ONLINE COLLABORATIVE TOOLS AND KNOWLEDGE MANAGEMENT WITHIN A DECENTRALIZED ORGANISATION

Building virtual relationships

OUTILS DE COLLABORATION EN LIGNE ET GESTION DES CONNAISSANCES AU SEIN D'UNE ORGANISATION DÉCENTRALISÉE

Développer des relations en ligne

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Acknowledgements

I would like to thank the people who supported me throughout this project: my girlfriend and my kids. Both had an impact, in their own way. For instance, somewhere in 2017, I became increasingly tired of working in public relations. It had been about 15 years and I was struggling to explain to my kids what I was doing in an interesting way. They were a mirror reflecting a sad person. At one point, I was even offered an opportunity to become manager of our outreach division; it meant more money for doing more stuff in the same field. It really didn't sound fun. So, I decided it was time to move in another direction. I told my partner I was planning to complete my Master's degree. We were in the kitchen. She was supportive; but didn't pay too much attention to this formal announcement (it was announced between the dishes and bringing the garbage outside).

I had started this Master's program in 2005 while I was working in Indonesia with CUSO for a human rights organisation. The online format of the Public Administration program at the Royal Military College was exactly what I was looking for. I did a few courses, and then stopped due to changes in my capacity to cover registration fees. Fast-forward to 2017, the Master's degree was now part of a plan to shift my career towards something fun, bold and linked to a world I always wanted to be involved in: the space sector! I was obsessed with the 2014 movie "Interstellar", still playing space Lego with my kids, and reading Sean Caroll's "From Eternity to Here: The Quest for the Ultimate Theory of Time". Specifically, the thesis was to be used to investigate where to go next. I soon discovered that the Canadian Space Agency (CSA) had a policy office in Gatineau very close to home. This was the "Eureka" moment. I started investigating why space agencies were the way they were today, and I connected with the CSA office in Gatineau to learn more on what policies they were working on and the challenges ahead - while trying to get hired in the process. On top of that, there was this new technology called "blockchain". It was an interesting discovery that led a small group of individuals from the United States and Europe to create Space Decentral. The organisation wanted to become a "decentralized autonomous space agency that will utilize blockchain technology to enable collaborative, transparent and self-directed action toward building the future of space exploration." It became my case study.

This leads to the third person I wanted to thank: my supervisor Fernando Fachin, Assistant Professor at the Department of Management. He has a strong organisational background and a history of investigating open innovation. He was patient in helping me draft this thesis from scratch and guiding me through the reviewing process. His comments were instructive and super helpful in striking the right balance between current organisational theories (he is the one who introduced the concept of "boundary objects" to me), and the impact of emerging and sophisticated online collaborative tools such as MS 360/Team or Google Docs, and - of course - blockchain. I would also like to send my thanks to Catherine Beaudry, professor in the Polytechnique Montréal's Mathematics and Industrial Engineering Department. Having her as a co-supervisor was a great opportunity to test the solidity of this research that fits her research interests in innovation ecosystems, networks and economics. Another person that I would like to thank, even though we never met, is Stéphanie Bélanger, professor and Chair of the Master of Public Administration at the RMC. I remember her response following my proposal: "It is a fascinating topic and your proposal is extremely well structured and well developed". These words gave me the support I needed to begin an investigation on something that few people had brought forward.

So, here you go. Without my girlfriend's support and my kids' brutal honesty - in addition to the people who followed me throughout this research - I might have stayed idle and stuck in my former position, instead of kicking the can towards a new direction. But I have to admit that completing online courses and writing a thesis is freaking hard work for a full-time employee. Fortunately, it paid off. I was eventually hired by the CSA, just before the pandemic where online collaborative tools became common place. Not too shabby.

Abstract

Purpose: This thesis aims to better understand how individuals working in a virtual organisation can co-create effectively using online collaborative tools, while mitigating the challenges.
The research objectives: Identify the most important co-creation activities from a virtual organisation; Define the scope of the open source culture of Space Decentral and explore how it influences aspects of governance and knowledge management; and, Review the gaps in managing activities collaboratively within virtual organisations.
Design/methodology/approach: This research uses the literature on the concepts of boundary objects and open source in a co-creation environment to analyze online collaborative tools. Data were collected from conversations and documents found on chat platforms and websites related to the case study called Space Decentral. This material was analyzed through netnography, a relatively new research technique related to ethnography, and text-mining / collection and management of documents from the web. The founding members of Space Decentral wanted to create an open and virtual space agency.
Findings: The study of a virtual organisation seems to have led to a different sequence of the co-creation stages and activities established by Frank Piller and Joel West's 2014 co-creation framework. Members of Space Decentral focused, first, on the *Collaborating* co-creation stage and, then, the *Defining* one - which is the launch of the co-creation process which seeks to address the problems(s) of engaging external partners in the co-creation effort. Overall, the analysis found recurring themes. They were open source; governance and decision-making; and, leveraging external knowledge - especially within the blockchain community such as Aragon and Ethereum, which include programmers and miners as well. What we found is that online collaborative tools could not "cope" during Space Decentral growth or evolution, especially beyond the structuring of the governance and decision-making framework.
Practical implications: The role of virtual organisations as a managerial agency must shift to include both the management of knowledge and expertise, in addition of the management of their online collaborative tools.

Résumé

Objectif : Cette recherche vise à mieux comprendre comment les individus travaillant dans une organisation virtuelle peuvent co-créer efficacement à l'aide d'outils collaboratifs en ligne, tout en atténuant les défis.
Les objectifs de la recherche : Identifier les activités de co-création les plus importantes d'une organisation virtuelle; définir la portée de la culture *open source* de Space Decentral et explorer comment celle-ci influence les aspects de la gouvernance et de la gestion des connaissances; et, examiner les lacunes dans la gestion collaborative des activités au sein des organisations virtuelles.
Conception/méthodologie/approche : Cette recherche utilise la littérature sur les concepts d'objets frontières et d'*open source* dans un environnement de co-création pour analyser les outils collaboratifs en ligne. Les données ont été recueillies à partir de conversations et de documents trouvés sur des plateformes de discussions et des sites Web en lien avec l'étude de cas appelée *Space Decentral*. Ce matériel a été analysé de manière netnographique, une technique de recherche relativement nouvelle en lien avec l'ethnographie, en plus de l'exploration, la collection, et la gestion de texte sur le web. En quelques mots, les membres fondateurs de Space Decentral souhaitaient créer une agence spatiale ouverte et virtuelle.
Constats : L'étude d'une organisation virtuelle semble avoir conduit à une séquence différente des étapes et des activités de co-création du cadre de Frank Piller et Joel West en 2014. Les membres de Space Decentral se sont d'abord concentrés sur l'étape de « collaboration », puis sur celle de la « définition » - qui est le lancement du processus de co-création et cherche à résoudre les problèmes impliquant des partenaires externes dans la co-création. Dans l'ensemble, l'analyse a révélé des thèmes récurrents. Ils étaient l'influence de la culture *open source*; la gouvernance et la prise de décision; et, le fait de tirer parti des connaissances externes - en particulier au sein de la communauté blockchain comme Aragon et Ethereum, qui incluent également des programmeurs et des « mineurs » de blockchain. Ce que nous avons découvert, c'est que les outils collaboratifs en ligne ne pouvaient pas "faire face" à la croissance ou à l'évolution de Space Decentral au-delà de la structuration du cadre de gouvernance et de prise de décision.
Implications pratiques : Le rôle des organisations virtuelles en tant qu'agence managériale doit intégrer à la fois la gestion des connaissances et de l'expertise, en plus de la gestion de leurs outils collaboratifs en ligne.

Table of Content

Tables and Figures

1. Introduction

The world is going through an organizational experiment at the moment with remote working. Since March 2020, public, non-profit and private organizations are using online collaborative tools to discuss, task, and make decisions – among other organizational activities. Employees and managers shifted from a physical office-oriented environment to a virtual, decentralized one, supported essentially by online platforms, such as MS Team, Google Workplace, Slack or Skype. These platforms are real-time collaborative word processing, social media and video conferencing tools, etc., with sometimes centralized cloud storage capacity and security controls and data loss prevention. These online collaborative tools are very common within the software developers' community. It is also linked to the "open source" culture where platforms such as Github are used to discuss, manage projects, and develop codes collaboratively to increase a program's applicability or enable new applications (Rossitto and Lampinen, 2018).

COVID-19 is likely to force all kinds of organizations to keep working remotely for a long time. Some have already made a decision to do so permanently, such as Shopify. In September 2020, Shopify, a multinational company with more than 5,000 employees and contractors, decided to vacate its Ottawa headquarters and allow its employees to work remotely on a permanent basis. [1] Alternatively, for companies that won't let go their offices, business magazines such as Forbes expect that the physical space will be "optimized for a hybrid reality", functioning as spaces to bring people together. [2] Hence, the key assumption we make is that online collaborative tools are here to stay. In this context, as we move into the 21st century, an increasing number of new employees and new managers will mostly experience collaboration through these online tools. There are advantages. The most important for young remote workers are: flexible working hours and saving time on commuting to work (Magdalena, 2017). In terms of challenges, authors like Elena Rocco (1998) found that text-based chat fosters "personal benefit instead of the common good". Then, there are issues working through different time zones and cultures (Olson and Olson, 2000). Either it leads to different workers having more or less time to complete their work, difficulties related to where participants are with their circadian rhythms. And do today's managers have the skills and knowledge to both manage employees and online tools for specific tasks?

The collaboration model

This leads to the issue of collaboration in this changing environment. How will we collaborate in a post-Covid world where hybrid or remote working will be more and more the norm? In the 2014 "Firms, Users, and Innovation: An Interactive Model of Coupled Open Innovation", Frank Piller and Joel West

[1] Financial Post, September 2nd, 2020: https://financialpost.com/technology/shopify-to-vacate-its-ottawa-headquarters-in-virtual-office-push - retrieved on January 15, 2022.
[2] Forbes, January 14, 2022: https://www.forbes.com/sites/theyec/2022/01/14/three-office-trends-that-will-shape-the-future-of-work/?sh=15fbb7c93b51 – retrieved on January 15, 2022.

looked at the big picture and developed a sequence of stages and activities related to the co-creation process. The authors found that user innovation literature had focused on interactions between users and firms, but research on the process of collaboration between users and firms was still "rather" scarce (Piller and West, 2014: p. 33). In their analysis, it included the creation and implementation of the processes for collaboration, in addition to tools such as IT-enabled platforms that facilitate the collaboration process (p. 40).

These IT-enable platforms - or online collaborative tools - have mostly been studied in the field of Computer Supported Cooperative Work (CSWC). Chiara Rossitto and Airi Lampinen (2018) contributed to research on CSCW by illustrating "grassroots efforts to create alternative ways of organizing nomadic work and navigating non-traditional employment arrangements" (p. 947) through interviews, participant observation, and workshops. But their focus was mostly on individuals using their home as a temporary workplace using social media platforms like Facebook.

This research is going further. This research explores how organizations co-create virtually. The term virtual in this case means that individuals meet, are recruited and work together through online tools. In essence, the goal of this thesis is to:

- Better understand how individuals working in a virtual organization can co-create effectively using online collaborative tools, while mitigating the challenges.

Online collaborative tools and boundary objects

The CSWC literature has used the boundary object concept to study online collaborative tools. Boundary objects were introduced by Star and Griesemer in 1989 and are defined as abstract or physical "things" that reside in the interfaces between organizations or groups of people (Huvila *et al.*, 2017: p. 1807). They are seen as "both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Lee, 2007: p. 309). The research community used the concept to assess how one "thing" can communicate information to facilitate cooperation and mutual understanding, and bridge perceptual and practical differences among communities (Karsten *et al.,* 2001).

In total, the literature review of Huvila *et al.* (2016) identified numerous boundary objects in the past 30 years. They associated each author with the "things" in fields such as management, archival science, development studies, economics, education, document studies, and library and information science. Islind *et al.* (2019) also showed how boundary objects are used during different design phases. Their examples are boundary objects used in the creation of a healthcare-related digital platform with inputs from individuals from various communities. But this design exercise was also only temporary. In addition, besides repositories and digital libraries or geographic information systems (GIS), Huvila *et al.* (2016) have not identified researchers who have looked into online collaborative tools, especially in a virtual and co-creation environment.

The reader might think a research on the dynamic role of online collaborative tools within a virtual organization on a permanent basis is exaggerated. Those online collaborative tools are just that:

platforms that connect individuals within a network, such as Github or Slack. The social structure of pre-COVID organizations will be maintained, while managers and employees do their jobs as usual. But as we recruit more and more employees virtually, from various locations, how will that impact intensive knowledge sectors such as space organizations? Authors like Olson and Olson (2000) found that space physicists could easily transition to this remote working environment thanks to a strong tradition of collaboration through remote interactions (Olson and Olson, 2000: p. 164). On the other hand, it is hard to know how other communities of practices without any past online collaboration culture or open source software development experience as found in CSWC literature might be affected. The more we know, the more efficient we can become.

The case study: Space Decentral

To better understand how individuals within organizations can work effectively in a virtual environment, I followed the activities of an organization called Space Decentral between January 2018 and December 2019. The founding members of Space Decentral wanted to create an open and virtual space agency. Based on their White Paper, it stated that *New Space* entrepreneurs such as Elon Musk or Jeff Bezos are incorrect in not leveraging the power of various communities of practices to launch space missions to better humanity. The White Paper mentioned that few firms led by billionaires couldn't pull the same feat as 400,000 people who worked together "to put a dozen men on the Moon" (Space Decentral, 2018a: p. 1). This is the reason why members of Space Decentral were motivated to foster a co-creation environment using online collaborative tools and develop blockchain applications to further develop space innovations supported by these communities.

Blockchain technology was introduced in 2008 (Seebacher and Schüritz, 2017: p. 3). The first definition of blockchain comes from Satoshi Nakamoto (a pseudonym) who said it is a "a peer-to-peer network" where the "network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof-of-work" (Nakamoto, 2008). Proof of Work is where "network participants have to solve so-called 'cryptographic puzzles' to be allowed to add new 'blocks' - a set of transactions - to the blockchain" (Ouben and Snyders, 2018). A blockchain can also be described as "an open-source technology that supports trusted, immutable records of transactions stored in publicly accessible, decentralized, distributed, automated ledgers" (InterPARES Definition, retrieved on July 22, 2019). In other words, it is "a peer-to-peer network, enabling collaboration between different parties" (Seebacher and Schüritz, 2017).

All in all, members of Space Decentral believed their online collaborative tools would establish new norms, standards, and rules to govern efficient collaborations and interactions. In early 2018, they even received several hundreds of thousands of dollars from Aragon, a company building blockchain applications, to develop Space Decentral's application to recruit members, manage space missions, and reward contributors – this application was to be integrated with other online collaborative tools. That collaboration, however, didn't last. Space Decentral ended its operations abruptly early 2020 and their website closed later that same year. Very few details transpired, but we learned that Aragon - that same organization that had funded Space Decentral to develop their blockchain application called Open

Enterprise - had launched legal actions against the decentralized space organization due to unauthorized funds management and the lack of agreement on the type of resolution mechanism to use.

At this point, I am proposing this research question. Based on the experience of Space Decentral, this thesis will investigate:

- How do online collaborative tools foster co-creation activities within virtual organizations?

The research objectives are to:

- Identify the most important co-creation activities from a virtual organization;
- Define the scope of the open source culture of Space Decentral and explore how it influences aspects of governance and knowledge management; and,
- Review the gaps in managing activities collaboratively within virtual organizations.

The three research objectives will lead to insights on Space Decentral's evolution related to the sequence of co-creation activities, and the relationship between its activities and the initiatives of the broader open source and blockchain communities. In the end, both the *Findings* and *Discussion* chapters will synthesize the data, make connections, and then identify the gaps – or issues – that have arisen during the two years of Space Decentral's existence.

Way forward

To be clear: this research does not investigate specific software or platforms in particular. For instance, MS Team and Google Workspace have very similar tools (word processing, video-conferencing, repositories / cloud storage, email, etc.). Instead of focusing only on what members of Space Decentral used, this research will look into what was shared and done on these platforms, using these online tools that allowed people to share stuff (such as ideas, text, images, audio, or video) and work on their projects.

The next chapter (*Literature Review*) outlines the results of the literature investigation on the scope of the research related to the concept of boundary objects in a co-creation environment, in addition to the concept of open culture which came back often in various documents. Then, the *Methodology* chapter will introduce the Space Decentral organization as the explorative case study, and its online collaborative tools (including the application to be developed on blockchain technology). The research technique used is netnography, a qualitative ethnography methodology using online platforms to study the behaviours, social structures and shared beliefs of members of Space Decentral. It was used to collect the data to answer the research objectives.

Then, the *Findings* chapter is separated in two. The first section (Phase One) focuses on primary sources. It is structured to classify the conversations found on the online collaborative platform called Riot using Frank Piller and Joel West's 2014 co-creation framework. Phase One also looked into the conversations and documents related to Space Decentral's two pilot projects: Space Mission Activation Process (SMAP) and Coral. SMAP was essentially for the development of space-related projects in general. Coral was specifically to demonstrate in-situ resource utilization (ISRU) and 3D printing technologies on the

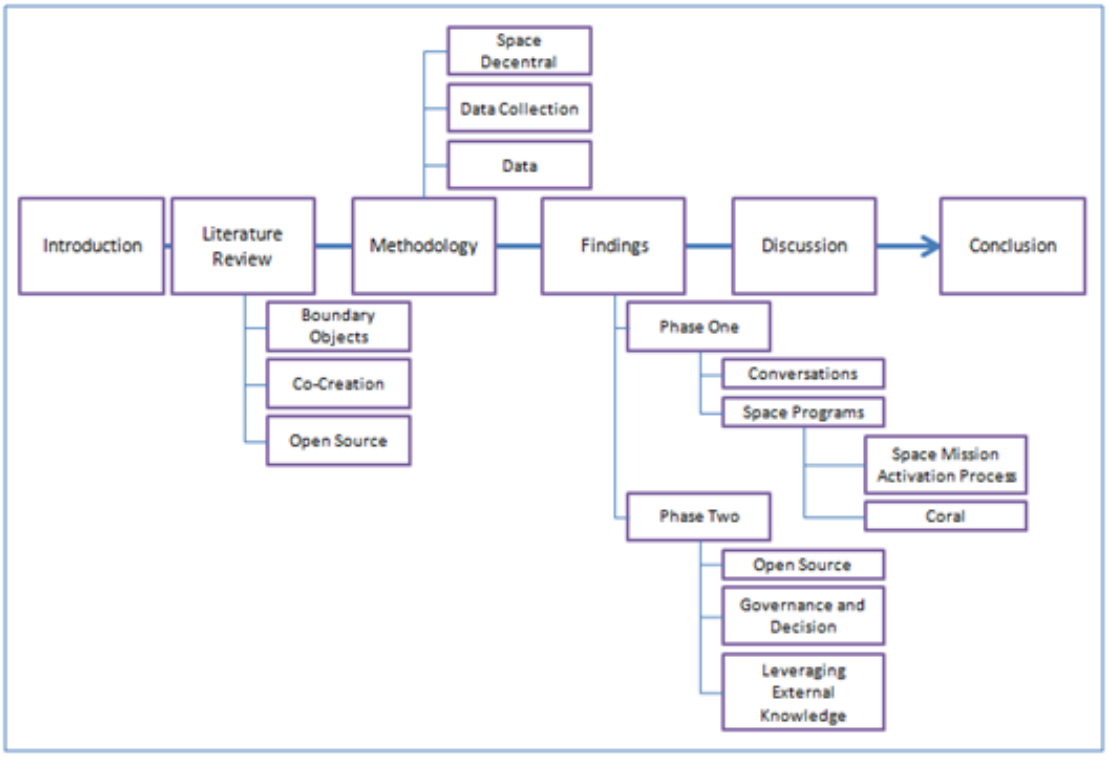
Moon's surface using lunar regolith. Although both were designed to be managed with a combination of online collaborative tools and a blockchain application in mind, members of Space Decentral were not successful in implementing any of them. Nevertheless, Phase One of the *Finding* chapter looks into the first research objective and identifies the most important co-creation activities from Space Decentral's point of view, and where online collaborative tools acting as boundary objects failed to work.

The second section (Phase Two) in the *Findings* chapter focuses on secondary sources. It defined the scope of the open source culture of Space Decentral and explored how open source culture influences aspects of governance and knowledge management within a virtual organization such as Space Decentral - the second research objective. This is done using documents related to Space Decentral's mission (i.e., the White Paper and Governance paper) and other policy documents from organizations that have looked into these issues impacting the space sector, a community of knowledge-intensive organizations, such as the Organisation for Economic Cooperation and Development and Canadian Blockchain Research Institute.

Once this is completed, the *Discussion* chapter examines the research goal by assessing the overall results, in addition to reviewing the gaps in managing activities collaboratively within virtual organizations based on the experience of Space Decentral.

Figure 1.1 outlines to roadmap of this thesis.

Figure 1.1 – The roadmap



In summary, this investigation is timely. The world is accelerating towards an expanding intangible economy due to safety measures imposed by the pandemic which are likely to remain in the years to come. The intangible economy is a model that relies on knowledge-based assets such as software, research & development (R&D), design, training and new business processes (Haskel and Westlake, 2018: p. 22). This economy pushes the adaptation of soft infrastructure such as norms, standards, and rules that govern collaborations and interactions among the private sector, government and people (Haskel and Westlake, 2018: p. 241). Consequently, the intangible economy may have impacted various pre-COVID conceptions, especially the management of intangible assets such as knowledge and ideas. Knowledge management is a public policy issue likely to become more and more significant in the years to come, pressuring all kinds of organizations to adapt their functional activities accordingly to grow and flourish. The space sector, for instance, is full of highly qualified personnel a few years away from retirement. In 2005, it was known that "NASA's workforce under 30 years of age is one-third the size of its workforce over 60" (Oborne, 2005: p. 199). A review of a range of human resource policies will likely be required to engage former personnel after their retirement to enable a vast network of organizations to benefit from their knowledge in a virtual setting.

The story of Space Decentral can also be seen as a cautionary tale of individuals operating in a decentralized and virtual organization. The research suggests that virtual organizations may need to take a new role at the inter-organizational level. This role is not only to manage the organization's own

projects but the various tools and networks actively contributing to the co-creation activities as well. Also, the experience of the members of Space Decentral shows how online collaborative tools are not *passive*. As I witnessed during this investigation, online collaborative tools as boundary objects and artefacts "brake" in some situations. They don't automatically engage participants to reflect on certain co-creation activities, especially what Frank Piller and Joel West (2014) have identified as the *Problem formulation* activity and the *Finding participants* stage. As a result, there is a need for skilled managers able to either *repurpose* objects or *create* new artefacts along the way to maintain coherence and increase the chance of success of the virtual organization. This is relevant as we move towards various styles of hybrid online / in-person working environments. This shift obviously impacts the research community still focused on pre-COVID conceptions about virtual collaborations and the role of online collaborative tools. Virtual organization will likely need to develop strategies associated with each of the co-creation stages.

2. Literature Review

This chapter outlines the results of the literature review based on the concepts of boundary objects and open source in a co-creation environment. Both are essential in a context where online collaborative tools are the "things" that bind people together. These tools have a range of capabilities or functions. As such, the boundary object concept was the starting point of this research. Then, the concept of boundary artefact was included thanks to authors like Charlotte Lee (2007) who pioneered the concept. Lee's 2007 paper introduced the "boundary negotiating artefact" concept for "non-routine and novel collaborations" (Lee, 2007: p. 314). The open source concept was also added as the analysis progressed. It was frequently mentioned in discussion platforms and in many documents of Space Decentral.

In total, I have identified more than 60 relevant articles from mainstream journals. Articles from conferences or theses were not included. The main platforms used to find articles were Google Scholar and Research Gate. The filtering of articles was based on specific keywords. They are:

- Boundary AND objects AND (co-creation OR cocreation OR collaboration OR co-design OR co-development)
- Boundary AND (artefact OR artefacts OR object OR objects) AND (co-creation OR cocreation OR collaboration OR co-design OR co-development)

To research the literature on the open source concept, I used the same platforms (Google Scholar and Research Gate) using a more direct approach with specific keywords:

- Open AND source AND literature AND review

Also, I used the "artefact" terminology throughout the thesis for consistency reasons, but kept "artifact" if taken from direct quotes or article titles. In the end, both "boundary objects" and "boundary artefacts" concepts were considered, while using the "co-creation" keyword to filter the right articles to study the online tools used in a co-creation environment.

2.1 Boundary objects

Boundary objects have been a popular concept in the past three decades. In their literature review, Huvila *et al.* (2017) found that Star and Griesemer's 1989 article - the first one to cover the concept explicitly. Star and Griesemer (1989) assessed that boundary objects are these "things" that act as translation devices, having different meanings across various social worlds, while adopting a structure "common enough to more than one world to make them recognizable" (p. 393). Social worlds are defined as spaces where individuals communicate through shared discourse (Strauss, 1978) or broader "communities of practice" that interact in a shared cultural space (Wenger, 1998).

Concrete examples of boundary objects selected by Star and Griesemer (1989) were maps and guides. They were regarded as tools for communication, cooperative work, acting as translation devices to reach mutual goals in the absence of consensus. In total, the literature review of Huvila *et al.* (2016) identified numerous boundary objects research in the past 30 years. They associated each author with

the “things” in fields such as *management*, *archival science*, *development studies*, *economics*, *education*, *document studies*, and *library and information science*. In addition, researchers from the Computer Supported Cooperative Work (CSCW), a field that studies the design and use of technologies that affect groups, organizations, communities, and networks, have been particularly interested in boundary objects (Huvila *et al.* 2016: p. 16).

Table 2.1 illustrates a list of “things” that have been analyzed as boundary objects in the field of Information Science. We can see from Huvila’s *et al* 2016 literature review on boundary objects in information science that very little research investigated software or online platforms.

Table 2.1 - Types of artefacts theorized as boundary objects

Artefact	**Reference**
activities	(Macpherson *et al.*, 2006)
archival standards	(Yakel, 2004)
cancer (as a conceptual artefact)	(Fujimura, 1992)
community information	(Westbrook & Finn, 2012)
concepts	(Langenohl, 2008; Ridenour, 2016)
design concepts	(Eriksson, 2008)
digital literacy	(Huvila, 2012b)
documents	(Huvila, 2012; Østerlund, 2008a)
gender	(Burnett et al., 2009)
genre	(Østerlund, 2008b)
group affiliations	(Lindberg & Czarniawska, 2006)
information services	(Huvila, 2012b)
medicine	(Frost *et al*., 2002)
metaphors	(Koskinen, 2005)
methods	(Olsen *et al.*, 2012)
musical scores	(Winget, 2008)
ontologies	(Shepherd & Sampalli, 2012)

policies	(Emad & Roth, 2009)
repositories and digital libraries	(Star & Griesemer, 1989; Van House, 2003; Worrall, 2015)
room / space	(Jornet & Steier, 2015)
technical standards, geographic information systems (GIS)	(Harvey & Chrisman., 1998)
visual representations	(Henderson, 1991)
water	(Carroll, 2012)

Reproduced from Huvila et al., 2016: p. 4

Building on the works of Star and Griesemer (1989), Bowker (2000), Star (2010), and Steger, Cara *et al.* (2018) classified four types of boundary objects used to assist in the integration of diverse forms of knowledge across social worlds and organizations. (Table 2.2)

Table 2.2 - Definitions and examples of the four types of boundary objects

Type	**Description**	**Examples**
Repositories	Indices that order and group objects; users can reference this index without negotiating purpose with other users	Libraries or museums; federal register; encyclopedias
Coincident Boundaries	Commonly recognized boundaries allow different and overlapping content; users conduct work autonomously while cooperating with a common reference	Maps or political boundaries; jurisdictional agreements; cadastral tax maps
Ideal Type	A model, term or concept that fails to adequately describe any one particular thing; its abstraction allows for communication and cooperation	Biological concept of a species; atlases
Standardized Forms	A device for organizing information that facilitates communication; requires simplification to ensure objects are legible despite limited information about their origin or context.	Data collection form; US census data; tax forms; legal requirements

Reproduced from Steger et al., 2018: p. 155

To be eligible to enter this table, the objects must have these three features in common (Steger, Cara *et al.*, 2018: p. 154) – see below. In addition, the objects have to resist the exercise of time. The authors stated that, for objects to "continue to function as a boundary object, depends on its evolution through flexible, organic collaborations and continued use across different social worlds" (p. 156).

