analysis is based on evidence from a detailed analysis of secondary data, in particular, comparative document analysis [5,6], as well as original ethnographic work through interviews with professionals [7] (SMEs' CEOs or CTOs) and social network analysis [8,9], all completed between 2014-2017. The qualitative work presented here is centred on a structural analysis of qualitative data based on a small set of typical cases [10], though I examined all core Scottish Space Sector SMEs identified through extensive participatory engagement [11] with the sector.

Through this analytical work, I propose that by applying the recently emerging conceptualisation of living laboratories (or Living Labs) [12–17], Scotland can be framed as an ideal test-bed for a variety of space/satellite applications, due to its mature scientific and R&D ecosystem and infrastructure, combined with a diverse natural environment, highly-skilled workforce and significant earlyadopters/lead-users community. Hence, I propose that the Living Labs approach to sectoral development, coupled with a loose vertical value chain integration proposed by the industry itself – something many Scottish players refer to as “the Agile Space” [18]- is paving the way for a new business and innovation approach.

Based on my original analysis using new empirical data, I specifically argue that the crucial difference in the form of the innovation process between the traditional Space SMEs and the “new Space” ones, can be characterised as the structured and formalised new product development model including a local network of interdisciplinary stakeholders, mainly from the public sphere. Such an approach to innovation is clearly related to the conceptualisation of the Living Labs open innovation model. Furthermore, based on the main findings of this work, I propose a future research agenda for a detailed analysis of the mechanics of these high-tech innovation processes, the emergence of structural linkages across the sector, and the role of innovation intermediaries in its development.

This paper begins by reviewing the two key concepts: on one hand, the “Living Laboratories” conceptualisation of emerging open innovation systems framework, and other the other hand, cross-sectoral linking and a new form or vertical value chain integration within the New Space Sector in Scotland, termed “Agile Space”. Then, I outline through empirical data how downstream Scottish Space Industry effectively deploys the Living Labs approach, illuminating some of the key elements and effects of the combined Agile Space Living Labs approach through innovation networks mapping, qualitative analysis of new product development processes and a specific application case study. Finally, I turn to the substantial leads for further research, which can deepen our understanding of this emerging innovation paradigm.

“Real World” Innovation and Living Labs

A new understanding of systemic changes in high-tech innovation has occurred with the emergence of Living Laboratories or Living labs conceptualisation [12,14,15,17,19–21]. In particular, this concept outlines the practical configuration of the innovation processes as they break away from the traditional association of high-tech R&D with a technology-push dominated product development, i.e. that technology developers come up with new solutions first and only later look for what demand/need might they be targeting to bring the technology to market [22]. Such “linear flow of innovation” within these “technology-push” models is associated with technological determinism, which is persistent, even though they have been analytically discredited [23]. The gist of these approaches is underlining the development of the technology itself as the primary concern in innovation studies and presuming a one-directional “progress” from innovator’s ideas, through the development process and towards the user.

However, such view of innovation process has been severely criticised, by the more inclusive systems-based approach, acknowledging the “fuzzy” or “messy” nature of the activities leading to the emergence of (successful) new products [24]. In particular, a crucial role of external actors in the context of the innovation organisation has been highlighted, in particular in terms of acquiring knowledge, expertise and other resources from research institutions and other sources, as well as involving users in the process of development [25,26]. Such a view is embedded in the analysis of “open innovation”, i.e. innovation process crossing firms’ boundaries [27,28], “innovation systems”, i.e. the necessary capacity for innovation being a product of a larger system involving different actors and linkages [29–32], and “innofusion” and “social learning”, i.e. the crucial role of users and user groups in innovation [33,34].

All of the above suggests the process of innovation is highly interdependent on its localisation and social/economic/political/etc. context. The Living Laboratories innovation framework, originally emerging from the information technologies sector, also follows these new principles of "open", "systemic" and "social" R&D, in particular by stressing the coordination between innovators and (lead) users [15], with the interaction having evolved from "consumption" of innovation to "co-creation" [21]. The crucial premise behind the Living Labs model is the systemic interconnectedness of all actors within a bound (most often geographical) unit or activity, thus creating a "living R&D laboratory" [12].

A specific geographical and sectoral focus is also significant in terms of aligning with the understanding of localised economic development initiatives. Specifically, there is growing importance being placed on the development of regional competitive advantage in order to successfully perform in the global economic system(s) [35], such as through the European initiatives for (regional) Smart Specialisation Strategy [36]. The smart specialisation policy framework is built around a (regional) economic development theory, in particular, the presumed need for regional competitive advantage in order to successfully perform in the globalised economic system [35]. At its core is a crucial reliance upon fostering innovation system, in order to develop a "related variety" of research, industry and entrepreneurial activities, resulting by the region becoming a global leader within a specific sector of economic activity [37].

Some of these "laboratories" can be very small and erratic, such as an individual classroom in a school, though on the other hand, the largest Living Labs can extend to encapsulate vast international areas, such as the coast of North Sea. Conversely, the "construction" of these "laboratories" is more often than not very project-specific, i.e. it depends on the sector or group of technologies developed as to what relevant actors and geographical boundaries are most applicable. Though these are sometimes deliberately configured in advance, they are often more clearly recognised or "discovered" only within contemporary or historical analytical work. Here, by recognising their dual political and phenomenological nature, and by bringing together the leading conceptual definitions, methodologies and modalities of Living Labs, I propose to establish a set of contextual identifiers which can be used to characterise emerging innovation practices as part of the Living Lab conceptual framework. In doing so, I hope to establish a clear analytical framework with which I can examine the emerging features of emerging high-tech innovation ecosystems, in particular, the critical example before me, the New Space Sector in Scotland.

