Study on the Convergence Between the Space Industry and the Internet Industry

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Executive Summary

This thesis is focusing on the convergence between the space industry and the internet industry. To better scope the topic, this thesis is started with the definitions of the two industries, and the definition of industry convergence. A specific model and a universal research framework are developed for this topic.

A new approach, bibliometrics with co-occurrence method is developed in this thesis to analyze the status of convergence. The results show that there is an on-going and speeding-up convergence between the two industries. This new approach not only shows the capability to identify the status of convergence like other tools but also has potentials to derive more information: (1) the internet technologies are dominating the convergence process; (2) the US, China, and the EU are the main contributors for the convergence; (3) the cooperation between countries is a common phenomenon.

Six convergence scenarios between the space industry and the internet industry are discussed, which are space tech supporting internet, internet tech supporting space, satellite-based internet service, imagery based on Big Data and AI, satellite Supporting IoT, and interplanetary network. The analysis reveals the characteristics of convergence scenarios: (1) the convergence in substitute and in complement coexist; (2) the maturity, the opportunities, the risks, and the disruptiveness all vary; (3) Convergence scenarios in substitute bring opportunities to both industries; (4) Convergence scenarios in complement result prevailingly in sub-industries of internet with high potential, high risks and high disruptiveness.

The external drivers for the convergence are discussed following the structure of PESTEL. The results show that the external drivers are mainly playing a positive role in the convergence. The main motivations are from the technological progress and the needs of economic development. Negative drivers lie in the political, environmental and legal domains with low influences.

The implications and recommendations of convergence lie in both country level and industry level. For countries, cooperation is inevitable, and investment for R&D is encouraged. For the space industry, it is integrated into the value chain of the internet industry, and facing an upgradation of industry scale. For the internet industry, it can meet the needs of continuous growth. The risks and opportunities are realistic for the two industries and related firms. For the two industries and related firms, choosing the right strategy by being aware of risks and crucial technologies is the lynchpin.

Keywords: Industry convergence, Space industry, Internet industry, Bibliometrics, Co-occurrence.

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1 Introduction

1.1 Background

The world has shown interest in the convergence between space industry and internet industry. Some startups like OneWeb, who are dedicated in creating global internet connection by space infrastructures, are gaining more attentions from the public, the medias and the capital (Micheal 2017), which preliminarily support the convergence between the space industry and the internet industry. But the image is still blurred because of the lack of detailed analysis and investigation.

Convergence is not a brand-new topic in academic or professional context. Studies on convergence between specific industries have been conducted, e.g. convergence between the food industry and the pharmaceutical industry (Weenen et al. 2013), convergence in ICT-related[1] industries (Curran & Leker 2011; Xing et al. 2011), convergence in the chemical and pharmaceutical industry (Curran & Leker 2011), convergence between nutraceuticals and functional foods (Bröring et al. 2006), convergence between agriculture and chemistry (Preschitschek et al. 2011). However, there was barely any study on the convergence between the space industry and the internet industry.

1.2 Importance of the Research

The consequences of industry convergence are the root cause of its popularity. Generally speaking, industry convergence provides unprecedented opportunities as well as risks by breaking existing balance and market continuity. The convergence can determine the future of a firm or an industry, resulting in the enlargement, shrink or even vanishing. It can also result in the value chain reconfiguration (Wirtz 2001) and the industry paradigms (Hacklin et al. 2009). Moreover, industry convergence can provide more opportunities for firms by enlarging the market (Hacklin et al. 2009), accompanied with more competitions (Borés et al. 2003; Greenstein & Khanna 1997). The competition can lead to a high probability of the adjustment of industry structure together with M&A (Chamata 2017) etc. That is to say, it is vital for the survival and development of a firm, an industry, even an economic entity.

The convergence between the space industry and the internet industry is becoming a buzzword. The future of related firms and the two industries will be deeply influenced by the potential trends. As a strategic industry, space industries are critical for main players in the world arena. The developing direction of the space industry will strongly impact the balance between great powers in the world. Internet industry is continuing to change the world

[1] ICT stands for the Information and Communications Technology

dramatically, not only in the way of wealth but also human life-styles. The future of internet industry will impact the human society in all respects. To some extent, the convergence between the space industry and the internet industry is a matter of the utmost concern, which might bring a broad range of effects from human life to the balance of the world.

1.3 Scope of the Research

This research project attempts to answer the following Sub-Research Questions (SRQs):

SRQ1: What is the status of the convergence between the space industry and the internet industry?

SRQ2: Where does the convergence between the two industries emerge?

SRQ3: What are the drivers for the convergence? Positive or negative?

SRQ4: How does the convergence influence the future of the two industries?

SRQ5: What can be done to cope with the trends of convergence between the two industries?

2 Literature Review

2.1 Definitions of the Space Industry and the Internet Industry

To measure the industry convergence, an industry should firstly be clearly defined. To demarcate industry boundaries, a theoretical definition is not enough, but an industry classification standard is required. The formulation of an industry classification standard is mainly for the purpose of statistics. The classification should satisfy the requirement that every economic activity falls in one and only one industry category. However, the classifications of industries for statistics are not always consistent or practical, especially when the study is focusing on some industries which are not used in classifications. In this section, the industry classifications and their definitions for the space industry and the internet industry are reviewed and discussed.

The phrases of 'space industry' and 'internet industry' are commonly existing in the academic, governmental and professional context, but to some extent it is impossible to find unanimous definitions for them. There are mainly two origins to find the definition of an industry, including the governmental statistical agencies and the financial industry, which we discuss separately below.

2.1.1 Industry Definition from Governmental Statistical Agencies

The most significant governmental statistical industry definitions include NAICS (North American Industry Classification System)[2] from the United States together with Canada and Mexico (Anon 2017a), ISIC (International Standard Industrial Classification) from the United Nations (Anon 2008) and NACE (Nomenclature statistique des activités économiques dans la Communauté européenne) from the Europe (Eurostat 2008).

Since NACE and ISIC seem less adapted to the emerging service and knowledge economy than NAICS (Lind 2005), NAICS is primarily discussed for the topic.

The NAICS classification builds on grouping around the production process and the supply side of the economy. Firms using similar production methods are grouped together. NAICS uses Sector, Sub-sector, Industry group, Industry (2 level: 5-digit and 6-digit) to categorize industries. NAICS consists of 20 broad industry sectors and 1,057 industries (Anon 2017a). There is no specific space industry or internet industry. The internet industry can be found in the Information sector, such as the Data Processing, Hosting, and Related Services sub-sectors and the Software Publishers sub-sector. But the definition of the internet industry is still

[2] https://www.census.gov/eos/www/naics/

ambiguous. The space industry can be related to the Aerospace Product and Parts Manufacturing industry group and the Space Research and Technology sub-sector, which give a clear definition of the space industry as a manufacturer of satellites and launching vehicles with manufacturing and R&D activities.

2.1.2 Definition of an Industry from the Financial Industry

In addition to the official industry classifications, there are some taxonomies developed in the private sector. The financial industry has developed an alternative classification system, GICS (Global Industry Classification Standard)[3]. GICS is developed by Morgan Stanley together with Standard & Poor's. It is adapted for listed companies and its structure, which consists of 10 top level sectors, 24 broad industry groups, 62 industries and 132 sub-industries.

In GICS, there is no specific space industry or internet industry, but there are Aerospace and Defense industry (level 3), Information Technology sector (top level) and Telecommunication Services sector (top level). The space industry can be categorized into the Aerospace industry. The definition for the Aerospace and Defense industry is “Manufacturers of civil or military aerospace and defense equipment, parts or products. It includes defense electronics and space equipment”, which is strictly limiting the industry by manufacturing. Although this definition includes not only the space industry, but also the aeronautic industry and the defense industry, it presents a good reference to define the space industry. The internet industry can be related to the Information technology sector and Telecommunication service sector, which is not accurate for this research, and is too broad for the internet industry.

2.1.3 Definitions Used in the Article

For the space industry, the definition is clear enough. The definition described above demarcates the space industry as manufacturers of civil or military space equipment, parts or products with manufacturing and R&D activities.

But, the definition of the internet industry is still blurred. The categorizations above are not precise enough to provide clear boundaries for the internet industry. Thus, more information to demarcate the boundary of the internet industry. To some extent, the convergence of industries will affect all related stakeholders. We introduce value chain concept to help demarcate the boundary. According to the internet value chain proposed by A.T. Kearney (Page et al. 2016), the value chain comprises five categories, which are content rights, online services, enabling technology and services, connectivity, and user interface. By combining the definitions mentioned above and the value chain concept, the definition of the internet industry used in this article is the groups of companies related with content rights, online

[3] https://www.msci.com/en/gics

services, enabling technology and services, connectivity, and user interface in Information Technology Industry and Telecommunication Industry.

2.2 Definition of Industry Convergence

2.2.1 Review of Industry convergence

As the importance of industry convergence draws more and more public attentions, the researchers have endeavored to understand this phenomenon by defining the term "industry convergence". The definition of industry convergence comprises different dimensions, including the direct definition, categorization and sequential model.

A series of studies on the definition of industry convergence have been conducted by various researchers. Rosenberg (1963) used the word "technological convergence" in his study about the early evolution of American machine tool industry. Langlois and Robertson (1995) described the definition of convergence as industry restructuring without mentioning the word convergence. Bröring, Cloutier, and Leker (2006) proposed the definition of Industry convergence as the blurring of boundaries between industries. Curran and Leker (2011) discussed the definition of convergence (not industry convergence) together with fusion as "a blurring of boundaries between at least two hitherto disjoint areas of science, technology, markets, or industries".

A model of convergence, which comprises two types of convergences, substitutes and complements, was discussed by (Greenstein & Khanna 1997). A 2*2 matrix, which comprises four categories of convergence, is introduced to categorize the industry convergence. One dimension comprises Supply Side and Demand Side, and the other comprises Substitute and Complement (Pennings & Puranam 2001). Stieglitz (2003) used the same 2*2 matrix but different labels of Technology vs. Product based convergence instead of the Supply-Demand dimension (shown in Figure 1). In this model, technology substitution means that a new technology replaces different technologies in established industries. Technology integration means that technologies previously associated to different industries are integrated, thereby maturing new industries. Product substitution means that established products from one industry substitute products from other industries by integrating similar features. Product complementarity means that two products from different industries are turned into complements.

	Substitutes	Complements
Technology-based convergence	Technology substitution	Technology integration
Product-based convergence	Product substitution	Product complementarity

Figure 1 Types of industry convergence

Lind (2005) discussed the definition of industry convergence and chose a taxonomy without demand side (or product side) convergences, because "the demand side (or product side) convergences are less helpful" for the specific study.

The convergence between industries is categorized into four stages, which are knowledge convergence, technological convergence, applicational convergence and industrial convergence (Hacklin et al. 2009).



Figure 2 Convergence stages suggested by Hacklin, Marxt, and Fahrni

Curran, Bröring, and Leker (2010) gave a similar sequential process of industry convergence, by relabeling the stages (Figure 3).