- "Embody interpretive flexibility - meaning that it is able to satisfy the needs of users from different social worlds while facilitating communication between them (Star and Griesemer, 1989). This is the most studied feature of boundary objects;
- Address information needs arising from work processes, such as a need to classify or organize data. This phenomenon influences the form and structure of dialogue; and,
- Require movement between a general, ill-structured form and local, tailored applications of a given idea."

2.1.1 Boundary objects and knowledge management

When they classified the types of boundary objects, Steger, Cara *et al.* (2018) found that although standardization facilitates implementation, it "may diminish [the object's] ability to function as a communication device for bridging social worlds and disciplinary perspectives" (Steger *et al.*, 2018: p. 154). This issue had been raised by Lutter and Ackerman a decade earlier in 2007. They had stated that most research on standards failed to address "the analytical power that boundary objects bring to understanding negotiation and mediation in routine work" (p. 6). Lee (2007), who is considered to have launched the debate over artefacts the same year, added that "the dependence of boundary objects on the premise of established standards is inherently problematic for theorizing incipient, non-routine, and novel collaborations" (p. 314). Actually, Lutter and Ackerman believed boundary objects should be viewed through a temporal lens, "within a history greater than themselves"; *history* in this case is being defined as a series of "perpetual negotiations and renegotiations surrounding the boundary objects" (p. 32). The authors qualified these objects as "lifelines" to its users thanks to their boundary spanning qualities. These qualities allowed communities to embrace both the plasticity and rigidity of boundary objects (Huvila, 2016: p. 16), even though Lutter and Ackerman (2007) warned that organizational memory was the only thing allowing the reuse and recontextualizing of the information for the negotiations. Otherwise, the data doesn't make sense (Lutters and Ackerman, 2007: p. 33). This is why Star and Griesemer (1989) wrote that the development and maintenance of boundary objects are critical processes to sustain coherence where social worlds meet (p. 393). Carlile had also highlighted the issue of coherence, stating that boundary objects "help create a shared context between specialized communities" acknowledging "the importance of developing common meaning as a way to address interpretive differences across boundaries" (Carlile, 2004: p. 559).

In summary, this perspective on boundary objects is relevant for this research looking into the usage of online collaborative tools among a group of individuals getting together to build a network where there is an expectation that others from different social worlds – with different knowledge – will connect. As a result, what we saw in section 2.1.1 framed the conditions for online collaborative tools to work, but showed how the "standardization" and the "maintenance" of these tools are dynamic processes. These

processes help construct and strengthen the "meaning" of the objects – the "coherence" – to carry the share context of the network. This will be important to keep in mind for what follows.

2.1.2 Issues related to boundary objects for knowledge management in a network

First, knowledge is "both a barrier to and a source of innovation in a product development setting" (Carlile, 2002: p. 454). Carlile found that specialization is a major impediment blocking the flow of knowledge "across functional boundaries and accommodating the knowledge developed in another practice" to transform that knowledge into innovation. Furthermore, by resorting to diverse and multiple knowledge holders across boundaries (Teece, 1992), organizations face greater difficulties in knowledge management (Salvetat, Géraudel and d'Armagnac, 2012: p. 3). In other words, in addition to developing common meanings across organizational boundaries, boundary objects must also be flexible enough for existing "knowledge boundaries" within organizations to operate effectively. Table 2.3 shows how Carlile (2002) described these knowledge boundaries.

Table 2.3 - Type of knowledge boundary, category, and characteristics of boundary objects

Types of Knowledge Boundary	**Categories of Boundary Objects Characteristics**	**Characteristics of Boundary Objects**
Syntactic: recognition of the existence of a shared and sufficient syntax at a given boundary; differences and dependencies have been specified and agreed to in advance.	Repositories	Representing
Semantic: recognition that differences exist or emerge overtime; emergence of novelty on one or both sides of the boundary is a natural outcome.	Standardized Forms and Methods	Representing and Learning
Pragmatic: recognition that differences in knowledge are not always adequately specified; individuals must represent, learn, negotiate, and alter the current knowledge and create new knowledge.	Objects, Models, and Maps	Representing, Learning, and Transforming

Reproduced from Carlile, 2002: p. 453

In the 2010s, Maenpaa *et al.* (2016) worked to better understand and find approaches "to facilitate knowledge integration for networked innovation", which include transaction networks and co-creation networks (p. 25). Gyrd-Jones and Kornum (2013), however, caution on the usage of "networks" when they are made of stakeholders. The authors stated that "a 'stakeholder ecosystem' is co-created by the complex interaction of a network of stakeholders within each holding specific and individual identities"

and that “every action or input modifies the nature of an ecosystem and this iterative, systematic process differentiates an ecosystem from a network” (p. 1).

This is important for this research considering the strong software development environment. Even when the boundary object is well understood by an homogenous community within a network, it could still impede the common understanding and innovation within the ecosystem. For instance, Huvila *et al.* (2017) studied the CSCW field, where the community considers Information and Communication technologies (ICTs) as boundary objects serving coordinating functions (p. 15). In their literature review, the authors concluded that ICTs can support processes, but there was no guarantee that these boundary objects would bring coherence or convergence (Huvila *et al.*: p. 13). In fact, it was found that most ICTs have been designed to work as standalone applications (Adamides and Karacapilidis, 2017: p. 8), while the work of Lee (2007) and Lutters and Ackerman (2007) showed the social aspect must be considered alongside the technical (Meyer, 2014).

Calton *et al* (2013) set the boundary of networks - or ecosystem - at the location where “the shared ‘messy’ problem (i.e., complex, interdependent)” is, and where it impacts participants separately, as well as together. In other words, knowledge boundaries would be situated where the interests, values, or perspectives of participants are analyzed and challenged by others who also occupy the contested problem domain or community of practice (p. 726). For instance, Maenpaa *et al.* (2016) analyzed the output and outcome of three multi-stakeholder workshops of “knowledge utilization” (ideation, innovation, and analysis) aimed at designing boundary objects for networked innovations. Six types of boundary objects for design were identified: four classified as *concrete* (memos; pictures and blueprints; presentations; and a factory tour) and two as *metaphorical* (a new structure and a former structure). These designing activities led to the creation of new knowledge, the sharing of knowledge, and an increasing openness between stakeholders. Maenpaa *et al.* (2016) concluded that managers must take boundary objects into account when designing processes of collaborative and networked innovation by communicating the role of the boundary objects among the stakeholders (p. 9). It was proposed that “simple and scalable solutions for targeted collaboration, resource discovery and exploitation” should be contemplated to facilitate and boost innovation activities (Adamides and Karacapilidis, 2017). The authors recommended paying “attention to standardization to make existing data and software reusable with the minimum effort and without introducing new standards” (p. 8). Lee (2007) supports this view. She found that, when “opening the box around boundary objects”, it is important to consider “more comprehensive and richly specified models of negotiation and enactment” (p. 335).

This is why the effectiveness of standard boundary objects, especially in the field of ICTs where tools that are mainstream among the general population are used to easily create networks, shows some limitations. This impacts this research studying novel or multidisciplinary collaborations using online collaborative tools as boundary objects. There is a need for both *concrete* and *metaphorical* objects to be included in the design of a virtual organization, while managing them on an ongoing basis. Consequently, the work of Lee (2007) was included in the analysis. She invited the research community to look at “boundary negotiating artefacts” for non-routine and moderate complex projects. She learned

that: 1) “collaborative work can be highly contested”; and, 2) “practices and artifacts are not always well understood” (Lee, 2007: p. 335).

2.2 Boundary artefacts and their role in co-creation activities

Lee (2007) actually reflected on the first steps of the boundary objects development stage analyzing more free-form boundary negotiating artefacts seen as less structured and standardized. She stated that “artifacts can serve to establish and destabilize protocols themselves and that artifacts can be used to push boundaries rather than merely sailing across them” (p. 307).

Artefacts have since been identified as important vehicles of human activities and useful to mediate interactions (Mariano and Awazu, 2017). For this research, artefacts will be defined as words, concepts, methods, stories, documents, links to resources, etc. (Wenger, 2003: p. 83). These are used to help knowledge-related processes such as knowledge creation, growth, transfer, sharing or reproduction (Mariano and Awazu, 2017) for non-routine and novel collaborations. As a result, Mariano and Awazu’s (2017) research will be central to this research.

The authors have studied the role of collaborative knowledge building in the co-creation of artefacts. Co-creation is the practice of developing systems, products, or services through collaboration which creates value through interactions (Galvagno and Dalli, 2014: p. 643), between a company and individuals (*Piller and West*, 2014: p. 39) who can be customers, managers, employees, and other company stakeholders (Ramaswamy and Gouillart, 2010: p. 5). Co-creation is also a complex process with many layers such as governance, knowledge sharing, complementary capabilities and assets (Grover and Kohli, 2012).

The intent of the literature review of Mariano and Awazu’s (2017) investigation, assessing 58 articles published in six knowledge management-related journals, was to help managers understand the complexities of collaborative knowledge building practices. By “collaborative knowledge building”, they mean “a social communicative process aimed at the co-creation of knowledge artifacts” (p. 781). This is to increase overall organizational effectiveness and performance. The authors found that “the majority of previous work has focused on already existing artefacts but has not yet formed enough insights on how these artefacts can be produced through purposeful co-creation processes (p. 3). The investigation led to the identification of four contextual levels that influence the design - or co-creation - of artefacts in collaborative knowledge building activities (Table 2.4).

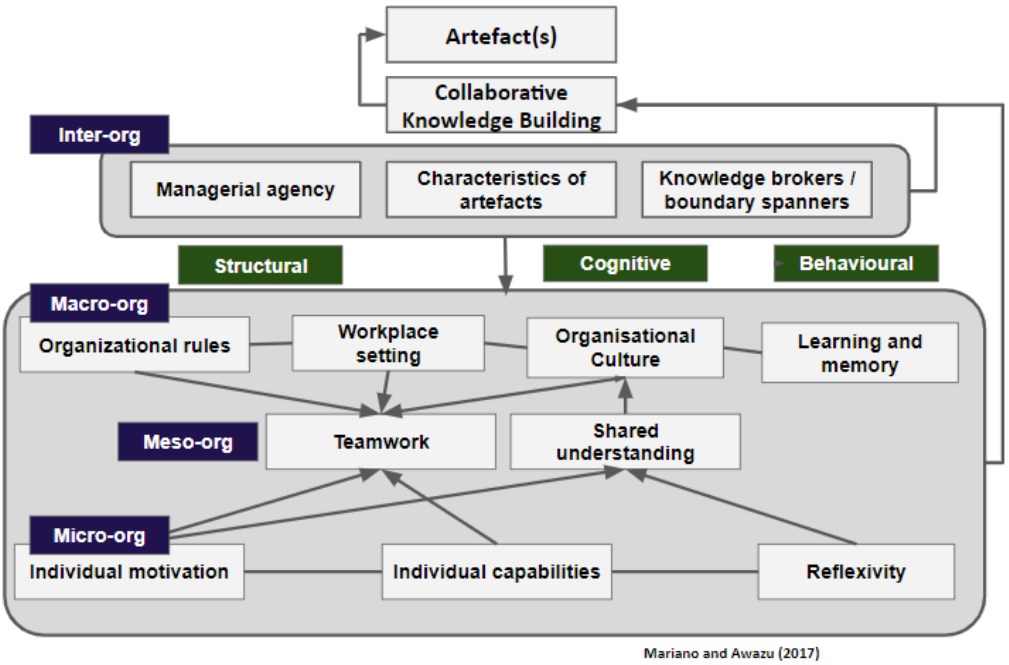
Table 2.4 - Contextual levels and factors involved in collaborative knowledge building aimed at the co-creation of artefacts

Level	Questions asked	Influential factors found
Micro-level	Does individual motivation contribute to teamwork and shared understanding in collaborative knowledge building? Do individual capabilities influence teamwork? Does reflexivity have an impact on shared understanding in collaborative knowledge building?	Individual motivation, capabilities and reflexivity are likely to influence the co-creation of artefacts in collaborative knowledge building at the micro level of analysis.
Meso level	Do teamwork and shared understanding influence organizational culture? Does organizational culture influence teamwork in collaborative knowledge building?	Teamwork and shared understanding are likely to influence the co-creation of artefacts in collaborative knowledge building at the meso level of analysis
Macro level	Do organizational rules and workplace settings influence teamwork activities in collaborative knowledge building? How are organizational culture, and learning and memory likely to influence the co-creation of artefacts at the macro level of analysis?	Structural (organizational rules and workplace setting), behavioural (organizational culture), and cognitive (learning and memory) factors are likely to influence the co-creation of artefacts in collaborative knowledge building at the macro level of analysis.
Inter-organizational levels	How are managerial agencies, characteristics of artefacts and knowledge brokers and boundary spanners likely to influence the co-creation of artefacts in collaborative knowledge building at the inter-organizational level of analysis?	Managerial agencies, characteristics of artefacts, and knowledge brokers and boundary spanners are likely to influence the co-creation of artefacts in collaborative knowledge building at the inter-organizational level of analysis.

Adapted from Mariano and Awazu, 2017

It also gives an interesting role to organizations as “Managerial agencies”. They stated that “strong leadership and commitment levels by top managers were found to determine the success or failure of projects involving large numbers of objects” (Mariano and Awazu, 2017: p. 787). Figure 2.5 from Mariano and Awazu’s (2017) article illustrates their approach in a structured way. This is important since our audience are employees and managers. This figure will help understand the best practices using online collaborative tools to help organizations work virtually, especially for this case study. Space Decentral had a plan to develop their own suite of online collaborative tools – a suite of blockchain applications to support their projects in a decentralized environment with management, monitoring and reward functions, for instance. Mariano and Awazu’s research, however, did not address collaborative knowledge building best practices within an online community, only how individuals at the inter-organizational levels influence the co-creation of artefacts.

Figure 2.5 - Contextual levels, influencing factors and proposed relationships



2.2.1 Coopetition within the space sector

This section illustrates the challenging environment that the space sector is operating in. It is important for this investigation of Space Decentral's activities, but also could be significant for the future of organizations in general. Space firms are often involved in a coopetition relationship, as a means of mutualizing resources, finding subsidies, and gaining markets (Salvetat, Géraudel and D'Armagnac, 2013: p. 10). Salvetat, Géraudel and D'Armagnac (2013) had actually found three specific issues when operating in a coopetition environment. They are: Inter-organizational knowledge management, knowledge flow control, and learning management (Table 2.6).

Table 2.6 - Coopetition issues within the space sector

Issue	**Description**
Inter-organizational knowledge management	Sharing know-how and knowledge between firms is initially managed by the contract, which organizes the knowledge management within the coopetitive process. The knowledge generated by this coopetition is the subject of specific clauses. Conditions for attributing the patent rights frame the behaviours in terms of the knowledge engaged in during the coopetitive process.
Knowledge flow control	Knowledge acquired by coopetitors incurs two main risks. Partners can be prone to adopting opportunist behaviour and using a coopetitive situation as a way of appropriating the knowledge produced by a partner. Moreover, information leaks are numerous between teams of

	rival firms working on the same cooperative project.
Learning management	Teamwork within a coopetitive system generates new knowledge. Coopetition mutualizes resources, with the aim of an advance for each partner. Two types of learning are described below: inductive, which has its roots in planned collaboration and which meets the previous objectives; and deductive, which consists of the consequences of the cooperative process beyond the pre-planned scheme and is accomplished via an extended collaboration according to opportunities.

Reproduced from Salvetat, Géraudel and D'Armagnac (2013)

In summary, section 2.2 – and especially 2.2.1 – brings an important challenge when we look at the impact of online collaborative tools on the management of each individual's knowledge within a network or a decentralized organization. Within a borderless community, where individuals contribute under no authority (the decentralization culture of Space Decentral, supported by the mission of the blockchain community who is developing an online infrastructure void of a central authority), one's knowledge becomes "open" and circulate freely. This raised the question of intellectual property. Hence, in the next section, we looked into these issues of decentralization, coopetition and intellectual property that were captured throughout this research. This is important considering that Space Decentral was operating within a software development community with a profound open source culture.

2.3 Open source

As indicated, to define the scope of the open source culture, we first have to look at the software development community. Krogh and Hippel (2003) have defined open source software as "software that is made freely available to all" and the development being made by "communities of software developers who voluntarily collaborate to develop software that they or their organizations need" (p. 3). This is similar to Gassmann and Enkel's (2004) definition of the open source approach within cooperative software development. The authors stated that it is "independent software programmers who, on demand, develop lines of codes to add to the initial source code to increase a program's applicability, or enable new applications" (p. 2). Teece in 1986 had already identified, in other words, how innovation by users "relates to the user's or producer's complementary assets, such as distribution channels, specialized capabilities, and complementary technologies (Teece, 1986).

Then, to define the scope of the open source culture I found a few articles from the past five years (from 2016 to 2021) that investigated open source practises within organizations. For instance, I selected the work of Franco-Bedoya *et al.* (2017) who studied open source software. The authors took 82

publications out of 652 papers published between 2003 and 2015 to assess the open source software ecosystem. They found that "the essence of open source is not the software. It is the process by which software is created" (p. 24). It is similar to what West and O'Mahony (2006) found. They said that "open source" had become a "culture" - it "encompasses both an intellectual property strategy and a development methodology" (p. 1). This culture is very noticeable throughout the growth and failure of Space Decentral.

Franco-Bedoya *et al.* (2017) also added a total of four types of common open source relationships to the research field, either in the context of an actor-organisation or a community-based perspective. They are: software development process; project contributions and collaboration; governance; and, the "co-" concepts. The "co-" concepts they are referring to are: "co-evolving", "cooperation", "co-develop" and "co-creation" – or the "competence and collaboration between different entities about a specific topic" (Franco-Bedoya *et al.*, 2017: p. 24). In terms of hierarchy, Franco-Bedoya *et al.* (2017) literature review also expanded the open source structure, beyond just the role of users, developers and firms. It begins with software projects, and moves on to products, communities, and organizations. Within this hierarchy, the roles depend on the level of participation. We find: users, reviewers, contributors, administrators, partners, and developers.

The overall findings on open source culture, relationships, and hierarchy are all key insights that, combined with the work of Mariano and Awazu (2017) on collaborative knowledge building activities, contributed to assessing this research on Space Decentral as a case study. However, Franco-Bedoya *et al.* (2017) found that "quality management and operationalization of software ecosystems is still an immature discipline" (p. 26). In fact, historically, the research community has focused extensively on the successes of software developers working with firms to develop Linux, the Apache server or Freemail in an open source environment – but rarely did they look at failed cases. (On that note, I must highlight the research of Neff *et al.* (2010) that looked at the performance of a digital *building information modelling* software that "failed to bridge knowledge gaps across organizational and disciplinary boundaries". This digital tool, which included databases, was supporting inter-organizational process in the construction sector to represent buildings in three-dimension to facilitate coordination and communication within building projects among stakeholders. Although this research was not related to open source, the authors had found that "the work of collaboration and communicating across organizational boundaries is not fully understood and needs to be further researched" (p. 570)).

Nevertheless, research projects on open source "launched a series of discussions on opening up the company's internal innovation process" (Gassmann and Enkel, 2004: p. 2). This explains why researchers like Gassmann and Enkel wanted to see if the open source innovation approach was transferable to other sectors. They looked into the impact of open source in the conventional innovation process by studying 124 companies. Their findings are important for this research since the space sector is often in a collaborative environment with other competitors during space projects (the "coopetition" – see above); some knowledge must be shared to complete a joint project, all while protecting the other knowledge they do not wish to share (Salvetat, Géraudel and d'Armagnac, 2012: p. 7). Gassmann and Enkel stated that "the relationships with other companies, complementary companies and competitors

can be a firm's major assets and a necessary precondition for the linked process within an open innovation strategy" (p. 15). On the other hand, they mentioned that further research needs to investigate the required capabilities of organizations to be successful. This research was able to provide some insights behind a failed open source project.

To conclude the *Literature Review* chapter, we looked into the various research projects that has been done in the past 30 years related to boundary objects and artefacts, in addition to the concept of open source. First, we learned that boundary objects and artefacts must have specific functions to work among social worlds or various and often different communities. That knowledge was useful to analyze the usage of Space Decentral's online collaborative tools, and where members of the decentralized organization failed to optimize the utilization of the online collaborative tools to grow their network and implement their activities. This is why one of the research objectives is to explore how online collaborative tools in an open source environment influence aspects of governance and knowledge management. This is relevant considering that the space sector is often in a collaborative environment with other competitors for space missions (i.e., coopetition); some knowledge must be shared to complete a joint project, all while protecting the other knowledge they do not wish to share - i.e., intellectual property (Salvetat, Géraudel and d'Armagnac, 2012: p. 7). All in all, the analysis will contribute to the literature on boundary artefacts and boundary objects by improving the development of best practices in the usage of online tools for a growing number of organizations operating in a decentralized environment - especially those who are adopting an open source approach such as Space Decentral. Its growth and the unsuccessful outcome of their mission are informative. The following chapter will focus on explaining the case study and the research methodology.

3. Case Description and Methodology

This thesis is looking into the future. As explained above, COVID-19 is likely to force all kinds of organizations to keep working remotely for a long time. As indicated in the introduction, the key assumption we make is that online collaborative tools are here to stay. In this context, an increasing number of new employees and managers will mostly experience collaborations through these online tools. This research therefore wants to better understand how individuals and managers working in a virtual organization can co-create effectively using online collaborative tools, while mitigating the challenges.

The objectives of the research are to 1) identify the most important co-creation activities from a virtual organization; 2) define the scope of the open source culture of Space Decentral and explore how it influences aspects of governance and knowledge management; and, 3) review the gaps in managing activities collaboratively within virtual organizations.

First, it is important to clarify that the term "online collaborative tools" is used by companies such as Google and Slack to brand their software as "collaboration" enablers. [3] As a result, we will continue to brand the applications used by the case study to be introduced below as "online collaborative tools", such as Google Workplace, MS Team, Riot, Github, Zoom, and others. Furthermore, as seen above - and especially in Table 2.1 - although abundant literature has investigated the concept of boundary objects, and the connection between boundary objects and co-creation, these online collaborative tools have not been studied much using the boundary object concept as "things" that can have various functions for transformation, translation, and negotiation. The case study will be useful to help in that regard.

As a result, Section 3.1 of this chapter will lay out the history of Space Decentral since its creation early 2018, the leadership behind Space Decentral, and the preliminary investigation that led to the choice of Space Decentral as the exploratory case study. The term "exploratory" is explained by the fact that their mission to be virtual was not really mainstream before March 2020 where the world switched to remote working almost the next day. Then, we will move to Section 3.2 introducing the data collection technique. I will be using netnography, a relatively new research technique. It was decided that netnography would be useful considering its close relationship with ethnography. This will be particularly useful in a context where the case study (Space Decentral) was an unknown organization before 2018, with little perspective on its potential longevity.

Finally, I will lay out the data collected over two years, between January 2018 and December 2019, and the tools used to support the analysis. Specifically, Section 3.3 will explain why there are two phases to the *Findings* chapter, and how they will help answer the three research objectives and discuss how online collaborative tools foster co-creation activities within virtual organizations .

[3] See the Slack website and the Google Workplace websites.

3.1 Space Decentral - An exploratory case study

Space Decentral is an organization created in February 2018 by a team of individuals – see Table 3.1. Their purpose was to use blockchain technology to "reinvigorate the push for space exploration" in order to "design space missions collaboratively, share research for peer review, crowdsource citizen science efforts, and crowdfund projects that lack national budgets" (Space Decentral, White Paper, 2018).

> "Recent years have seen the Internet empower more people across the world to connect and collaborate - while blockchain technology promises to expand collaboration options even further by removing the need to have a centralized enforcement institution to police the activity of individual participants." (Space Decentral, 2018a)

In other words, Space Decentral's goal is to lower the *barriers to entry* for individuals interested in participating in space missions and foster collaboration through online collaborative tools, including blockchain applications.

The choice of Space Decentral was not difficult. In 2018, there were not many candidates operating in the field of space, with members scattered around the world using mostly online collaborative tools, and experimenting with blockchain technology. SpaceQ, a blog communicating the latest news from the space sector in Canada and abroad, had listed some organizations - in April 2019.[4] But the interesting factor was that Space Decentral aimed to develop blockchain applications to facilitate co-creation activities and develop or contribute to space missions. Based on the White Paper, their mission was to "utilize blockchain technology to enable collaborative, transparent and self-directed action towards building the future of space exploration" (Space Decentral, 2018a). The *New Space* movement and the success of the open-source software community was the rationale for Space Decentral members to move confidently forward.

3.1.1 The history of Space Decentral

The organizational structure of Space Decentral was integrated to the development of a Decentralized Automated Organisation (DAO) to support a range of space projects and its expected governance structure. DAOs are the "promise of decentralized and spontaneous coordination over the Internet between users who do not know or trust each other", thanks to blockchain technology and the support of applications (Voshmgir, 2019: p. 104). According to Space Decentral's White paper, members of Space Decentral saw the use of blockchain applications as the "conduit to reinvigorate the push for space exploration with the public in control" and become one day a "decentralized autonomous space agency" (Space Decentral, 2018a: p. 1).

In fact, another reason why I selected Space Decentral as a case study was the White Paper and Governance Paper published in 2018. It communicated a roadmap to build a blockchain infrastructure supported by online collaborative tools. These documents gave the research a stronger argument to

[4] Source: https://spaceq.ca/blockchain-and-space-the-companies/ - retrieved on March 7, 2020.

investigate an organization with a plan to advance on an unbeaten path towards developing a decentralized space agency. Also, as a professional working at the Canadian Space Agency and for someone who spent over seven years in the fields of academic research and science, seeing a small group of individuals launching such an initiative was impressive.

Hence, to support Space Decentral's plan to be a DAO, the White Paper describes the infrastructure to be built on tokens. Tokens will be further analyzed later in the *Finding* chapter as an online collaborative tool, but can be introduced right now as follows, based on Space Decental's definition in the 2018 White Paper:

> "Blockchains utilize cryptographic tokens, which can also be used as cryptocurrencies, as a way to represent privileges and rights within a network. When actions are tokenized, transactions with unique digital identifiers are permanently and indelibly stored in the blockchain itself. A DAO uses these features intelligently to streamline and spontaneously coordinate workflows and business logic." (Space Decentral, 2018a)

The leadership of Space Decentral

The selection of Space Decentral as a case study in 2018 is also explained by the engagement level of the leadership and the composition of the team. The organization is crewed by members from various locations in the world that includes engineers, architects, futurists, and software developers (Table 3.1).

Table 3.1 - Members of Space Decentral [5]

Suzi Bianco	Paolo Tasca
Dr. Marc M. Cohen	Brent Sherwood
Sean Marquez	J. Simmons, Ph.D.
Yalda Mousavinia	Vanessa Pepe
Giulio Prisco	Patrick Donovan
Kevin Siegler	Arthur Lunn
Radek Zasiadczuk	Otto Garcia

Lastly, in 2018, Space Decentral began developing a network supported by a community of space enthusiasts and software developers, a reach that went beyond the boundaries of the organization. One example is the growing involvement of members from Aragon, a blockchain-led organization that funded the first iteration of Space Decentral's blockchain application. Throughout 2018 and 2019, both organizations became more intertwined and that relationship had a significant consequence on the growth of Space Decentral.