Context Identifiers for "Discovering" Living Labs

Though Living Labs label originates from practitioners in innovation management and public policy arena, it has featured in several analyses of new modes of innovation in innovation and entrepreneurship literature [14,38]. Of particular importance here is the involvement of (lead) users in identifying and creating demand for new solutions and in designing and testing products and services to satisfy these needs [39]. Hence, this framework moves beyond the typical clustering or (eco)systemic analysis of relevant firms and institutions supporting innovation, by noting the roles performed by actors other than business and research organisations and crucially, by more directly addressing the role of (natural and social) environment in the development process.

Furthermore, the Living Laboratories paradigm resonates strongly with an observation by science and technology scholars, who have long argued that in order to launch successful transformative technologies into society, it is the "outside world" that has to become more akin to the physical and social environment within the laboratory [40,41]. In order for such an endeavour to work, not only has the scientific and technological development be supplemented by political and social capital to achieve societal recognition and acceptance, but the proposed solution has to be credible and made to resonate amongst the society as a way to frame and address an existing acute challenge.

Hence, in the current knowledge/data-driven economy and noting the current "grand societal challenges" [42], mainly related to global ecology, the construction of Living Laboratories-type innovation processes to deploy new technological solution into the society is a continuation of a long-established tradition of science's "enrolment" of other actors [43], both within the natural context, as well as within the social one, into new instances of epistemic ordering. The Living Labs framework can be seen as making these crucial elements of the innovation process, and their alignment within and outwith organisations engaging in innovation, an explicit and central feature. In particular, it postulates the interdependency of natural and social elements within an "innovation ecosystem", i.e. linking appropriate access to the natural environment with societal structures such as a mature scientific and R&D ecosystem and infrastructure.

European Network of Living Labs Conceptualisation [13,21]	**Living Lab User Involvement Methodologies** [14]	**Key Components of a Living lab** [20]	***Proposed Enabling Contexts for a Living Lab***	***Scotland***
Multi-stakeholder Participation	User Centred	Partners	*Geographically, Politically and Economically Bounded*	✓
			Appropriate Scale and Size	✓
Real-life Setting	Design Driven	Application Environment	*Diverse Natural Environment*	✓
		Technology and Infrastructure	*Physical and Digital Infrastructure*	✓
Multi-method Approach		Organisation and Methods	*Research Capabilities*	✓
Co-creation	Participatory	User	*Highly Skilled and Educated Workforce and Community*	✓
Active User Involvement	User Driven			✓

Table 1 – The proposed set of Living Labs framework contextual identifiers and their presence in Scotland. By cross-matching the key leading conceptual definitions, methodologies and component modalities of Living Labs, specific practical enabling contexts are proposed. These can serve as normative suggestions for the construction of new Living Labs or analytical identifiers for "discovered" ones.

Specifically, I propose that by intersecting the key concepts within the Living Lab framework with its key methodologies and components a new model emerges whereby one can identify a de facto living lab from the presence of its contextual enabling factors. I propose these to be Geographical, Political and Economical Boundedness, Appropriate Scale and Size, Diverse Natural Environment, Physical and Digital Infrastructure, Research Capabilities, and Highly Skilled and Educated Workforce and Community. This is based on recognising that the bases of these identifiable "real-life" contexts are rooted in framing and inclusion, settings and technologies, and engagement of users [13,14,20,21]. This conceptual derivation of these factors, and their presence in Scotland, is outlined in Table 1.

Hence, by identifying these elements within any innovation grouping, which is attempting a functional consolidation, such grouping can be recognised as a Living Lab. This is also consistent with the pivotal definition of Living Labs as "methodology aimed at co-creating innovation through the involvement of aware users in a real-life setting" [12]. Therefore, having outlined the Living Lab conceptualisation, its importance for the understanding of the current innovation contexts, I return my attention to the New Space Sector. In particular, I will outline in the next section its emergence in Scotland and the set-up of the “Agile Space” approach to innovation and sectoral development. Following from the framing of “discovered” Living Labs outlined above, I will also link some of its key elements to the derived contextual identifiers.

The Making of “Agile Space”: Space Sector in the UK and Scotland

The Space Sector is currently in a major industry transition from Space 2.0 to Space 3.0 (i.e. into “New Space”) [4]. Though as before the markets are built around the three main areas of applications: Earth Observation (EO), (satellite) navigation and telecommunications/broadcasting, the significant amount of growth in this area and the increasing economic and political value and importance emerged on the back of cheaper core technology (electronics, hardware, 3D printing), open source data (from public programmes, such as ESA/EU’s Copernicus) and new system/operation solutions (e.g. cloud-based platforms for operation and data management). These developments enabled new entrants to the market to emerge from traditionally peripheral geographies, such as Scotland.

Importantly, the UK space industry was in many ways the key for the transition between the 1st and the 2nd phase/generation as the UK was the first country to commercialise its launch capability [44]. Furthermore, due to the leading role of UK in commercialising space applications, for instance, the dominance of UK-based BSkyB in satellite (TV) broadcasting [44], it is hoped that the UK can capitalise on similar leadership in the current transition. This is further encouraged through the support for innovation as a means to capitalise on the UK’s pole position in research in (basic) science and engineering [45]. Hence, the political interest in generating economic and societal impact from the continuous development of the Space Sector is unsurprising. However, in the UK, and perhaps even more specifically in Scotland, the conditions surrounding this development are of particular interest in understanding the process of innovation in a highly specialised industry such as the Space Sector.