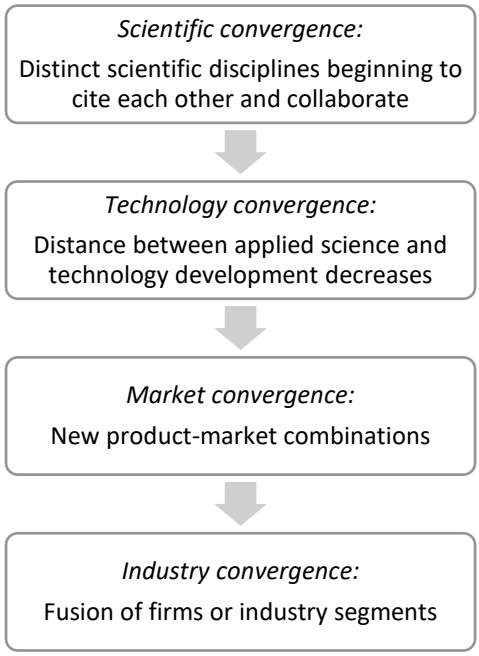

Figure 3 Convergence stages suggested by Curran, Bröring, and Leker

Whereas, Curran and Leker (2011) improved the former model of industry convergence, which is shown in Figure 4. Under different conditions, the routes of industry convergence will vary.

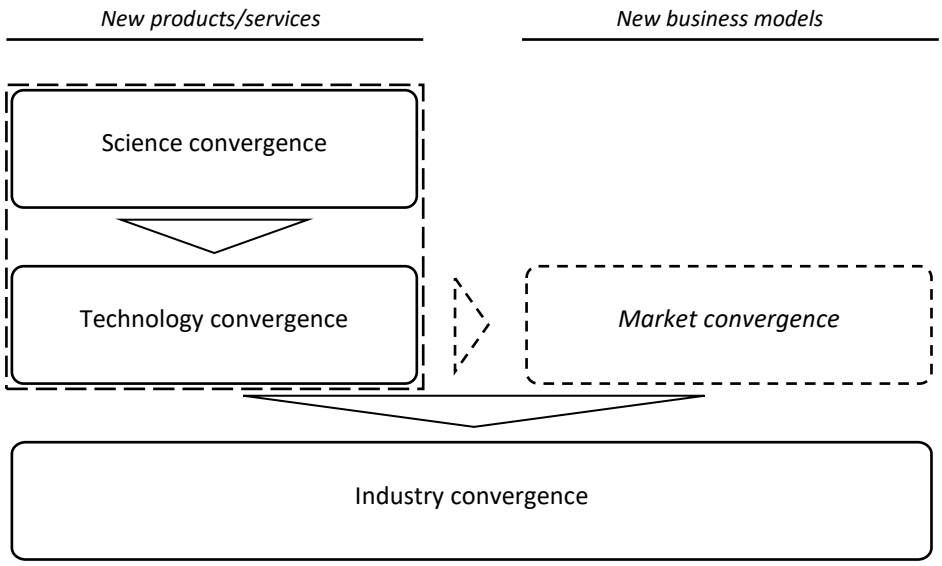

Figure 4 Sequence of industry convergence suggested by Curran and Leker

2.2.2 Convergence Definition and Model Used in the Article

In this article, industry convergence is defined as a blurring *PROCESS* of boundaries between at least two industries. The key word "process" indicates that, when discussing industry convergence, the drivers and the effects are relevant but not included. This definition will

facilitate the categorization and the sequential model of industry convergence. Some related concepts, e.g. the effects of convergence, can be excluded from the convergence model.

The categorization of convergence is not consistent with the definition. The popular definition established by Stieglitz (2003) has some complexities to demarcate the product side and the technology side. When industries are converging with each other, it is very hard to define a product of convergence without involving technology convergence. The problem seems to be the close entanglement between products and the underlying technologies inside the products. It is hard to envisage a demand side convergence without any reference to the underlying technology (Lind 2005). This article will only take the technology side into account, treating the product convergence as a collateral outcome and the demand as a driver (Figure 5).

	Substitutes	Complements
Industry convergence	Technology substitution	Technology integration

Figure 5 Categorization of industry convergence

Previous researches have a divergence on the sequence of industry convergence. The divergence point is related to the market (applicational) convergence. Market convergence cannot emerge by itself, because it is the outcome accompanying with the industry convergence. It is a stage of industry convergence, at which the industry convergence is finalized. The market convergence is equal to the final stage of complement convergence. For substitute convergence, the indicator is not market convergence, rather a new product or new business. The industry convergence mentioned in other models is deemed as "fusion of firms or industry segments", which is actually the effects of industry convergence, but not the industry convergence itself. According to the arguments above, the sequence of industry convergence comprises three stages, including the scientific convergence, knowledge convergence (technological convergence) and industry convergence (Figure 6). In this model, market convergence is a collateral results or implications of complement convergence, which means that the market convergence is part of the extension of convergence. Thus, the discussion of convergence itself does not contain the implications part.

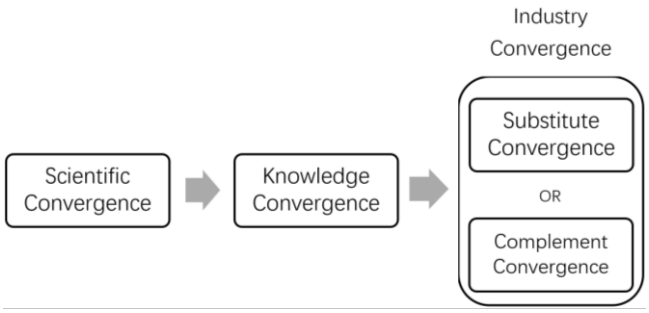

Figure 6 Sequential model of industry convergence

In this model, the knowledge convergence (technological convergence) is the intermediary of convergence process, which is the theoretical basis of the method of analyzing patents.

2.3 Research Scope of Industry Convergence

Weaver (2007) proposed a theoretical framework of convergence (Figure 7). Industry convergence research can be divided into four domains - namely divers of industry convergence, industry convergence, consequences of convergence and firm effects. Even though firm effects can, to some extent, be classified into the consequences of convergence, this framework has a high value for reference.

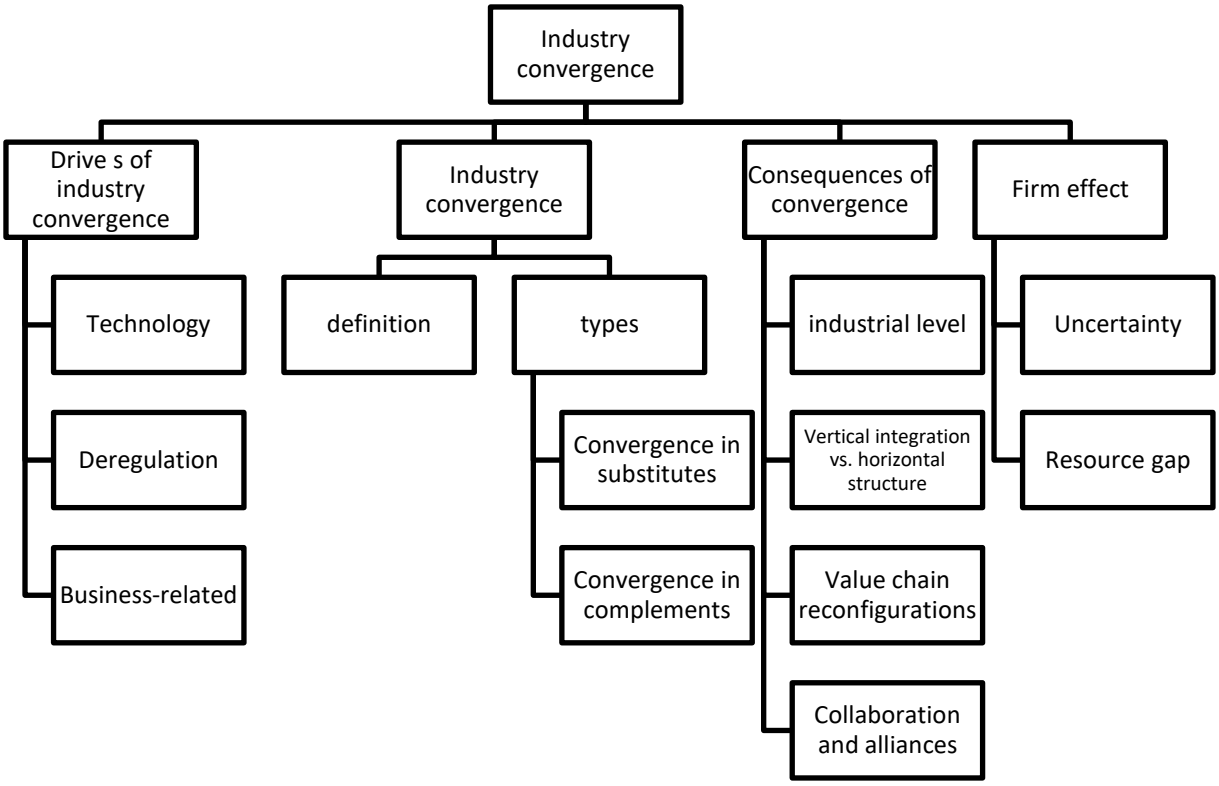

Figure 7 Theoretical framework of convergence study

Geum, Kim, and Lee (2016) reviewed and analyzed the study of industry convergence. Generally speaking, All the studies are related to inputs or outputs of industry convergence.(Figure 8). For industry convergence inputs, the object of convergence, the driver of convergence, and academic fields are the main topics. For industry convergence outputs, the value or the effects of the industry convergence are discussed. This review gives a notion of interest of studies on industry convergence. As for the study of convergence between the space industry and the internet industry, the critical points are the objects and the drivers of convergence for inputs as well as the value and the effects for outputs.

Even if there is no fully consistent narrative when talking about convergence research framework, the significant aspects are generally similar.

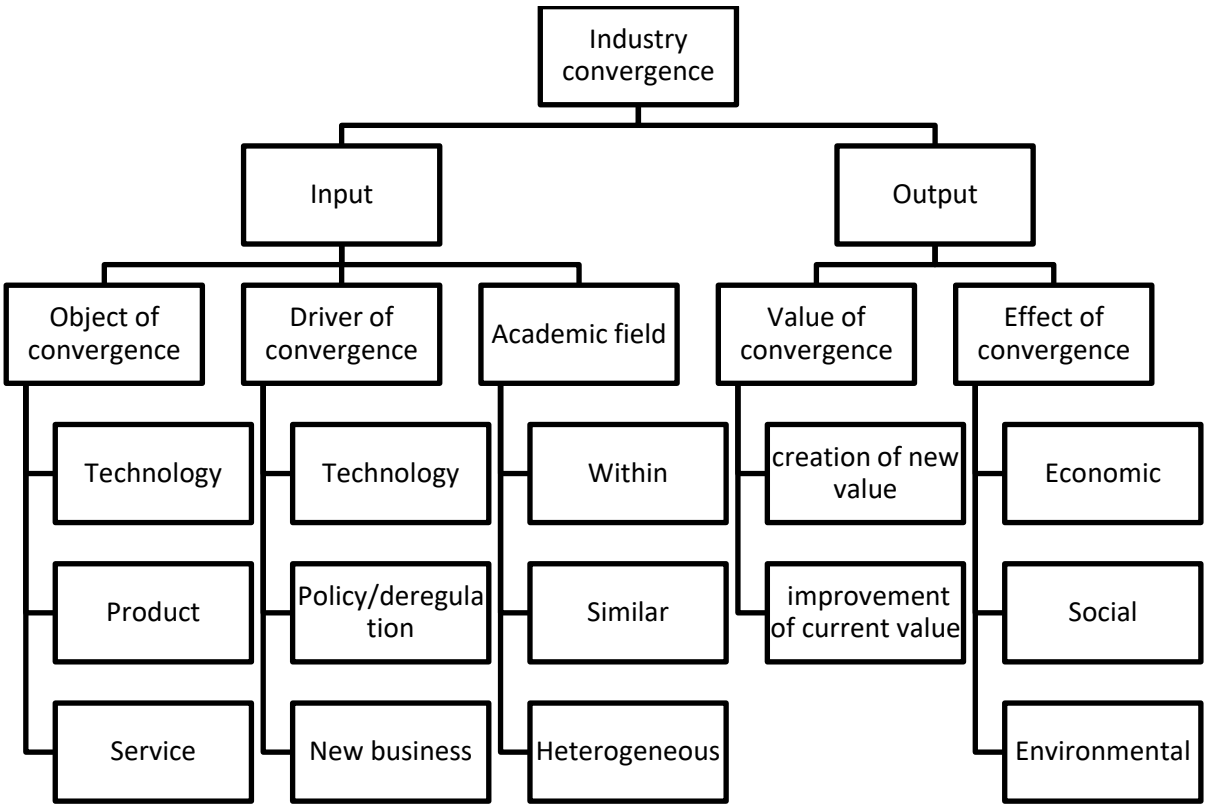

Figure 8 Analysis of previous studies regarding industry convergence

3 Research Design

Previous study review shows that there is no consensus about the definition of convergence or the research approaches. Based on different purposes, most of the former researches focus on specific aspect(s) of industry convergence. Some of the researches have different statements on the research framework, the definition and the methodologies. To be more pragmatic for a specific industry, a holistic design of research framework is inevitable. This article will focus on the convergence between the space industry and the internet industry by a harmonious and comprehensive design of definition, research framework together with research approaches.