3.1.2 The rationale behind the selection of an exploratory case study

This case study also had to be branded as "exploratory". An exploratory case study is an adequate way to observe individuals, communities and organizations to extract insights (Stoecker, 1991: p. 88); to

[5] The team at Space Decentral - https://spacedecentral.net/team - retrieved on March 9, 2020.

explore situations in which the environment being evaluated has no clear, single set of outcomes (Yin, 2003: Baxter and Jack, 2008), and to retain the holistic and meaningful characteristics of real-life events (Yin, 1988). In essence, table 3.2 highlights some of the advantages.

Table 3.2 - Fundamental lessons that can be conveyed by a case study

1. It permits the grounding of observations and concepts about social action and social structures in natural settings studied at close hand.
2. It provides information from a number of sources and over a period of time, thus permitting a more holistic study of complex social networks and of complexes of social action and social meanings.
3. It can furnish the dimensions of time and history to the study of social life, thereby enabling the investigator to examine continuity and change in lifeworld patterns.
4. It encourages and facilitates, in practice, theoretical innovation.

Reproduce from Feagin J., Orum, A. and Sjoberg, G., 1991

This was important considering the novelty of their approach. During the research period, they secured funds, managed an active blog and a forum, in addition to generating a relatively sustained level of interaction on various online collaborative tools. However, something happened along the way. As laid out in Figure 3.3, Space Decentral's roadmap found in the White Paper was impacted by real-life events, disrupting not only their initiatives but the existence of the organization itself.

One important moment for Space Decentral was the $150,000 US from the Aragon Foundation for the development of "*The Planning App"*, a blockchain-related project to tackle alternative models for incentivizing open source initiatives.[6] Aragon is an organization developing blockchain-based applications built on Ethereum, a global, open-source platform for decentralized applications.[7] The relationship between Aragon and Space Decentral was strong during most of the research. Based on Space Decentral's White Paper, Aragon "offers many of the features needed for decentralized organizations such as financial planning, payroll, plus privilege management - which is at the core of Aragon and also a core need for operating a decentralized space agency" (Space Decentral, 2018a: p. 11).

However, in early 2020, members of Space Decentral announced that they were hit by a legal action from Aragon, the same organization that had supported them in the development of their Open Enterprise application through their grant program. [8] It impacted the research since the access of Space Decentral's website began to be an issue. Crumbs of information about that legal battle can be found on Twitter. Luis Cuende, *c*o-founder of Aragon and Executive Director of the Aragon Association,

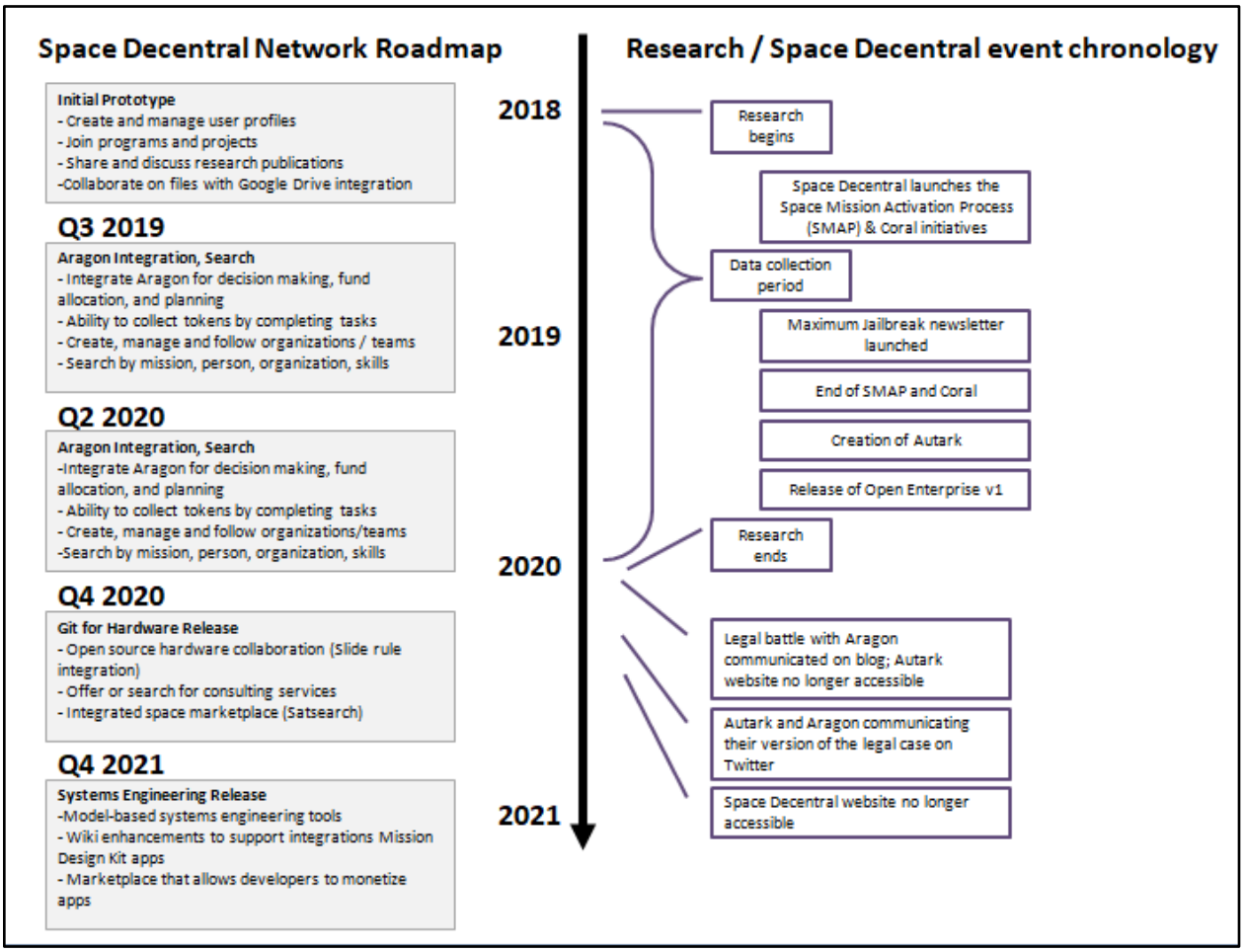
[6] Space Decentral: The DAO for Space Exploration, Medium, https://medium.com/giveth/space-decentral-the-dao-for-space-exploration-2af372d310af - retrieved on January 28, 2020.
[7] Source: https://ethereum.org/ - retrieved on January 28, 2020.
[8] DAO Legal Battle: Aragon vs Autark Community Grant Dispute. https://defirate.com/aragon-autark/ - Retrieved on December 2020.

announced on May 22, 2020, that "the Aragon Association has taken legal action against Autark [Space Decentral's sister company mandated to develop the blockchain application]... This is ugly, but they threatened to sue the Association and claimed a whooping amount of $800k" (Twitter, 2020a). [9] He said that the legal action was launched because members of Space Decentral "breached their grant agreement" (Twitter, 2020b)[10], while members of Space Decentral claimed that "the grant was approved by the community, but then Luis & Jorge [the cofounders of Aragon] cancelled [the grant], the community had no voice" (Twitter, 2020c). [11] The online magazine Decrypt summarized the situation as a "split between those who support Aragon's decision to go to traditional legal courts, while others argue the dispute should have been resolved in the project's own court". This, the failure of their projects in early 2019, and lack of engagement from the community afterward, forced Space Decentral to stop its activities.

Figure 3.1 highlights what was the plan of Space Decentral (on the left) with what actually happened during the research period and beyond (on the right). As we can see, at the release of the White Paper in 2018, Space Decentral had activities and milestones identified until the end of 2021. Unfortunately, as soon as early 2019, there were signs that indicated some activities or pilot projects were either too ambitious to be implemented or had to be abandoned. In the end, the roadmap was never updated and Space Decentral ceased its activities early January 2020. This will be further addressed in the *Finding* chapter.

[9] Source: https://twitter.com/licuende/status/1263845843125370880
[10] Source:https://twitter.com/licuende/status/1263880695648313345
[11] Source: https://twitter.com/ameensol/status/1264265206949011456?ref_src=twsrc%5Etfw

Figure 3.3 - Space Decentral roadmap vs actual Space Decentral events and research chronology



Reproduced from Space Decentral White Paper in 2018 with actual events

3.2 The data collection technique

The culture of Space Decentral was to be decentralized and transparent. The activities of the organization and its leadership were accessible on their website and online collaborative tools. However, the number of platforms and the scope of unstructured entries were particularly challenging. Coding these conversations through convenience sampling (Patton, 2002) was a good approach, using a netnography approach and text mining / collection and management of documents from the web. Convenience sampling is a type of sampling where the first available primary data source will be used for the research without additional requirements. Considering that Space Decentral's culture was to post all key documents, decisions and conversations online, these techniques were to be adequate. In fact, similar to an anthropologist observing the real world, I observed and conducted research on this new ecosystem taking shape primarily over the Internet.

3.2.1 Netnography

Netnography is designed to study cultures and communities online, "extending the traditional notions of field and ethnographic study" (Bowler, 2010: p. 1271). It is also an adaptation of the qualitative methods utilized in consumer research (Belk, Sherry and Wallendorf, 1988), cultural anthropology (Geertz, 1973; Altheide and Johnson, 1994), and cultural studies (Jenkins, 1995), with the goal of facilitating a study of the consumer behaviour of virtual communities and cyberculture (Kozinets, 2011: p. 4). Kozinets (2010), the researcher who developed the methodology, suggests following these methodological stages and procedures for netnographic studies. (Table 3.4)

Table 3.4 - Stages and procedures for netnographic analysis

Stages	Procedures	Chapters
Entry	Formulation of research questions and identification of appropriate online communities for a study.	Introduction Methodology
Data collection	Verbatim copy from the computer-mediated communications of online community members and observations of the community and its members, interactions and meanings.	Data collection
Analysis and interpretation	Classification, coding analysis and contextualization of communicative acts.	Findings and Analysis Discussion

Reproduced from Kozinets, 2010

Herring (2004) warned this model is well suited for "analyzing and comparing discrete online phenomena, and for revealing systematic regularities in discourse use", but challenging in analyzing content quantitatively. The process of counting could "distort" the analysis of "complex, interacting, ambiguous or scalar phenomena", forcing them to be classified artificially into categories (Herring, 2004: p. 25). This will be considered for the Phase One stage in the Finding chapter - to be explained in section 3.2.3. It includes analyzing the shared history, purpose, culture, norms, in addition to the emergence of roles, hierarchy, governance, rituals, etc. In other words, netnography was the right technique to study online interactive behaviours (Stommel, 2008).

Researchers using netnography are also expected to be embedded into the online culture (Kozinet, 2010). Such participation would have included a planning stage to frame how I would have represented myself, how I would have interacted with Space Decentral's members, and how I would have managed the "disruption" created by my interactions with the communities or cultures I am studying. I introduced myself to the main members in the Spring of 2018. I reached out to Suzi Bianco and Yalda Mousavinia by email with the generic Space Decentral address. They didn't reply. Then, later at the end of the summer of 2018, I reached out to them via personal emails shared on the Riot channel. In my messages, I introduced myself and talked about my research project; however, I didn't get any response. At the end

of 2018, I abandoned the idea of a more direct research technique such as interviews, and focused mostly on the interactions as an observer. As a result, even though I wasn't "embedded into the online culture" as proposed by Kozinet, I still had access to their files on Space Decentral's website, in addition to their forums and online discussions, which helped investigate this explorative case study.

3.2.2 The process of structuring the data

The first objective is to identify the most important co-creation activities from a virtual organization. This meant gathering data from discussions members of Space Decentral got involved in. The obvious platform was Riot, Space Decentral's most active platform. Gathering the data had to be structured in some way to assess the co-creation component. A two-step process was therefore introduced to classify the information and create common themes framed in a co-creation perspective. This is where Piller and West's (2014) four process stages for co-creation projects were introduced. They are: Defining; Finding Participants; Collaborating; and, Leveraging - each with their own definitions and activities. (Table 3.5) This will be Phase One, out of two.

Table 3.5 - A process model for co-creation projects

PROCESS STAGE	KEY ACTIVITIES
Defining	- Problem formulation - Institutions and rules - Resource allocation and strategic commitment
Finding participants	- Identifying participants with right characteristics - Motivating and retaining a critical mass of collaborators - Selecting the right participants
Collaborating	- Governance of the collaboration process: organizing, monitoring, policing - Interaction platform and other tools - Openness of firm attitudes, structure and processes
Leveraging	- Integrating external knowledge - Commercializing the knowledge through products and services

Reproduced from Piller and West, 2014

3.2.3 Phase One & Phase Two

As indicated, the data obtained using the netnography technique was analyzed in two phases. The first one will focus mainly on structuring the conversations that occurred on the Riot platform between January 2018 and December 2019, based on Piller and West's framework. The usage of Riot for this exercise is explained by the fact that most Space Decentral's conversations happened on this platform throughout the research period. Phase One will include as well the analysis of the information found in the Blog and the Discussion Forum that are related to the two main initiatives or pilot projects

supported by members of Space Decentral, which are the Space Mission Activation Process (SMAP) and Coral. However, I will not use Piller and West co-creation framework to classify that information.

Phase Two was geared towards bringing together governance, decision-making and policy-oriented insights. This was led by the content of Space Decentral's White Paper and the Governance Paper. Both documents contained the core of Space Decentral's expected mandate, activities, and blockchain applications to be developed. Furthermore, collaborators, networks and organizations that are mentioned in these documents from 2018 were useful to give the research more depth on the scope of Space Decentral's network and the blockchain movement in general. This perspective was complemented with reports from national and international organizations that have covered the emergence of online collaborative tools within organizations, the intangible economy and space policies. Table 3.6 shows a summary of the Phase One and Two approach, with their link to the

Table 3.6 - Summary of Phase One and Phase Two

PHASE	SUMMARY & LINK TO RESEARCH OBJECTIVES
Phase One	**Summary:** Calculate the number of conversations among Space Decentral members related to one of the four co-creation stages of Piller and West co-creation framework on Riot, with complementary information from other platforms and the website related to SMAP and Coral. **Research Objective:** Identify the most important co-creation activities from a virtual organization.
Phase Two	**Summary:** Analyze data related to Space Decentral planned activities and roadmap found in the White and Governance Paper. Capture complementary insights from a policy point of view from reports of national and international organizations not directly linked to Space Decentral's network. **Research Objective:** Define the scope of the open source culture of Space Decentral and explore how it influences aspects of governance and knowledge management.

3.3 The data

3.3.1 Environment scan: Space Decentral's members and their online collaboration tools

Members of Space Decentral

Space Decentral is a virtual organization with a mission to use online collaborative tools to co-create space projects with its members and the public. As indicated earlier, over the period of the research, from January 2018 to December 2019, members of Space Decentral also founded Autark. The new

organization's mandate was "to serve organizations that operate with the transparency and participatory spirit of open-source projects, with the efficacy and scale of a transnational enterprise" (Autark; retrieved in February, 2020). The objective was to develop blockchain applications; the Open Enterprise. However, due to the legal issue with Aragon in early 2020, both Space Decentral and Autark websites were no longer accessible in the summer of 2020, but the Open Enterprise webpage on Autark remains live as of November 2021. [12] Table 3.7 shows the evolution of Space Decentral's core team, from the time they created Space Cooperative to the creation of Autark somewhere in the fall of 2018.

Table 3.7 - Space Decentral vs Autark

Space Decentral Foundation - February 2018	**Autark Foundation - End of 2018**
https://spacedecentral.net/team Suzi Bianco Dr. Marc M. Cohen Sean Marquez Yalda Mousavinia Giulio Prisco Kevin Siegler Radek Zasiadczuk Paolo Tasca Brent Sherwood J. Simmons, Ph.D. **New members:** Vanessa Pepe Patrick Donovan Arthur Lunn Otto Garcia	https://www.autark.xyz/ Yalda Mousavinia Arthur Lunn Kevin Siegler Otto Garcia Radek Zasiadczuk **New members:** Chad Ostrowski Javier Alaves Ola Kohut Emilio Silva Schlenker Peter Phillips

Source: https://spacedecentral.net

Online collaborative tools

Between January 2018 and the end of December 2019, members of the Space Decentral interacted significantly with participants on various online collaborative tools, which also include social media platforms. Space Decentral had a Blog (on Medium), a Forum (embedded in the website), and a Chat platform (Riot), in addition to being connected to mainstream social media platforms such as Facebook, Twitter, Youtube, and Github. Also captured were documents / webpages related to the Maximum Jailbreak newsletter, in addition to the Space Mission Activation Process (SMAP) and the Coral initiatives, which had their own sections on the website. Overall, Table 3.8 illustrates the type of data gathered, the source and number of entries.

[12] Source: https://autark.gitbook.io/open-enterprise/ as of November 12, 2021.

Table 3.8 - Data linked to Space Decentral organization

Data Type	Sources
Conversation-related and other social media platforms	- Riot (102 single replies or broader threads with multiple exchanges over multiple days or weeks) - Discussion Forum (68 single replies or broader threads with multiple exchanges over multiple days or weeks) - Medium / Blog section (21 articles) - Github - Facebook - Twitter - Youtube (three community meetings and nine presentations from members of Space Decentral at various conferences)
Space Decentral-related information	- Maximum Jailbreak (19 articles) - Documentation related to Space Mission Activation Process - Documentation related to Coral (Space Decentral's Lunar Program)

The conversation platform - Riot

The only platform with sustained engagement was Riot. However, when you create an account on Riot, it allows the usage of a pseudonym. Many participants used their real names, others did not. In some cases, it made the identification of each contributor and its connection with Space Decentral difficult. Nevertheless, pseudonyms were changed into generic ones (SD_user1, SD_user2, SD_user1, …) to protect the anonymity and confidentiality of all participants, including founding members of Space Decentral.

The entries on Riot from January 2018 to December 2019 gave a good picture of the most important co-creation activities among the Space Decentral's community. They were used to define the most discussed stages of co-creation, based on Piller and West's (2014) framework (see Table 3.5). These conversations were central to craft a comprehensive ranking of the level of interest per co-creation stage by Space Decentral's members. This is linked to the foundation of Space Decentral and the development of a blockchain infrastructure to support their operations, in addition to discussing what type of governing system interplanetary humans should have.

Each conversation was inserted in one of the four "key stages" and then classified into one activity under that co-creation stage. Table 3.9 highlights the "evaluation sheet" with questions I used to assess each entry, inspired by the work of Piller and West (2014).

Table 3.9: The assessment questionnaire

Key stage	How entries were evaluated
Defining	Are members talking about: - the definition of the problem(s) that Space Decentral is seeking to address? - institutions or rules of engagement? - broader appropriability rules of the society or economy? - the resources Space Decentral is willing to provide? - Space Decentral's level of strategic commitment to the collaboration process?
Finding Participants	Are members talking about: - searching for suitable external partners with the right knowledge? - the acquisition of such knowledge that will depend on understanding and strengthening the motivations of external partners to create and share their knowledge?
Collaborating	Are members talking about: - creating and implementing the processes for collaboration? - providing suitable tools (such as IT-enabled platforms) that facilitate the collaboration process? - the willingness of Space Decentral to open itself to external partners?
Exploiting	Are members talking about: - The suspicion and other resistance to externally sourced ideas? - structural barriers and intellectual property risks that impair collaboration? - commercialization processes, and evaluating their value?

Adapted from Piller and West (2014)

Tables 3.10 - and corresponding Tables 3.11, 3.12, 3.13 and 3.14 - provide the output of that data entry exercise on Riot per stages and activities. This was the main output of Phase One and the findings required to identify the most important co-creation activities from a virtual organization - the first research objective. It also shed light on how the "*crowd*", who were Space Decentral members, wanted to structure a space organization from the ground up. Taken together, you end up with Table 3.15 that ranks the co-creation activities based on the most discussed to the least. These quantitative results would guide Phase Two and the *Discussion* chapter.

Table 3.10 - Classification of entries on Riot based on Piller and West's (2014) four stages for co-creation projects

Key stages	Mentions
Collaborating	42
Defining	37
Leveraging	13
Finding participants	10

Table 3.11 - Number of mentions related to Collaborating

Key activities of Collaborating	Mentions
Governance of the collaboration process: organizing, monitoring and policing	21
Interaction platform and other tools	16
Openness of firm attitudes, structure and processes	5

Table 3.12 - Number of mentions related to Defining

Key activities of Defining	Mentions
Problem formulation	10
Institutions and rules: including contract terms, IP	14
Resource allocation and strategic commitment	13

Table 3.13 - Number of mentions related to Leveraging

Key activities of Leveraging	Mentions
Integrating external knowledge	11
Commercializing the knowledge through products and services	1

Table 3.14 - Number of mentions related to Finding Participants

Key activities of Finding Participants	Mentions
Identifying participants with right characteristics	5
Motivating and retaining a critical mass of collaborators	6
Selecting the right participants	0

Table 3.15 - Piller and West's co-creation activities, ranked, based on entries from the Riot platform from January 2018 to December 2019

1. Governance of the collaboration process: organizing, monitoring, policing
2. Interaction platform and other tools
3. Institutions and rules: including contract terms, IP
4. Resource allocation and strategic commitment
5. Identifying participants with right characteristics
6. Motivating and retaining a critical mass of collaborators
7. Integrating external knowledge
8. Problem formulation
9. Openness of firm attitudes, structure and processes
10. Commercializing the knowledge through products and services
11. Selecting the right participants

The conversation platform - the Blog and Discussion Forum

Beside Riot, another forum was the Blog (via the Medium website). It was also used by Space Decentral to communicate with their members and the general public. The type of articles found in the Blog section were news, historical features, and interviews with members of Space Decentral. Here are the authors and titles of the entries in the Blog section in chronological order, from the earliest to the oldest. (Table 3.16)

Table 3.16 - Articles on the Blog section (Medium platform)

Title	Date
Space Decentral spinoff Autark funded to develop next-gen collaboration software	Feb 4, 2019
Maximum Jailbreak is live!	Jan 11, 2019
Space Decentral's SMAP 2019 deadline approaching	Jan 4, 2019
1969–2019: Back to the Moon, forward to the Moon	Dec 28, 2018

Chang'e 4 brings back some of the Christmas magic of Apollo 8	Dec 21, 2018
SMAP 2019 — an interview with Mikkel Haaheim, one of the participants	Dec 14, 2018
The meek will inherit the Earth. The rest of us are going to the stars	Dec 7, 2018
Coral — November 2018 Update	Nov 30, 2018
Coral Interviews — Carlos Gonzalez-Rivera	Nov 23, 2018
Potential roadmap for the Coral program	Nov 16, 2018
Coral Team — John Paterson	Oct 5, 2018
Space Mission Activation Process: October 2018 Update	Oct 12, 2018
The official terms for Space Decentral's pilot missions	Sep 19, 2018
Initial mission ideas for Space Decentral's SMAP —From the Moon & Mars to Vertical Earth Farms	Aug 10, 2018
Space Mission Activation Process	Jun 20, 2018
Bringing people together to contribute to humanity's drive to explore	Jun 8, 2018
Asteroids, orbital space habitats, and what we give up and leave behind when living in space	Apr 25, 2018
Craig Beasley wants to go Outbound — to Space	Mar 18, 2018
My name is Brayden DeVito and I am a Manufacturer of Space hardware	Mar 3, 2018
My name is Suzi Bianco and I am an Architect of Space	Feb 24, 2018
Introducing myself: Giulio Prisco	Nov 21, 2017

The Discussion Forum section on Space Decentral's website was used as well to share ideas and comment on others' entries. Here are the posts classified by categories and subcategories, with the number of replies. (Table 3.17)

Table 3.17 - Posts and engagement level on the Discussion Forum

Categories	Subcategories	Number of entries or replies
Martian Spring	Martian Farms	13
Building Block	Software Development	13
Spaceship Earth	Low Earth Luxury Titanium Shores Power-4-All Space Cooperative Manufacturing Labs (SCML)	11
Lunar Odyssey	LunaVeR; Luna City; Coral	11
Operations	[none]	6
Maximum Jailbreak	[none]	5
Asteroids Commons	Solar Regatta	4
Black Sky	Kepler 452b	4
Space Engineering	[none]	1
Marketing and Design	[none]	0
Strategy	[none]	0

The conversation platform - the mainstream social media

Online collaborative tools had to include social media, such as Twitter, Facebook and others. In May 2019, a quick assessment of Space Decentral's mainstream social media accounts was undertaken in order to define the value of adding this data into the investigation. The accounts of both Space Decentral and its members were analyzed by using the statistics communicated by the platforms in their members' section. Twitter clearly indicates the number of followers, followings, and messages. Github provides similar data. In the end, seeing the lack of engagement on Space Decentral's Twitter account, compared to personal ones from each member, I decided to not pursue that direction. As for Github, it was included in the analysis only to monitor activities related to the SMAP and Coral initiatives, in addition to its purpose related to the blockchain application called Open Enterprise. (Table 3.18)

Table 3.18 - Engagement statistics from Space Decentral core team on Twitter and Github[13]

	Space Decentral	Yalda Mousavinia	Suzi Bianco	Vanessa Pepe	Patrick Donovan	Radek Zasiadczuk	Kevin Siegler	Giulio Prisco	Arthur Lunn	Otto Garcia
Twitter										
Messages	101	1,360	52	268	n/a	n/a	n/a	n/a	n/a	1,139
Following	23	601	63	621	n/a	n/a	n/a	n/a	n/a	4,173
Followers	475	1329	14	225	n/a	n/a	n/a	n/a	n/a	1,366
Github										
Contributions	n/a	823	n/a	n/a	106	384	458	n/a	699	1139

Besides Twitter and Github, members of Space Decentral also had uneven engagement statistics on Youtube and Facebook. For instance, Space Decentral's Youtube account had only three videos of their community meetings (February, March and April 2018). On their Facebook account, their statistics were similar to Twitter. In the end, for Phase One, it was decided to focus mainly on Riot to identify the most important co-creation activities in a more structured way, with complementary perspectives from the Discussion Forum and the Blog that help frame the two pilot projects of Space Decentral: Space Mission Activation Process and Coral.

The vision documents

For Phase Two, table 3.19 highlights the scope of the documents that were available on Space Decentral's website. The White Paper and the Governance Paper are the core references to the analysis for Phase Two. Together, they led the research and helped understand its connection with Aragon, the entity supporting Space Decentral financially in the development of a blockchain platform for the creation of a Decentralized Autonomous Organisation (DAO).

Table 3.19 - Data linked to Space Decentral's White and Governance papers

Data Type	Sources
Documents	**Space Decentral** - Governance - White Paper **Aragon** - Aragon Planning Application - White Paper - Aragon Roadmap

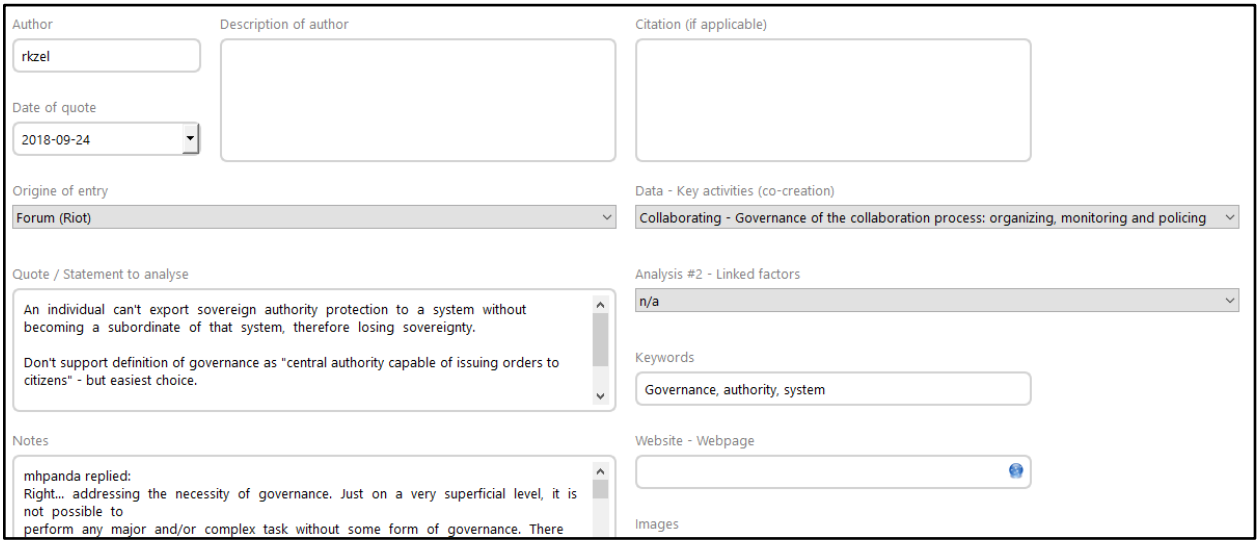
[13] Retrieved in May 2019.