The overall development of the sector in the UK is crucially framed by the Space IGS vision and action plans [46,47] which provide detailed development agenda, and by the “economic case” presented in the “Case for Space” reports [48,49]. Since 1992 the industry is also monitored in the biannual “The Size and Health of UK Space Industry” survey [50–54], which is the basis for the Case for Space reports (discontinued in 2017) and have now become the baseline to evaluate the performance of the overall development strategy. Specifically, this government-backed policy aims to an increase of the UK share of the global space industry market from 7% to 10% by 2030 [44,46,47], worth £40bn out of the predicted £400bn total. Similarly, Scottish Enterprise acting on behalf of the Scottish Government (under UK devolution) has the ambition to see 10% of that economic activity based in Scotland [3,55].

The critical component of these policies and ambitions is their reliance on the development of new enterprises (SMEs) through an improved entrepreneurial climate and incentives for knowledge transfer from basic and applied research and demand-driven innovation. This approach is related to two key phenomena. Firstly, the New Space transformation is still limited in the valorisation of its markets and producing the promised turnovers. This observation is particularly applicable to the more radical technological innovations and new products aimed at individual consumers. Until a clearer market opportunity is proven, the larger companies are less interested to enter this arena. Secondly, by and large, the New Space innovations are not competing with "classical" or "traditional" space products, but rather complement and extend the space domain reach.

Not only there is little competition with traditional space actors, these new products in fact still rely on continued investment in classical space. For example, nano-satellite platforms currently still predominantly rely upon spare capacity in bigger projects for space launch. Furthermore, big geostationary navigation systems are used by nano-satellite for flight control. In the downstream segment, most of the new applications are being developed using data from (open source) Earth Observation satellites, which, particularly the more complex radar-based systems, are results of public investment and produced by "classical" space actors. This status quo, which enables SMEs relatively uninterrupted development of new products and markets, may not hold for long, though. In particular, nano-satellite proliferation is likely leading to certain services offered by new space players surpassing the larger firms' offerings. Hence, a shift in bigger players attitude has already been seen in some pivotal key global cases such as the provision of global internet coverage. Whilst this was initiated as a "new space idea", underpinned by the increasing availability of large constellations of smaller (and cheaper) satellites, the key developers, a group called One Web, have been subsumed as a venture between some of the largest global space firms (namely Airbus, their subsidiary Ariane Group/Arianespace and Virgin Galactic). Crucially, this enabled input of capital (including a $1.2bn investment) and political leverage for the project [56], its transformative potential for an ecosystem of smaller businesses (a central premise of the New Space transition) did not (yet) manifest once these bigger firms took over.

The Configuration of Players Within the Scottish Space Sector

In the context of the global industry transition to “New Space” and the increased political and economic interest in these activities in the UK, Scotland is an interesting case study to analyse these emerging trends. Specifically, even though the space industry in the UK has been a strong sector for a long time, this was mainly centred on the South-East, particularly Surrey and Oxfordshire, and Scotland was mainly left out. One of the factors for the emerging prominence of the Space Sector in Scotland may be related to Scotland’s Government political ambition over the past decade to create high added-value sectors [57]. In particular, this was done in order to diversify from the traditional dominance of oil and gas, financial services and tourism in the Scottish economy, whilst at the same time build upon the traditional engineering skill base. This framing presents the clear geographical, political and economic boundary, which can be seen as the initial core factors in the establishment of a Living Lab innovation process.

However, the kind of sustained big-scale investment as seen in the renewables sector was not directed towards the Space Industry and most funding projects in this area are led by the UK government. In contrast, Scotland has invested more in networking efforts, with over £200k investment in establishing an integrated network of space-related activities [58] and including space as one of the key sectors supporting the creation of innovation generating initiatives, within the Living Labs framework [57]. The aim is to join up-sectors with common interests, in particular, space-data based Geosciences/Earth Observation and the energy sector, both in fossil fuels as well as renewables, promoted in particular through partnerships with NERC and Satellite Applications Catapult’s Scottish Centre for Excellence.

The industry attitude towards this analysis and the development plans were examined between 2014 and 2018 based on qualitative data collected through a small series of targeted semi-structured interviews. This qualitative data shows that the Scottish Space Sector is enabled by a strong R&D cooperation, including cross-disciplinary links with academia, due to the specific “city campus” University environment. This is particularly important for network mediated knowledge transfer by attracting non-space and non-technical partners into Space Sector projects. This is in line with a comment by a space SME CTO interviewed about the importance of non-space actors for the kinds of products they develop. He explicitly mentioned:

"When I go to a space cluster there is a lot of companies clustered together, but it is just high-tech [...]. I think what Scotland needs to champion is the idea that our Space Industry is embedded in larger entities – which is the cities. [...] I think what space needs to do is to move out of the Space Industry and into these other sectors and I don't think that is something you can do in a campus environment [...], it needs to be in a city environment where they are surrounded by other non-related sectors."

Scottish cities, due to their highly educated workforce and good provision of facilities and services are commonly seen as an asset for developing and growing high-tech clusters, for example, biotech [59]. Hence, there is a strong indication from my research, that it is precisely this historic make-up of the Scottish academic system that makes a key contributing factor for the significant uptake and rapid growth of the "New Space" sector in Scotland, as innovators can make direct and varied linkages to cutting-edge research as well as contingent user-base in the course of their new product development. A highly skilled workforce and good infrastructural provision are also two of the core elements of a Living Lab innovation process.