3.1 Research Framework

The previous discussion clarifies the connotation and the extension of convergence. Based on the characteristics of convergence between the space industry and the internet industry, a research framework is designed (Figure 9). First step is to study on the status of convergence between the space industry and the internet industry, in order to answer SRQ1. This part only discusses the existence and tendency of the convergence between the two industries. The third one is to present potential convergence scenarios, in order to answer SRQ2. The second one is to analyze potential drivers for the convergence, in order to answer SRQ3. The forth one is to make a consequences analysis, in order to answer SRQ4. The last one is to give recommendations to those who are interested in the potential business, aiming to answer SRQ5.

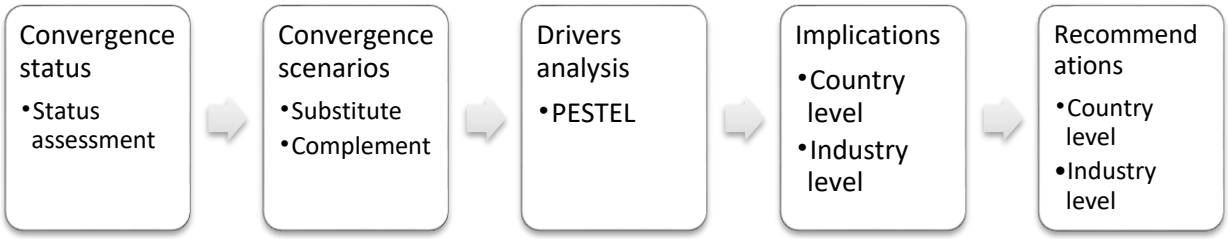

Figure 9 Research framework

In this article, a quantitative analysis, which is proposed in this article, is applied to the first part. For other parts, the qualitative arguments are made based on the results of quantitative analysis and other information.

3.2 Bibliometrics with Co-Occurrence for Analyzing Convergence Status

3.2.1 Rationale

To understand the extent of industry convergence, researchers developed different approaches to analyzed indirect data. As an significant indicator of innovation, patent is used to analyze industry convergence by several groups of researchers (Curran & Leker 2011; Curran et al. 2010; Preschitschek et al. 2013; Weenen et al. 2013). Kim et al. (2015) used newspaper article as input sources to analyze firm's interorganizational dynamics in order to understand the convergence between industries. This method is capable to analyze a big amount of industry simultaneously by handling more than 1 million articles. The results show the convergence tendency between industries. But, the newspaper articles are sometimes the results for the latter stage of the convergence, because the co-occurrence of firms' names is collateral the effects of the convergence. The essence of the aforementioned methods is co-occurrence, which indicates convergence by identifying the co-occurrence of elements from different industries. Case study is another popular approach for industry convergence analysis, which is used in a series of studies (Lind 2005; Xing et al. 2011; Weaver 2007). But, Case study is based on some independent incident, which tends to be wise in retrospect. Compared with other approaches mentioned above, case study is a qualitative method, rather a quantitative one. To study a complicated issue like convergence between industries, a hybrid of qualitative and quantitative methods will be more persuasive.

Academic articles are scientific and technological outcomes of research and development. An article related with two or more industries indicates the technology related can promote the convergence of industries. Similar with patents, academic articles are the outcomes of scientific research. Patent information generally explains possible outcomes, rather than discussing current advancements (Kim et al. 2015). Whereas, the academic articles are mostly peer-reviewed, which means that academic articles are more rigorous and more reliable than patents. Newspaper articles are Compared with newspaper articles, academic articles are more structured and more objective (i.e., no media preferences). But, academic articles are always focusing on science and technologies. Thus, they are more effective in analyzing the convergence between technology-driven areas.

Bibliometrics, a statistical tool for analyzing academic articles, is used to provide quantitative analysis of academic literature (Bellis 2009). In this article, the essence of co-occurrence methods used in some of the aforementioned articles is introduced to the bibliometrics. That is to say, if keywords from different industries are identified simultaneously in one article, it is an evidence for the convergence. Bibliometrics combined with co-occurrence method provides a new approach to analyze industry convergence. Similar with other co-occurrence methods, this approach my contain noisy information (Kim et al. 2015). This article ignored it to focus on the trends, rather than on the accuracy. For this purpose, the effects of noisy information will be at the same level for different years, and will be acceptable.

The articles, which contain keywords from the space industry and the internet industry simultaneously (this kind of articles are named as “the articles in convergence”), are the evidences for the convergence between the two industries. More specifically, the following presumptions are introduced to the research:

Presumption 1: The tendency of the number of articles in convergence indicates the tendency of convergence;

If the world is putting more efforts on the convergence between the space industry and the internet industry, the intermediate products like patents and academic papers will increase, and vice versa. Therefore, if the number of articles in convergence is relatively increasing, the convergence process is strengthening, and vice versa. This is also the same logic used in other co-occurrence methods (Kim et al. 2015).

Presumption 2: The articles in convergence found in the journals from one industry indicate the influence of technologies from this industry during the convergence process;

For a technology-driven convergence, the convergence is highly determined by the technologies under development. The articles, as the outcome of R&D, can be an indicator of determinants, which means that we can estimate the predominant industry during the process in terms of technology. Figure 10 illustrates the efforts flow of convergence. The influence of technologies from one industry can be relatively estimated by the relative number of articles published in related journals. For example, an article in convergence published on a space-related journal means potential influence of space technology for the convergence. More specifically, if the number of articles in convergence found in the category “Engineering: Aerospace” is prevailing those found in categories related with internet, it means that space technologies are dominating the convergence process, and vice versa.

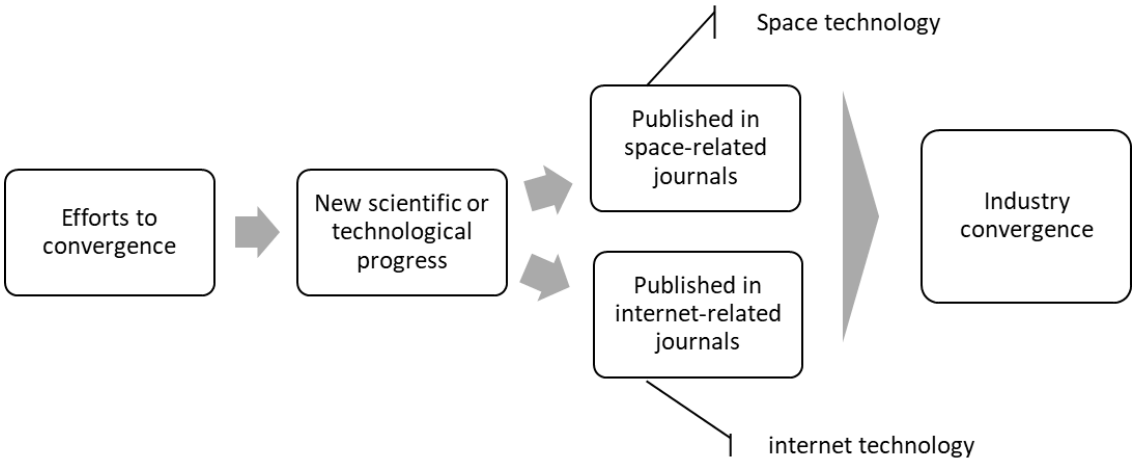

Figure 10 Efforts flow of industry convergence

Presumption 3: The statistics of authors from different indicates the contribution, the competitiveness, and cooperation among countries;

Following the similar logic in the presumption 1, if a country is putting more efforts on the convergence technologies, the outcome will be more. Thus, the number of articles in convergence can be an indicator of the contribution of participating countries. In other words, it indicates the competitions between countries.

If a group of authors are working together, the articles as outcomes are supposed to be authored together, according to the basic principle of academic discipline. When researchers from different counties work together on the topic of technologies towards industry convergence, which means cooperation among countries, the cooperation can be derived from the authors.

3.2.2 Procedure

To study the trends in the past years, a specific range of articles ought to be fixed. In this article, the targeted database is Web of Science (WoS), which is providing the largest online subscription-based scientific citation indexing service. The articles in WoS are classified into 252 categories[4], which facilitates the further analysis by narrowing down the scope. According to the aforementioned definitions of the space industry and the internet industry, different research categories are chosen for the space industry and the internet industry. For Space

[4] Web of Science Categories:
http://images.webofknowledge.com/WOKRS5251R3/help/WOS/hp_subject_category_terms_tasca.html

industry, the category "Engineering: Aerospace" is chosen as the target. For the internet industry, three categories, which are Computer science, Telecommunications and Communication, are chosen. Those categories involve wider domains than the two industries. Thus, specific keywords, as indicators for the space industry and the internet industry, are used to screen out related articles. Two series of indicators are used (Table 1 for the space industry and Table 2 for the internet industry). Those indicators are from the interview with specialists from the two industries. Those indicators don't mean to identify all the articles precisely. The tendencies are far more valuable than the absolute values.

Table 1 indicators used for identifying articles related with space industry

#	Indicators	Case sensitivity
1	satellite*[5]	No
2	orbit*	No
3	spacecraft*	No
4	space object*	No
5	space bod*	No
6	solar	No
7	planet*	No
8	lunar*	No
9	astronaut*	No
10	space robot*	No
11	space environment*	No
12	space debris	No

Table 2 indicators used for identifying articles related with the internet industry

#	Indicators	Case sensitivity
1	internet*	No
2	network*	No
3	IoT	Yes
4	bigdata	No
5	*communication*	No
6	artificial intelligence	No
7	AI	Yes
8	topolog*	No

The analyses for two industries are supposed to be conducted respectively to find more accurate information about each industry. Figure 11 shows the data identification processed for each industry. For instance, the category "Engineering: Aerospace" includes articles for aeronautic industry. The first step is to derive data from WoS. The second step is to identify those only related with the space industry (i.e., to eliminate the article with aeronautic industry, etc.). The last step is to identify those related with internet in the remaining articles.

[5] asterisk (*) is a wildcard character.

To get full understanding of the convergence status and tendency, the data for the last ten years (from 2007 to 2016) are derived and analyzed in this article.

