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From imitation to innovation: The discursive processes of knowledge creation in the Chinese space industry

The quantum jump from ballistic missiles to space docking in recent decades symbolizes China's new product innovation potential in technologically complex industries. Drawing on theories of knowledge creation and discourse, we explore how the discursive practices of imitation, adaptation, and the reconfiguration of competitors' technologies help transform China from a duplicative assembler to a dynamic innovator in the global space industry. To this end, we argue that the processes of imitative knowledge-creation through oral, written, and gestural texts underpin China's new product innovation in the space industry. This innovation mechanism adopted by China, we found, involves discursively constructed ensembles of in-house knowledge generation for specialization in the production of space related products in context of high complexity and uncertainty. Discourse among sanctioned innovation actors in the industry, we argue, serve as a vital source of knowledge for integrating learning, strategic assets, and expertise to meeting the evolving needs of sole end-users. We conclude with some implication of our study to the theory and practice of imitability and transferability of knowledge and innovation in technologically complex industries.

Keywords: China, discourse, imitation, innovation, knowledge creation, organizational mechanism, space industry

Introduction

China's space industry has come to represent a symbol of Chinese knowledge-creation processes and new product innovation in technology-intensive industries (Nolan and Zhang, 2003; Medeiros et al, 2005; Logan, 2007). Following the footsteps of their western competitors, the Chinese space industry has made a quantum jump from developing narrowly defined ballistic missiles to space docking and a mix of broad dual-use technologies. However, the Chinese space industry is built on a distinct administrative heritage and processes reflecting the impact of historical events, decisions, and unique actions of the country's upper echelons (David, 1985; Grant, 1996; Sydow et al, 2009; Vergne and Durand, 2011). These historically conditioned decisions and actions, we observe has enabled (and impeded) the industry in accessing new ideas and limited a selection of innovation choices (Djelic and Quack, 2007; von Foerster, 1984; Vergne and Durand, 2011; Koch, 2011). Yet, we know very little about how the dynamics of the Chinese space industry which is made up of a cluster of state-owned enterprises, business partners, specialized suppliers, service providers, and associated institutions (Foo et al., 2015; Medeiros, 2005). In particular, we have a very limited understanding as to how the 'nascent' Chinese space industry managed to develop the capabilities that allowed it progress and transition from an imitator to an innovator given that other potential 'latecomers' probably find themselves locked out in accessing promising knowledge and technologies in this complex and complicated industry (Trebat and De Medeiros, 2014; Nelson and Winter, 1982).

As the Chinese space industry gains stature and legitimacy, the search practices and mechanisms it employs to pin-point knowledge relevant for innovation and developing novel space products that meet growing demand on performance, capacity, and reliability, has come under intense scrutiny (See: Trebat and De Medeiros, 2014; Gao, 2005). A vast body of literature suggests that the Chinese space industry thrives on knowledge creation approach in which foreign competitors technologies are reverse-engineered, mimicked, or explicitly copied (Heymann, 1975; Cheung, 2011;

Hu, Jefferson and Jinchang, 2008; Pollpeter, 2011). This strategy, we follow Leloglu and Kocaoglan (2008) to argue reduces uncertainties and risks associated with the sequential phases of idea generation, design, engineering, prototype development, and testing. Accordingly, innovation scholars have become particularly interested in understanding how the industry through its imitative strategy leverages distant knowledge in explorative and exploitative ways (Savino et al, 2015), to compete successfully in this technologically complex industry (Leloglu and Kocaoglan, 2008; Brockhoff, and Guan, 1996).

We contribute to this body of knowledge by accounting for the transformation of China from a duplicative to a dynamic innovator in the space industry. In doing this, we draw on discourse and knowledge-creation as a meta-theoretical lens to explore the linkages between imitation and innovation, and how the discursive processes and structures of its knowledge-creation strategy has contributed to enhancing China's technological capabilities and innovation. We argue that the discursive processes of knowledge-creation through oral, written, and gestural texts undergirds the acquisition, absorption, and the transfer of knowledge driving Chinese space product innovation. In other words, we concur that the processes from imitation to innovation involve discursively constructed ensembles of in-house knowledge generation for specialization in the production of space products, which makes the late comer a vibrant competitor in the context of high complexity and uncertainty. We focus on internal bulletins (2010), private letters (1956-2000), and unstructured interviews (2010 and 2012) with leading protagonists in the Chinese space industry. Our discursive process approach offers an alternative explanation on how discourse could shape and give form to the creation, transfer, and utilization of technical knowledge to drive innovation in technologically complex industries. The research question driving our empirical inquiry, therefore, is: How does the transition from imitation to innovation in the Chinese space industry come to be identified, labelled and judged within the discourse of knowledge creation?