My analysis based on stakeholders reports, internal documents and primary data show that the core of the more innovative Space Sector activities in Scotland is clustered around three main subsectors in three different industry and geographical areas: component electronics and communications systems engineering in Dundee, manufacturing of nano-satellites in Glasgow and satellite data analytics and applications in Edinburgh. Each of these cities/clusters has also been linked to a research specialisation of the local University: the Dundee one is centred on data transfer and space communications electronics at the University of Dundee; the Glasgow (Strathclyde) one is centred on space hardware engineering and astrodynamics at Strathclyde University; and the Edinburgh one on applications of Earth Observation satellite data, in particular in the field of geosciences through the University of Edinburgh. Here we find another of the Living Lab core enabling factors – the research capabilities.

An Alternative Model of Vertical Value Chain Integration

The Agile Space Group was launched as part of Data. SPACE 2017 conference in February 2017 in Glasgow. The key partnership at the core of this group is the one between upstream nano/cube sat satellite platform developers, Clyde Space, and downstream data analytics company, Ecometrica. Though the two seldom collaborated on a specific project together in the past, they are the undoubted primes and critical thought leaders of in the upstream and downstream arena of thee R&D-active part of the Scottish Space Sector. Through this leadership, they have a significant influence on other players, especially their collaborators.

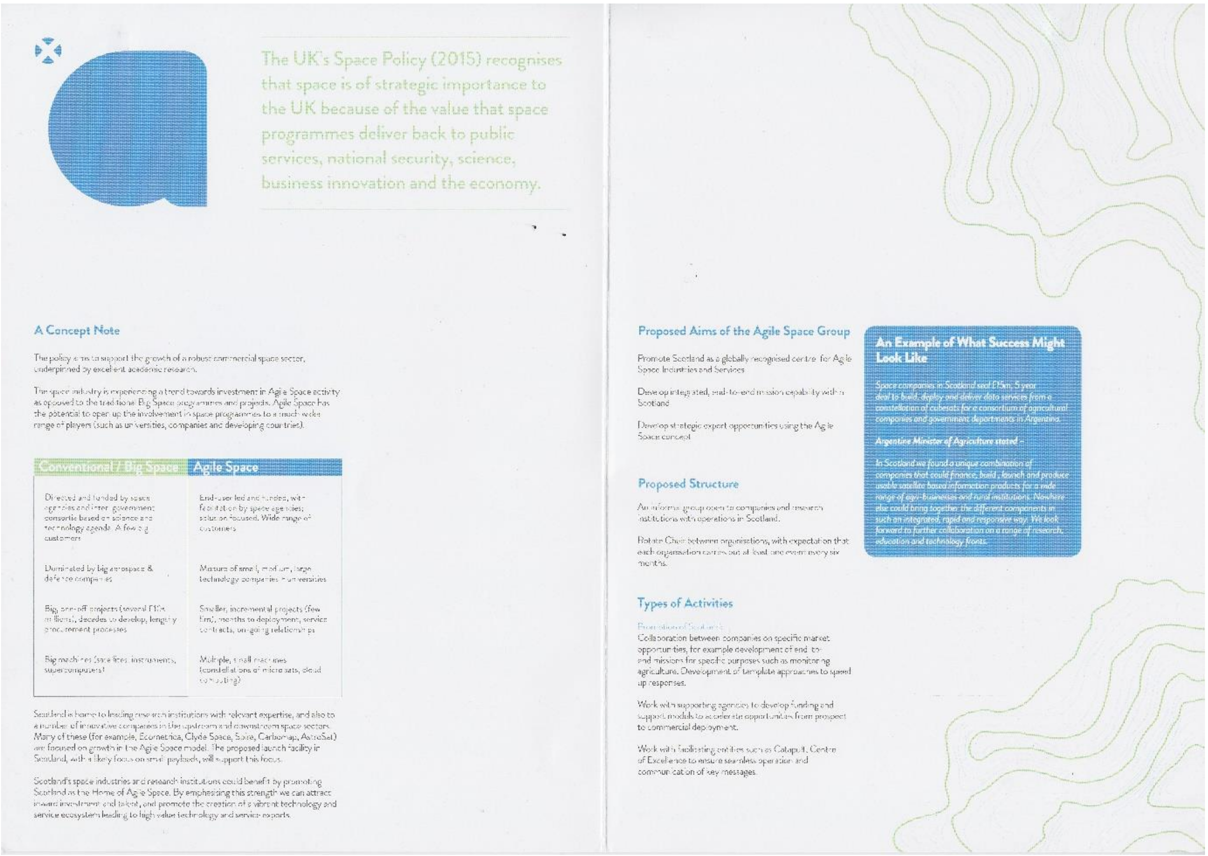

Figure 1 - Agile Space Group's promotional flyer outlining some of the key concepts behind its creation, in particular, its oppositional pitch with respect to the "Conventional / Big Space" and the noted loose organisational aims, structure and activities. (Scanned by the author.)

The express state purpose behind the establishment of this group (see the scanned leaflet on Figure 2) was the consolidations of dispersed players across Central Scotland, to care a globally unique offering of a dynamic, flexible, and loosely integrated nano-satellite data value chain, by which at some point in the future a potential customer could obtain all required technology and service capability at a single place (i.e. In Scotland) (also see schema in Figure 3). Due to specificities of the emerging New Space market, the Group explicitly aims at a non-institutionalised/formalised assemblage of players, by which complex and dynamic offerings are convened ad hoc, without much draw on resources or any physical infrastructure. As such, the groups' eventual operational structure is unclear and it is possible to foresee several potential configurations, such as trade/industry body, a permanent consortium, or even an incorporated subsidiary of multiple shareholders. A further objective for this group is to represent the stakeholders in the New Space Industry in the (Scottish) political arena and promote them internationally.