Phase Two will also pull perspectives from national and international organizations which offer a valuable view for the public sector on policies related to the growing “online” and “decentralized” organizational trends, its connection with the intangible economy, the open source culture and its impact on the space sector using co-creation applications to foster innovations. Overall, these documents provided insights to the second research objective of the thesis, which was to define the scope of the open source culture of Space Decentral and explore how it influences aspects of governance and knowledge management.

3.3.3 Data analytical platforms

Lastly, the coding was enabled by the Mendeley Desktop and Symphytum software. They were both free software with enough positive comments and easy to set up. Based on its webpage on Github, Symphytum is a “free and open-source personal database software”. [14] It was very useful to easily input the various types of data that were captured throughout 2018 and 2019 on Riot, such as Author, Description of author, Origin of entry, Date of quote, Quote, Data / Key activities linked to Piller and West co-creation framework, and keywords. I used the “Notes” section to add the replies triggered by the Author’s quote. (Figure 3.20)

Figure 3.20 - Symphytum screen



The Mendeley Desktop application was, I have to admit, quite amazing. Based on the website, it allows the creation and organization of personal libraries (articles, PDFs, etc.) with a strong search function. It also lets you save the libraries in the cloud, and can pull citations. [15] I was able to classify articles in folders and use the search function to bring sense to various research. This tool was very useful for the literature review.

[14] Source: https://github.com/giowck/symphytum/blob/master/README.md#introduction
[15] Source: https://www.mendeley.com/reference-management/mendeley-desktop

3.4 What's next

In summary, the *Case Description and Methodology* chapter highlighted why Space Decentral was selected as an explorative case study, with additional information on the outcome of their partnership with Aragon which led to the interruption of their activities. The chapter then communicates the research period and what was included in the data collection exercise, with information on the tools used to collect, store and analyze the data.

The upcoming *Findings* chapter is divided into two parts (Phase One and Phase Two). Phase One synthesizes data from conversations found on the Riot platform based on the co-creation framework from Piller and West from 2014. Phase One also focuses on data found in the Blog and the Discussion Forum that are related to the two main initiatives or pilot projects supported by members of Space Decentral, which are the Space Mission Activation Process (SMAP) and Coral. The vision documents (the White Paper and the Governance Paper) were analyzed as part of Phase Two, along with policy documents related to the open source phenomena. The *Findings* chapter tells the story of individuals with very good intentions of developing a decentralized space agency. Their story will help look into the first two research questions: 1) Identify the most important co-creation activities from a virtual organization; and 2) Define the scope of the open source culture of Space Decentral and explore how it influences aspects of governance and knowledge management. They unfortunately ended up having to abandon their vision for reasons to be explored in the *Findings* chapter where we will also look into the last research question: the gaps in managing activities collaboratively within virtual organizations using online tools.

4. Findings

This research project aims to find out how online collaborative tools foster co-creation activities within virtual organizations. As a reminder, the scope of Space Decentral as a virtual organization would be individuals who meet online, are recruited online, and then work together virtually most of the time. They might have met face-to-face at one point because of the proximity of members (i.e., many were from California) or at conferences; but most did not.

The *Findings* chapter is divided in two. Phase One focuses on structuring the conversations found on the Space Decentral's Riot platform between January 2018 and December 2019 using Frank Piller and Joel West's 2014 co-creation framework. These insights will be accompanied by additional conversations found on the Blog and the Discussion Forum linked to the two other initiatives of Space Decentral: the Space Mission Activation Process (SMAP) and Coral. Next, Phase Two focuses on Space Decentral's White Paper and the Governance Paper. These documents explain the core of Space Decentral's expected mandate, activities, and integration of online collaborative tools in their decentralized environment, in addition to blockchain-based applications.

It, however, should be noted that Space Decentral was able to create its blockchain application (Open Enterprise), but will never implement it. As a result, attention will be paid to the theoretical usage of such online collaborative tools based on the design elements and rationale communicated in their White and Governance papers, in addition to analyses from external sources, such as reports of organizations that have investigated blockchain technology, online collaborative tools and emerging decentralized organizations.

4.1 Phase One

The Phase One analysis is mostly focused on conversations found on Space Decentral's Riot platform to identify the most important co-creation activities from a virtual organization - the first research objective. Phase One is separated into two parts. The first one will aggregate the threads from Riot and classify them in one of the four co-creation stages. The second part of Phase One will pull the data from other conversation-type platforms; this time mostly related to Space Decentral's two key initiatives: the Space Mission Activation Process (SMAP) and Coral. This assessment will complete Space Decentral's preliminary assessment of how online organizations manage their co-creation activities differently than Piller and West's 2014 co-creation framework.

4.1.1 The conversations

The conversations (or threads) from the Riot platform are mostly pasted as-is and in a *chronological order* (when possible). That chronological narrative is relevant for the reader to understand the organic approach that influenced the design of a decentralized space agency from scratch, and the influence on the linearity of the co-creation framework developed by Piller and West in 2014. The names of the writers are highlighted in ***bold italic*** to help the reader throughout the exchanges.

All in all, section 4.1.1 could be called: let's collaborate first, on which platforms, and then work on the problems. As indicated by Table 3.10, members of Space Decentral have focused mostly on the *Collaborating* co-creation stage. In fact, this is what Piller and West (2014) considered the "heart" of their model on co-creation. *Collaborating* represents how firms collaborate with external partners - or users - in a relation of exchange of knowledge and benefits, which also include creating and implementing the processes for collaboration with the provision of suitable tools (IT-enabled platforms) to facilitate the process. Piller and West also mentioned that organizations during that stage "face the daunting challenge of selecting the most promising ideas from dozens or thousands of potential contributors". One such issue is the "risk of leakage of internal firm insights must be weighed against the new insights gained by empowering external collaborators" (p. 40-41).

4.1.1.1 The *governance of the collaboration process*

Considerable number of conversations related to governance was found. The "Governance of the collaboration process" activity is defined as the "structures and processes that allow the firm to stir, monitor, and police its value creation through collaborative efforts with external partners", which include the type of interactions and the scope of control that the organization provides to external co-creators (Piller and West, 2014: p. 45). But in a virtual organization, it is normal that interactive platforms were discussed with the same interest. In fact, Piller and West considered these interactive platforms and other tools as the "backbone of modern co-creation activities'' enabling "a broad collaboration with customers and other individuals at low transaction cost" (p. 45).

On Riot, the individual named ***SD_user3*** is one of the core members of Space Decentral. He was also the main participant with the most entries on the subject of "Governance of the collaboration process: organizing, monitoring and policing". The individual's optimism that humanity will become a multi-planetary species is evident, hence - from his perspective - the requirement for a decentralized and secured infrastructure for collaboration. ***SD_user3*** said he had been "working for a number of years on developing a 'grass roots' system for an emergent government that could one day serve as the foundation for an interplanetary government". In summary, ***SD_user3*** supports a set of universally accepted "principles" to base the authority of the governance structure. ***SD_user3*** then added that "the most important authority/function of governance is to enforce decisions to 'secure, develop, and preserve' the sovereign authority of the individual." He explained additional functions in a lengthy thread (over 600 words), and concluded that "the system of governance should encourage members to work together, and should help provide the tools necessary to do so". ***SD_user4*** replied to the very personal vision of ***SD_user3*.** He/she was also a core member of Space Decentral and suggested to "start with the 'Why' before answering 'How'. Why do we need governance?" She then said it was important to identify and classify the use cases, such as people living on the Moon or Mars, in order to design the governance structure, "rather than questioning whether it is needed at all." ***SD_user4*** then provided with a summary of her thoughts about governance and the motivation of the "residents" [her words] to remain within this type of system, which is "1) cooperate for safety and security (i.e., to survive - including protecting its inhabitants from itself); and, 2) ensure that its inhabitants see a point of living within its realms."

The question of a centralized authority and efficiency was brought up by ***SD_user6*** when he discussed which platforms to use. ***SD_user6*** talked about governance issues by saying that “one big centralized organism of governance should not be bogged down by power struggles resulting in poor performance, waste of resources, delays, etc.” He said that "decentralization is great, providing there is at least a protocol of communication (at the individual and group level) between various authority centers”. He specified that the communications network should be based on computing power instead of “unreliable human factors” - where he/she added a wink - “;)”.

SD_user4 hinted on the type of platforms to be used when he/she said that the “need for synchronization” is mistaken for the “need for a central authority” adding that “proper synchronization and a good feedback mechanism provide whoever has authority with relevant and immediate feedback”, making the need for central authority not necessary. ***SD_user3*** disagreed, saying “central authority allows a population to tie together resources that would not otherwise be available for large projects”. Also, he/she pointed out that a “code of law” and a “national electorate” can also be considered a central authority. ***SD_user7***, who commented for the first time on this thread, stressed the need for “contract enforcement”, a mechanism to hold people to agreements made while they were a member of the constituency”.

So far, it is clear that the governance discussion on Riot was not only on Space Decentral’s organization. Participants spent time defining the “territory” of these “residents” working under some kind of virtual authority like a “contract” - but not necessarily Space Decentral’s. Hence, it sounded more like they were creating a new society when humans would be in space, and how interactive computer-assisted platforms would make sure there is efficiency in decisions because humans can generate “waste” due to “unreliable human factors” and “power struggle”.

Additional conversations related to *Collaborating* led to the introduction of the *open source* concept for governance. For instance, ***SD_user3*** said that “the idea of an ‘open’ constituency suggests that this system could be agnostic to geography and function more like a political party or social organization”. ***SD_user5*** then compared the concept of “open” constituency as a mix of “a fairly middle-of-the-road republic with libertarian and/or classical liberal principles”. From his perspective, this was to be used to define the boundaries of government authority, and not only how it operates. ***SD_user3*** replied that governance is based on “constituency” and not “territory”. In this scenario, “residents could ‘opt-out’ of the authority [and] claim their personal sovereignty”. It should be noted that no information was provided as to what authority these “sovereign residents” would be under, if any.

Finally, on October 13, 2018, ***SD_user1*** reframed the conversations on governance towards the priorities of Space Decentral:

> ***SD_user1*** said: “Start simple - no need to introduce processes just for the sake of processes” (...) “Our core governance at the moment is related more toward the Space Mission Activation Process and curating missions - which you can read about in our SMAP [Space Mission Activation

Program] Guidelines. Our Governance Paper has some higher level decision-making frameworks outlined as well".

On another level, Space Decentral was dealing with a more space-related issue: international laws. ***SD_user8*** highlighted, in September 2018, major obstacles in terms of regulations. He/she said that "virtual space organizations have ITAR [International Traffic in Arms Regulations] to look at when building tangible items where rules across borders have an impact on the feasibility of missions." ***SD-user4*** also talked about the ITAR issue. He/she explained more in detail the challenges, saying "this means no development outside the USA for an open-source project, and even within the USA there might be a bunch of rules to follow. A lot of hassle. " Some options identified were if the hardware developed by Space Decentral would be found outside the United States, but "then it could be ITAR classified as soon as it reaches the [US] borders". In the end of that conversation, ***SD_user1*** stressed that the first step would be to think broadly: "Let's start testing and experimenting and then let the ideal solution emerge as time passes" - a message very similar to the one she wrote on October 13, 2018.

4.1.1.2 The *interaction platform activity*: between *Collaborating* and *Defining*

This brings the second most discussed topic on Riot: the *Interaction platform and other tools* activity for co-creation. Although under the *Collaborating* stage, the extent in which these platforms were used overlapped with the *Defining* co-creation stage. *Defining* is the launch of the co-creation process. Based on Piller and West (2014), the first step required for a co-creation activity is "to define the problem that it is seeking to address via engaging external partners in the co-creation effort" (p. 40) - thou called *Problem formulation*. From a Piller and West perspective, this is the first key activity. It is "to create a task description that can be used to attract external contributors - and also to think about the characteristics of such contributors" (p. 41).

For instance, in March 2018, ***SD_user2*** communicated to members on Riot how problem formulation should work. He/she defined the purpose of the Riot platform, and compared it with the Discussion Forum. He/she reiterated a message in May 2018, saying that the Riot platform was where "you drop ideas to chat and discuss and get people interested", and Github was to be used to vote on final submissions since they [Github] had "a better infrastructure for voting". Early 2019, ***SD_user2*** was, however, changing his/her mind. He/she was now encouraging the community to share and discuss proposals in the Discussion Forum section of the Space Decentral website instead (https://spacedecentral.net/forum). Although he/she said it "was not a superb tool", Space Decentral wanted to see that section grow and become "the birthplace of awesome projects." On the other hand, ***SD_user2*** didn't talk about which problems to tackle with which platforms.

SD_user1 proposed to work as well with the appropriate working group on the Discussion Forum instead of brainstorming on Riot. This is in line with a comment he/she shared in August 2018 saying that: "Riot is just not the best communication medium at the moment for such brainstorming, as it's also difficult to analyze an idea like this outside the greater context of the system". Related to the usage of visuals, she suggested capturing thoughts in a Google Document and focusing on engineering drawings instead of generic visuals.

In April 2019, another member (***SD_user9****)* pointed out that the purpose of the Riot channel to submit ideas was not clear. Later in June 2019, he/she asked "isn't it a bit late in the game to define roles and responsibilities, platform to use, in addition to strategies related to a PR [public relations] section linked to Space Decentral (i.e. Maximum Jailbreak [the newsletter project)?" ***SD_user8*** proposed that the Space Mission Activation Process (SMAP) should be used for ideation and defining high-level mission concepts, which didn't bring clarity to the question. That conversation didn't get any additional entries.

We also learned throughout 2018 and 2019 that Facebook and MeetUp were also used by the community to brainstorm ideas. Meetup is a platform designed to find and create local communities. Participants of the Space Decentral Riot channel shared policies/guidance documents to support the organization of local meetings. This is an indication that small groups of Space Decentral members were interested to meet in person. In April 2018, ***SD_user11*** shared a draft Meetup Guide to launch "Space Decentral Meetups worldwide". In June 2019, ***SD_user1*** created a "Space Decentral Community Sync" event on Facebook. He/she said it would be easier to invite people to the event and share it on social media. No updates or reports were shared on the outcome of these initiatives.

4.1.1.3 The Github way

The best example of the ambiguous role of the *interaction platform* selection activity in a co-creation environment is Github. In a few words, we can say that Github is a platform to foster software developer collaborations. It also influenced how Space Decentral was managing its activities. Members of Space Decentral talked about how to proceed with the platform and its task management function. ***SD_user5*** supported the idea of a "Github way" to create teams with specific roles such as Project Managers, Task Managers, Task Reviewers, Contributors, defining different permission for each team. However, ***SD_user4*** said that he/she had "access privilege" problems on Github, not being able to "close the issue" function for one particular project. ***SD_user4*** even admitted later that he/she didn't understand the interface as well. This led ***SD_user2*** telling ***SD_user4*** "to hold off on creating new tasks on Github right now" since the individuals managing Space Decentral's Github account were "in the middle of re-organizing our whole tasking strategy".

The usage of Github, where a large number of organizations use as well, began to influence Space Decentral governance decisions. Members noticed that similar organizations had developed interesting content, such as organizational governance structure papers and rules of engagement. For instance, ***SD_user8*** said he/she began to invest time in drafting bylaws for Space Decentral. He/she stated that he/she wanted to "borrow heavily from Aragon's Governance Proposal repository located on Github: https://github.com/aragon/AGPs" - the "Aragon Governance Proposals". However, ***SD_user8*** admitted later that the platform was more for software enhancements, and Github couldn't be used for improving governance models.

4.1.1.4 From openness of firm attitudes, structure and processes to intellectual property issues

Another direct overlapping example between the *Collaborating* and the *Defining* co-creation stages in a virtual organization is the relationship of the *Openness of firm attitudes, structure and processes* activity with the *Institutions and rules* one. For instance, the intention to move from a raw brainstorming environment on Riot to a more structured one, led to discussions on openness and transparency, in addition to intellectual property when developing products for one community under a contract signed with a particular organization. In October 2018, ***SD_user7*** talked about the challenge of retaining talent within the decentralized organization. He/She said that "iteration only matters if I am planning to stay inside the community", but that individual might just easily pick up and go to a new community after ripping off the first one". ***SD_user7*** then talks about the employee-employer relation in a system where contract enforcement is carried out by a third party. ***SD_user7*** says the employer cannot choose not to pay the employee who is doing his/her job, but the employee has the ability to leave the community. He/she says there is a need for some type of enforcement and a need for trust between the employee and employer. ***SD_user7*** adds that "the fact that one side of the agreement is an abstract entity/organization doesn't actually seem to make much of a difference." Interestingly, for an organization like Space Decentral that wanted to build a blockchain infrastructure to make individuals trust each other without the need of a central authority, no one commented how technology could create a trust environment between employee and employer.

This last comment illustrated the essence of the *Defining* stage, which encompasses a number of activities to tackle a range of issues, including the *Problem formulation* one. We also saw the way that platforms used during the *Collaborating* stage were now being questioned during the *Defining* co-creation stage. Members of Space Decentral didn't seem to agree on their relevance for the type of work Space Decentral was at, or where it was going towards. Overall, based on the discussions above, Space Decentral spent time "to determine the resources that it is willing to provide and, more broadly, its level of strategic commitment to the collaboration process" (Piller and West, 2014: p. 40), *vis-à-vis* the challenges ahead, such as more appropriate platforms to support space-related regulations and what platforms to use for to move beyond the brainstorming activity. They needed help. This is where the *Leveraging* stage begins.

4.1.1.5 Leveraging

Piller and West (2014) have defined *leveraging* as "integrating external knowledge" and "commercializing the knowledge through products and services'' (p. 40). The authors stated it is, however, complex. It depends on the nature of the contribution; some will generate ideas for further internal development, some will occur during the design of a product or service; others will come in to evaluate new offerings being examined before entering the market (p. 46). Piller and West (2014) highlighted as well the challenge to utilize co-creation to create radical innovations. From their perspective, radical innovation, either in the world or within the firm, could be done if the organization uses the right tools to help users "surface their unmet needs" (p. 46).

The Space Decentral community on Riot wanted to leverage its communities in various ways. But in the end, very little attention was paid to *Leveraging*. Members of the network proposed a few ideas to leverage external knowledge, infrastructure and science platforms to integrate to their organization. One such member is ***SD_user10*** who said that he/she had "direct access to the W.M. Keck Center of 3D printing" at the University of Texas at El Paso. ***SD_user10*** said he/she could "do a quick cost analysis (if feasible) compared to the list of companies that may be too pricey or overpriced", but confirmed that "the place is huge, has an incredible amount of research and testing, and I'm sure I can get any of us access in case we need it."

Other discussions focused on leveraging new platforms for Space Decentral's data management needs in a decentralized environment, with the expertise that came with them. These discussions occurred early in 2018. For instance, ***SD_user8*** shared that he/she "talked to the OpenMBEE developers" for "the view editor on mms 4.0". Based on the OpenMBEE website (OpenMBEE for Open Model Based Engineering Environment), the software "is an open source collaborative engineering system. It enables engineers to work in the language of their choice and share and document their work across other tools". [16] But ***SD_user8*** also indicated that "the data abstraction layer [of OpenMBEE] is heavily dependent on MongoDB, meaning any organization wanting to interchange with another database will have difficulties". MongoDB is a distributed data platform, similar to SQL. [17] He/she then confirmed that "this is partly by design, since MongoDB offers the most flexible database schema, but it's a concern that's righteously acknowledged".

Still about database platforms, ***SD_User3*** supported the utilization of a software called IPFS as a potential file storage system for Space Decentral. Based on their website, the InterPlanetary File System - or IPFS - is "a new protocol to develop a network as the Internet does, ensuring a connection, with or without being connected to the "traditional" Internet". [18] ***SD_User3*** seemed to have been investigating "a viable option for facilitating serialization of data between IPFS, Github, and Ethereum." ***SD_user1*** replied saying, "IPFS is the only way to preserve data without hosting your own data", but warned that one cannot rely on others to store their own mission critical data". His/her opinion is that long-term data storage and maintaining its integrity are a critical issue for the space sector. ***SD_user1*** asked the community on Riot if 5-10 years were to be considered, or 20 to 50 years or 50 to 10,000 years. He/she also wondered openly if only one platform would be sufficient, or if multiple ones were better, and how secure it should be or if the idea of an open source storage platform would be viable.

In April 2018, ***SD_user12*** reached out to the group to comment on the required data infrastructure with a quick summary on the needs of Space Decentral. I pasted the whole entry as-is considering its value for the *Discussion* chapter.

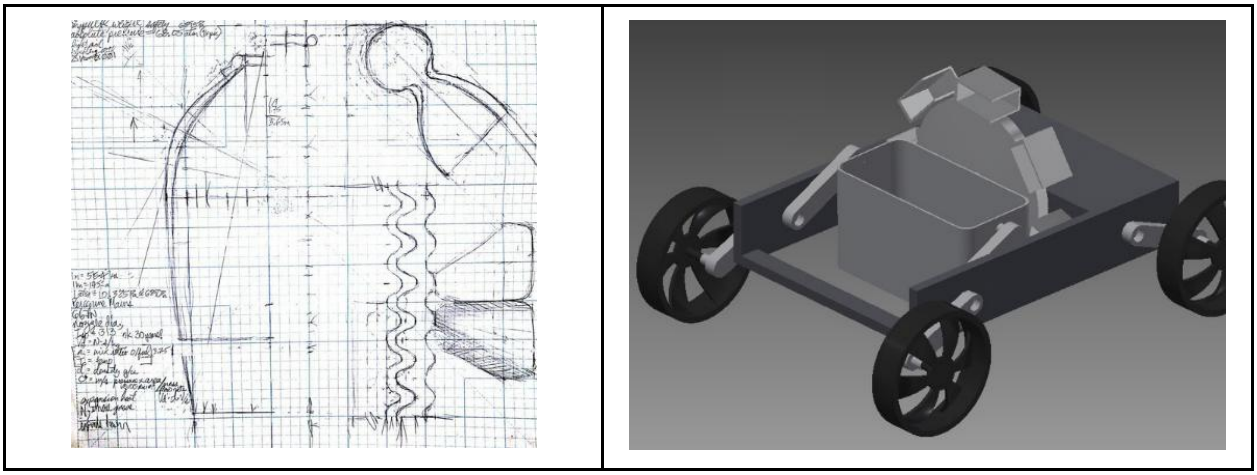
> ***SD_user12*** said: "One can never rely on public infrastructure to work 100% of the time." (...) "The engineering models/knowledge base are mission critical, because in the very near future,

[16] Source: https://www.openmbee.org/
[17] Source: https://www.mongodb.com/faq
[18] Source: https://ipfs.io/

when that data gets further than any one person can recall verbatim by memory (not totally impossible, but improbable) we will rely on the source(s) of that data to be true. That means that we will be relying on Operating Systems [such as Windows], file systems for data storage, network connectivity for access to those systems, and cryptographic algorithms that are not based on provable code, to give us reliable/secure access to those systems. A small one byte change in an algorithm is enough to make an issue that because it is believed to be reliable, that will allow for major issues when running calculations because a small part of a formula was changed." On the same day, a member pointed to the fact that NASA and ESA do not host all of their data on infrastructure connected to the Internet." ***SD_user1*** replied that, for now, "the use case we are discussing isn't mission-critical data, at least not to begin with. It's more open source / engineering models / knowledge base".

Lastly, there was only one (long) entry related to the "*Commercializing the knowledge through products and services*" activity under the *Leveraging* stage on Riot. It was related to the Coral initiative. ***SD_user1*** was leading the conversation related to NASA's 2018 Request for Information sent to companies for Commercial Moon Lander Services. Based on the NASA website, the published Request For Information was "to be used to gauge interest from the private/commercial space sector in building domestic lunar landers". The request asked for concepts related to small-scale cargo landers. [19] Members of Space Decentral had set up a "Landing Integration Group" Weekly Meeting via Riot. It was to submit a proposal to NASA. The participants shared sketches on the proposed rover to go on the lander (see one example in Figure 4.1).

Figure 4.1 - Proposed rover design to go on the lander for the Coral initiative



Source: Riot / Space Decentral

Based on the only Record of Discussion found related to these *Landing Integration Group* meetings, there were considerable exchanges on computing resources and software requirements. It led to very technical discussions. The best example is this entry below from ***SD_user13***, pasted as-is. It shows how specialized the language was and - very likely - the type of knowledge required to decipher the message.

[19] Source: https://www.nasaspaceflight.com/2018/03/nasa-courts-commercial-options-lunar-landers/

> ***SD_user13*** said: “Lander related, dust protection is hardshell, the spacesuit is way too heavy, 4000 series skin is 100g, 4.75m², vs suit with thermal, emf& rad over a kilogram, can fit with slots for the positioning & release clips. This seals electronics and rovers with doors, a radiant loss barrier for in transit with widest temp swings to 110 to -110C, can be charged to remove anodic currents, the suit used neoprene for rad. This idea can go into the RFIs [Request for Information]. Thermal contraction needs a really hard look at possible cold elastomers for maintaining the seals on anything, especially rovers with rotary joints, 6-leg needs them. Nights are best for working, radiant loss a main factor to handle.” (...) These should take 2 rovers 56 days with down time, skipping terminator events for sure, last task paving the road back. The paver is pick.n.place 3-minute bakes, excavating based on sided-augers that shoot it at 30° or so off 40m max in 5x5x50cm volume removals at 1/second for the 688m³/900yd³ in the core. The other has 2,50cm wands for walls and a gouge for corners with a pair of lasers for slicing the spines & sealing paver roofs and overhangs.”

As seen above, leveraging external knowledge, critical data storage infrastructure, and ensuring a satisfactory output of the collaborative efforts are challenges in themselves. As indicated by Piller and West, that stage consists of “integrating the innovation into the firm and then commercializing the innovation at market” (p. 46). It showed the type of discussions a space organization is exposed to in regards to space projects or data management, and the various inputs from stakeholders sharing their knowledge. This time, it was a group of amateurs who were doing what NASA engineers do, but solely through online collaborative tools. Gaps or unknowns were found in terms of bringing projects to fruition - hence a need to find the right expertise in more areas. This leads us to the conversations related to the fourth and last stage of co-creation: *Finding Participants*.

4.1.1.6 Finding participants

Piller and West (2014) define *Finding Participants* as the stage of locating participants “who have the relevant skills and interest to contribute to the firm’s goals” (p. 42); in fact, the authors said that “the first step of any collaboration is identifying participants”. Piller and West highlighted three types of approaches: open call (call for participation to an undefined, large network of external actors); selective open call (similar to open call, except there is a selective process based on expertise, location, etc.); and, open search (identify suitable actors within a large set of possible partners, and then explicitly invite then to join the co-creation activity). This stage is supposed to be linked to both the search for and the acquisition of knowledge, and “the typical individual participant is an expert for a specific domain or task, either because of his/her profession (i.e., industrial designers participating in ideation contests; a lab scientist participating in a technical contest), or his/her prior use of knowledge in a similar situation” (p. 43). Piller and West also stressed that success “will depend on understanding and strengthening the motivations of external partners to create and share their knowledge”.