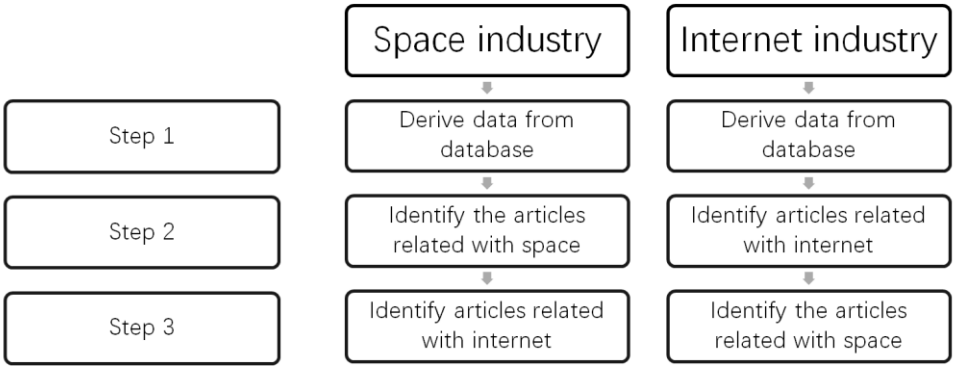

Figure 11 Identification processes for the space industry and the internet industry

3.2.3 Criteria for the Tendency of Convergence

The number of articles published in specific domains are generally increasing year by year. How the increment of articles represents the convergence is determined by the following criteria:

(1) The position of the industries

If the growth rate of articles related with one industry is higher than the average, the industry is developing than the average, which is called superior industry. Those whose growth rate of articles is lower than the average is called inferior industry. The superiority is caused by the advantage of internal development and/or convergence with other industries, and vice versa. The positions of industries are the basis for further analysis.

(2) The weak indicator of convergence

For superior industries, if the growth rate of articles in convergence is lower than that of all the articles related with those industries, but higher than the average growth rate of all articles from all industries, it is a weak indicator of convergence. For inferior industries, if the growth rate of articles in convergence is higher than that of all the articles related with this industry, but lower than the average growth rate of all articles from all industries, it is also deemed as weak indicator of convergence.

(3) The strong indicator of convergence

For superior industries, if the growth rate of articles in convergence is higher than that of all the articles related with this industry, it is a strong indicator of convergence. For inferior industries, the strong indicator of convergence is that the growth rate of articles in convergence is higher than the average growth rate of all articles from all industries.

(4) Other circumstances

For other circumstances, there is no indicator for industry convergence development.

3.3 PESTEL for Analyzing Convergence Drivers

The convergence process is driven by external forces, which are called drivers in this article. PESTEL[6] is introduced as framework to standardize the process. For a technology-driven process, the convergence is influenced much more by technologies than by other factors. Even though the technologies are in the sequential model of the convergence process, it is still can be deemed as an external driver, as part of PESTEL. Generally, some of the drivers are supportive of the change, whereas others not. Thus, the drivers can be classified as positive drivers and negative ones. Because the magnitude of the influence is not measurable, a qualitative discussion is deducted in this article.

[6] PESTEL is an acronym for Political, Economic, Social, Technological, Environmental, Legal. PESTEL analysis is a framework of macro-environmental (external environment) factors used in the environmental scanning component of strategic management

4 Analyses and Discussion

4.1 Convergence Status

This part is to answer SRQ 1: the status of the convergence between the space industry and the internet industry. When talking about the status, it is a broad topic. The topic is not only about the existence and the trend, but also about the status of involved countries and industries.

4.1.1 Preliminary Results of Bibliometrics

4.1.1.1 Preliminary Results for the Space Industry

In the category "Engineering: Aerospace" of WoS, full records including authors, titles, sources, abstracts and cited references are derived from the database. The total number of articles is 27,577. Figure 12 shows the numbers of articles found from 2007 to 2016. After the second step and third step of identification processes shown in Figure 11, the total number of articles related with the space industry is 8,234 and the number of articles related with two industries is 1,750 (Figure 13 and Figure 14). The results illustrate that articles from the aerospace industry and the space industry remained steadily with fluctuations in the first six years, and then increased in the next four years from 2013 to 2016.

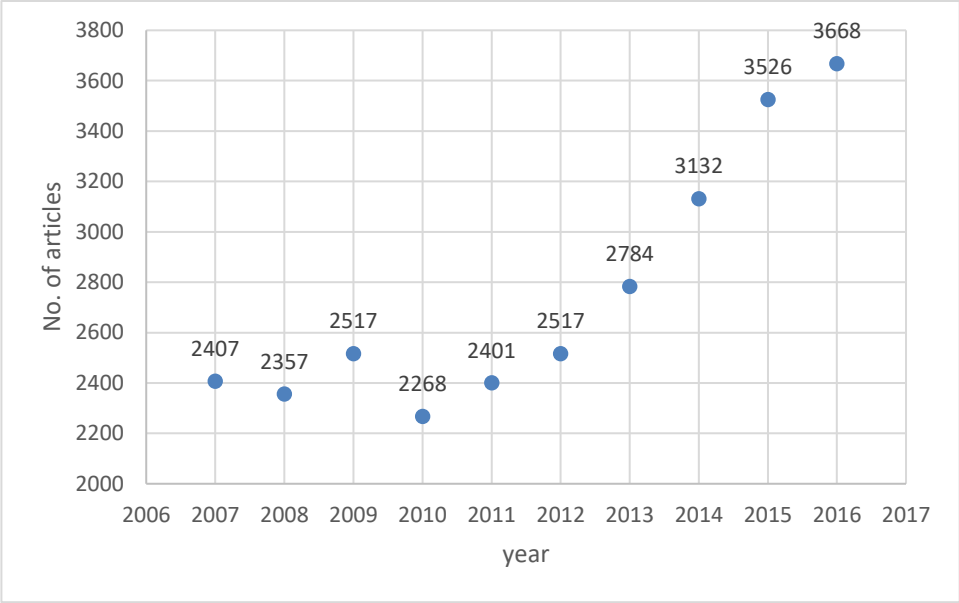

Figure 12 No. of articles for aerospace industry in WoS, 2007 to 2016[7]

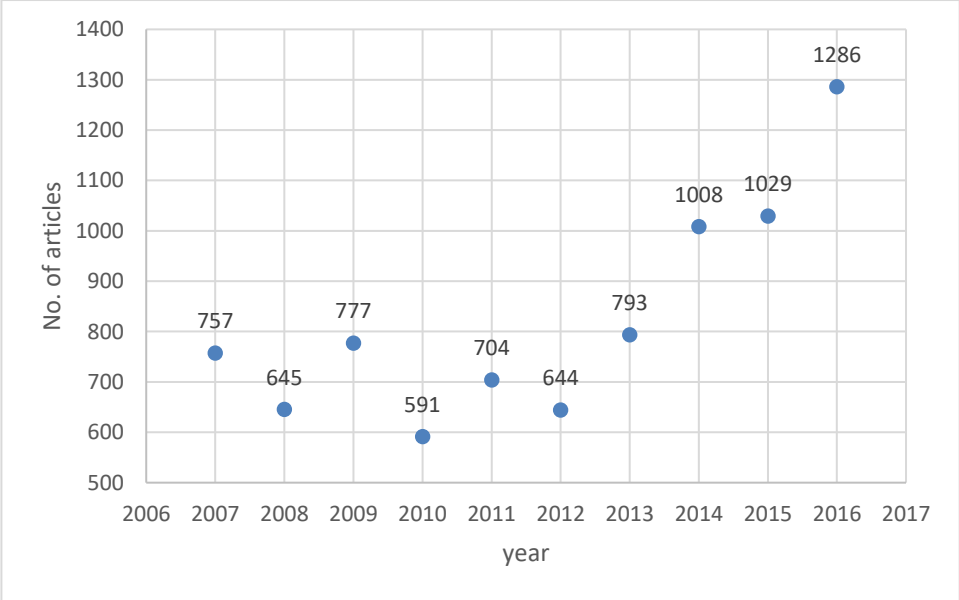

Figure 13 No. of articles related with space industry, 2007 to 2016

[7] Data derived on 15 Aug, 2017.

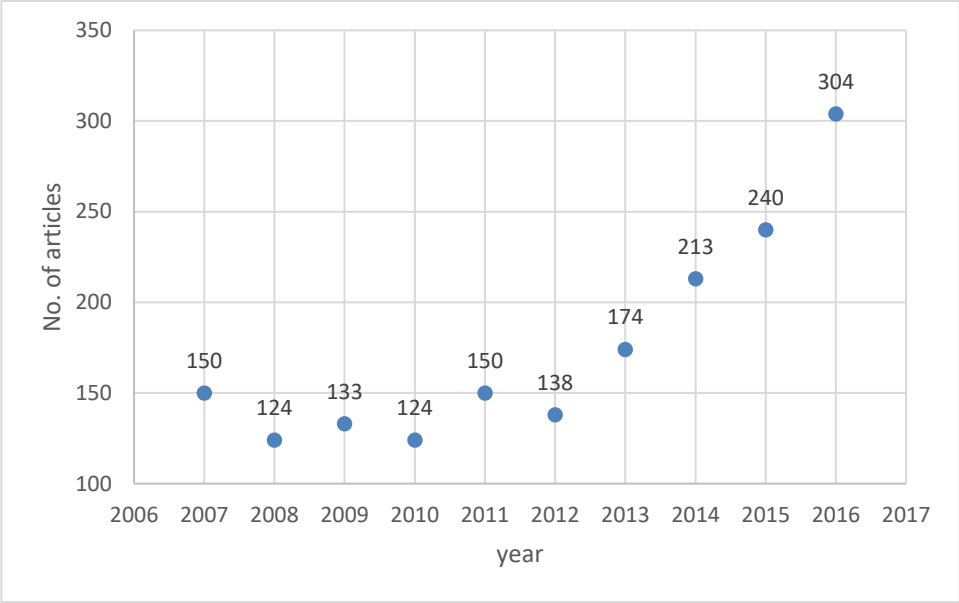

Figure 14 No. of articles related with internet in space-related articles, 2007 to 2016

4.1.1.2 Preliminary Results for the Internet Industry

Similarly, full records including authors, titles, sources, abstracts and cited references are derived from the database in the internet-related categories (Computer science, Telecommunications and Communication). The total number of articles is 522,026, which is more than half a million. Figure 15 shows the numbers of articles found from 2007 to 2016. The total number of articles related with the internet industry is 226,586 and the number of articles related with two industries is 4,006 (Figure 16 and Figure 17). The results illustrate that articles related with the internet industry keep increasing in the last ten years from 2007 to 2016.