Other firms, for instance (Stevenson) Astrosat, based near Edinburgh and originally a downstream space data analytics firm, has begun processes of expanding activities along the value chain. In particular, they have engaged in the acquisition of satellite data receiving "ground stations" and commenced involvement in upstream hardware development. This approach can still be seen as somewhat complementary to the overall vertical value chain integration proposed by the "Agile Space" group, as it aligns with the core message/vision of "agility" in innovation and cross-sectoral collaboration in developing appropriate products/services and their support infrastructures. As such, the "Agile Space" paradigm can be framed more as an approach to innovation and business development, rather than any formal institutional grouping, a point further examined in the next section.

This critical mass of development in the (New) Space arena has also been touched upon in a regional development strategy: Aerospace, Defence, Marine and Security Industrial Strategy for Scotland 2016 led by the Aerospace, Defence, Marine and Security Industry Leadership Group (ADMS-ILG) at Scottish Enterprise, the regional economic development agency [3]. A more detailed and specific action plan is currently being developed to enact this strategy in practice in each of the subsectors, including a separate plan for Space Sector, and engage across the industry. Here too, the "Agile Space" seems to be used as a type of collective branding for the ecosystem's innovation offering, rather than any formal consortium.

Figure 2 - A conceptual representation of the completeness of the Scottish space sector SMEs "loosely-integrated" value chain, from components manufacturing and hardware integration (top left) through emerging launch capabilities (bottom left) and then data downlink (bottom right) and analytics applications (top right). Some degree of circularity is achieved as data demands are then leading the development of new hardware. (Collage created by the author.)

Hence, I propose that in the context of the transformative industry transition to New Space, the evidenced emerging and expanding Scottish New Space Sector and its consolidation around the somewhat elusive "Agile Space" concept, using the "Living Labs" framing of innovation is a promising avenue for understanding the emergence of this new innovation environment. Specifically noting the solid geographical, political and economic boundedness, the crucial links between firms and their environment, the interdisciplinary clusters around Scottish city-based universities and moves towards new types of value chain integration/stabilisation, I propose that a more systemic model of innovation is needed to frame these developments – a combined Agile Space Living Lab. In the next section, I develop further the analysis of these links using primary empirical data from my ethnographic study.

The Emergence of an Innovation Paradigm: “Agile Space Living Labs”

As referenced earlier, critical for the emergence of Living Labs innovation framework are R&D projects in information technologies, particularly as related to other modern societal challenges, such as combining resources-intensive urban living with concerns for environmental protection and the proposed solutions requiring the introduction of smart infrastructure [60]. The challenges associated with technology development in these “laboratories” are most often identified as big data (analytics) and the interconnectivity of human and non-human actors, often referred to as “internet of things”, while the social challenges most often relate to information distribution and trustworthiness of such. Closer integration of users in the R&D processes supposedly on one hand enables a better understanding of the requirements on the production of information and dissemination of solutions, as well as on the other hand establishes a greater degree of trust in the validity of the design of such applications [61,62].

Crucially, space-enabled technologies already play a significant role in this arena in particular by the use of spatial data and services in the development and operation of applications. In particular, this is to do with front-end use of Earth Observation (EO) data in analytics, the meta-level integration of satellite positioning data for geolocation of other data and information solutions via global positioning services (GPS), and the indirect back-end use of satellite-enabled telecommunications for distributed (cloud) hosting of applications. This multi-layered integration of space-related technologies is very common across a variety of modern IT applications and is particularly prevalent in social media/ networks and information services (such as internet browsing and navigation).

However, in the recent decade, a more direct application of Space Sector’s solutions is also emerging, whereby the key data-source for an application is closely related to a specific set of space-derived/enabled data. An interesting example of such is a host of environmental monitoring solutions which relate to urban infrastructure and (agricultural) land use and management. For instance, heat detection from space is used as a rough indicator of energy efficiency, waste management can be tracked locally via GPS and analysed for carbon footprint, and satellite images used to monitoring irrigation of land can help maximise farming yields and spot structural problems leading to landslides and/or erosion. All of these are just some of the examples of applications pursued by SMEs in the downstream New Space Sector in Scotland.

Importantly, these applications clearly combine the scientific value of data from space-enabled technologies and user-driven demand for information solutions, whether on an individual or community level. Hence, this integration of techno-scientific and social spheres requires an inclusive approach to innovation which fits well under the Living Labs labelling. Though many Living Labs solutions rely solely on user-generated data and have little connection to Space Sector, in many cases those (meta-)relationships already exists and with the more flexible and user-tailored approach to the development of New Space industry more broadly, the relevance of the Living Labs model for Space Sector is increasing. As highlighted in the quote from one of the Scottish Agile Space SME’s mentioned earlier, it is precisely this expansion of the innovation activity across a wider geographical area (city or region) and to non-sectoral stakeholders, which makes Scottish Space SMEs different from more “clustered” counterparts in campuses such as the Space Gateway at Harwell in Oxfordshire and hence perhaps better suited to exploit a Living Lab configuration through a wider network of stakeholders and users, a fertile social environment and sufficient infrastructure and natural diversity.