This is, however, the least stage discussed on Riot and there wasn’t one comment related to the *Selecting the right participants* activity from members of the Space Decentral community. This may raise concerns about their capacity to recruit new members. In fact, the number of active users on Riot never

reached above 90 individuals. One example is the entry of ***SD_user14*** on May 3, 2019, who submitted two comments. They are expressing an interest in contributing to Space Decentral. He/she had been following Space Decentral since its announcement, and was "very interested in learning about [their] progress and challenges". That individual was also looking for help for the development of a "Federation initiative on the other side of the Atlantic" - i.e., the United States. He/she was actively involved in this Federation. Based on the website, the Federation is a Centre national d'études spatiales initiative that "aims to open up the world of space infrastructure to as many people as possible so that each citizen can anchor their action in a process of creating a future world". The Federation believed that "space knowledge and materials can be developed and produced in a collaborative, open and responsible manner". [20] It was supported by the Centre national d'études spatiales (CNES) which is the government agency responsible for shaping and implementing France's space policies in Europe. [21] The only person who replied to this invitation is ***SD_user10*** to give a very limited and disinterested update in bullet form (pasted below, as-is); no other info, explanation about acronyms, or guidance was shared by others.

SD_user10 said:

- ***SD_user8*** is working on an OpenMBEE
- ***SD_user2*** is cracking on the CONOPS
- ***SD_user15*** and ***SD_user16*** have been forced to go lone wolf on the Solar, and Laser Sintering reports, respectively. Help here is greatly appreciated.
- ***[Name of Space Decentral member]*** is on FMLA
- **SD_user1** and her team at work made this badass Planning Suite set up on Rinkeby.
- ***SD_user10*** on recruitment: Projet Manager and High Schooler.

On another topic, but still related to *Finding participants*, ***SD_user2*** informed the Riot community in January 2019 on where they were at in their process with participants and recruitment activities related to the Coral initiative. It was a very positive message, even though the Coral pilot project wouldn't be active a few months later.

> ***SD_user2*** said: "We had our second Coral meeting this week, and our team is still growing! This is our first collaborative mission, and I am so excited to see how the project will unfold. Right now we are in the foundational research phase, splitting up into specialized working groups of Mining, Process, Manufacturing, Assembly, Subsystems, and lastly Mission Engineering/Community. If you haven't signed up already and are interested in joining one of these working groups, please sign up for the Coral team (http://bit.ly/Coral-Signup) and we will notify you in advance when our next meeting occurs!)"

Beside Coral, the Maximum Jailbreak newsletter is another initiative mentioned on Riot, linked to the *Finding participants* stage. Maximum Jailbreak is a "space magazine" launched by Space Decentral in November 2018. Space Decentral was planning to make the online magazine "a virtual reality space for talks, events and informal gathering".[22] Nineteen articles were written in total. However, similar to

[20] Source: https://www.federation-openspacemakers.com/fr/decouvrir/a-propos/
[21] Source: https://cnes.fr/en/web/CNES-en/3773-about-cnes.php
[22] Source: https://maximumjailbreak.com/maximum-jailbreak-a-new-space-media-project/

Coral, this entry by ***SD_user3*** in September 2019 indicated that no tangible recruitment strategy had been put in place to support this initiative. ***SD_user3*** asked if Space Decentral was looking for a Maximum Jailbreak editor. He/she offered to help 5-10 hours per week. Pay was also discussed, since ***SD_user3*** was "also looking for new sources of revenue". He/she said it would "increase my contribution considerably if it results in a paid position". This was in response to ***SD_user9*** - apparently the unofficial editor and (unpaid) writer of Maximum Jailbreak - who questioned the existence of the magazine, "since no one has volunteered to be editor". ***SD_user9*** asked if "we could work out some kind of peer editing system?"

All in all, we saw Space Decentral losing ground in terms of engagement in the last half of 2019. For instance, ***SD_user9*** pointed out that "***SD_user1*** and the other space cooperative members are putting pretty much all of their effort into software development right now." (...) "As far as I've seen, they [*members of Space Decentral*] are not really supporting any of the organizations or websites that they have already developed, so I'm not sure if it would be more productive to try and restart Maximum Jailbreak right now, or wait until they are ready to launch the stuff that they are currently working on." ***SD_user9*** later added to this conversation that "[*Name of Space Decentral member - deleted for confidentiality*] was the editor of Maximum Jailbreak back in January [of 2019]" and that "he shot down a bunch of article ideas and then left". ***SD_user1***, who was also involved in other activities, responded that he/she would "try to start with taking on the editing role", but "was moving to Berlin, so nights don't work" and suggested regular meetings on the weekend instead.

In summary, there were no clear entries related to the *Selecting the right participants* activity; only on the *Identifying participants with right characteristics* and *Motivating and retaining a critical mass of collaborators* ones. Interestingly, the conversation indicated a strong relation between the ideation process of 2018, the actual implementation of activities and the pressure on resources available. We also witnessed the lack of responses from someone connected to an established space community in France with the Centre national d'études spatiales, issues related to the maintenance of a newsletter initiative, and lack of support to maintain Riot as a dynamic platform to engage the community, especially to motivate and retain participants.

4.1.1.7 Analytical summary

To conclude section 4.1.1, I provided an overview of what was discussed on Riot, a conversation platform used by Space Decentral to address various topics. I aggregated the threads and classified them in one of the four co-creation stages based on the number of entries for each. This mini-analysis led to a different sequence than the one established by Piller and West (2014). Governance was one very important topic, even though Space Decentral members were looking centuries in the future instead of assessing the appropriate governance structure for their virtual organization. Then, the *interactive platform* activity was found to be almost part of the *Collaborating* and *Defining* stages, depending on how the online collaborative tool was presented and integrated in the activities on Space Decentral. Github is the best example; it even influenced Space Decentral with what other organizations like Aragon had posted on their Github accounts.

The surprising element in this section is the lack of onboarding or engagement from Space Decentral to recruit new members. Even though their website had ways to subscribe to their newsletter, the initiative itself was not encouraged or developed sustainably months after being implemented. This is not because of lack of funding; we know that Aragon was funding Space Decentral at the same time to develop their blockchain application. This helped answer part of the first research question on identifying the most important co-creation activities from a virtual organization; we can almost assume that the least discussed activities might have been quite important for the space organization in their evolution from a startup to something more mature.

Following below is section 4.1.2, the second half of Phase One. It is related to the entries and documents related to the Space Mission Activation Process and Coral initiatives. These are the main pilot projects that Space Decentral launched in 2018 and 2019. If the conversations on Riot were unstructured, the data from the Blog and Discussion Forum, in addition to the documents related to the two initiatives, will provide more structure to the analysis and perspective on how members of Space Decentral managed their initiatives within a decentralized environment using online collaborative tools.

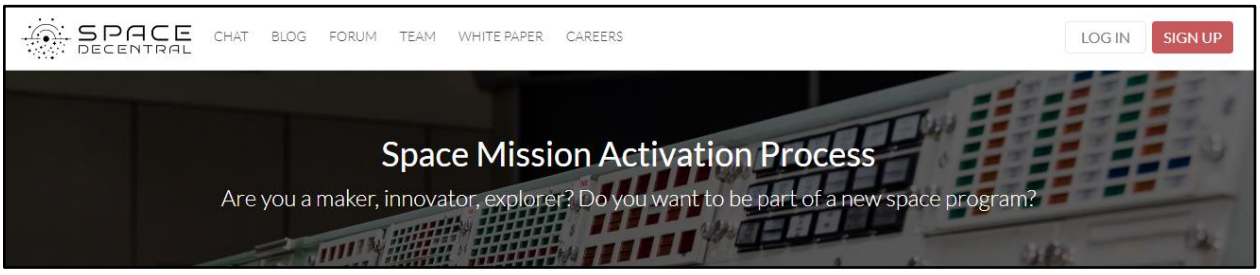
4.1.2 The Space Mission Activation Process and Coral initiatives

As seen above, the exchanges on Riot were used to classify and rank the number of interventions based on the four stages of Piller and West's co-creation framework, and their related co-creation activities. These discussions helped identify the most important co-creation activities from a virtual organization. They also contributed to the development and formalization of the two main Space Decentral's pilot initiatives: the Space Mission Activation Process (SMAP) and Coral. If SMAP is for the development of space-related projects in general, Coral was specifically to demonstrate in-situ resource utilization (ISRU) and 3D printing technologies on the Moon's surface using lunar regolith. Below is an assessment of the data found in the Blog, Discussion Forum, and overall Space Decentral's website related to SMAP and Coral. It will bring more substance to answer the research question on how online collaborative tools foster co-creation activities within virtual organizations.

4.1.2.1 The Space Mission Activation Process (SMAP) initiative

In 2018, a dedicated section on Space Decentral's website invited participants to submit ideas for the SMAP. The description of SMAP is communicated on the main page (Figure 4.6).

Figure 4.2 - The header of the Space Mission Activation Process



> "The Space Mission Activation Process (SMAP) is the pilot system for selecting Space Decentral's missions. While we have many interesting ideas being discussed in our forum, the activated missions will obtain an 'official' status, as they will be peer reviewed, vetted, and featured on spacedecentral.net. Once a proposal is activated as a pilot mission, the community collectively develops the mission, with contributions tracked using a suite of blockchain applications." [23]

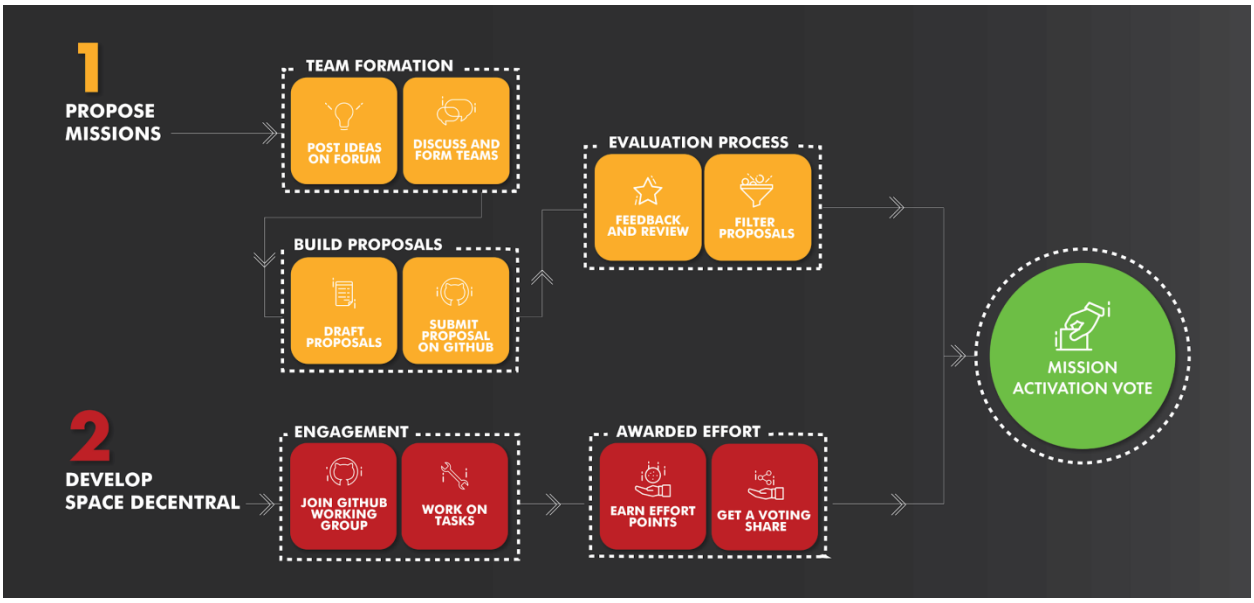
In a June 20, 2018, article in the Blog section, the author and lead of the SMAP project, shared the expectations in regards to the initiative and its process with visual illustrations. [24] This was to complement the SMAP webpage and the Rules and Guidelines document which had been published at about the same time, acting as the main references to communicate how Space Decentral envisioned the collaborative process. In essence, she stated that "while any idea proposed in the Space Decentral forum can be developed as a collaborative project with the community, the missions activated through this process will obtain an 'official' status". This meant that there would be "peer review" activities, which would filter the concept ideas submitted. Then, successful entries would be assigned to teams for further design in order to reach the objectives set. Although there was an expectation that the whole process would be managed through a blockchain infrastructure - as indicated on the webpage and the Governance paper – the author said this pilot project would be done through simpler tools, while making this process as open as possible.

The space sector being a highly R&D sector, the question of intellectual property (IP) was raised early. The same June 20, 2018, article mentioned the approach related to IP to be included in the SMAP process. It stated that "due to the collaborative and open nature of Space Decentral's space mission development, by submitting an idea and proposal, all of our community participants acknowledge and agree that the intellectual property ("IP") they contribute to this ecosystem must be open source". It meant that Space Decentral would be following the same open-source license as the General Public License format, a policy that allows users to have access, use and modify software for free. [25]

Essentially, members of the Space Decentral community were invited to participate in two types of activities: propose missions and/or support Space Decentral's activities (Figure 4.7). The "Evaluation process" and "Awarded effort" stages were to be integrated in a functional blockchain infrastructure, based on the Governance Paper.

[23] Space Mission Activation Process, 2019 - https://spacedecentral.net/smap - retrieved on February 21, 2020.
[24] Space Mission Activation Process, Space Decentral, 2018 - https://spacedecentral.net/docs/SMAP_Guidelines.pdf - Retieved on February 21, 2020.
[25] Source: https://www.gnu.org/licenses/gpl-faq.en.html#DoesFreeSoftwareMeanUsingTheGPL

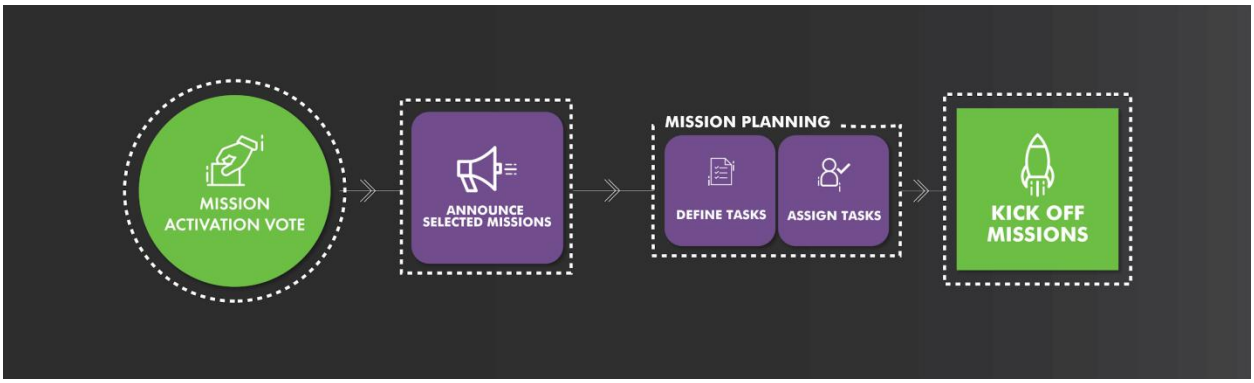
Figure 4.3 - How SMAP will evaluate submissions and Space Decentral members will evaluate them



Reproduced from: "Space Mission Activation Process" - retrieved on February 21, 2020

Based on this process, once the "Mission Activation Vote" stage is completed, the project reaches a "pilot status". Figure 4.8 shows the next steps of the SMAP initiative, which is the announcements of selected missions, the definition of tasks and their assignment. Again, it is Space Decentral's goal to support these stages with a suite of blockchain applications that track tasks, decisions and transactions.

Figure 4.4 - The Tasking Stage



Reproduced from: "Space Mission Activation Process" - retrieved on February 21, 2020

Overall, during 2018, a number of ideas for SMAP were shared and communicated via the Blog and the Discussion Forum (Table 4.9). Here are the ideas received, pasted *as-is*, from the article "Space Mission Activation Process: October 2018 Update" published on October 12, 2018. [26] No information was

[26] Space Mission Activation Process: October 2018 Update, October 12, 2018 - https://medium.com/spacedecentral/space-mission-activation-process-october-2018-update-94082c94bd62 - retrieved on March 14, 2020; however, it must be mentioned that this particular article appeared to have been frequently updated throughout the research period, leading to changes in the articles

communicated related to the criteria or selection process that led to their announcement on the website.

Table 4.5 - SMAP project ideas submitted

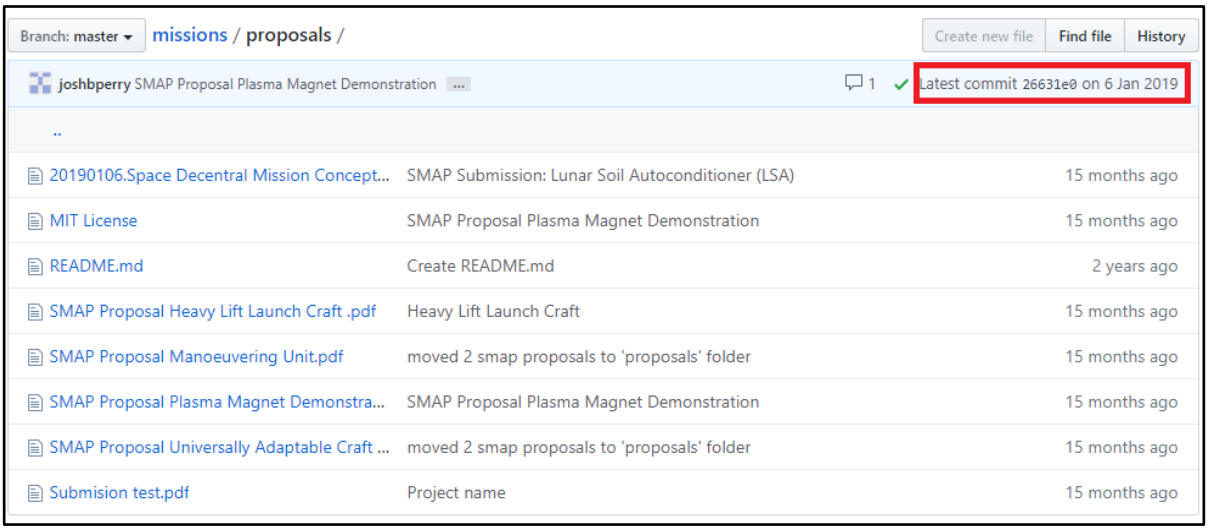
Title of project	Description
Lunar Soil Auto-Conditioner to Bootstrap a Farming Vitality on the Moon	Craig's proposal envisions the development of a technology to facilitate the generation of workable farming soil from Lunar regolith.
Maneuvering Unit	Mikkel proposes to design a "universal" maneuvering unit that can be arranged and combined into different configurations, according to the needs of each mission. Mikkel is also looking for team members for his other proposals.
On-orbit Servicing	Faz is proposing an On-orbit Servicing mission, with the objective of developing robotics for servicing satellites in LEO, MEO and GEO orbits, creating an infrastructure that will make space more affordable and less risky.
Plasma Magnet Technology Demonstration Mission	Josh Perry is proposing a technology demonstration mission for the Plasma Magnet propulsion concept using a cubesat, aiming to raise this technology's TRL to 7.
The UniHab Scale Model Project	Doug's proposal intends to design and build a scale model of an inflatable habitat, testing the technology and usability of such a construction technique.

Reproduced from: Space Mission Activation Process - October 2018 Update

Then, early 2019, it was found that the SMAP initiative had supposedly been cancelled. One indicator that supported this statement was found on Github. The SMAP "mission" folder had not been operational since January 2019 (Figure 4.10). [27]

[27] Github, Missions - https://github.com/spacedecentral/missions - retrieved on April 05, 2020.

Figure 4.6 - Space Mission Activation Process



It's only later, on the Riot platform, March 24, 2019, that ***SD_user9*** confirmed the status of SMAP. It was the last entry to mention SMAP before the end of December 2019. He/she mentioned that "SMAP was cancelled, essentially for lack of interest". He then added that he never believed that the "If you build it, they will come" strategy would have worked. On the other hand, if you look at the type of projects they intended to work on (Figure 4.10), we can only imagine how complex these seemed to be (Heavy Lift Launch Craft, Plasma Magnet Demonstration, …) Meanwhile, members of Space Decentral had to develop the blockchain applications and revive the Maximum Jailbreak newsletters that didn't have an editor.

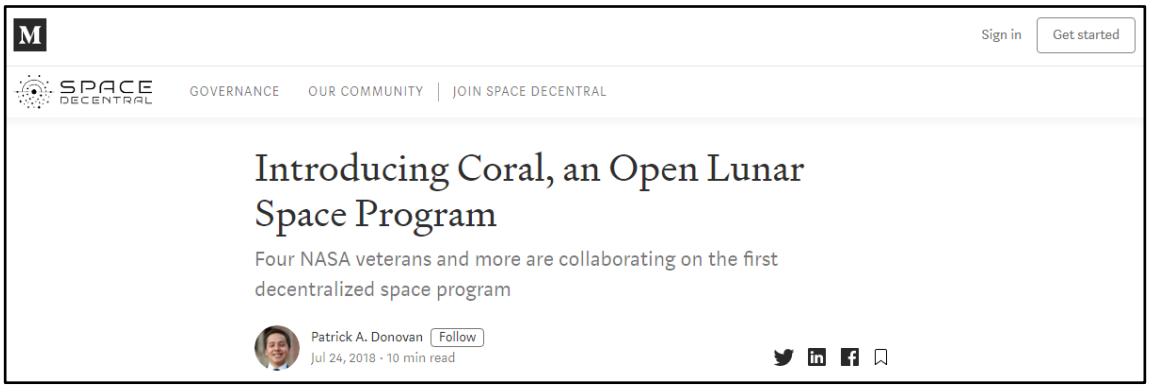
4.1.2.2 The Coral initiative

On July 24, 2018, ***Patrick Donovan*** introduced the Coral initiative (Figure 4.11), via the Blog section, branding it as "the first decentralized space program". He said:

> "While Space Cooperative is initially leading the program, it [Coral] is presented as a collaborative project for Space Decentral, the decentralized autonomous space agency. Together, we will lay out the open source processes for the world to progressively develop the essential capability for lunar ISRU [in situ resource utilization]. We will be leveraging blockchain technologies and processes invented by Aragon, Giveth, and Harbour Project, alongside our Planning App, to develop a citizen-led space program. In these early phases, tasks will be managed on Github, but later this year we will be going live on Aragon using an additional suite of apps developed specifically for this purpose." [28]

[28] Introducing Coral, an Open Lunar Space Program, July 24, 2020 - https://medium.com/spacedecentral/introducing-coral-an-open-lunar-space-program-702e293c9869 - Retrieved on March 15, 2020.

Figure 4.7 - The introduction of the Coral initiative

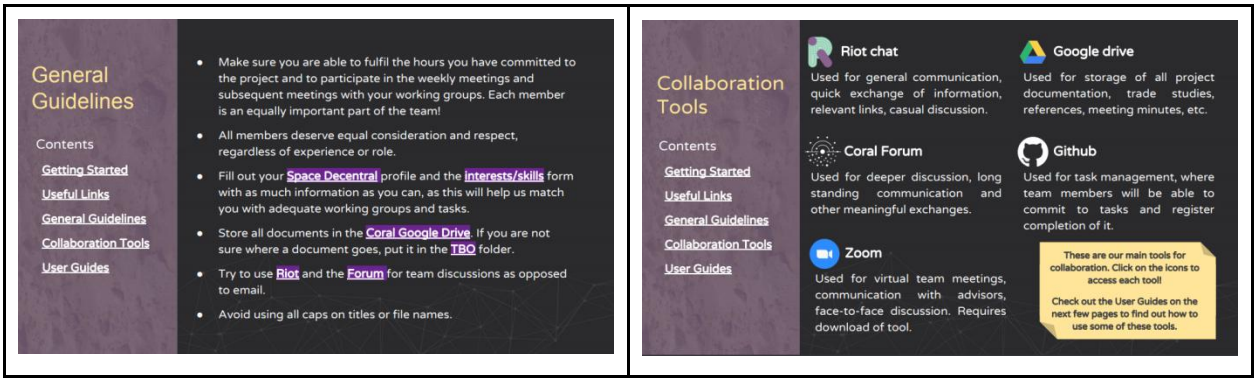


A more detailed description can be found on the Discussion Forum, which seemed to be the primary platform for the Coral initiative. It stated that "the purpose of the Coral program is to demonstrate and develop the ability to use lunar regolith to produce a prototype habitat in-situ". [29] The plan was to begin a concept study and then develop the technology into a series of phases to increase its readiness. Considering that the Coral initiative was to develop technology using lunar regolith (Moon sand), members of Space Decentral expected the construction of a prototype habitat structure on the lunar surface.

Space Decentral also created a handbook to explain the program. It provided the scope of the infrastructure to be developed, supported by community meetings, emphasizing also on the utilization of numerous online collaborative tools such as Riot, the Discussion Forum, Zoom, Google Drive, and Github, in addition to online forms to fill to better know who the interested participants were. [30] (Figure 4.12). It was basically the first time Space Decentral had mapped the online collaborative tools and explained how they were planning to use them.

Figure 4.8 - Coral initiative handbook

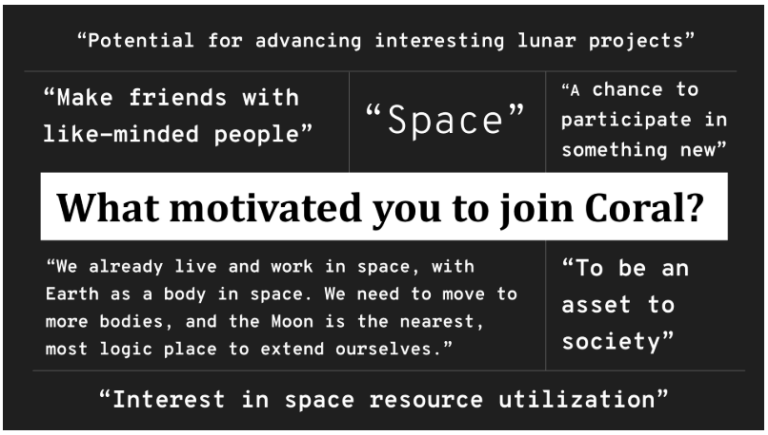
[29] Coral, 2018 - https://spacedecentral.net/programs/coral - retrieved on March 14, 2020.
[30] Coral Handbook - https://spacedecentral.net/docs/CoralHandbook.pdf - retrieved on March 15, 2020.



Source: Coral Handbook - retrieved on March 15, 2020

In a November 2018 article, the author from Space Decentral gave an update on the Coral program. Figure 4.13, that can be found in the article, illustrates the reasons why participants were interested in collaborating on the initiative, along with its challenges. No information is available about the number of respondents to this survey.

Figure 4.9 - Motivating reasons to participate to Coral



Source: Space Decentral, November 2018 Update

The article included challenges. They were laid out as follows:

- The mission started without a clear project definition;
- Coral mission used Github to define and manage tasks. The initial tasks were too open-ended and were defined in such a way where it was difficult to assess completion. Github's repository became more of an outline of what to study than an actual task list;
- It will be impossible to develop a space mission without hierarchy. But the goal is that the team members will decide when hierarchy is necessary, and that people who end up in leadership roles won't necessarily have more power than those at the lowest levels; and,
- Teamwide communication is another area that needs constant work and predictably - not all contributors are on the same page regarding communications tools.

In the end of the article, it stated that communications was the main issue:

> "Our forum is not yet able to offer the agility necessary for real-time discussions, so another alternative was to use the Riot chat. But not everyone is comfortable joining a group chat — so we end up having a few loose email threads — which become very confusing with large groups and constantly mutating discussions." (...) "We have yet to find the best strategy for team communication that caters to our demographics (team members are 20 to 70 years old), but we are constantly trying out new ideas, and are hoping to come to consensus (or build) the ideal communication tool in the future."