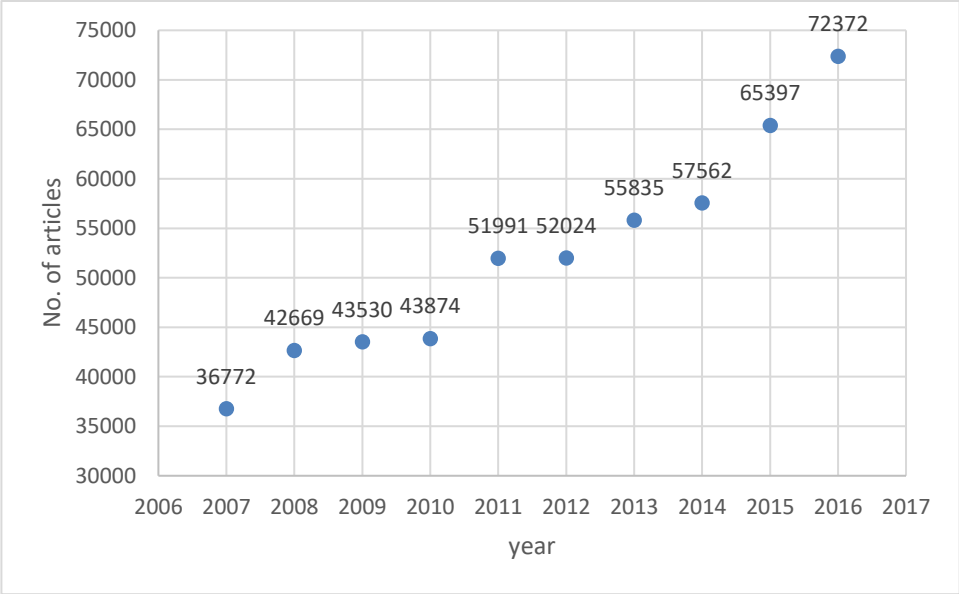

Figure 15 No. of articles from the three categories in WoS, 2007 to 2016[8]

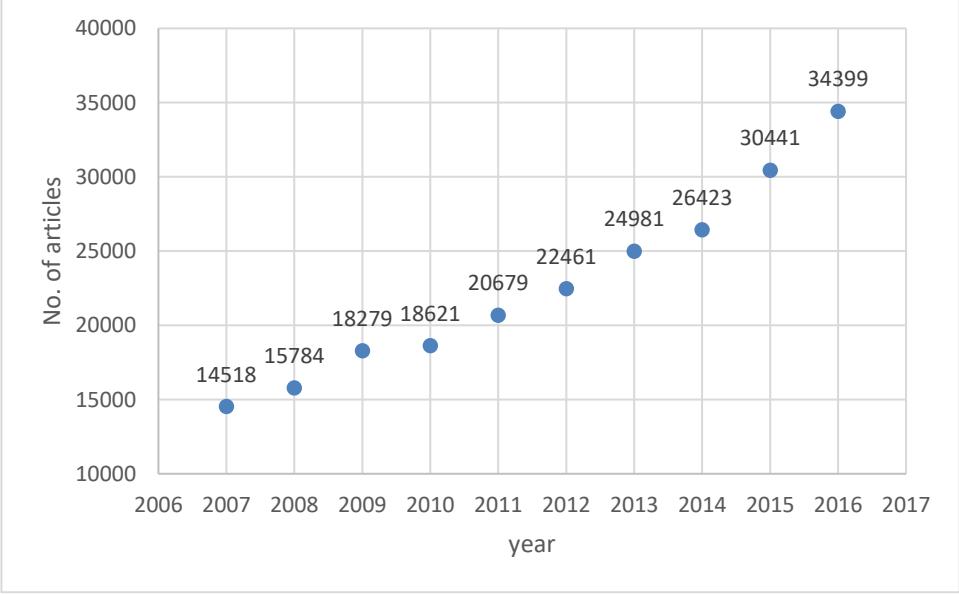

Figure 16 No. of articles related with the internet industry, 2007 to 2016

[8] Data derived on 16 Aug, 2017.

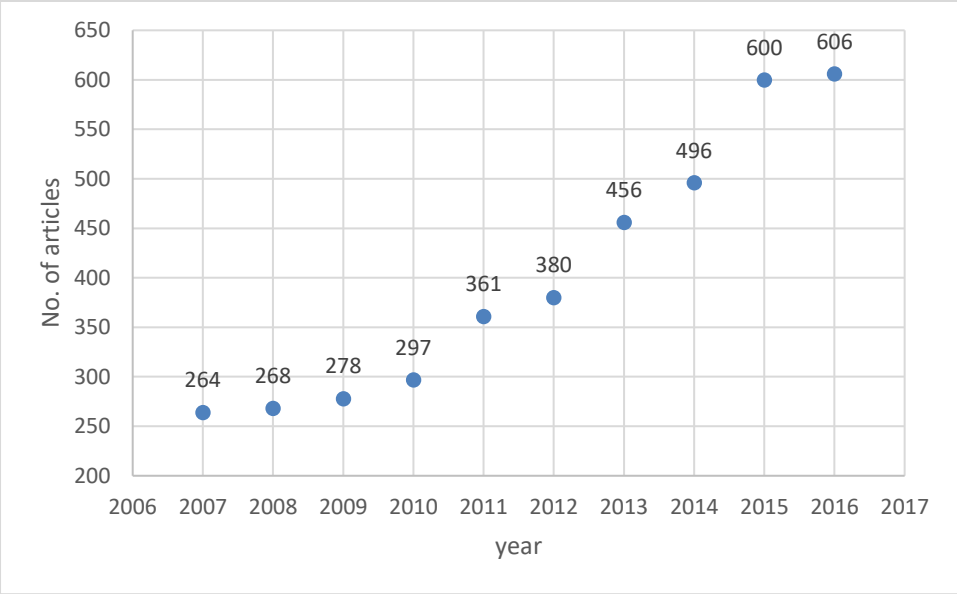

Figure 17 No. of articles related with space in internet-related articles, 2007 to 2016

4.1.2 Tendency of the Convergence

The growth rate of articles related with the space industry and the internet industry (9.9%)[9] is higher than the growth rate of all the articles from all the industries (5.8%) during 2007 to 2016. Thus, the targeted industries are superior ones.

By combining the data from two industries, the tendency of the convergence is revealed by the numbers of articles related with two industries simultaneously (Figure 18). The results depict the general tendency of the convergence between the space industry and the internet industry data from 2007 to 2016. Over the period from 2007 to 2010, the numbers remained stable with slight fluctuations. The growth rate (0.5%) is lower than the growth rate of average growth rate of all the articles from all industries (5.1%) and that of articles related with the tow industries (7.9%). Thus, there is no indicator for a developing convergence process during the period of 2007 to 2010. From then on, the numbers sharply went up from 421 to 910 with an average growth rate of 13.7%, which is higher than the growth rate of articles of two industries in the same period (10.9%), and the growth rate of articles of all the articles from all the industries (6.2%). It is a strong indicator for the convergence between the space industry and the internet industry from 2010 to 2016. The spots show that the trendline should be a speeding-up one. To regress the trend, several types of trendline are selected and compared in Table 3. The values of R^2 show that exponential and polynomial method give more accurate results, and that they both illustrate a speeding-up increase (Figure 19).

[9] Space industry, 6.1%; internet industry, 10.1%.

By now, the convergence between the space industry and the internet industry is clear that there is an ongoing and speeding-up convergence between two industries from 2010.

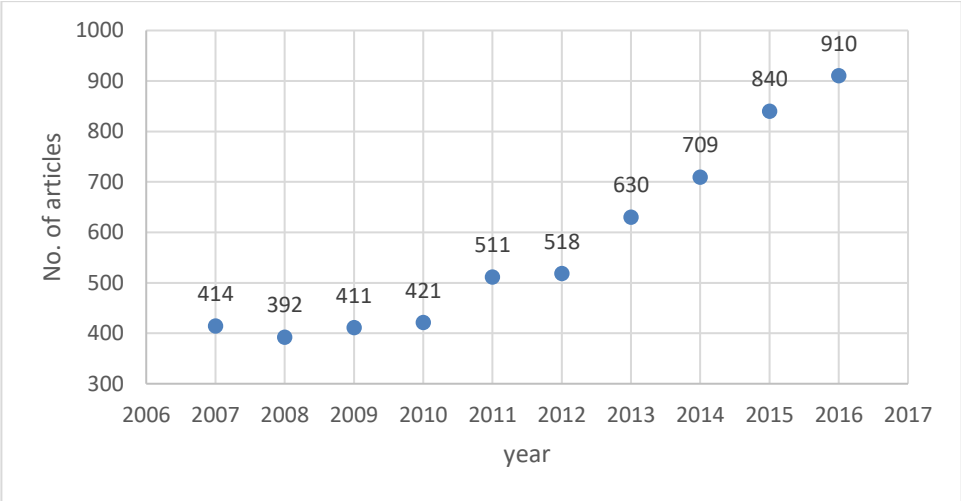

Figure 18 No. of articles related with two industries in all, 2007 to 2016

Table 3 four types of regressions for the convergence indicator

#	Type of trendline	Equation[10]	R^2
1	Linear	y = 58.933x – 117969	0.8932
2	Exponential	$y = 1E\text{-}84*1.104287^x$	0.9267
3	logarithmic	y = 118520ln(x) - 900961	0.8928
4	Polynomial	$y = 7.6477272727x^2 - 30{,}707.8735x + 30{,}825{,}684$	0.9895

[10] y presents the number of articles, x presents the year.

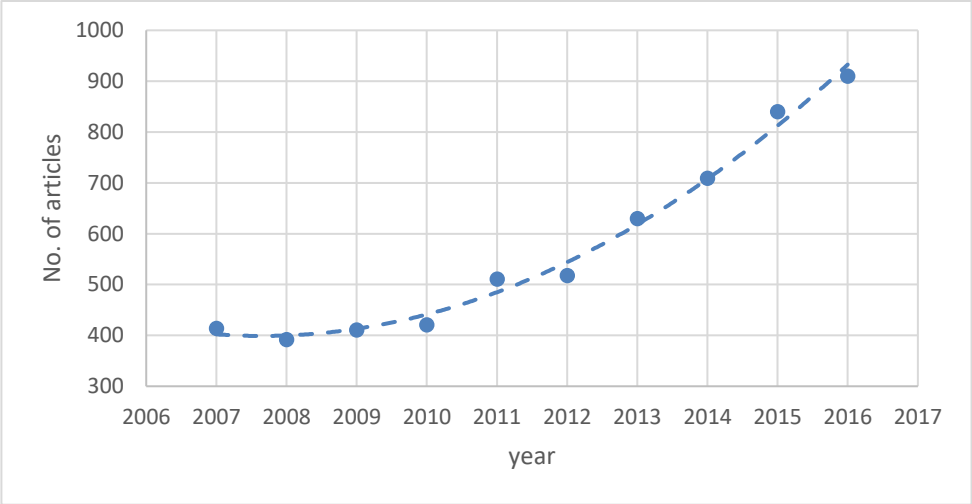

Figure 19 No. of articles in convergence with polynomial trendline, 2007 to 2016

4.1.3 Influence Between Industries

Under the presumption that the number of articles indicates the potential influence of technologies from one industry, the percentages of article in convergence from two industries represents the influence power of technologies between industries. Figure 20 illustrates that the balance of influence inclines to the internet industry during the past ten years with slight fluctuations. This result is an epitome of the fact that the internet industry prevails the space industry, and the fact that internet technology has changed and is changing the world in every aspect more than others.