Key Features of Agile Space-Powered Living Laboratory

The combination of the emergent New Space industry and excellent conditions for forming Living Laboratories in Scotland led to a particularly fruitful environment to research these new/emerging trends. I have completed a firm-level analysis of the innovation processes deployed in a selection of typical cases [10] (downstream firms in “New Space”, “Transitional”, “Classical” Scottish Space Sector segment), as well as the evolving organisational and operational structures within the firms. Specifically, qualitative examination of the new product development (NPD) [63–66] projects and social network analysis (SNA) [8,9] of the innovation networks of leading downstream/EO SMEs in Scotland was performed in order to understand the key notable trends in the development of the Agile Space Living Lab innovation model. This is supplemented with a more detailed product-level case study to illuminate further the development of interactions and gradual changes in emphasis on various possible alignments of the available technological solutions, or pathways for their development, and the “outside” “real world” interest in addressing particular societal challenges.

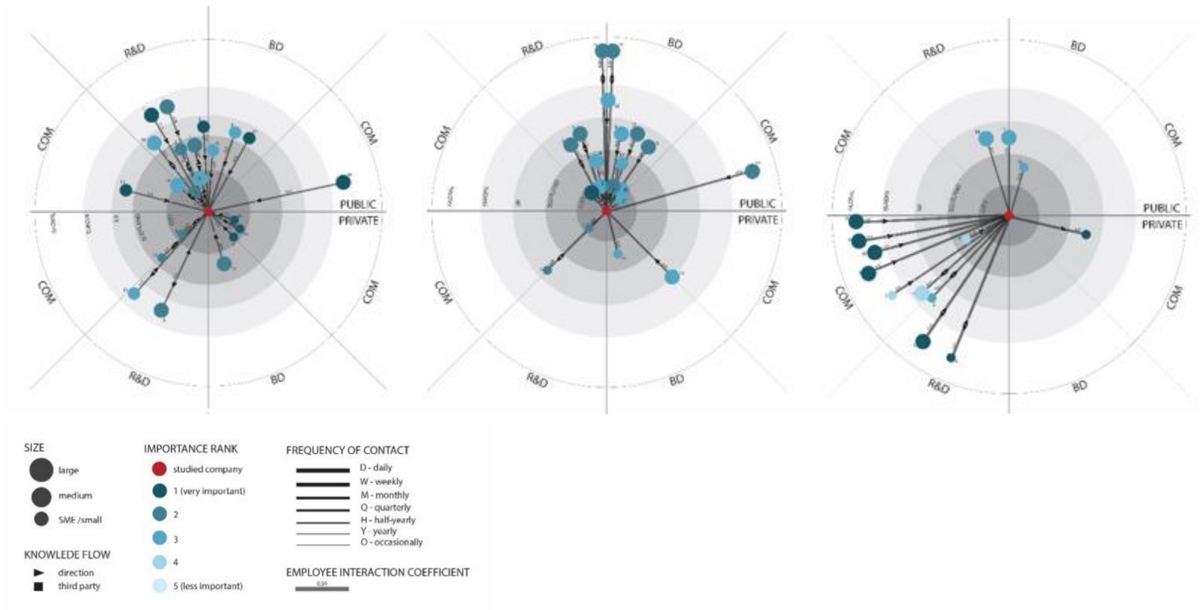

Figure 3 - Innovation networks of three Scottish downstream SMEs. The most recent “New Space” firm at the left has the densest, yet the most local network of partners, whilst the right one, established firm, is the most globally oriented. A similar trend is also noted in character of the firms’ partners, where the public sector (academia, intermediaries, development agencies, government) are more heavily present in the left “New Space” SMEs’ network, whilst the right one has the fewest of public partners.

From such analysis, I have identified several significant trends. For instance, the innovation networks within the New Space downstream segment of the Scottish Space Sector – i.e. Agile Space -, show that these emerging enterprises link with a greater number of actors in their NPD processes in contrast to their more “traditional” predecessors (as seen in Figure 4). They also engage more with public sector partners, in particular, academia, inter-organisational brokers and intermediaries, and (public) lead users, who are often (local or national) government or citizen groups. Furthermore, the geographical distribution of these partners indicates that the Agile Space firms have a far greater density of local partners in comparison to global ones, contrary to the previous generations of Scottish downstream space SMEs.

Expanding networks also lead to a more “open” mode of new product development (NPD), due to an increasing necessity to accommodate dispersed expertise and interdisciplinarity, leading to a breakdown of the traditional hierarchical structures within the firm, yet an increasing need for formalised and standardised project management, in order to harness all available internal and external capacity. This is evidenced in qualitative data I have collected, as the “New Space” firms adopted a structured project management approach to new product development including stages such as “defining user and technological requirements”, “prototyping”, “productising” and “beta-testing”, and progressing through formal stages of development such as the technology readiness levels (TRLs), involving research partners, lead users and other stakeholders (funders, regulators, etc.) at different points along the way. This is in contrast to the older, more established and less “agile” firms, who develop new products in more top-down manner with the management team and new recruitment the key drivers for embarking on new innovation projects, which are often conceived on the “back of a napkin” and only tested with users once the “design” is nearly complete.

Overall, these changes noticed across the Scottish downstream SMEs are underlining a transition between two different approaches to innovation – from a “closed” hierarchical model with smaller and more global innovation network, to a more intense “open” innovation model linking to a variety of public sphere partners and deploying a much more interdisciplinary and inclusive new product development processes. These changes critically impact the way exploratory work is done within firms and is of particular significance for the firms’ ability to build “agility” in the face of changing opportunities and difficult markets. Hence, in the next section, I turn to an example of the importance of deploying an Agile Space Living Laboratory in practice in a downstream New Space NPD project in Scotland.