Similar to SMAP, the project was cancelled sometime during the summer of 2019. Here is a screen shot of the last few meetings and information on the Coral program. [31] The last meeting occurred on August 27, 2019 (Figure 4.14).

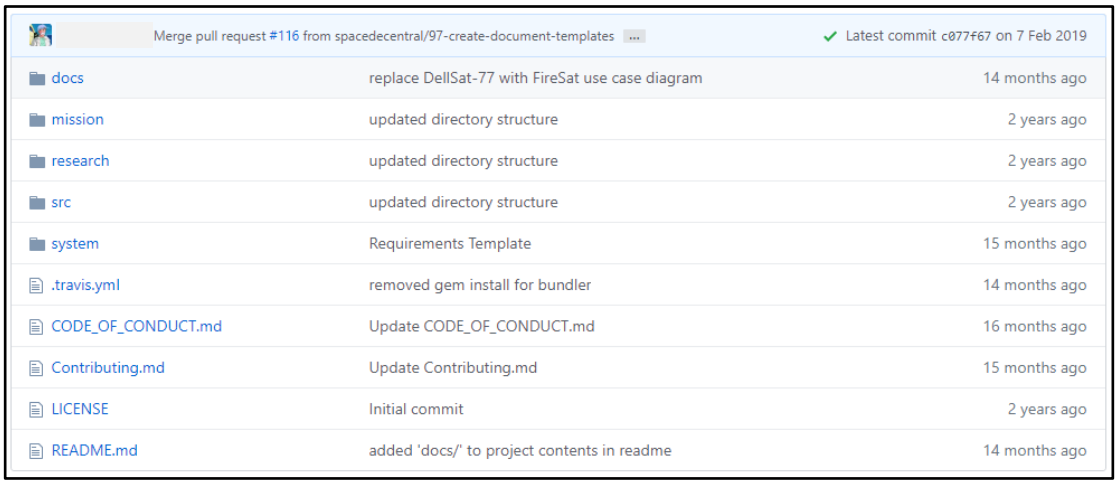
Figure 4.10 - Entries related to Coral meetings on Google Drive

Nom	Propriétaire	Dernière modification ↓	Taille du fichier
#25-2019-02-04	Suzana Bianco	6 févr. 2020 Suzana Bianco	–
#52-2019-08-27	Udit Kumar Sahoo	27 août 2019 Udit Kumar Sahoo	–
#48-2019-07-22	Suzana Bianco	25 juill. 2019 Suzana Bianco	–
#46-2019-07-08	Suzana Bianco	21 juill. 2019 Suzana Bianco	–
#47-2019-07-15	Suzana Bianco	21 juill. 2019 Suzana Bianco	–
#41-2019-06-03	Suzana Bianco	9 juin 2019 Suzana Bianco	–
#35-2019-04-15	Suzana Bianco	15 avr. 2019 Suzana Bianco	–
#33-2019-04-01	Suzana Bianco	2 avr. 2019 Suzana Bianco	–
#32-2019-03-25	Suzana Bianco	26 mars 2019 Suzana Bianco	–

Other signals on the lack of engagement about the Coral initiative since January 2019 were visible on Github. Under the Coral section, the most recent entry was "14 months ago" (when we last looked into the Github account), so approximately in February 2019 (Figure 4.15).

[31] Space Decentral was using Google Drive to share information on the meetings, decisions, and projects. Permission was required to access the data, which was granted to me in early 2020.

Figure 4.11 - Coral section on Github



Access to the Coral last meeting's Record of Discussions was given to the researcher. These minutes were not signed by someone in particular. The last meeting confirmed that the project had issues and announced it was terminating its pilot project and reflected on a modified version of the initiative to be launched at a later date. Here is the text in its entirely:

> "As with any decentralized and large-scale project, we also faced our fair share of hurdles. Coral doesn't have a client — we are doing this because we feel that it is one of the best ways to contribute to the development of space exploration. This means we are not financially backed. We, as humans, made it possible to achieve what Coral is currently. We pursued this project because of our mutual interest in space and for the sense of pride we get by contributing to space exploration."
>
> "However, the environment in which Coral started and in which it is operating now has changed drastically. Our most important assets are the people who contribute to this project. These people took time off their regular work and personal life to support their passion for space exploration. As a project, we were not able to reward people for their contribution that made a significant impact to them. People have commitments and responsibilities which take priorities over passion, and we have lost touch with some of our greatest contributors. We understand that and respect their decisions."
>
> "With this, as Coral, we want to change the way we operate and want to transform ourselves according to the current situation to support people who put their faith and passion in Coral. We are going to take the necessary steps to reshape Coral as an international start-up in the space manufacturing sector. With a vision to "be the first step to a new world", we want to be "the most valuable entity in the space manufacturing business". Our meeting no 52 focused around this topic and we plan for the next two months to give it our best shot."

Nevertheless, a October 2019 blog indicated that a blockchain application was envisioned to create more structure within Space Decentral's operations:

> "As we move on to a new phase, we are reviewing and refining our task management processes. The Planning group is meeting weekly to define a points system for the tasks that have somewhat been worked on, and future discussions will define values for the new tasks. These point values will be used next year once we take the Planning Suite being developed on Aragon live, and award contributors tokens for their work." [32]

Unfortunately, the legal actions against Autark[33] by Aragon at the end of 2019 interrupted the deployment and continued improvement of the *Planning App* - which was to be called Open Enterprise. This application will be addressed in Phase Two of the *Finding* chapter.

4.1.2.3 Analytical summary

The 4.1.2 section focused on two main Space Decentral's pilot initiatives: the Space Mission Activation Process (SMAP) and Coral. SMAP was for the development of space-related projects in general. Coral was specifically to demonstrate in-situ resource utilization (ISRU) and 3D printing technologies on the Moon's surface using lunar regolith. Unfortunately, neither was successful. The November 2018 article exposed some of the challenges or reasons behind these failures. In fact, these challenges are directly linked to the co-creation stages and key activities we spoke of in the first half of Phase One when we looked at the conversations on the Riot platforms. We had found that the most discussed co-creation stage to the least was *Collaborating*, then *Defining*, *Leveraging*, and *Finding participants*.

However, the online collaborative tools threw a wrench in the analysis. These findings bring forward the notion that online collaborative tools are not static or objective. They bring a strong brainstorming function, some level of engagement and transparency. On the other hand, some functions required by virtual organizations as they evolve seem to require "upgraded" online collaborative tools that look the same, but act differently, especially to support decisions (governance), management of projects (such as SMAP and Coral, including evaluation mechanisms), recruitment activities (and salaries distribution), and retention strategies (for both employees and volunteers). At one point, managers of a virtual organization or network must make a conscious decision about the type of changes required to "upgrade" these online tools with the organization as it evolves.

In summary, we learned about Space Decentral's intentions to contribute to the space sector, how they wanted to engage their community to contribute, how they wanted to select ideas and implement them by assigning teams. But they failed along the way for various reasons that have not been clearly communicated. There seems to be more and more evidence that Piller and West co-creation framework needs to be revised when a decentralized organization such as Space Decentral wants to work in a virtual environment. This will be addressed in the *Discussion* chapter when we review the gaps in managing activities collaboratively within virtual organizations. This brings us to the next section of the *Findings* chapter: the Phase Two assessment.

[32] https://medium.com/spacedecentral/coral-november-2018-update-1ed9baf32546

[33] Autark is Space Decentral's "sister" organization with a goal to maintain and improve its blockchain applications for decentralized projects.

4.2 Phase Two

In Phase One, the entries on Riot, the Blog and the Discussion Forum were captured, supported by documents produced for the two pilot initiatives: the Space Mission Activation Process (SMAP) and Coral. It gave an aggregate picture of the topics of interest of Space Decentral's community, the mechanisms put forward to manage space-related projects in a co-creation environment with online collaborative tools, the challenges met and solutions discussed. Unfortunately, as we have witnessed, these projects launched in 2018 didn't come to fruition. Nevertheless, we saw how Space Decentral intended to move forward to lower the barriers for space enthusiasts interested in working on space-related projects.

Phase Two will gather information on Space Decentral's activities between January 2018 and December 2019 focusing on formal documents, such as Space Decentral's White Paper and Governance Paper, in addition to reports related to the space sector and blockchain applications from relevant national and international organizations. This is to answer the second research objective: Define the scope of the open source culture of Space Decentral and explore how it influences aspects of governance and knowledge management. It is related to our goal to better understand how individuals working in a virtual organization can co-create effectively using online collaborative tools, while mitigating the challenges.

Phase Two will also introduce Autark, the short-lived organization founded by members of the Space Decentral project in the second half of 2019; which was briefly mentioned in Phase One. Autark's goal was to develop a suite of blockchain applications that the team of Space Decentral had been talking about on various platforms (i.e. The Planning App or - later - Open Enterprise). This blockchain infrastructure was to support Space Decentral activities, which will be described later. As a result, building on the findings of Phase One, Phase Two is divided into three recurring themes surrounding Space Decentral's literature and conversations: open source; governance and decisions; and, leveraging external knowledge.

4.2.1 Open source

Throughout Space Decentral's website and online collaborative tools, it was found that the concept of "open source" was being addressed extensively in various ways. As we saw in Phase One, members of Space Decentral were talking of a network of individuals living on the Moon or Mars as *an open constituency*, agnostic to geography, which would function like a political party or social organization. This is explained by the central position of the open source culture within Space Decentral's mission statement in the White Paper published mid-2018:

> "The Space Decentral Network seeks to make participation in such projects [space-related projects] more accessible by offering a suite of open source tools, data, and foundational knowledge. With a curated toolset, training material and a unified vision, being able to spend time working on our collective celestial dreams will no longer be a privilege, but a human right." (Space Decentral, White Paper: p. 6)

Furthermore, the Governance Paper of Space Decentral dedicates a whole chapter on open source development for projects such as software, hardware development, project plans, biological innovations, basic science, in addition to contributions to the knowledge base, long-term strategic plans and decadal surveys (Space Decentral, Governance Paper, 2018). If the White Paper and the Governance Paper are combined, both documents use the term "open" concept in the following areas, presented in Table 4.16:

Table 4.12 - Types of open source concepts in White Paper and Governance Paper

open source development	open source projects	open source tools
open source Hardware	open source space missions	open source roadmap
open source astrodynamics library	open source tasks	open source bounties
open source contributions		

One assumption of the origin of Space Decentral's very strong open culture engagement may reside in the *Planning App* proposal. Sometime in 2017 and early 2018, Space Decentral received $150 000 (US) from the Ethereum-based organization Aragon in 2018 to develop a blockchain-based management application. In fact, a 2020 article explaining the legal battle between Space Decentral with Aragon, suggested that two grants of "roughly $2.5M in funding vested over the course of multiple years" had been given to Space Decentral. [34]

4.2.1.1 The influence of Aragon

The Aragon community is very linked to the open source culture communicated by Space Decentral. Based on their website, the Aragon organisation "is an open-source, community-driven project with the mission to empower freedom by creating [blockchain] tools for decentralized organizations to thrive" (Aragon, About Us, 2020). [35] Its Manifesto states that the organization aims to "building free, libre, open source technology to allow the creation and management of decentralized organizations; experimenting with new governance models that comply with the Manifesto's values; and, creating a crypto-network for decentralized organizations to thrive" (Aragon, Manifesto, 2020). [36] In addition to being inspired by Aragon's governance paper on Github, both Aragon and Space Decentral were now focusing on developing blockchain applications to strengthen this open source culture.

Interestingly, open source is not explicitly found in OECD's "Blockchain Primer" report, which aims to explain the basics of the new technology. It only indicates that the openness of a blockchain application is dependent on the "permission" level the administrator wants to allow. On the one hand, it states that

[34] The Defiant (2020). Aragon Drama Pushes On-Chain Governance Idealists to the Meatspace. https://newsletter.thedefiant.io/p/corrected-aragon-drama-pushes-on.
[35] Source: https://wiki.aragon.org/about/what_is_aragon/ - Retrieved on July 25, 2020.
[36] Source: https://github.com/aragon/AGPs/blob/master/AGPs/AGP-0.md - Retrieved on July 25, 2020.

“public blockchains (like Bitcoin) are open for anyone to read and view [the registry of the people who own Bitcoin), while private blockchains can only be viewed by a chosen group of people” (OECD Blockchain Primer, 2018: p. 2).

Nevertheless, Space Decentral’s White Paper stressed they will “utilize blockchain technology to enable collaborative, transparent and self-directed action towards building the future of space exploration” (Space Decentral, 2018a: p. 4). It adds that “a suite of open source tools, data, and foundational knowledge” will enable this vision since “humankind lacks a network where participants can collectively govern, develop, and fund large-scale projects such as missions to the Moon or solving global challenges” (Space Decentral, 2018a: p. 8). In fact, the 2005 OECD report “Space 2030: Tackling society's challenges” supports the idea of a more open business environment in the space sector. It explains that “an open business environment at international level contributes to overall economic development by fostering a more efficient allocation of resources, by encouraging the introduction of new innovative products and services which can take advantage of a larger market base, and by facilitating the rapid diffusion of new technologies” (OECD, 2005: p. 265).

Actually, the OECD report suggested that “open standards” could help cut costs and foster the scalability of systems. Based on the report, these open standards “play a major role in the marketplace” by providing opportunities for economies of scale. That scaling capability is possible thanks to “compatibility” and “interoperability” of the equipment, which - based on the OECD report - strengthens competition among equipment manufacturers” (OECD, 2005: p. 313). From a Space Decentral point of view, these were good reasons to move forward with their business model. The output of the network supported by Aragon’s blockchain infrastructure included not only equipment, but also tools, data, and knowledge (Space Decentral, 2018a: p. 8). And as indicated in Phase One, under the *Leveraging* co-creation stage, topics like data infrastructure and its interoperability were recurrent discussions for members of Space Decentral.

4.2.1.2 Open source, intellectual property and data

This open source environment brings the question of intellectual property (IP). IP is a complex concept to describe in a co-creation setting. Piller and West (2014) wrote that IP has to be managed comprehensively in an open business environment. The traditional approach has always been managing IP through patents and licensing contracts. However, Piller and West noted that users working in such an environment must adopt a culture of “free revealing” or manage IP through “creative commons licenses” (Piller and West, 2014: p. 31).

Space Decentral communicated similar commitments towards building an open source culture, and its related policies on intellectual property. Their position can be found on the Space Mission Activation Process section of the website. The initiative - now cancelled, as it was mentioned - invited members to

submit "open-source action plans through a competitive 'request for proposals' process". [37] It also stated that the action plan must have an open source license: [38]

> "Space Decentral aims to engage the community's willingness to contribute useful, innovative ideas to our collective cause. With this in mind, all of our community participants acknowledge and agree that the intellectual property ("IP") they contribute to this ecosystem must be open source. This means something very specific: Any contributions of IP must be available with an open source license (such as the GPL - *General Public License*) so that such IP (a) can be used freely by the Space Decentral ecosystem's Participants and (b) will not in any instance be used to directly or indirectly obstruct, block or interfere with the use of the IP in projects, innovations and/or projects that this ecosystem was designed to promote and protect." [39] (Space Mission Activation Process Guidelines)

Considering the high interest of Space Decentral related to data, one can question how their business model would fund the infrastructure required to store, manage and create value with this data - while maintaining it open. The Chamber of Digital Commerce (2018) presented a report highlighting explicitly a range of patentable solutions related to data infrastructure (Table 4.13). The organization highlighted that "the U.S. Supreme Court has stated that 'anything under the sun' that is made by humans can be eligible for a utility patent. The subject matter to be patented does not need to be revolutionary or awe-inspiring. If the innovation can help do something better, faster, or more efficiently, then it is likely patent-eligible" (p. 7).

Table 4.13 - Patent and non-patent eligible innovations

Patent-eligible	Non-patentable
A process (including data manipulation by software)	Performing repetitive calculations
a machine (or structure)	Receiving, processing, and storing data
an article of manufacture;	Electronically scanning or extracting data from a physical document
a composition of matter	Electronic record keeping
any new and useful improvements to the above.	Automating menial tasks

[37] Space Decentral - https://spacedecentral.net/ - Retrieved on February 9, 2020.
[38] Space Mission Activation Process Guidelines - https://spacedecentral.net/docs/SMAP_Guidelines.pdf - Retrieved on February 9, 2020.
[39] Space Mission Activation Process Guidelines - https://spacedecentral.net/docs/SMAP_Guidelines.pdf - Retrieved on February 9, 2020.

	Receiving or transmitting data over a network (using the Internet to gather data)

Source: The Chamber of Digital Commerce, 2018

Even though Space Decentral, via its open source culture, seemed to be against restrictive intellectual property strategies, the Chamber of Digital Commerce was supporting them. It stated that an "IP strategy is important for open source projects, considering that the same businesses might have to compete among each other through the individual strengths of their respective IP portfolios that are proprietary and closed" (The Chamber of Digital Commerce, 2018). Besides, Space Decentral was moving forward in a highly competitive environment. IP issues were likely to become more prominent as the private sector plays an increasingly important role in the development of space assets. Furthermore, the OECD had found that "the proper, transparent and effective protection of intellectual property generated in the context of space activities is one of the most important legal issues for private entities interested in investing in space" (OECD, 2005: p. 181). It also quoted the World Intellectual Property Organisation who had observed that countries were unwilling to put aside their IP policies:

> "Although national intellectual property laws are relatively well harmonized, different national laws still apply different principles. Once a dispute arises, national laws regulate questions of international jurisdiction. Thus, a lack of a reliable international legal regime requires parties to negotiate intellectual property clauses in each international cooperation agreement, which may include, for example, issues of ownership, rights of use, rights of distribution and licensing of data, information capable of legal protection and confidentiality" (OECD, 2005: p. 182).

In summary, Space Decentral demonstrated a strong commitment towards enabling an open source culture and an open source business model using online collaborative tools; all while operating across numerous national laws. That culture was shared among its members and stakeholders, like Aragon. On the other hand, Space Decentral didn't seem to have developed a strong business model to generate revenue. The only known income was Aragon's funding / grant to develop the blockchain application. Also, how were they planning to fund space projects under SMAP and Coral, in addition to providing recurrent salaries to active members of the community? This question led to the topic of rewards and incentives to maintain an efficient level of engagement, strengthening co-creation activities, especially those related to the *Finding Participants* stage. The Blockchain Research Institute highlighted this issue in their report by stressing the importance of rewarding "the people who, in this open-source environment, are developing the source code of the core protocol even though they get no direct income or monetized gain from that work" (BRI, 2017: p. 25). The themes of rewards and incentives; engagement; and codes are linked and will be addressed under the "Governance and decisions" section below, while introducing new potential online collaborative tools: blockchain tokens and the Open Enterprise blockchain-based application.

4.2.2 Governance and decisions

As seen in Phase One, activities related to governance were the most discussed theme. It was also mentioned extensively in Space Decentral's White Paper and Governance Paper. The plan for the

members of the organization was to build momentum with mainstream online collaborative tools and later add their Aragon funded blockchain application to assist in governance and decision-making activities. The White Paper of Space Decentral explained that the organization will use tokens as both a cryptocurrency and a tool to represent privileges and rights within a network - similar to a membership card. Each transaction using a token would therefore be attached to a unique digital identifier and recorded on a ledger (i.e. the blockchain). The contribution-privilege-reward system is introduced in the Governance Paper. This was linked to their vision of enabling various "privileges" supported by the usage of tokens quantifying rewards:

> "With the advent of decentralized organizations, we can now experiment with new ways of automating privileges that tie those privileges directly to actual contributions. Space Decentral has decided to adopt this approach to automating privileges for the Membership class of the network. And while we support some projects that are not open source, for those projects that are open source, volunteers will be rewarded automatically for their contributions with enhanced privileges." (Space Decentral, 2018b: p. 2)

4.2.2.1 The tokens

The plan of Space Decentral was to use this online tool to streamline and coordinate workflows and decisions (Space Decentral, 2018a), similar to an enhanced Github application for tasking Space Decentral members on various projects, but also record non-programmer-related decisions. The plan mentioned the usage of two tokens, as shown in Table 4.14: one for governing the network (i.e., the Space Decentral Network token or SDN) and one for knowledge contributions to the network (i.e., the Faster Than Light token or FTL).

Table 4.14 - The two tokens of Space Decentral

Token	Description
The FTL token	The FTL are transferable tokens with a purpose to raise funds for "the development of the infrastructure and incentive structures necessary to facilitate decentralized space mission planning, peer review of solutions, and tools for distributed engineering on the Space Decentral Network". Its purposes are: have more influence on the Space Decentral program depending on the amount of FTL obtain; invest in open source projects and have governance rights; allow non-members to pay to submit proposals to be considered by Space Decentral; and, be used as a remuneration mechanism for members providing consulting services.
The SDN tokens	The SDN tokens are, on the other hand, non-transferable and used mainly as an accounting tool to measure contribution activity levels. They are minted by Space Decentral and allocated (i.e., not sold) against tasks and earned by contributors - similar to a reputation system.

	For instance, SDN tokens are intended to be allocated in exchange of software development tasks, including but not limited to decentralized apps, design, flight systems software, and tool development; contribute to the Space Decentral wiki, including cataloguing common knowledge for all projects in addition to project-specific knowledge bases; perform peer review on Space Decentral missions; and design and development of solutions that are merged into to the Space Decentral program.

Reproduced from Governance Paper, Space Decentral, 2018

Specifically, the reward mechanism of Space Decentral for participating members involved in their pilot projects (i.e.: SMAP and Coral) was linked to a voting mechanism using tokens. The Governance Paper explained that, under "Voting Privileges", members who actively participated in setting their policies and making decisions would have had a voting weight "based on average weekly contribution to open source projects" (Space Decentral, 2018b: p. 7). The level of the contribution and the number of rewards was expected to be measured with the data generated by token-led transactions.

Space Decentral's White Paper also described how the two tokens would have interacted. First, SDN tokens would have been allocated to open source tasks based on codes - or mathematical formulas - using dedicated applications via the Aragon-funded blockchain application. This would have allowed FTL rewards "to be distributed efficiently and fairly to collaborators" (Space Decentral, 2018a: p. 6). Each contribution from the members would have therefore been tracked with the SDN token and visible to anyone. For instance, the idea of a leaderboard is suggested. The plan was to post the top contributors being recognized, supported by the database on the blockchain - that decentralized Excel sheet, "adding an element of cooperative competition" (Space Decentral, 2018a: p. 6).

Piller and West (2014) supported the concept of "incentive and reward systems" since they "have been shown to be instrumental for successful exploitation, reinforcing the use of external learning" in co-creation activities (Piller and West, 2014: p. 47). Unfortunately, it is hard to grasp any further the scope of this token-led system, how it would have been implemented, what monetary value would have been associated for each task based on the type of services provided, and its impact on engagement. Very little specific or use case information was available, either on Space Decentral's website or on Riot. Without more data, assessing the tangible usage of tokens in virtual organizations as an effective reward mechanism was not possible.

4.2.2.2 Roles and responsibilities

Another theoretical usage of tokens was to classify members of the Space Decentral network into three types of stakeholders: Members, Explorers and Council. Each Space Decentral's stakeholder would have been granted "voting privileges" based on their contribution which would have created an ecosystem aimed at allocating "influence" based on a mathematical formula (or algorithm) to individuals who are active and engaged.

To visualize the scope of the governance system imagined by Space Decentral, it was important to paste their vision *as-is* in the next few pages to help the reader understand how complex it was, starting with Table 4.15 which describes the type of responsibility and what stakeholders would be expected to vote on. Space Decentral management expected that the continuing engagement would be secured through sets of rewards, or "bounties" in the form of a monetary value.

Table 4.15 - Voting privilege by proposal and stakeholders

Proposal	Stakeholders		
	Member	**Council**	**Explorer**
Determining project ideas to develop into Request for Proposal (RFPs)	**X**		
Determining % of FTL/SDN tokens to allocate to RFPs	**X**		
Updating network parameters	**X**		
Updating budget allocations of the Network	**X**		
Fund Nominate and elect Committee members	**X**		
Arbitration related to Committees, Builders, Affiliates	**X**		
Sensitive, high-level infrastructure decisions	**X**		
Determining best solutions to become validated for funding		**X**	
Arbitration related to Members		**X**	
Determining the higher-level space program			**X**

Reproduced from Governance Paper, Space Decentral, 2018

Table 4.16 illustrated the responsibilities for each stakeholder in relation to decision-making. Once this was coded in the blockchain application, the plan of Space Decentral was to invite these stakeholders - and non-members (aka: the public) - to "propose, debate, and implement worthy ideas", which a more detailed look on the process can be found in Table 4.17 - again pasted from the 2018 Governance Paper.

Table 4.16 - Project development: event sequence

#	Event	Stakeholders	Contract Calls
1	**Idea Sourcing** Community participants can propose	Anyone	Non-Members pay a fee [with tokens] to submit ideas

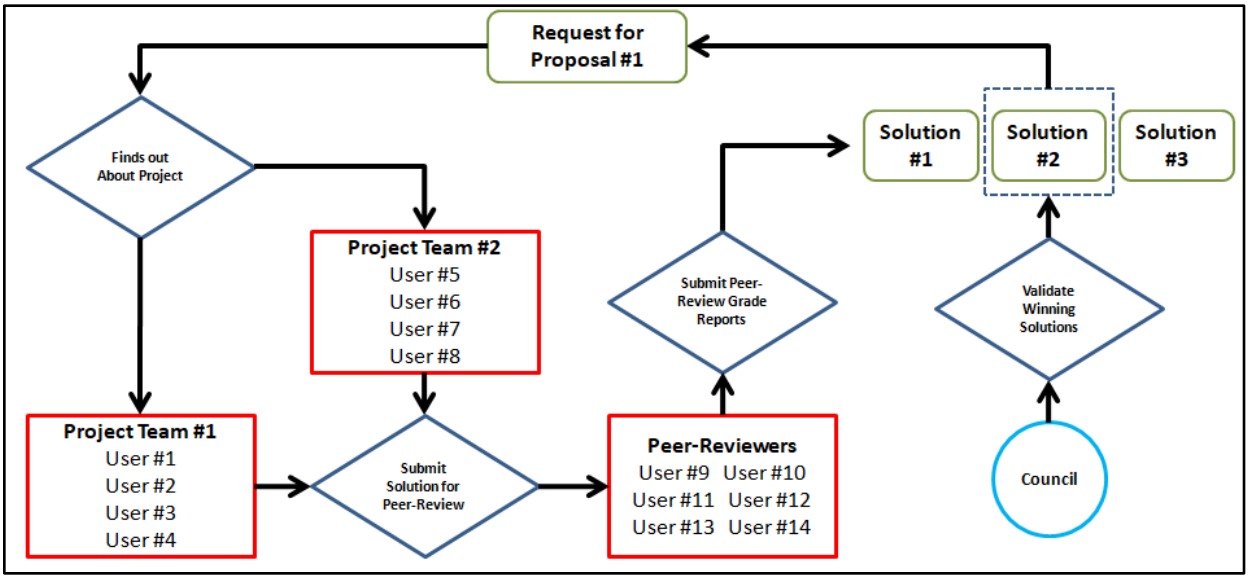
	different ideas to be considered for the Space Decentral program. These are not expected to be full solutions yet, but “ideas” that should be considered for the RFP process.		
2	**Idea Vetting** Members will review the ideas and the network’s signals. A Member vote will occur across the network to determine the highest-ranking ideas.	Members	
3	**Request for Proposal (RFP) Definition** An RFP is written per activated program/project. Bounty amounts are allocated per RFP. This period is expected to include internal debates amongst the stakeholders. It’s possible for multiple ideas to become consolidated into a single RFP.	Members, Council	Bounties are allocated per Request for Proposal
4	**Solution Sourcing** The RFPs are announced. Community participants form Project Teams, develop detailed proposals, and submit solutions to the RFPs.	Project Teams	Non-Members pay fee to submit solution
5	**Solution Peer Review** Peer review will occur for community-vetting of submitted solutions.	Members	
6	**Solution Vetting** The Council will review the submitted solutions and peer review results in addition to broader community signals. Top proposals for each project will be selected.	Council	Winning Project Teams and Peer Reviewers receive rewards
7	**Fundraising** Funds are collectively raised , with appropriate fundraising strategies chosen on a case-by-case basis, to support the development, testing, and	Anyone	Project is open for crowdfunding

	launch of the top proposals.		
8	**Development, Launch, Operations** Successfully funded solutions are activated for development, manufacturing, launch and operations.	Project Team	Project Team receives funding on milestone-basis to fulfill the contract

Reproduced from Governance Paper, Space Decentral, 2018

Figure 4.17 illustrates the Project development flow more in detail for Steps 4 to 6.