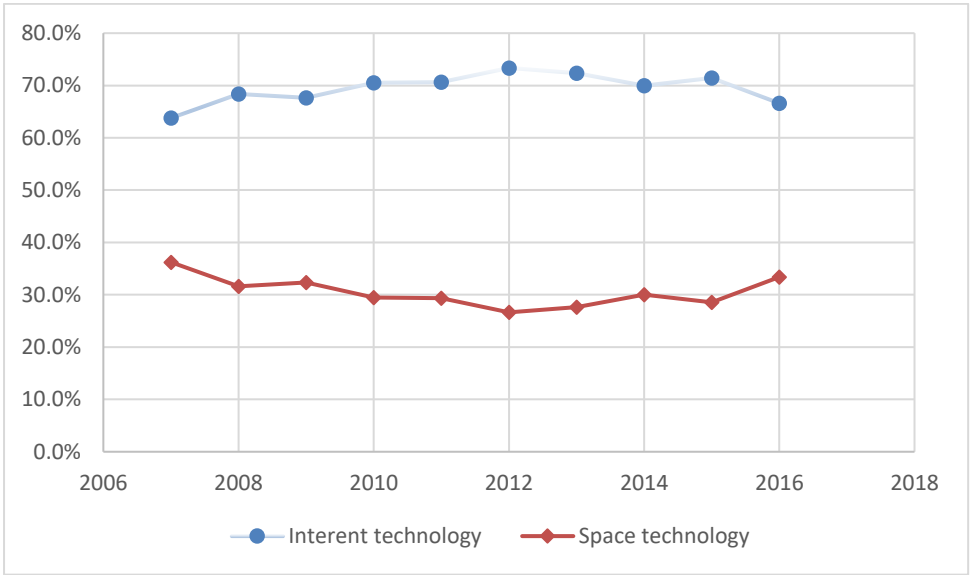

Figure 20 percentage of articles from two industries

4.1.4 Status of involved Countries

The presumption that the number of articles published by one country indicates the country's contribution means the efforts from different countries vary, which manifests the competitiveness among countries. Figure 21 shows the numbers of articles published by authors from different countries in the period of 2007 to 2016. The USA, China and the EU are the main contributors for developing convergence technologies. The increment of the articles is mainly contributed by China and the USA. Articles from other countries slightly increased with fluctuations. Figure 22 shows the percentages of articles from different countries. The percentage occupies by China and The USA increased slightly during the past ten years, which is more that 50%. In the meanwhile, China substituted the USA as the greatest contributor in terms of convergence between the space industry and the internet industry, and all other countries' shares are shrinking.

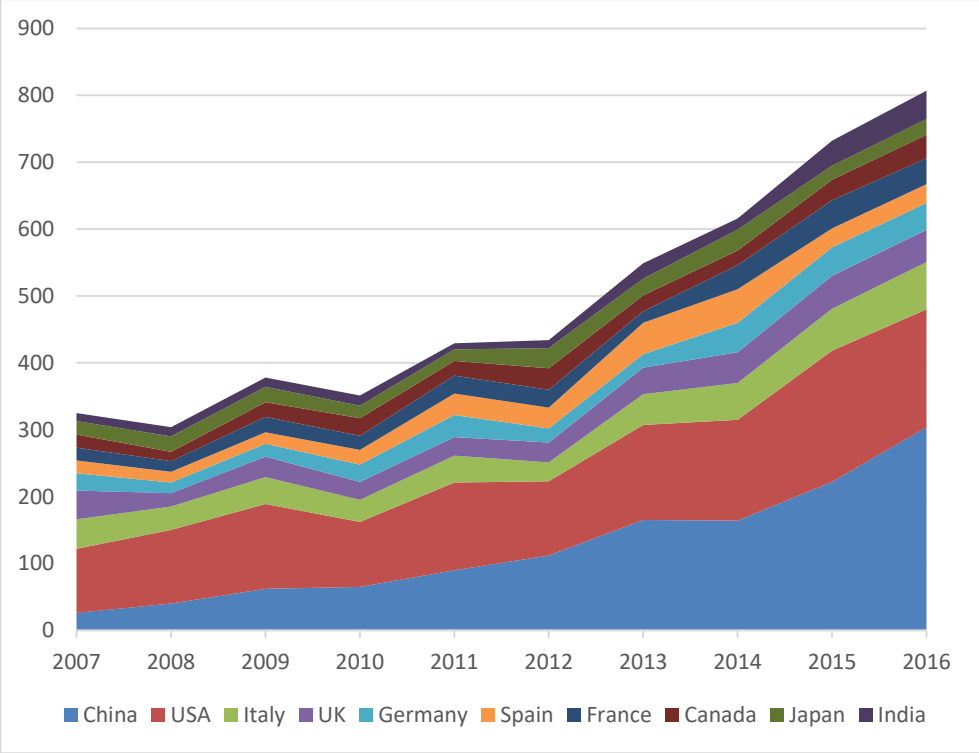

Figure 21 Numbers of articles classified by countries

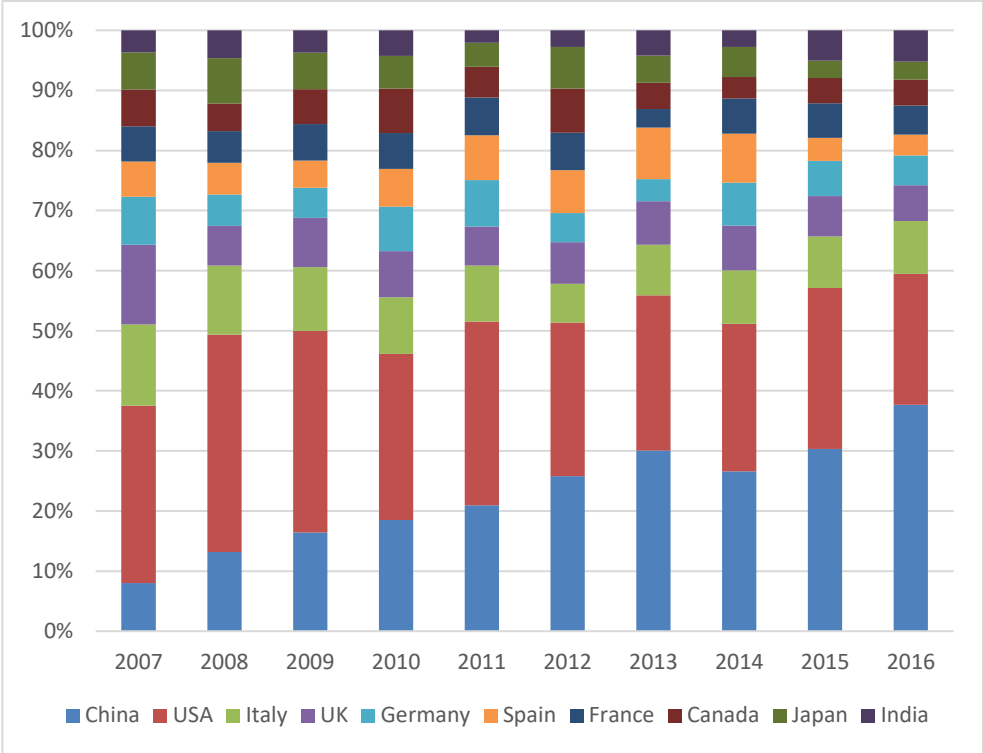

Figure 22 Percentages of articles classified by countries

Figure 23 illustrates the situation of co-authoring. China and the USA are reciprocal largest collaborators. The European countries tend to cooperate more than others with partners all over the world. Japan, India, Brazil and South Korea are willing to work independently.

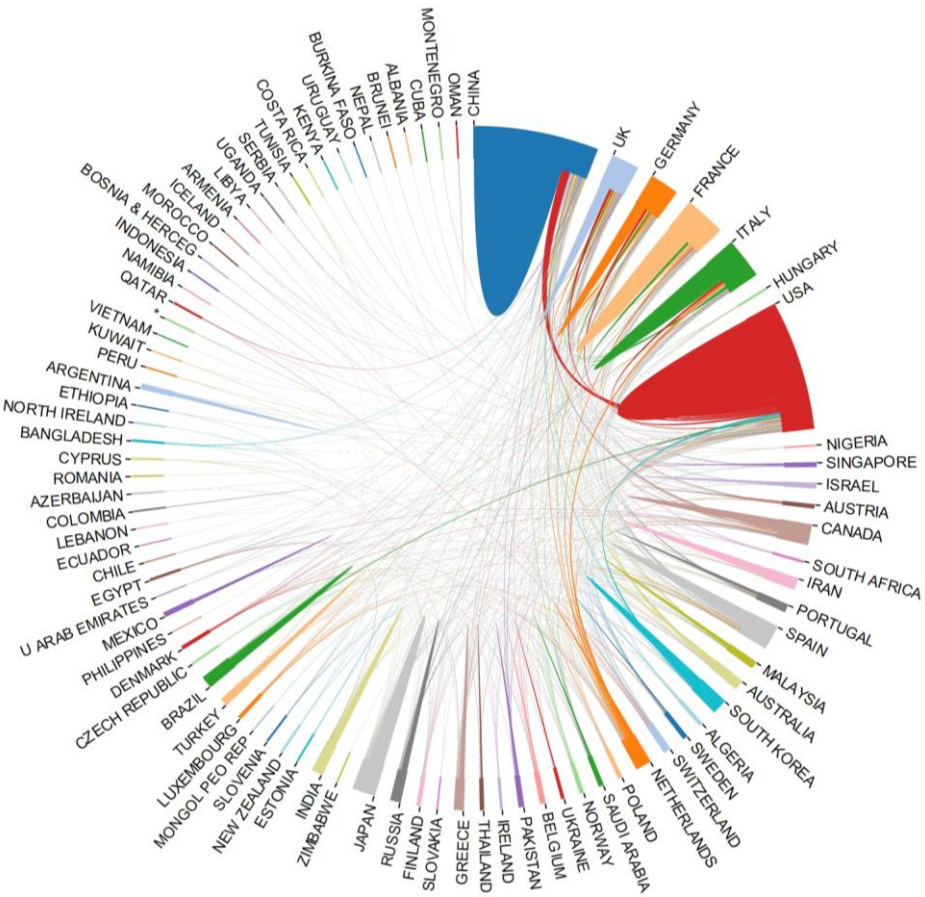

Figure 23 Co-authors from different countries

4.2 Convergence Scenarios

This part is to answer SRQ 2: What are the convergences between the space industry and the internet industry. The convergence between industries isn't something isolated, but happens in several points. A convergence point is called a ***convergence scenario*** in this article. In this part, the question where the convergence between the space industry and the internet industry is emerging or will emerge is discussed.

Because of the essence of technology-driven process, the convergence between the space industry and the internet industry is based on the technological trends in two industries. Technologies in one industry solve the issues faced by the other one or both, resulting in convergence. The convergence can emerge in numerous scenarios. In this article, a series of convergence scenarios will be discussed. The selection of convergence scenarios is based on three principles: (1) a scenario must deeply involve two industries, i.e., one industry relies on the other one in this scenario, (2) it must have a potential to influence the future profoundly, in terms of life, economy or politics, and (3) it must have some extent of feasibility.

Figure 24 shows the convergence scenarios (C1 – C6) between the two industries. Generally, the convergence is classified into convergence in substitute and convergence in complement according to the model mentioned in Figure 5. The convergence scenarios in Figure 24 are only examples based on the aforementioned principles, but not intended to cover all the cases.

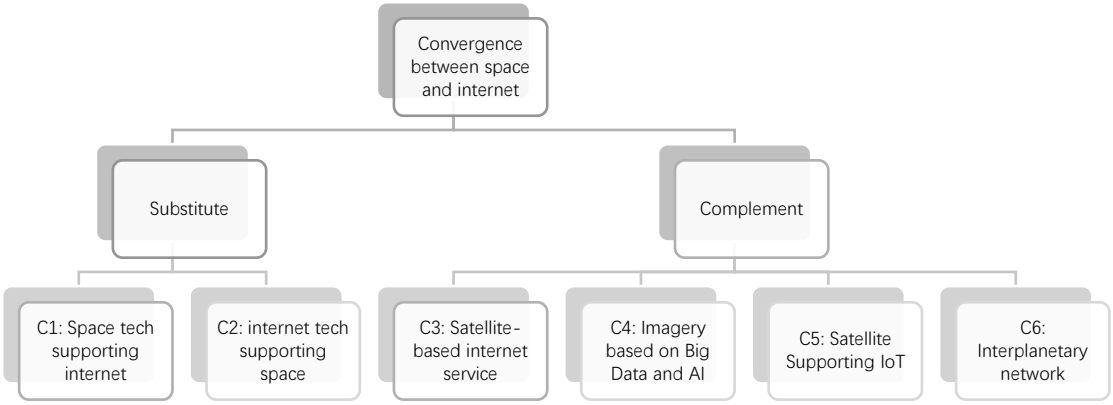

Figure 24 Convergence Scenarios between the space industry and the internet industry

4.2.1 Convergence in Substitute

Technologies developed in one industry then used in another to improve the performance or to change the way of working is classified into substitute convergence. This kind of convergence between the space industry and the internet industry is not rare, but is easily neglected when talking about convergence.