Case Study: Living Laboratory Experimentation Enabling Business Development

Since the expansion of the Earth Observation programmes, and in particular in the recent era of open access to space data, applications developers have predominantly targeted climate (change) as a key target market [67]. However, due to political contestation and limited commercial value of Earth monitoring, the attention of most developers, in particular in countries with newly emerging space sectors like Scotland, has shifted towards more developed markets, such as agro-food and forestry. One case of deploying a living-laboratory-enabled “transitional” project is outlined in Box 1, below.

Wall to Wall Soil Alerts for the UK

This project was developed by Ecometrica, an Edinburgh based geospatial intelligence and mapping applications SME, whose platform is marketed as allowing businesses, governments and organisations to make smarter decisions and build long-term value. Their initial products related to large-scale environmental mapping and monitoring, in particular, to tackle carbon management and related challenges posed by climate change. However, as the company was interested to explore other, more mature markets, too, specifically, agro-food and forestry.

Hence, the aim of the specific project analysed here was to investigate the feasibility of acquiring timely and accurate soil moisture content (SMC) data for the UK from Synthetic Aperture Radar (SAR) remote sensing, specifically from the new European Space Agency’s Sentinel-1 SAR sensors, the data from which is available for free. The work assessed soil moisture at field sites across the UK using SAR data returns and compared it to ground measurements to see if it was feasible to use SAR remote sensing for establishing a wall to wall alerts for soil moisture extremes.

The project was looking at the development of a new service for the public sector. The estimated potential market value of such service is in the region of £1.2 to £1.5 million. It could also deliver significant societal and economic impact as significant benefits are seen to be in the following applications:

- Flood prediction
- Diffuse pollution

- Agriculture advice: identifying priority areas for renewal of field drains and trafficability information
- Nitrogen Vulnerable Zones (NVZs) and slurry management
- Peatland management, fire prevention and wetting
- Improved greenhouse gas estimation for soils.

This could bring about potential annual savings to public sector services and their stakeholders in the region of £11 to £35 million. This was also noted as a key concern with the main funders of this feasibility study project, the UK Government's Space for Smarter Government Programme, as flooding was seen at the time (2015) as a big societal issue and an acute problem. In addition, European Space Agency (ESA), UK Space Agency and the Satellite Applications Catapult were eager to invest in R&D to exploit newly released (publicly funded) space data from the Sentinel satellites.

In fact, for Ecometrica, this is one in a series of projects which aim at exploring the public sector markets, as their current main customers are private firms. Though technological barriers prevented this project from becoming a full commercial service, it is believed that future work with improved technology (available in the near future) and more comprehensive data could see this as a major business opportunity. Most importantly, through establishing a consortium of partners who worked on this project, and which include potential lead users (and customers), the company began the process of positioning itself within the market to exploit further opportunities. This included several national institutes, crucially Scotland-based James Hutton Institute and Scottish Rural University College.

Box 1. An example of an agro-tech project from a leading Scottish space data applications developer.

This is not an isolated case, with the majority of downstream SMEs in Scotland (5 out of 7) developing at least some of their products in either agro-food or forestry domains. These solutions, however, can only be effectively launched into highly competitive markets, if they have established credentials for reliability and robustness. The process of the on-the-ground validation or "ground-truthing" [68,69] is particularly important, as well as is user-friendliness of the final application. These are established by integration of lead users into the NPD projects through expanding innovation networks, in order to use both on-the-ground data as well as evaluate the usability of test solutions within the partner's work processes.

For such, the Living Lab framework provides an excellent model, whereby the physical and social infrastructure enables a consciously evolving (re)configuration of research organisations, enterprises and concerned stakeholders (various user and public groups). These actors can exchange not only ideas for new product development and later incremental improvements, but critically shape the demand/market for new technological solutions, as well as define their value, both in general/concept as well as specific/product terms. For instance, looking at the project presented in Box 1, the SME involved was creative in applying for a funding programme with a feasibility study for a product, which was addressing an acute need in the target market at the time (public sector) and was tapping into a specific interest by the same stakeholders (i.e. government). They attracted several key partners and users to the project and are in the process of establishing a "consortium" of SMEs and research organisations with related complementary products.

In particular, the partnerships established here are seen as the key "breakthrough" to access the target market as well as means to reach end users (i.e. farmers). The company considers that further buy-in is needed by these stakeholders before roll-out (including product validation, which is currently in progress). Though the product at the centre of this study has not yet reached the market, the company benefited from further investment (including a government grant of over £150k) and experienced a reasonable amount of growth on the back of it. It is particularly interesting that this project, and many others across the industry, are also acting as catalysts for firms' transitions into new markets. Specifically, many firms are moving away from public sector dominated environmental monitoring and towards commercially larger agro-food and forestry sectors. Such moves are in part from necessity, as public funding for Earth Observation and Remote Sensing solutions is limited, as well as through discovery of opportunities of by engaging with lead users and entering into markets previously exclusively dominated by big business, which also sometimes stall technological development through institutional and systemic entrenchment.

Of further interest is the emergent prioritisation of solving (global) societal challenges of sustainability of agricultural production, though shying away from a potentially bigger emerging crisis of ecological disruption due to climate change. Partially, this could be explained through the political and economic context of these challenges, though one can pose an additional observation related to innovation as a phenomenon. As noted on the network diagrams in Figure 4, it is the emerging (New) Space firm who has the densest, yet also the most localised network of external partners, which is a notable feature of a Living Lab configuration. However, the prevalence of local partners also shifts interest to local issues and challenges, and whilst improving (smarter) agriculture is a direct interest to many if not most or even all locales, the acute societal challenge of global warming is seen as a global problem, with still relatively insignificant local impact in most places.