Figure 4.17 - Project development flow



Reproduced from Governance Paper, Space Decentral, 2018

In summary, ideas would be voted by stakeholders (as seen in Table 4.15) and supported with rewards and/or "bounties" for participating in the selected projects or missions (as seen in Table 4.16). You may note that there is no mention of the criteria to evaluate the quality of the teams in terms of expertise and contribution (linked to the *Finding Participant* co-creation stage) or how allocation of rewards would be shared within each team, and not only on an individual basis.

For Space Decentral, this governance model for transparent and open decision-making processes was to be coded and integrated into the Aragon-funded blockchain application to automate the selection and reward distribution. Meanwhile, it was expected that other online tools would be used throughout the process to engage with the stakeholders and the community at large (i.e., Google Drive, Github, Riot, Zoom, etc.). It would have been very insightful to witness the implementation of this theoretical system, especially now in a Post-Covid world with a strong remote working environment. What we could only access was the first iteration of the Aragon-funded blockchain application. The next section addresses the launch of that long-awaited blockchain application called *Open Enterprise* by Space Decentral and its community to support space activities in a decentralized environment. In addition to tokens, this is

another online collaborative tool built on blockchain technology to be investigated in this research on how online collaborative tools foster co-creation activities within virtual organizations .

4.2.2.3 The Open Enterprise application

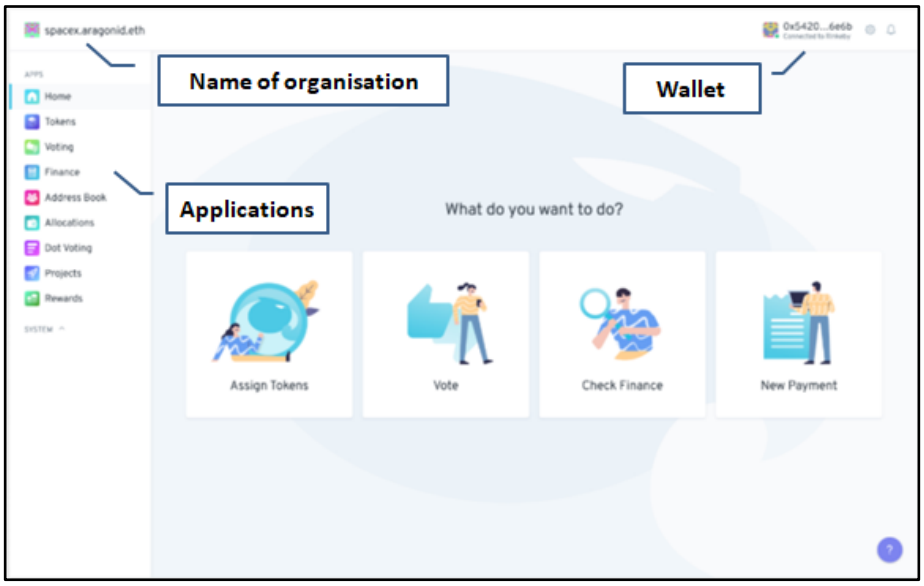
Space Decentral expressed a strong interest in relying on Aragon's infrastructure to launch their blockchain application that would support its governance and decision-making activities. This application would enable the required infrastructure that Space Decentral had envisioned to become a decentralized organization. Their White Paper had indicated that "privilege and role management is at the core of Aragon's infrastructure" (Space Decentral, 2018a: p. 5). In fact, in 2018 and 2019, the Aragon infrastructure was expected to provide the basic functionalities needed for Space Decentral in the areas of financial planning, payroll, and privilege management:

> "Aragon is built on the Ethereum blockchain and provides the governance infrastructure to maintain Space Decentral's bylaws and operating procedures, in addition to providing collective decision-making features. The tool [Space Decentral's blockchain application] will be capable of, yet not limited to: Managing voting privileges and committee creation; Submitting and evaluating proposals for network or feature upgrades; Approving budgets & financial transactions; and, Settling disputes by utilizing arbitration services."

The name did evolve quite a bit from the White Paper to the official launch at the end of 2019. In a September 2018 interview, Space Decentral announced that the "Planning App*"* would become *The Planning Suite*. The Planning Suite, as described by the co-founder of Space Decentral, was now defined as "a toolkit of new Aragon apps that are meant to be complementary to the existing apps". [40] Then, in July 2019, the same individual communicated on Github that The Planning Suite was renamed *Open Enterprise*. Supported by the Aragon blockchain infrastructure, stakeholders could access "pre-configured templates" of the Open Enterprise application. They could select either a Project management, a Fundraising, a Membership or a Reputation "organizational" template. Inside each template (see Figure 4.18), they would access functionalities, such as Token creation, Voting, Finance, Address Book, Allocations, Voting, Projects, and Rewards. Each is explained in Table 4.19.

[40] Aragon. "Nest Team Interviews: That Planning Suite", https://blog.aragon.org/nest-team-interviews-that-planning-suite/ - retrieved on February 15, 2020.

Figure 4.18 - Open Enterprise webpage and functional applications



Source: https://client.aragon.org/

Table 4.19 - The application available in the Open Enterprise template

Type/Function	Description	Features
Tokens - Manage an organization's token supply and distribution	The Tokens app is used to manage the supply and distribution of an organization's token. Each installation of the Tokens app manages only one token. Tokens can be used to give different types of powers or rights to members of an organization, such as the power to vote on proposals or the right to receive a share of the organization's profits. The Open Enterprise template installs a Tokens app with transferable tokens, meaning that each of your organization's members can hold any number of tokens, and transfer them freely as wanted. It is different with the Membership template, for instance, where tokens are non-transferable; i.e., one token, one member. In this step users are able to deposit funds to members by adding the addresses of the	- Issue new tokens and remove existing tokens. - Browse a list of all token holders and see how tokens are distributed among them. - Get an at-a-glance view of stats about the token, such as the token name and ticker symbol, the total supply, and whether or not the token is transferable.

	people that they want to participate in the organization.	
Voting - Create and participate in votes	The Voting app is used to create and participate in votes. Votes can be linked to an action, such as issuing a new token or transferring funds, or be purely informative. When you set up the template, you need to specify thresholds for the % of support and number of members a vote requires to pass, as well as the default vote duration. These transactions are signed and stored on the blockchain.	- Create a new informative vote. - Vote "yes" or "no" on open votes. - See details about open and past votes, including how many tokens have voted and how much time is left before a vote is over. - Give the Voting app permission to perform actions in other apps so those actions have to be approved by a token holder vote before they can be executed.
Finance - Manage an organization's financial assets	The Finance app allows the management of an organization's financial assets.	- Deposit and withdraw ETH, ERC-20-, and ERC-677-compatible tokens. - Include a reference with deposits and withdrawals to let the organization know what a transaction is for. - See the current balance of all assets held in the organization's Vault. - Browse a full, exportable and filterable transaction history of all past deposits and withdrawals made using the app.
Address Book - Assign human-readable names to Ethereum addresses.	The Address Book app assigns human-readable names to Ethereum addresses.	- Add, edit and remove new entities to your address book. - Label your address book entities as individuals or organizations.
Allocation - Manage multi-recipient financial allocations that are budget-controlled	The Allocations app is used to manage multi-recipient financial allocations that are budget-controlled.	- Create and edit budgets that set spending limits on allocation categories. - Create multi-recipient allocations, whose values are determined based on a vote. - See details about past allocations, such as the portion of the allocation each recipient was awarded.
Dot Voting - Participate in multi-option dot	The Dot Voting app is used to participate in multi-option dot votes, where each voter	- Participate in the allocation of funds from proposals originating from the

votes, including locations and issue curations	has 100 dots that can be distributed across each option. The voting weight will be determined by multiplying the voter's token balance at the time the proposal opened by the number of dots for the option. The outcome (e.g. top ranked options) is based on the average voting weight received per option. The Dot Voting app currently supports financial proposals from the Allocations app and issue curation proposals from the Projects app.	Allocations app. - Distribute allocations dynamically, based on the results of the dot vote. - Participate in votes for curating GitHub issues from the Projects app.
Projects - Fund bounties and prioritize GitHub issues	The Projects app is a project management app that synchronizes GitHub repositories to your organization, enabling bounties to be allocated to issues and issue curation to determine priorities.	- Synchronize any of your GitHub repositories with your organization. - Fund issues by placing bounties, either following hourly or fixed pricing models. - Coordinate application and work reviews on bounties. - Curate a set of issues, forwarded to Dot Voting.
Rewards - Compensate token holders with rewards and dividends	The Rewards app is used to compensate token holders with dividends, which can either occur on a one-time or recurring basis.	- Create one-time or recurring dividends that reward members of your organization based on holding a certain asset at specific disbursement dates. - Create one-time merits that reward members of your organization based on accruing a certain non-transferable asset over a specific period of time.

Reproduced from a combination of sources: https://www.autark.xyz/apps & https://autark.gitbook.io/open-enterprise/introduction

This is how Space Decentral framed how the Open Enterprise would support the governance and decision-making system to enable their vision to be a decentralized organization. Visually, it is a very complex infrastructure where the terminology is more inspired from a Github environment than an organizational one. In fact, the project management function had to be associated with a Github account to synchronize the "issue management" sub-function. This was to be solved in a future update with a stand-alone application.

Another layer of complexity exists within the code operated in the background of the Open Enterprise platform. In the last half of 2019, I found an audit of the Open Enterprise application that had been made by a third party organization called MixBytes in November 2019. This was to provide a "security assessment of the Open Enterprise Suite" (MixBytes, 2019). The auditor categorized issues as follows:

- CRITICAL: Bugs leading to Ether or token theft, fund access locking or any other loss of Ether/tokens to be transferred to any party (for example, dividends).
- MAJOR: Bugs that can trigger a contract failure. Further recovery is possible only by manual modification of the contract state or replacement.
- WARNINGS: Bugs that can break the intended contract logic or expose it to DoS attacks.
- COMMENTS: Other issues and recommendations reported to/acknowledged by the team.

Based on the report, here are examples of a Critical issue found in the Reward sub-application, a Major issue found in the Allocation sub-application, a Warning issue found in the Project sub-application, and one Comment associated with the Address Book sub-application. These following bullets are to illustrate the type of issues that had to be solved with the associated language used by MixBytes; a language common to programmers, but not really accessible to ordinary people.

- CRITICAL: Rewards.sol#L84 - There is no check that the user has not already claimed his reward. As a result, anybody with some reference token amount can claim all reward tokens from the vault.
- MAJOR: Allocations.sol#L528 - Earlier than the _nextPaymentTime (_accountId, _payoutId, _ candidateIndex) time, an account with the EXECUTE_ALLOCATION_ROLE rights is trying to call the runPayout transaction. This transaction will end in error on line 528, that in turn will not allow all other candidates to be paid.
- WARNING: Projects.sol#L340 - When a repository is deleted, funds in open bounties related to repository issues become (at least temporarily) blocked. We recommend you keep score of open bounty repositories and prohibit deleting them if this entails a loss of funds.
- COMMENTS: AddressBook.sol#L64 - IPFS addresses have the form of <encoding>.encode(multihash(<digest>, <function>)), which makes the check of line 64 valid only for base58 encoding of sha256 hashes.

Besides issues within the code, no information was available on how Space Decentral was planning to monitor and secure the verification of each transaction through the *Proof-of-Work system*. Based on the work of Victoria Lemieux, Associate Professor of Archival Science at the School of Information and lead of the Blockchain research cluster, Blockchain@UBC at the University of British Columbia, proof-of-work is a mechanism in a blockchain infrastructure where a category of users called "miners" compete with their computers to solve a complex set of algorithms, and upon completion, broadcast their results to the rest of the miners who will then confirm that the result is correct. When a majority of miners confirm the resolution of the algorithm, the block of information is cryptographically sealed and added to the blockchain (Lemieux, 2016). Lemieux stated that the incentive for the miners to process the

transactions come in the form of Bitcoins or other cryptocurrencies that are awarded to "winning" miners (i.e., the ones who were the fastest to solve the algorithms).

It is important to highlight the role of programmers and miners in Space Decentral's ecosystem. They were not mentioned frequently by Space Decentral members on Riot, even though they are key in the decision-making mechanism and the record/storage stage of the data on the blockchain. First, programmers are obviously important to write, manage and strengthen codes and algorithms. We can therefore easily assume that they are enablers of the voting mechanism, reward distribution, and decision-making activities. Furthermore, we can assume the level of complexity within the code is proportionally linked to the level of specialization required to fix or maintain the system - and the cost of hiring the right programmers for the job. This is a question of making sure Space Decentral's data infrastructure is resilient to its long-term vision. Also, we learned that there is an expectation that miners will be paid to bring the blocks (the transactions of Space Decentral) on the blockchain; hence, another type of stakeholders to engage and reward.

Section 4.2.3 will address these issues further through the theme of *Leveraging external knowledge*. Piller and West (2014) wrote that incentives and reward systems are paramount in a co-creation environment. The authors found that firms that emphasize external learning and absorption behaviour as bases for appraisals and rewards will be more likely to acquire and utilize external knowledge. That external knowledge, in Space Decentral's case, was mainly the Aragon network. Aragon had the capacity to support Space Decentral in the development of their Open Enterprise project; but somewhere in 2019, things didn't go as planned.

4.2.3 Leveraging external knowledge

This last section of Phase Two ends the *Findings* chapter of the research and looks into understanding how individuals working in a virtual organization can co-create effectively using online collaborative tools, while mitigating the challenges. Throughout 2018 and 2019, we captured discussions on Riot, assessed Space Decentral SMAP and Coral pilot projects that were to be managed virtually using online collaborative tools, and analyzed a series of documents from Space Decentral and reports related to the development of decentralized organizations using blockchain applications. Besides capturing the scope of their open source culture and the governance and decision-making mechanism, another co-creation theme emerged during the data collection stage: leveraging external knowledge. This is directly linked to Piller and West (2014) *Leveraging* stage. The authors stated that this activity depended on the nature of the contribution by the community who would generate ideas for internal development, the design of a product or service, or the evaluation of new offerings for the market.

Leveraging Space Decentral's community and external stakeholders was integrated in the organization's daily activities. In an Aragon interview with one member of Space Decentral, published on September 6, 2018, more details were communicated about the intention of Space Decentral to foster an open source culture integrating knowledge and talent from Aragon and other external organizations. The individual said that "we all share a passion of building toward a future where progress can be accelerated by

making it easier to coordinate, and making it fairer and more transparent as well." [41] This illustrated the direction that Space Decentral took to bring key members from its organization to Autark founded at the end of 2018 (see *Table 3.7 - Space Decentral vs Autark*), while maintaining a mandate similar to Space Decentral's (Table 4.20).

Table 4.20 - Comparison between Space Decentral and Autark mission statement

Space Decentral	Autark
Space Decentral is a decentralized autonomous space agency that will utilize blockchain technology to enable collaborative, transparent and self-directed action toward building the future of space exploration. [42]	We are interested in advancing civilization, with a special focus on DAOs, Aragon, worker-autonomy, and tools to enable open source development of mega-projects.[43]

Autark organization's goal was: "[to equip] the Aragon ecosystem with tools that enable DAOs to collaborate more seamlessly — by building discussion tools that are integrated with voting, rich user profiles, and expanding governance models to support patronage dividends". [44] Moreover, Autark's vision stated that: "Humans have flourished as a result of large-scale coordination, but today's global challenges demand we collaborate in unprecedented ways". In September 2019, we also learned that Autark was now an Aragon Network organization and their goal was to leverage collaboration challenges in a decentralized environment as "an opportunity for revolutionizing work".[45] Leveraging the Aragon infrastructure and its communities were therefore part of both Space Decentral and Autark plans, but basically involving the same members.

Moreover, Aragon is part of the larger Ethereum ecosystem. Created in 2015 by Russian-Canadian Vitalik Buterin, the Ethereum blockchain was launched as a community-driven, open-source software project. [46] Its membership is unknown, but the official Ethereum account on Twitter grew from about 500,000 followers in January 2021 to close to 2 millions in December 2021. Ether - Ethereum's token - was the second-highest-valued cryptocurrency after Bitcoin.[47]

The Aragon's White Paper further explains what the organization is about, with its culture, membership and vision:

> "The Aragon Network is an Aragon organization that provides infrastructure and services to users of the Aragon platform, and is governed by ANT holders [ANT is the token used by the

[41] Aragon. "Nest Team Interviews: That Planning Suite", https://blog.aragon.org/nest-team-interviews-that-planning-suite/ - retrieved on February 15, 2020.
[42] White Paper, Space Decentral (2018) - https://spacedecentral.net/White_Paper.pdf - retrieved on June 25, 2019.
[43] Autark - Our Story, https://www.autark.xyz/our-story - retrieved on June 25, 2019.
[44] Autark / Open Work Labs - https://blog.autark.xyz/autark-open-work-labs-march-2019/ - retreived on January 28, 2020.
[45] Autark, 2019. Retrieved on September 30, 2019
[46] Ethereum, White Paper, https://ethereum.org/en/whitepaper/ - Retrieved in December 2019.
[47] As of December 2020; https://twitter.com/ethereum retrieved on December 31, 2020.

> Aragon blockchain infrastructure]. The existing Aragon infrastructure enables users to create and manage organizations. Each Aragon organization exists as a set of smart contracts that define the organization's stakeholders and their associated rights and privileges. However, some rights and privileges require subjective constraints that cannot be encoded in a smart contract directly" (Aragon White Paper). [48]

Also, in Aragon's Manifesto video, members of the Aragon team highlighted that "society has evolved" but current governance structures are "hundreds of years old". Their solution is "to fund projects that produce true social good and provide value to the most undervalued parts of humanity" with free, transparent, open source codes, experimenting with governance models "in the comfort of your sofa", and creating something that resembles a fractal structure with supranational protocols. [49]

However, leveraging the knowledge of external communities has challenges. As indicated in the previous section, managing codes requires programmers - an essential workforce within a virtual organization. On top of programmers, miners are mandatory to manage and integrate transactions in the blockchain. Also, while the OECD explained that the goal of the blockchain community is to "eliminate the need for a central authority" (Berryhill *et al.*, 2018), it cautioned on such messages stating that a certain form of central authority still remains in a blockchain infrastructure. Furthermore, it stated that "the levels of decision-making, and the integration of such decisions in the platform's code, are contingent on the code previously drafted" (Berryhill *et al.*, 2018). It confirms as well our observation that the development and maintenance of the applications - and the blockchain infrastructure itself - is "governed by code developers, engineers, and other decision makers who have been entrusted with key roles for the development of a Blockchain platform". Based on the report, these individuals are therefore automatically seen as the central authority. Finally, the OECD highlights that "their composition and actions and underlying decisions coded into a blockchain may not be as transparent as the transactions themselves".

The BRI has expressed similar conclusions in terms of capacity to code blockchain applications. One report highlights some challenges, especially for non-profit entities. It stated that private companies have "deeper pockets" which make it difficult for the non-profit sector (such as Space Decentral) to compete for developers or other experts in the field. The report quotes Lucian Tarnowski, CEO of BraveNew, an online community, who fears that the "developers become too powerful, leaving the communities that depend on their software as 'slaves to the algorithm'." He worries that "monolithic, math-based blockchain protocols cannot accommodate the great many ways real human beings lead their lives" (BRI, 2017: p. 14). The report, however, notes that "the biggest companies got to shape, indirectly, the development of open protocols since it was their donations that kept research programs within universities moving ahead".

[48] Aragon White Paper - https://github.com/aragon/whitepaper - retrieved on April 15, 2020.
[49] [video] Aragon - Fight for our Freedom - https://www.youtube.com/watch?v=AqjIWmiAidw - retrieved on February 18, 2020.

4.2.3.1 Analytical summary

In summary, the foundation of Space Decentral was not built on solid grounds right from the start. The literature review of Victoria Lemieux, Associate Professor of Archival Science at the School of Information and lead of the Blockchain research cluster, Blockchain@UBC at the University of British Columbia, stated that "the security of the system is wholly dependent upon the network of users in conjunction with the strength of the written code that underlies the technology. (...) "Users" include not only users in the network, but the coders and miners" (Lemieux, 2016: p. 97). As a result, the open source culture communicated throughout 2018 and 2019 by members of Space Decentral seems to be less open now due to the opacity of the code underneath online collaborative tools. And it is even more obvious with blockchain applications and tokens.

Furthermore, adding layers of complexity, such as a governance system based on codes/algorithms and new Github-inspired roles and responsibilities, to an already established ecosystem such as the space sector, brings the assumption that Space Decentral might have aimed too high. It, however, laid out openly - and organically - a new theoretical governance system for decentralized organizations and some interesting ideas by combining various components related to an effective online community. Nevertheless, Space Decentral remains a cautionary tale about working virtually with organizations such as Aragon whose network is 100s times bigger, without agreeing to a clear conflict resolution mechanism - which was either through Aragon's own "court of law" or the organization's country court of law.

In summary, Phase One and Phase Two of the *Findings* chapter aggregated the conversations from online collaborative tools and Space Decentral's website in a more structured way based on Frank Piller and Joel West co-creation framework. The most popular co-creation stages assessed during Phase One were, from the most discussed to the least: *Collaboration*, *Defining*, *Leveraging*, and *Finding Participants*. Then, during Phase Two, the recurrent topics from Space Decentral's literature and related reports from external organizations were: *open source; governance and decision-making;* and, *leveraging external knowledge*.

During Phase two, I was also able to find answers related to the third research objective: Review the gaps in managing activities collaboratively within virtual organizations. These are gaps that Space Decentral had not clearly foreseen in the management of their activities. They are the integration of programmers and miners in their stakeholders chart, side-by-side with members and decision makers. There is also the development of a comprehensive reward / incentive system to recruit and retain talent, while identifying an appropriate conflict resolution mechanism between two decentralized organizations. The legal fight between Space Decentral and Aragon shows the limitation of relying on a blockchain infrastructure to solve complex problems. This illustrates that the blockchain community open source culture seems to break at some point when divergent interests or money is involved.

These findings will contribute to the analysis in the *Discussion* chapter. This chapter will focus on explaining and evaluating what I found, showing how it relates to my literature review and research questions (How online collaborative tools foster co-creation activities within virtual organizations). I'll do

an assessment of what was learned about the concepts of boundary objects and open source, and how the objects (online collaborative tools, including tokens and the Open Enterprise application) had what it took to function virtually in a knowledge management environment.

5. Discussion

This research aims to better understand how individuals working in a virtual organization can co-create effectively using online collaborative tools, while mitigating the challenges. We used the boundary artefact / object and open source concepts to explain the usage of online collaborative tools within a co-creation environment. Space Decentral is the explorative case study. Their activities and literature were assessed through their own online collaborative tools. As seen in the Phase One section, that virtual co-creation environment has led to a different sequence of the co-creation stages and activities established by Frank Piller and Joel West's 2014 co-creation framework. Phase Two added more substance to the research by exploring further the recurring themes of open source; governance and decision-making; and, leveraging external knowledge - especially within the blockchain community such as Aragon and Ethereum, which include programmers and miners as well. The *Discussion* chapter will therefore assess these findings with the boundary object concept, as defined by Star and Griesemer (1989), Star (2010), and Steger, Cara *et al.* (2018), in a co-creation environment led by individuals with a strong open source culture. It will help investigate what the literature can tell us about online collaborative tools and their ability to support virtual organizations as translation devices. In fact, based on what we now know, something - somewhere - got lost in the translation.

Firstly, the introduction of standard online collaborative tools among the STEM community such as Github influenced the design of Space Decentral (the virtual organization) and its Open Enterprise application, and its effectiveness at the periphery of Space Decentral's community of practice. Secondly, these online collaborative tools could not "cope" during the growth or evolution of Space Decentral. It was obvious as soon as members of Space Decentral moved beyond structuring their governance and decision-making framework. These tools, or the ability of members of Space Decentral to improve them, couldn't support the next co-creation stages and activities that had been identified by Piller and West. Thirdly, as the world moves forward in a hybrid physical and virtual working environment, managing individuals efficiently with online collaborative tools will be key to the success of most organizations. This chapter will consequently explore some answers found and look into possible future research. This is important to craft efficient knowledge management strategies within virtual organizations and especially those knowledge intensive organizations involved in long-term projects such as the space sector.

5.1 Online collaborative tools and startups

We must sympathize with the founding members of Space Decentral. Early 2018, Space Decentral's community of practice was limited to a few individuals. Members of Space Decentral, as seen on the Team section of their website, had backgrounds in computer science, software development, physics, and robotics (Table 3.1). The community was visibly narrow in terms of expertise; all fields were related to science, technology, engineering and mathematics - or STEM. Then, the organizations that worked with Space Decentral at that time, such as Aragon, were also very identical in terms of culture and knowledge. Most, if not all, were focused on developing a blockchain-oriented infrastructure using

STEM-related online tools to improve future collaborations among individuals - mainly space projects - within a decentralized environment void of central authority.

Online platforms as affordable recruitment tools for virtual organisations

Online collaborative tools were used as a strategy for Space Decentral to lower the barriers to space enthusiasts to inspire and recruit members with the promise to take part in space projects. These tools created an onboarding system, defining the basic virtual workplace settings. This was the decentralized ecosystem or network Space Decentral was envisioning, especially for their SMAP and Coral pilot project. These online collaborative tools were associated with "space", "innovation", "the future of society" and became an affordable recruitment tool. Related to inspiration, Steger *et al.* (2018) stated that it is a cultural service, an intangible benefit people obtain from ecosystems, like cultural identity and recreation. These types of services arise from intimate relationships between people and their environments. However, Steger *et al.* (2018) also said they are the "least" understood of the cultural services and are difficult to include in the decision-making framework.

Hence, as predicted in the literature, Space Decentral homogenous groups led to a smooth adoption of standard, common online collaborative tools already used by the STEM community: Riot, Google Drive, Medium, the forum on the Space Decentral's website, Github, and other more specialized applications such as this InterPlanetary File System (IPFS) to support the data created by the blockchain application Open Enterprise. This suite of common tools permitted the STEM community to dive in quickly into their roadmap and begin to communicate, write and share codes, develop applications, debate ideas, create virtual meetings, assign tasks, manage issues, etc. These standard and common boundary objects acted as the interface of knowledge domains and provided a shared syntax among this STEM community of practices (Carlile, 2004).

Lee, Olson and Trimi (2012) had found that these standard platforms help convert internal, external, collaborative, co-creative ideas into "organizational and shared value" (p. 818). But even when the boundary objects used are well understood by a homogenous community within a network, it could still impede common understanding and innovation. Carlile (2004) had found that a specialized community of practice could be a major issue blocking the flow of knowledge across functional boundaries, impacting the onboarding of new members and integration of their knowledge, in order to translate that knowledge into innovation. This is similar to what Steger, Cara *et al.* (2018) had found. Standardization, although it facilitates implementation, "may diminish its ability [*the object's ability*] to function as a communication device for bridging social worlds and disciplinary perspectives" (p. 154). These standard boundary objects seemed to have been too rigid for interested individuals at the periphery of Space Decentral's network.