Convergence scenarios C1: Space tech supporting internet

Space infrastructure is an indispensable part for the internet industry for the past, the present and the foreseeable future. Space infrastructure is supporting internet as its basis. The perfect example is Global Positioning System (GPS). GPS Time Servers are fundamental and essential parts of today's internet infrastructure and also many corporate networks. GPS time synchronization is essentially what keeps the internet ticking. Without GPS, the time synchronizations in the internet industry have to rely on ground-based atomic clocks, which are much more expensive than GPS. This convergence scenario is quite mature, but we can't say there is no opportunities for both industries. As GSP for internet, this kind of convergence scenarios will pose big opportunities for both industries.

Convergence scenarios C2: Internet tech supporting space

Internet technologies, such as Artificial intelligence, Big Data, and internet itself have changed the world from individual life style to social structure. The space industry has been influenced

by internet technologies for decades. The improvements in data processing, data transmitting contribute a lot for the progress of space industry. Burleigh et al. (2014) reviewed the forms in which internet supports space operations, and concluded that "the ability to apply the power of Internet technology to communications in support of space flight operations – in Earth orbit, at the Moon, and even in deep space – is now at hand." For better use of internet technology for space missions, under the support from Consultative Committee for Space Data Systems (CCSDS)[11], a new Solar System Internetwork (SSI) architecture is underway (Anon 2014). The Space Data Routers (SDR) project in Europe is implementing this concept to allow Space Agencies, Academic Institutes and Research Centers to share space-data generated by a single or multiple missions, in a natural, flexible, secure and automated manner (Goetzelmann et al. 2012). This extends space flight mission information access worldwide. This kind of convergence facilitates the upgradation of space industry, which is a good opportunity for space industry. But, the upgradation is generally promoted by the space industry itself, because the market capacity is not big enough for the internet industry to be interested.

4.2.2 Convergence in Complement

Convergence in complement means that technologies previously associated with different industries are fused or integrated, thereby giving rise to entirely new industries.

Convergence scenarios C3: Satellite-based internet service

This kind of convergence has already occurred between the space industry and the internet industry. Burleigh et al. (2014) reviewed how the space flight operations support internet. The earliest activity under this topic is the experimental satellite connection between ARPANET and European hosts in the early 1980s (Seo et al. 1988). Now, Satellite telecommunication is one of the most mature space applications. If the scope is limited to commercial space applications, commercial satellite telecommunication is the most mature one, which occupies 24% of the value of satellites launched in 2015 (Dr Adam Gorden et al. 2016). The market capacity of satellite-based internet service has become a multi-billion-dollar industry, e.g. $ 1.9 Billion for 2015 (Dr Adam Gorden et al. 2016). LEO (Low Earth Orbit) mass constellation of communication satellites is attracting more and more attention from both the space industry and the internet industry. Samsung discussed a LEO satellite system capable of carrying a total of at least one Zettabyte per month data traffic by employing thousands of high capacity micro- satellites, each operating at Tb/s or higher data rates (Khan 2015). OneWeb's constellation of hundreds of LEO satellites is going to be materialized from 2018, which got FCC approval (Dano 2017). SpaceX detailed concrete plans to deploy a constellation of some 4,425 satellites around the earth to provide low latency internet service (Kharpal

[11] Founded in 1982 by the major space agencies of the world, the CCSDS is a multi-national forum for the development of communications and data systems standards for spaceflight

2017). These so called micro-satellites in LEO orbit use less power due to proximity to Earth, are smaller in size, lower in weight, and therefore are easier to launch. Even though all the constellations are still under development, the new concepts will provide a global internet service, which is aiming at the needs of modern society. This convergence scenario is to integrate space facilities into connectivity part of internet value chain, which means a new sub-industry of the internet industry. This will change the space industry and the internet industry a lot, and the opportunities and the risks are quite high. It is actually a game changer in the convergence between the space industry and the internet industry. If a space firm doesn't participate in the new ecosystem, the minimum harm will be shrinkage in its market share. The probability of switching main channel of network traffic may lead to a new structure of the internet industry.

Convergence scenarios C4: Imagery based on Big Data and AI

Based on the progress in Big Data, miniaturization and other technologies, a new economic ecology of imagery service is undergoing. Planet (formerly Planet Labs), which is providing global coverage, daily updated, low cost imagery service, is one good example (Schingler 2016). It is arousing more and more attentions in the whole world, because it is designing, building and launching satellites faster than any company or government in history at drastically lower costs. The world record 88 satellites in one fire is made Planet (Schingler 2017). In this new field, all the participants are trying to demonstrate business model. Once, the acquisition of Skybox Imaging by Google for $478 million in 2014 is deemed as the first success story in the world of smallsat startups, but the merger of Terra Bella (formerly Skybox Imaging) and Planet is deemed as a new question mark for the emerging industry. In this convergence scenario, space infrastructures are producing the contents with rights in an internet business. Currently, satellites under this scenario are mainly manufactured by the burgeoning companies. The economic ecosystem of the space industry is not being influenced. It is a new chance for the internet industry, however it is not changing the industry itself.

Convergence scenarios C5: Satellite Supporting IoT

Other applications are emerging and being discussed. Internet of Things (IoT), which is among the buzz words of the internet industry, can profile the tendency. Space infrastructure has a strong potential to participate in the progress of IoT. Ahmed et al. (2016) reviewed the state of the art, taxonomy and open research challenges. Satellites are used in smart transportation, smart cities, and smart grid environments. The use of satellite communications becomes paramountly important when sensors and actuators are distributed over a very wide area, in some cases they are located in remote areas where they are not served by terrestrial access networks (De Sanctis et al. 2016). The satellite e-routed sensor system can provide a solution to realize global-scaled IoT ((Kawamoto et al. 2013). A series of system architecture are

discussed recently. For instance, a constellation of five Molniya[12] satellites for supporting IoT application is proposed, which shows advantages in comparison with LEO constellations (Sturdivant & Chong 2016). The development of IoT is still in progress, this convergence scenario between the space industry and the internet industry is still ongoing and in a preliminary phase. This convergence poses similar value chain structure like convergence scenario C3, i.e., satellites are playing a data-transmitter role in the value chain. In this scenario, it doesn't change the space industry a lot, which is only manufacturers of satellites. In most examples, the number of satellites is not huge, which means no change for the space industry in terms of production mode.

Convergence scenarios C6: Interplanetary network

Further out in the future, the prosperity of the space industry would prospect a much larger scale of interplanetary network, providing services from space infrastructures (e.g. Space-based solar power generation, mining of asteroids) to the earth (Burleigh et al. 2014). The image of this convergence scenario is keeping blurred, but it is still a business based on internet value chain. Space infrastructures are playing the same role in this scenario like in scenario C3, but far more important than in other scenarios.

4.2.3 Discussion on Convergence Scenarios

Several convergence scenarios between the space industry and the internet industry are discussed in this chapter. It is clear that there is an ongoing convergence between the space industry and the internet industry. The convergence is emerging not only inside industries (substitute), but also creating new industries (complement). The convergence scenarios are in different phases: (1) some are quite mature (e.g. GPS supporting internet), (2) some are still in preliminary phase (e.g. satellites supporting IoT and space imagery service), and (3) some are upgrading to a new phase (e.g. satellite-based internet access service). Different scenarios are supporting each other, because they are generally driven by related technologies. The convergence in complement stands more on the side of the internet industry than of the space industry. In the former three scenarios, space infrastructures are playing an irreplaceable role in the value chain.

The opportunities and risks posed by convergence scenarios vary. Table 4 presents the characteristics for C1 to C6. The disruptiveness is mainly lying in complementarity. Convergence scenarios in substitute pose mainly opportunities to both industries, which facilitate the industries' development and promote the performance. The only concern is the substituted technologies. Convergence scenarios in complement result prevailingly in sub-industries of internet, which may explain why the internet industry poses more

[12] A Molniya orbit is a type of highly elliptical orbit with an inclination of 63.4 degrees, an argument of perigee of −90 degrees and an orbital period of one half of a sidereal day.

competitiveness than the space industry in the former analysis. New industry/sub-industry will lead to a new form of competition. The companies lagging in the competition will be marginalized, or even vanished. Meanwhile, the risks are quite high, which may explain a little why traditional space companies are hesitating in the new businesses.

Table 4 Characteristics for the convergence scenarios

Convergence scenario	Opportunity	Risk	Disruptiveness
C1: Space tech supporting internet	Medium for the space industry, and low for the internet industry	Low risk for both, but should be aware of the substituted technologies	Low
C2: internet tech supporting space	Low for the internet industry, and medium for the space industry		Low
C3: Satellite-based internet service	High for both	High for both	High
C4: Imagery based on Big Data and AI	Medium or low for the space industry, and high for the internet industry	High for the internet industry, and medium for the space industry	High
C5: Satellite Supporting IoT	High for both	Medium for the space industry, and high for the internet industry	High
C6: Interplanetary network	Too far to discuss		

4.3 Convergence Drivers

4.3.1 Political Drivers

Political drivers relevant to the convergence scenarios above are listed in Table 5. Generally, most of the political drivers are supportive of the convergence between space and internet but not very much. Particularly, the driver P2 shows a slightly strong support for the convergence scenario C3. Political entities have the nature against the “Borderless” of internet, the internet connectivity from orbit will confront political hostility in some regions of the world.

Table 5 Political drivers of convergence

#	Driver	Positive or not	Target
P1	Political barrier for on-ground internet access service provider	Positive	C3
P2	Instability of developing countries	Positive	C3
P3	Political barriers against the borderless internet	Negative	C3/C4

4.3.2 Economic Drivers

Economic drivers relevant to the convergence scenarios above are listed in Table 6.

The keywords for economic drivers from the space industry is “low cost”. For launching service, reusable rocket triggered a revolution in the launching market in terms of cost and price. SpaceX, who developed reusable vehicles for space transportation, lists the base price of a Falcon 9 rocket launch on its website at $62 million, which motivated others to lower the cost and drop the price. For instance, United Launch Alliance has dropped the price of its workhorse Atlas 5 rocket flights by about one-third from a baseline of about $109 million (Klotz 2017). New low-cost models are developed for launching service (Executiva & Planejamento 2014). For satellite manufacturing, the low-cost principle is discussing from satellites to the ground equipment (OHB Sweden 2013; Vardalis et al. 2015). The reduction of cost and price for launching services and satellites will trigger the price collapse for the convergence.

The growth of data traffic is following the Omnify principle, which stands for Order of Magnitude Increase every Five Years. This increase in demand is similar to the memory and computing power growth following Moore’s law. However, with mobile data traffic explosion, current internet access systems face capacity challenges requiring deployment of more and more base stations with smaller coverage area. This dilemma makes it impossible for small cells alone to meet the unprecedentedly increasing demand in a cost effective manner (Khan 2015). The economic growth of the internet industry highly relies on data traffic. The unmet needs result in a maneuver in the way of establishing connectivity, which strongly supports the upgrade of satellite-based internet channel.