Conclusions and Further Research Agenda for Agile Space Living Labs

To conclude, the emergence of Agile Space Living Lab innovation practice marks an interesting evolution of the common wisdom about innovation in high-tech industries, which has already been similarly challenged by the ICT and biotech sectors. However, comparatively more complex systemic nature of the innovation in the Space Sector makes Agile Space example crucial for gaining an understanding of this paradigm shift in the practice of innovation, which is particularly important for deepening the understanding of the emergence and consolidation of new geographically-bound sectoral innovation systems (GSSI), which are also sometimes referred in policy arena as smart specialisation [70]. Here, the emergence and development of Agile Space and its relationship with the Living Labs concept provide a critical advancement of the core understanding of high-tech innovation and regional proliferation.

In particular, as outlined in the analysis of the trends and empirical data presented above, I have identified three notable trends:

- Firstly, there is an increasing role for localised public stakeholders and focus towards the public good, with the critical advantage of the interconnectedness of physical, digital and social infrastructure, in the Agile Space-type innovation paradigm. However, this requires a different approach to managing the innovation process - how does this look like in the practice of innovation (i.e. new product development) and what are its key characteristics? What are key similarities and differences with the traditional Space Industry (2.0)?
- Secondly, a new type of loose value chain integration is emerging from the Agile Space conceptualisation of the (New) Space Sector in Scotland. This is related to the structure of the Open Innovation and Living Labs-type of the innovation process, and the geographical dispersion and clustering of the different segments of the R&D activity. However, how does this loose integration of the value chain comes about, how is it structured and how does it operate?

- Thirdly, high-tech innovation activity is emerging in a new geographical domain, i.e. (New) Space Sector thriving in a previously peripheral country like Scotland. The application of a Living Labs-type of (open) innovation model, coupled with a loose value chain integration within the emerging (New) Space Sector, created a distinct competitive advantage of a type of Smart Specialisation in the form of Agile Space. Hence, a central new question emerged as to what is/are the role(s) of public stakeholders' (local, regional, national, international) in the support of the deployment of this innovation model and its focusing on a specific sector?

Based on these conclusions, a new set of key questions regarding the frim and network level mechanics of these innovation processes arose. In order to expand on these findings further, I propose the following three strands of future research:

Analysing Practice: Co-construction of Technology and Social Learning

The above innovation environment or system is built on the principles of co-development of technology, with a critical need for understanding the relationships between the various actors and artefacts involved [71]. As such, a deeper social-scientific understanding of innovation processes described above is needed, in order to conceptualise how Living Labs operate in relation to firms. In particular, as exposed in the various theories and conceptualisations of social learning in socio-technological systems, a major challenge is the alignment of interests and development of functional and meaningful intra-organisational interaction. In particular, a research framework has emerged: Biographies of Artefacts and Practices (BoAP), which is proposing to acquire such deep understanding of social learning in innovation processes by engaging in strategic multi-sited ethnography [72,73]. Future work in this area should examine the organisational structuring and interactions with external partners in the innovation process, and specifically analyse its (inter)dependence on external knowledge acquisition. This has been conceptualised through the Open Innovation paradigm [27,28,74] as a critical ingredient of contemporary new product development in SMEs, yet how this important dimension links to the Living Labs conceptualisation has not been fully explored so far. Furthermore, such micro-level analysis within SMEs should then lead to examining the meso-level development of intra-organisational networks and structures, to understand the collective emergence of the Agile Space paradigm.

Analysing Structural Linkages: Social Network Analysis of the Emergence of New Space in Scotland

Intra-organisational linkages and open innovation networks have been shown to be of central importance for the regional Living Lab conceptualisation [16], which can also be observed here in the analysis of Agile Space. In particular, the systemic nature of the (larger) Living Labs and the loose value chain consolidation proposed through Agile Space make it pertinent that those links and their structural assemblage in a regionally-bound sectoral innovation (eco)system are examined. Hence, additional research is required in the emergence, development and the current structure of these links and networks. In keeping with the above BoAP methodological agenda, I propose a bottom-up ego-centric social network analysis (Ego-SNA) as an optimal approach to such further work. A central interest beyond the structural and evolutionary concerns is also the role and degree of involvement and centrality of non-business and R&D actors, i.e. the innovation intermediaries. This ties in closely with developing and enacting (public) policy for technological advancement and economic development. This is further related to innovation development concepts such as absorptive capacity [75–79], which is the ability of an (eco)system to "absorb" and mobilise knowledge (and other related resources) to produce new products.

Analysing Policy: Innovation Intermediaries and Interventions

Further research is also needed to characterise better the policy options available to stimulate the growth of innovation activities in (eco)systems through SMEs operating in the high-tech arena(s). Here, lessons can be learned to expand the Space Sector in my case study, Scotland, as well as in other similar regions and areas. Furthermore, more board lessons can be learned applicable in many other high-tech contexts. Of particular concern is the current lack of clarity as to the various roles and actions performed by the innovation intermediaries [80] and the contextualised sectoral needs [81,82]. Hence, in order for Agile Space Living Lab innovation model to be understood and developed further, analysis of the roles and activities of innovation intermediaries is needed. In particular, a more typological model of available interventions, which can be deployed to assist in the development of geographically-bound sectoral systems of innovation would be welcomed by practitioners (policymakers and innovators/entrepreneurs) as well as analysts.

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