But the recruitment couldn't work if there was no target audience identified in a transparent plan to support the projects of Space Decentral. For instance, was Space Decentral's Open Enterprise released with a specific type of individuals in mind? By not identifying and implementing some kind of broad *Finding participants* and/or *Leveraging* strategy to advance Space Decentral's co-creation activities, especially during the design of the blockchain application (i.e., Open Enterprise), very few individuals

from other social worlds or communities of practice would have felt engaged or motivated to answer Space Decentral's call on social media or during public conferences. There was also a problem with Aragon's ability to engage individuals outside their own social world. While investigating the reasons behind the legal battle between Aragon and Space Decentral, Aragon's cofounder communicated his frustration on Twitter in 2020 saying that the "world understands less than 1% of it [i.e., the Ethereum blockchain infrastructure and its potential]". [50]

In summary, Space Decentral had portrayed their decentralized organization and blockchain technology as a new way for interested individuals to engage in space activities, "to be an asset to society" and have "a chance to participate in something new". There was also an expectation that the motivation would have been dealt with once tokens and the reward system were implemented on the Open Enterprise, and used as a way to integrate multiple perspectives, knowledge, and point of view. The reward system, as a motivation engine, was supposed to contribute at the micro-level to teamwork and shared understanding in collaborative knowledge building. Unfortunately, the reward system was not explicitly discussed within Space Decentral with charts or numbers, and not communicated at the release of the Open Enterprise application. Actually, based on the way reward allocation was presented for SMAP, it seemed that it was up to a small group of users to define the reward system for each task, something that Space Decentral didn't elaborate much on. As a result, even though "space" was used at the beginning as a contextual driver for mobilizing scientists, amateurs and space enthusiasts in supporting space endeavours, tokens as an innovative method to recruit, retain and enable a sustained co-creation momentum with rewards were missing.

A token engagement strategy would have influenced the co-creation of artefacts in collaborative knowledge building activities (Mariano and Awazu, 2017). What we witnessed was that, although conversations on Riot showed that space enthusiasts from around the world were interested to follow Space Decentral (i.e., the entry related to the space network supported by the Centre national d'études spatiale), Space Decentral's staff were too busy developing the blockchain application instead of supporting the organization or maintaining the website to leverage these individuals into their network. This raises the question about the value of creating a new online collaborative tool such as a blockchain application when such an endeavour absorbs so much resource. Meanwhile, mainstream online collaborative tools were used to launch SMAP and Coral in 2018 and 2019. This is an important question considering that in 2021, corporations like Google or Microsoft, in addition to smaller players, have developed enhanced platforms with additional suite of applications to fulfill the same needs that Space Decentral wanted to do with the Open Enterprise.

Efficiency vs coherence

This brings the question of velocity. One of the research objectives was to identify gaps in managing activities collaboratively within virtual organizations. On the one hand, the strength of Space Decentral was a like-minded community that launched their activities and pilot projects efficiently via a range of online collaborative tools thanks to a common understanding of their functions. Members of Space

[50] Source: https://twitter.com/licuende/status/1263459041411465216

Decentral already had an understanding of these tools; they didn't need to further clarify it - i.e., the common *repositories* and *forms,* one of the four types of boundary objects (Steger *et al*, 2018: p. 155). Specifically, Space Decentral members were able to move forward quickly in 2018 on certain initiatives, which led to the design of a virtual working environment and governance structure crafted by individuals possessing the same mindset, background and expertise. This is the "coherence" of the shared context between specialized communities. As stated by Neff, Fiore-Silfvast and Dossick (2010), "Co-creation of knowledge and knowledge sharing are limited to professional communities that already share conceptual models of the building framed by disciplinary concerns of form, function, and execution" (p. 558).

On the other hand, the gap in managing virtual communities or decentralized organizations is to be attentive to the coherence among the online collaborative tools as well. Space Decentral experience showed how standardized objects in information systems and management foster efficiency, at the expense of diversity and openness (Choo and de Alvarenga Neto, 2010: p. 606). In other words, these STEM-oriented online collaborative tools were put together without an organizational mindset beyond their community. Although these tools had the approval of the members of Space Decentral and the Aragon network to be reliable platforms to support and manage the development of the ecosystem, something was missing to build the "open and virtual organization" Space Decentral was aiming for. Huvila *et al.* (2017) confirmed the "missing link" among online collaborative tools used by Space Decentral. As seen previously, the authors studied the field of computer-supported cooperative work (CSCW), where the community considers Information and Communication technologies (ICTs) as boundary objects serving coordinating functions. In their literature review, the authors had concluded that ICTs can support processes, but there was no guarantee that these boundary objects would bring coherence or convergence.

The release of the first version of the Open Enterprise application seemed to be a conscious attempt by members of Space Decentral to build coherence in one broad suite of applications to foster open virtual organizations. Open Enterprise was meant to define different authorities for each individual, team, or external stakeholder (i.e., Members, Explorers and Council). Based on the White Paper, the application was to be at the core of Space Decentral's digital infrastructure to engage communities of experts, manage evaluations, votes and activities, while supporting financial transactions and decisions - all in a decentralized environment. Even though the first iteration of the blockchain-based application was aimed at a more generic audience interested in creating their own virtual organization, the developers behind the application were part of Space Decentral and Aragon – thou, they still crafted the application with a community in mind who were already aware of the basics. One example is the similarities between the Open Enterprise application and the functions of Github to create classes of individuals or classes of teams to manage various tasks (which explains why they had called the approach: the "Github way"). An individual without that prerequisite ICT knowledge wouldn't have been able to navigate the templates and create its own decentralized organization without assistance; which was missing. Nevertheless, within this application, I think there was a small revolution in terms of boundary artefacts: the introduction of *tokens* in a virtual organization environment. It had the potential to be the online collaborative tool to empower owners of knowledge.

The case of tokens

Similar to a tangible identification card, tokens are framed to be able to do much more, such as confirm the identification and authority of one individual within an online organization, and enable that individual to collaborate and record a range of "things" within a network supported by a blockchain infrastructure such as Ethereum. Tokens, as explained by Space Decentral White Paper, were to connect organizational memory with the individual who owns it - without being dependent on one single platform (Google, Apple, Slack, etc.). This individual's knowledge / organizational memory would be an enabler of that information, making sense of the data shared, as indicated by Lutters and Ackerman (2007).

Token owners bring the question of intellectual property being officially linked to an individual thanks to the records on the blockchain. This meant that, if successful, again based on how it was designed by Space Decentral, the individual's knowledge wouldn't have been only under the ownership or authority of an organization. This is important since it would have empowered each individual with a tool to create and manage their knowledge in an online infrastructure and profit from it; almost similar to an Uber application. Instead of using your car in the driveway to make additional revenue, you would make money by sharing what you know. In other words, tokens could be seen as an online collaborative tool - or *object* - to allow the management of the "organizational memory" or an "expert" within a network or community of practice.

Unfortunately, the story of Space Decentral doesn't provide much evidence on the success of such an approach, and how the protection of that knowledge would have been enforced. Their theoretical tokens were never deployed and used concretely. Without the implementation of a token infrastructure, the definition of its value and function, the scope of the perks it provided to the user, and benefits to the various networks in which that individual was involved in, the research can't provide much insight on how it could contribute to the boundary object literature. Also, considering its novelty, the literature on boundary objects never really investigated tokens as a virtual boundary object.

To conclude, the selection of the appropriate tools, including the Open Enterprise application, was part of the *Collaborating* stage. Space Decentral used them to develop their "governance" engine to support human decisions. These decisions were for the three most discussed co-creation activities (i.e., *Integration platform and other tools; Institutions and rules - including contract terms and IP;* and, *Resource allocation and strategic commitment*). These tools have structured the knowledge sharing activity and created a good onboarding system at the beginning of Space Decentral adventure. This led participants to commit to some kind of "online contract"; using Space Decentral online tools meant defining the basic workplace settings. For instance, Riot was for brainstorming and the Forum was to bring forward ideas for SMAP or Coral. This developed the decentralized ecosystem or the network Space Decentral was envisioning, especially pilot projects.

The adoption of a range of STEM-related standard platforms as boundary objects to manage common knowledge and ideas did bring a distorted "chronology" of the co-creation stages and activities, based on the Piller and West's framework. That distortion is not bad. It led to the first look of a new

"decentralized-led" or "online collaborative tool-led" virtual co-creation framework. On the other hand, a virtual organization must have the capacity to assess where it is at in its growth and adapt its tools along the way based on upcoming activities and pressures. The tokens were a first step to break these standard tools and better manage the knowledge and expertise required to bring a virtual organization deeper into a functioning virtual entity. For Space Decentral, it was to leave the "startup" status and bring more structure, using different online collaborative tools or repurpose the current ones.

5.2 Negotiating artefacts for growth in a virtual organization

At this point, it is tempting to suggest right away that future research could focus on how managers can consciously "repurpose" online collaborative tools and adapt them to where they are at related to the co-creation stages and activities. This is close to what Mariano and Awazou's (2017) "produced through purposeful co-creation processes". The online collaborative tools that Space Decentral selected for some *Collaborating* and *Defining* co-creation activities worked well. On the other hand, the same online tools failed to engage the community for the *Finding participants* and *Leveraging* co-creation stages. These were the least discussed topics, even though it deserves a lot of attention if a virtual organization wants to grow.

For instance, the first examples of boundary objects selected by Star and Griesemer (1989) were maps and guides. They were regarded as tools for communication, cooperative work, acting as translation devices to reach mutual goals in the absence of consensus. In 2021, the same boundary objects are now digitized and have been adapted to how and where people use them (on their smartphone, tablet, computer, in their car, etc.). It would support Mariano and Awazou's (2017) conclusions on knowledge co-creation in the context of networked relationships of stakeholders or ecosystems. The authors then invite managers to analyze the complexities of collaborative knowledge building practices to increase overall organizational effectiveness and performance within these evolving ecosystems that Pera *et al.* (2015) talked about. Mariano and Awazou identified "contextual levels" that influence the design of artefacts in collaborative knowledge building activities (see Figure 2.5). Mariano and Awazu, however, found that there weren't enough insights on how artefacts can be produced through purposeful co-creation processes.

This is where an *artefact negotiation* approach launched by Charlotte Lee could be used to investigate how we "repurpose" artefacts depending on where the organization is at related to the co-creation stage or activity within their stakeholders' ecosystem. For a virtual organization with limited resources, it is important to differentiate "repurposing" current online collaborative tools with creating new online objects. Instead of investing time and money in creating something new, members of that virtual organization negotiate among themselves to creatively use what is available to their needs. However, the right online collaborative tools as boundary objects need to be less structured and standardized in order to work. This "repurpose" exercise option for managers seems to follow what Star and Griesemer (1989) had found: that the development and maintenance of boundary objects were critical processes to sustain coherence where social worlds meet (p. 393). In the case of Space Decentral, it required a series of online artefacts flexible enough to respond to the evolution of Space Decentral activities as a virtual organization. That "repurpose" activity for online collaborative tools is very linked to growth.

To grow, you need people. Calton *et al.* (2013) had found that dealing with diversity requires embracing boundary-spanning roles, processes and structures. The challenges reside in managing an audience from different geography, income, culture, and language to leverage their experience in collaborative knowledge building activities at the micro level (p. 727). This cannot be truer when you develop a decentralized organization. The role of Space Decentral as the "Managerial agency" to optimize the usage of these online collaborative tools had therefore not been strong, since "strong leadership and commitment levels by top managers [is] found to determine the success or failure of projects involving large number of objects" (Mariano and Awazu, 2017). The issue throughout Space Decentral's experience seemed to have been the usage of few rigid boundary objects to support what was supposed to become a dynamic decentralized organization or network - or networks of stakeholders through an ecosystem.

Unfortunately, it was not possible to know exactly who these stakeholders were due to a weak *Finding participants* co-creation strategy. The roles we identified from Space Decentral literature were from a software developer community, not an organizational one. Who exactly the developers of Space Decentral had in mind when creating the Open Enterprise using blockchain technology? Branded as a great technology to improve collaboration, the blockchain application also didn't attract a lot of attention and its value was not communicated very well (i.e., to manage intangible assets such as votes, ideas, reputation, intention, teamwork, etc.).

This was a problem with Aragon as well. By working with Space Decentral, Aragon was not only investing in the promise of developing a suite of blockchain applications to create DAOs, it was also investing in the development of social capital, what Haskel and Westlake (2018) identified as "the strength, number and quality of the relationships among people in society" (p. 156). But, even today, that social capital doesn't seem to be successful outside the STEM community. The co-founder of Aragon communicated his frustration on Twitter in 2020 that the "world understands less than 1% of it [i.e., the Ethereum blockchain infrastructure and its potential]". [51]

Based on the boundary literature, it would have required that Space Decentral adopt a stronger broker role or outsource that role due to the scope of the work required to develop the Open Enterprise application. Their boundary objects (the common online collaborative tools and Open Enterprise) "would have been mobilized by the broker (or boundary spanners) to aid the exchange of information and to facilitate coordination between the actors in the collective" (Kimble *et al.*, 2013: p. 13). The suite of applications of Open Enterprise had actually outsourcing potential with their "Fundraising" or "Membership" application templates. As their title indicates, it meant that one team could work on raising funds for certain projects, while another one could have worked on the recruitment strategy - all under the same blockchain infrastructure. That infrastructure would have been supported by Space Decentral's general online collaborative tools and Aragon. This would have allowed information to be given more flexible meaning through more open interpretation, allowing new knowledge to be created by a diversified community. This diversity would have brought meanings and contexts related to the

[51] Source: https://twitter.com/licuende/status/1263459041411465216

projects Space Decentral had in mind as a potential "Managerial agency" (Choo and de Alvarenga Neto, 2010: p. 595).

In summary, a virtual organization needs to develop an online collaborative tool strategy associated with each of the co-creation stages. That strategy must be led and implemented by the managerial agency. But as we saw above, managing objects absorb as many resources as creating new ones, impacting the leadership on maintaining the effectiveness of these online collaborative tools, something that the community even complained about openly. Based on what we learned, this managerial agency has a dual role: manage the online collaborative tools and the organization / network / stakeholders' ecosystem. Unfortunately, Mariano and Awazu didn't have more information to share on what the research community found. They proposed exploring knowledge perspectives in "the context of networked relationships of stakeholders or ecosystems" (p. 791).

5.3 Managing knowledge to tackle challenges

Exploring the "managing knowledge to tackle challenges" issue is what we will attempt to do in this third and last section of the *Discussion* chapter. Space Decentral were aware of the problems they wanted to work on. The OECD had actually narrowed how space assets could help solve problems into five areas to benefit society along the way: the environment; the management of natural resources and agricultural practices; the increasing mobility of people and goods worldwide and its consequences; growing security concerns throughout society; and the move to the knowledge society (Osbourne, 2005). Oborne (2005) had also highlighted how policy circles around the world were giving greater attention to "moving the world's economy towards a more sustainable development path" (p. 55). One of the findings of the author was to "encourage space agencies to strengthen their partnerships with the secretariats of international treaties and conventions, notably those relating to the Earth's environment and sustainable development, to ascertain how space-based solutions might best be used for treaty monitoring and enforcement" (p. 246).

This is in line with the motivation shared in Space Decentral's White Paper. Members of Space Decentral intended to break the status quo within traditional space agencies to benefit from what space has to offer, which is a "rare intersection between good investment, meaningful impact, and a focal point for humanity's natural curiosity" (Space Decentral, 2018: p. 3). That intersection was the *Problem formulation* of what space could solve, the most important co-creation activity based on Piller and West. Interestingly, the *Problem formulation* activity has not been well studied in the boundary object field. Only a few researchers investigated this activity for contests seeking technical information (von Krogh *et al.*, 2012; Lüttgens *et al.*, 2014). Research still needs to be conducted on problem formulations for other forms of coupled open innovation (Piller and West, 2014). Specifically, Piller and West stated that co-creation literature has not covered this aspect beyond very brief references to its importance. And it is particularly important now that organizations are virtual and individuals own knowledge that can benefit more and one network.

Manage online collaborative tools to map functions and knowledge

This is where we suggest that online collaborative tools could be used to "map the interdependencies of shared boundaries and dependencies that exist between functional settings with different [boundary] objects and ends" (Carlile, 2006: p. 16) - the "workplace settings" component of Mariano and Awazou at the organisation macro level. These maps fit the concept of coincident boundaries, since these "commonly recognized boundaries allow different and overlapping content where users conduct work autonomously while cooperating with a common reference" (Steger *et al.*, 2018: p. 155). That *common reference* could be centralized at the *Problem Formulation* activity where boundaries meet and the cooperation begins among various communities of practices - or communities or experts - based on the agreed upon commitment in the *Collaborating* stage, or the rules of engagement agreed upon. We could almost upgrade the *Problem formulation* activity to a *stage*.

Throughout the literature review, it was also found that the problem solving activity doesn't seem to occur "until tensions are resolved at a more strategic level, and consensus is achieved on the 'object of activity'" (Macpherson, Jones and Oakes, 2006: p. 22). Therefore, not only virtual organizations as managerial agencies have to deliver and maintain their online collaborative infrastructure, they have to solve issues within the stakeholders' ecosystem prior to the *Problem Formulation* activity. A discussion platform like Riot is not recommended. Text-based platforms foster personal benefit instead of the common good. A better object is required to enhance the "open source" concept to bring forward the skills and abilities of each member to contribute to the design of artefacts and appropriate solutions to tackle the problems. This is related to the production of boundary objects to "resolve contradictions, articulate knowledge and develop shared understanding" (Mariano and Awazou, 2017: p. 785).

These objects would first act as the tools to raise the awareness and motivate potential users on the rules, the resource allocation activities and the strategic commitments to be put forward; all to be negotiated, recorded and tracked within the same online collaborative tools. The goal of these online tools would have to assist the managerial agency to build the "teamwork" culture and the "shared understanding" of the problematic(s) to be solved, and the rewards associated with any types of involvement. In other words, this decentralized co-creation framework supported by online collaborative tools would have to be flexible enough to develop an open culture, with porous boundaries for the stakeholders to operate in, but "rigid" enough for an object similar to Open Enterprise (if implemented within this hypothetical scenario) to be used as a monitoring tool for the managerial agency to identify members, record accomplishments, and allocate rewards to reinforce teamwork. Basically, we must admit that Space Decentral knew how to shape a virtual ecosystem. The members were just not prepared with the scope of the work in front of them. Without proper management, their objects fail to do their task.

This approach supports Christopher Lee's findings when she highlighted that boundary objects are supposed to "satisfy the informational requirements of each community of practice". She quoted Henderson (1999) and Subrahmanian *et al.* (2003) who found out that: 1) so-called boundary objects may require considerable additional explanation and discussion to be intelligible; 2) artefacts sometimes play a role in the active negotiation of shared understanding among communities of practice (and thus

can be used to enlist participation and can be adjusted through group interaction); 3) un-standardized artefacts that are partial, incomplete, or are intermediary representations are ubiquitous in collaborative work; and, 4) so-called boundary objects can "fail" to satisfy the informational needs of collaborating parties". Also, as indicated in the literature review, boundary objects analyzed in the context of relationships within an organization or a network must enable trust to work. Olson and Olson (2000) had found that knowledge is the first and foremost element to take into consideration and individuals must be aware of the knowledge that each one has, either in common or not. Then, we have shared experiences and norms, and where people reside and the culture they live in. This is a range of factors that strengthen trust - or diminish it - a fragile thing in a virtual environment. Consequently, Space Decentral might have found it harder to advance quickly in an environment where they needed to manage a range of diverse knowledge holders working on multiple problems.

Then, there is the issue of protecting that knowledge. Not everyone is willing to share their knowledge - even people within their own organization. These tensions created by the clash of past and novel knowledge, and the issue of intellectual property, require constant reflection on current practices (Miettinen and Virkkunen, 2005, p. 451). This is why, in the spirit of an ideal decentralized organization, implementing the right online tools or usage of brokers / intermediaries to manage activities related to the *Leveraging* stage supporting the *Problem formulation* activities would have had the potential to secure a more strategic diverse group of stakeholders and expertise. This *Leveraging* would have also increased the chance to bring the right knowledge to strengthen the *Commercializing the knowledge through products and services* co-creation activity in parallel. The usage of tokens as described above would actually be the right "thing" for sub-activities enabling multiple types of stakeholders to record their contribution, preserving the type of information required for intellectual property cases.

To conclude the *Discussion* chapter, we looked at what was missing and what would be required to make online collaborative tools foster co-creation activities within virtual organizations. We first looked into which online collaborative tools failed to work and why. Then, we learned that these tools couldn't always work at each step of Space Decentral's growth; they could not "cope" with the situation, especially the *Problem formulation* activity and all co-creation activities related to the *Finding participants* stage. We, however, found that managing individuals efficiently requires a managerial agency who masters these online collaborative tools, able to either repurpose or create new artefacts along the way. This seems to be the key to the success of future virtual organizations. This is also important for efficient knowledge management strategies within virtual organizations and especially those involved in long-term projects such as the space sector. This is where the first iteration of the Open Enterprise application must not be thrown away. It would have recorded important data, time-stamped, linked to the stakeholders' identity, and be searchable (depending on the permission settings), similar to what Steger *et al.* (2015) described as an ecosystem service production function, translating a standardized set of information into a consistent output. Alternatively, an upgraded Open Enterprise infrastructure could have innovated in bringing new market opportunities related to trends in processes, services and products, especially in the areas of data science, classification algorithms and artificial intelligence. This would have led to a comprehensive coopetition environment involving not only organizations, but individuals pooling their knowledge and know-how together to tackle complex

problems and be rewarded for it. This is where researchers in organization theory must reach out to those investigating the field of computer-supported cooperative work to further research that important phenomenon.

6. Conclusion

This thesis explored how online collaborative tools foster co-creation activities within virtual organizations. Using only online platforms, I investigated the discussions, literature and other documents related to my explorative case study: Space Decentral, a decentralized organization with a strong open source culture. This research project essentially used the concept of *boundary object* and *boundary negotiating artefact* to examine the utilization of online collaborative tools (including the advent of Space Decentral's blockchain application Open Enterprise) as "things" to manage knowledge across organizations and networks for co-creation activities. In the past few decades, these co-creation activities, structured under four broad stages based on Piller and West's 2014 co-creation framework, were studied in traditional collaborative environments where the utilization of virtual platforms was mostly limited or inexistent. Now in 2022, it is probably time to revisit these concepts.

As of February 2022, the pandemic remains in the news and organizations are cautious about reopening offices. Consequently, the advent of various hybrid office models will impact many common approaches to a good collaborative environment. In fact, as we saw during the investigation, online boundary objects/artefacts will likely reshape the way co-creation and organizations work - or the way people come together and share their expertise on a specific project in a decentralized organization or network. This will likely require a range of skills that some managers and employees might not possess yet. This also brings the need to reflect on the "managerial agency" role of organizations for both managing online collaborative tools and the stakeholders who are connected to the network.

Summary of the research

The research was divided into two subsections: Phase One and Phase Two. Phase One focused on structuring the conversations found on the Space Decentral's Riot platform between January 2018 and December 2019; data structured using Frank Piller and Joel West's 2014 co-creation framework. Phase Two focused on Space Decentral's White Paper and the Governance Paper, in addition to reports of organizations that had investigated online/virtual organizations, blockchain technology and the state of the space sector. It provided an aggregate picture of the topics of interest of Space Decentral's community, the mechanisms used by Space Decentral for managing space-related projects in a co-creation environment, and the challenges encountered. Furthermore, we witnessed the beginning and end of their two initiatives (i.e., the Space Mission Activation Process (SMAP) and Coral). We witnessed as well the creation of Autark, the organization founded by members of the Space Decentral project in 2019. Autark's goal was to implement a suite of blockchain applications that the team of Space Decentral had promoted as the infrastructure to build their future activities. This led to the release of the Open Enterprise application at the end of 2019 - and the legal battle that followed with Aragon, their main financial support. Paradoxically, both believed in blockchain technology, but failed to trust each other since the relationship was broken along the way.

All in all, three recurring themes were found during the Data Collection activity: open source; governance and decisions; and, leveraging external knowledge. Also, as we progressed in investigating the research question (how online collaborative tools foster co-creation activities within virtual

organizations), this led to the creation of a different sequence of co-creation stages and activities from the one we started with (i.e., Piller and West's). This new framework hinted at an emerging coopetition environment for individuals operating in a decentralized and virtual setting interested in participating within ecosystems of expertise to manage projects in a co-creation environment at the periphery of their current job.

Research limitations

Although this research looked into a failed decentralized experiment, I believe this *Space Decentral initiative* is only the beginning of a complex virtual environment to come in the world of organization theory. Unfortunately, the explorative case study only allowed data collection to a certain level. Finding similar case studies as Space Decentral relying on online collaborative tools for co-creation activities would be worthwhile. The student could follow them for at least three to five years to help improve our understanding on the evolution and influence of various online collaborative tools on the workplace.

Moreover, including targeted interviews with firms or organizations working on similar platforms would be advisable. Considering I was not able to embed myself into the activities of Space Decentral and share conversations with the members, one-on-one interviews could provide relevant insights on the creation and management of these online collaborative tools. This would further our knowledge related to co-creation activities in an online environment; even in situations where managers are not limited to their organization's boundary (i.e., they share their time with other initiatives online). For instance, the research could study what skills managers are using to work with these online collaborative tools within their own team, and with other communities. This could clarify the distinction between managing online collaborative tools sometimes as boundary objects (i.e., in an environment where resources are stable; the authority to dictate clear steps / process is clear; employees have experience and there is a clear division of labour; project goal is explicit; and, there is a simple organizational context) and sometimes as boundary negotiating artefacts (i.e., where projects are not part of the routine; steps are unclear; and, workers don't have experience or know each other).

At the inter-organizational level, it would be worthwhile to better define the type of work required for virtual *managerial agencies* to manage these online collaborative tools and its stakeholders. For example, there are other blockchain-led co-creation organizations such as Frankl, Matryx, and DAOstack. They started "*decentralized*" and want to develop similar blockchain applications. But their longevity remains to be seen. Alternatively, considering that society just began using online collaborative tools more intensively for day-to-day activities, future students could simply study how traditional organizations have supervised the shift while managing their stakeholders' ecosystem. This would be even recommended considering that numerous turn-key solutions are now available from conventional applications, such as MS 360, Google Workspace, Notion, etc. They are still using a centralized server but provide powerful tools with similar capabilities as blockchain applications, without the resources required to code and maintain a certain level of security.

Another research direction I would recommend would be looking into the *Problem formulation* co-creation activity in a virtual setting. It has barely been studied before Covid, and it now seems to be a

significant knowledge gap since our world today is now moving towards managing complex issues together, across organizations and nations. This research demonstrated that Space Decentral's community didn't invest time reflecting on how online collaborative tools could be used to formulate and provide incentives to work on problems. Members were mostly interested in institutional rules, privileges and automated decision-making. But working on broad problems together will be the challenge of the 21st century. The best examples are climate change and biodiversity, where everything is connected, even the space sector who's actually supporting researchers and firms by feeding them with space-based data from Earth observation missions to better understand climate change.

One area to contemplate would be to create policies to use the flexible infrastructure of a blockchain to power a LinkedIn-like decentralized platform for retired government employees interested in working part-time to support the public and private sectors. Their knowledge and expertise in navigating government systems, processes, departments and other bureaucratic rudiments could be quite valuable and efficient. Another type of policy would be related to human resources and recruitment. While traditional organizations needed a certain type of managers, decentralized organization might require educated individuals on the latest co-creative trends with skills to motivate and engage stakeholders through online tools.

The future of remote working

To conclude, I hope this research project shed more light on what is required from employees and managers who are shifting to a more intensive virtual environment. Even though it is now easier to access resources and talent from around the world, it, however, comes with many responsibilities and challenges. We now know that managers need to both manage the process of co-creation and the tools enabling this co-creation virtually. This research contributed to laying out the foundation of an evolving new system to manage and use individuals' knowledge efficiently inside a dynamic and decentralized ecosystem. Not only these investigations would break silos found in traditional organizations working on complex projects, but bring coherence among social worlds, while adding value to the "organizational memory" from skilled employees. And interestingly, traditional space organizations might just be the right entities to study it further.

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