Similarly, for large-scale sensor networks, the usage of satellites is inevitable to balance the system cost and the performance.

Startups in space-related business is attracting more interests from capital industry. From 2000 to 2015, the investment activity has increased dramatically. Statistics show that cumulative investment (including debt financing) in start-up space ventures since 2000 totals $13.3 billion. Nearly two-thirds of investment in start-up space firms since 2000 has occurred in the last five years. The investment from capital industry is a good indicator for the prospects and a booster for R & D and the maturity of business.

Table 6 Economic drivers of convergence

#	Driver	Positive or not	Target
Ec1	Lowering cost of space operations	Positive	All
Ec2	Omnify principle	Positive	C3
Ec3	Cost effectiveness for large-scale sensor network	Positive	C4
Ec4	The increasing interests from capital	Positive	C3, C4, C5

4.3.3 Social Drivers

Table 7 show social drivers for the convergence between the space industry and the internet industry.

The penetration rate of internet service has been growing from less than 15% to more than 30% in the period of 2008 to 2015. Geodemographics shows the potential growth of internet penetration is mainly relying on the least developed countries. Traditional fixed or mobile facilities aren't realistic under the circumstances, which leaves scope for satellite-based solution.

Climate change is influencing the whole planet and dwellers including human beings. Social awareness of climate change and other environmental issues is keeping growing, which makes it possible to provide real-time or quasi-realtime data of the earth to the public.

Although the social drivers actually exist, their influences are not as significant as the economic drivers.

Table 7 Social drivers of convergence

#	Driver	Positive or not	Target
S1	People in least developed countries expecting internet	Positive	C3
S2	Social awareness of environmental issues	Positive	C4

4.3.4 Technological Drivers

As a technology-driven process, the convergence between the space industry and the internet industry is highly relying on the technological progress, which enables the functions, promote the performances and lowers the cost. According to the results of bibliometrics, internet technologies are prevailing the process of convergence between the space industry and the internet industry. But the technologies in both industries are critical for the progress. Table 8 shows the technological drivers of convergence. All the technologies listed in the table are critical for the development of all the convergence scenarios between the space industry and the internet industry. Miniaturization, adoption of consumer electronics, and reusable launch system will lower the system cost of all space related missions, which will be one of the pillars for the profitability of commercial programs. Other technologies, including on-orbit servicing, LEO mass constellation, technologies for integrated space and terrestrial networks, and Free-Space Optical Communication, will enable the functions or support the operations to facilitate the convergence. Internet-related technologies like Artificial Intelligence (AI), Big Data, Internet of Things (IoT) are the driving forces of new business models for new sub-industries resulted by the convergence of the space industry and the internet industry, and will change the internal functions of the space industry. The recent successes from laboratory and space

demonstrations of those technologies indicate that the technologies are ready for operational deployment (Chan 2006; Reid et al. 2016; Jing et al. 2017; Anon 2017b; Benson 2017).

Table 8 Technological drivers of convergence

#	Driver	Positive or not	Target
T1	Miniaturization	Positive	All
T2	Adoption of consumer electronics	Positive	All
T3	On-orbit servicing	Positive	All
T4	Reusable launch system	Positive	All
T5	LEO mass constellation	Positive	All
T6	Technologies for integrated space and terrestrial networks	Positive	All
T7	Free-Space Optical Communication	Positive	All
T8	AI, Big Data, IoT, etc.	Positive	All

4.3.5 Environmental Drivers

The convergence between the space industry and the internet industry will lead to a boom in terms of the launching activities and the amount of spacecraft. The concerns about space junks left by mass constellations is increasing (Lewis et al. 2017). Whether this concern will become a reality is a critical issue for the development of some convergence scenarios (e.g. C3 and C4), which means, the environmental drivers pose negative impact to the convergence (Table 9). But the magnitude of the force is limited, because Active Debris Removal (ADR) is targeting them (Okamoto et al. 2017).

Table 9 Environmental drivers of convergence

#	Driver	Positive or not	Target
En1	Concerns about space junks	Negative	C3/C4

4.3.6 Legal Drivers

Although the internet is claiming that it is borderless, there are actually some borders. For instance, some internet services, like Facebook and Twitter, are blocked officially and legally in some countries, e.g. Turkey (Dockterman 2014). The internet accessed from satellites will bypass the current regulations. The resistance from domestic authorities will hinder the connectivity (Table 10). But it is not a big issue because of the inevitability of opening the internet.

Table 10 Legal drivers of convergence

#	Driver	Positive or not	Target
L1	Resistance from domestic authorities	Negative	C3/C4/C5

4.3.7 Discussion on Convergence Drivers

The analysis above shows that the external drivers are mainly playing positive roles to the convergence between the space industry and the internet industry. The main motivations are from technological progress and demands of economic development. Negative drivers lie in political, environmental and legal domains with limited influences.

4.4 Convergence Implications

4.4.1 Country Level

As the two strategic industries are converging, the competition and cooperation between countries will be intensified. The convergence between the space industry and the internet industry cannot be done by a single country. Thus, cooperation is inevitable. The position that a country chooses will define its influence in the process, and will finally determine its predominance in this field. Even though the internet is still bordered, the tendency of openness prevails. Thus, all the countries have to be prepared for the future. If the convergence between the space industry and the internet industry can change main channel of internet traffic and monitor the whole planet from the heaven, the convergence will even change the balance of power and the predominance in the world.

4.4.2 Industry Level

According to the discussion above, the convergence between the space industry and the internet industry is undergoing. The boundaries between the two industries is misted. Internet technologies dominate the convergence progress, whereas the contribution of space technologies is unneglectable. Convergence doesn't necessarily mean the vanishing of the space industry, other than the new growth points for the two industries, accompanying some new sub-industries. To some extent, the space industry is integrated into the value chain of the internet industry, where new sub-industries of the internet industry is emerging during the convergence. Currently, the space industry is disadvantaged in the convergence with the internet industry.

This provides the two industries more opportunities. The space industry is confronting an upgradation of industry scale. The internet industry can meet the continuous growing demand.

This also imposes threats upon the two industries, even potential crisis for some firms. The convergence between the space industry and the internet industry is driven mainly by technology upgrading. The industry which contributes more during the convergence will have more voice in the future. The market share for firms in each industry will vary. The internet

industry is bearing more risks than the space industry, because of its predominance in value chain and business model during the convergence.

4.5 Recommendations

4.5.1 Country Level

Those who want to take advantage of the convergence should put efforts into developing related technologies, which means more investment on R&D. Besides, since self-isolation will lead to backwardness, cooperation is a wise choice. In addition, the embrace of internet will establish initiative in the future, which means to be opener border of internet. Lastly, to better cope with the future, all the countries should be politically and legally open-minded to the potential transition.

4.5.2 Industry Level

To rise to the occasion, it is required that the space industry maneuvers a little bit to embrace the challenges. On the one hand, the space industry should be more aggressive on space technologies and non-space technologies. For space technologies, the emphasis should be put on lowering the cost (e.g. miniaturization, reusable rocket, etc.) and cutting edge technologies (e.g. on-orbit servicing). For non-space technologies, the space industry needs to develop core technologies aiming the convergence. On the other hand, the space industry should enhance the soft competencies, e.g. corporate culture.

For the internet industry, it is vital to take the risk management into consideration. The immaturity of technologies will lead to a catastrophic failure to those who involve themselves deeply in the convergence process. The evaluation of business model should be cautious. The political and legal issues should be assessed and controlled.

In general, according to the financial and technological status, choosing appropriate strategy is the key for the participants in the two industries to survive and to thrive the convergence.

5 Conclusions

The world is pacing more and more rapidly, due to the technological progress. The countries, industries and firms are being influenced by the industry convergences. As strategic industries, the convergence between the space industry and the internet industry will affect more than others.

To paint the image of the convergence between the space industry and the internet industry, we analyzed more than half a million academic articles from WoS from 2007 to 2016. The results show that there is an on-going and speeding-up convergence between the two industries. Internet technologies are dominating the convergence process. The US, China and the EU are the main contributors for developing relevant technologies. China substituted the USA as the greatest contributor in terms of convergence between the space industry and the internet industry, and all other countries' shares are shrinking during the past ten years. Besides competition, the cooperation among countries is another common phenomenon.

Six convergence scenarios are discussed and classified in this article. The convergence between the space industry and the internet industry is emerging not only inside industries (convergence in substitute), but also creating new industries (convergence in complement). The convergence in complement stands more on the side of the internet industry than of the space industry, and results in new sub-industries of internet. The convergence in substitute brings opportunities to both industries, whereas the convergence in complement has high opportunities, high risks and high disruptiveness.

We used PESTEL as the analytical tool to structure the drivers of the convergence between the space industry and the internet industry. The analysis shows that the external drivers are mainly playing positive roles to the convergence between the space industry and the internet industry. The main motivations are from technological progress and demands of economic development. Negative drivers lie in political, environmental and legal domains with limited influences.

Based on the analyses above, the implications and recommendations for countries and both industries are deducted. For the countries involved, it is critical to put efforts on technology development and cooperation. For the two industries and related firms, choosing the right strategy while being aware of risks and crucial technologies is the lynchpin. For space industry, it is appealed that the whole industry and firms should be more aggressive on space technologies and non-space technologies. For the internet industry, it is vital to take the risk management into consideration.

In addition, we contribute to the literature of industry convergence in several aspects. First, we introduced a new approach, bibliometrics with co-occurrence, for analyzing the status of

industry convergence. This new approach shows not only capability to analyze the status like other tools, but also potentials to get more information, such as the tendency of convergence, the dominant technologies during the convergence, and so on, which gives more information for further analysis and decision-making. This approach is easy to apply to other circumstances because of its simplicity. Second, we define the industry convergence as a blurring *PROCESS* of boundaries between at least two industries. Emphasis on process makes the categorization and the sequential model more concise. Third, we introduce a new way to define industries without unclear definitions to demarcate the boundaries by deducting the existing industries definitions and value chain concept. Forth, we propose a dedicated research framework for technology-driven convergence between industries, which might be valuable for other researches.

Ultimately, this research has some limitations. First, additional research is required to understand the convergence between the space industry and the internet industry with deeper analysis of the convergence scenarios and the drivers. One option may be to introduce some quantitative methods for analyzing scenarios, drivers and implications, which may consolidate recommendations and present more value for the evolution of the two industries and decision-making of related firms. Second, although bibliometrics shows potential to identify the convergence status between industries, this tool is limited to technology driven convergence, which isn't applicable in all other circumstances. Other approaches need to be developed. Third, bibliometrics with co-occurrence method may contain noisy information. A future study to overcome this limitation needs to be taken into accounts.

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Acronyms

ADR	Active Debris Removal
AI	Artificial Intelligence
CCSDS	Consultative Committee for Space Data Systems
GICS	Global Industry Classification Standard
GPS	Global Positioning System
ICT	Information and communications technology
IoT	Internet of Things
ISIC	International Standard Industrial Classification
LEO	Low Earth Orbit
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
NAICS	North American Industry Classification System
Omnify	Order of Magnitude Increase every five Years
PESTEL	Political, Economic, Social, Technological, Environmental, Legal
SDR	Space Data Routers
SRQ	Sub-Research Questions
SSI	Solar System Internetwork
WoS	Web of Science

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