The paper is organized as follows. First, we provide a brief review of the literature on knowledge-creation and discourse to explore the discursive processes of knowledge generation through imitation to innovation. Next, emphasizing the historical context of the Chinese space industry, we outline our analytical approach to capture the logic and transfer mechanisms of knowledge innovation to drive our empirical inquiry. Following, is our research methodology, after which we present our findings. We conclude with a discussion of our findings and its implications for imitability and transferability of knowledge and innovation in technologically complex industries.

Knowledge-creation, conversion and transformation

Knowledge, a 'justified true belief', is context specific in time and space (Nonaka *et al*, 2000; Nonaka, 1994; Spender and Grant, 1996; Teece *et al*, 1990; Nelson and Winter, 1982; Nelson, 1991). Knowledge, therefore, is a dynamic and relational process of justifying personal beliefs, and an aspiration for truth by following a set of rules to reason and test (Foucault, 1972; Philip1985; Nonaka, 1994). Highlighting the critical nature of knowledge, Polanyi (1966) contends that 'we can know more than we can tell'. At the core of this argument was Polanyi's effort to define and make a clear-cut distinction between what constitute tacit (intuitive and unarticulated) knowledge and explicit (codified) knowledge. Because tacit knowledge lacks extensive codification or falsification and can only be acquired through experience, the knowledge of scientists, for example, cannot be fully reduced to a clearly articulated set of rules, axioms, and statements (Howells, 2000; Gertler, 2003; Nonaka and Takeuchi, 1995). By contrast, explicit knowledge can be abstracted, understood, and shared without a knowing subject. In other words, it is tested and codified, as in manuals and blueprints (Lam, 2000; Popper, 1970; Fagerberg *et al*, 2005).

Nonaka (1994) argue that knowledge creation occurs when explicit knowledge, in essence, grounded in tacit knowledge dynamically interacts in organizationally useful ways. Critics of Nonaka's spiral theory on knowledge creation, however, points out that a limitation this does not explain how tacit knowledge held by individuals is justified and converted into explicit or organizational knowledge or vice versa by the way of construction and reconstruction over time for innovation (Easterby-Smith, 1997; Gourley, 2006). By contrast, Grant (1996) acknowledges the importance of transferability by maintaining that there are two forms of knowledge: knowing how and knowing about, which reflect their tacit and explicit nature; and the major distinction between them lies in transferability and the mechanisms for transfer across individuals, space, and time, if not transforming tacit knowledge. In an effort to bridge this transferability gap, Nonaka and Takeuchi (1995) observe that tacit knowledge is by nature unarticulated and tied to the sense, movement skills, physical experiences, intuition, or implicit rules of thumb, while explicit knowledge is uttered and captured in drawings and writings (Nonaka and von Krogh, 2009). Despite the contestations characterizing the distinction between the transferability of the two basic forms of knowledge, the nature of knowledge as articulated by these scholars' remains relational, dynamic, and humanistic, and the logic of knowledge creation is fundamentally the mobilization of individual tacit knowledge to reinforce the interaction with explicit knowledge.

The processes of knowledge creation at the organizational level, as argued by Grant (1996) include four stages: transferability, capacity for aggregation, appropriability, and specialization in knowledge acquisition, through which the firm is to integrating the specialist knowledge resident in individuals into goods and services. The crucial point of knowledge management is to maintain the balance between creation and application. Similarly, for Nonaka and Toyama (1994, 2003), the spiral processes of socialization, externalization, combination, and internalization (SECI) as a vibrant driver transcend time, space, and organizational boundaries to shape knowledge creation and utilization functions for innovation. The processes of creation, conversion and transformation by nature are about knowledge sharing and transferability through either daily business interaction or hands-on experience. This shared tacit knowledge; they go on to argue is articulated into explicit knowledge through the process of externalization (the first stage of conversion) as the basis of introducing new concepts, images and written documents. Synthesizing explicit knowledge is a last stage of conversion designed to translate one knowledge type into another through construction and reconstruction. Shared explicit knowledge is finally transformed into tacit one, which becomes new routines and inertia. In the end, this interactive process within the firm attributes to the self-transcending knowledge spiral of creation, conversion and transformation for innovation (Nonaka and Toyama, 2003).

A fundamental problem emerging from these frameworks on knowledge creation is that they fail to explain the cycle of how and by what way implicit knowledge is justified and converted into explicit knowledge, which is then transformed into implicit knowledge within the firm. For example, they seldom account for the extent to which the input and output functions of knowledge creation at the firm level may help to prevent core capabilities from becoming core rigidities, to translate core rigidities into core capabilities in innovation, or to manage its routines and inertia vis-a-vis new knowledge (Grant, 1996; Fagerberg et al, 2005; Leonard-Barton, 1992; Nelson, 1990). In this scenario, the processes of knowledge creation in the context of the Japanese notion of *'Ba'*, for example, which prioritizes individual and collective knowledge (Chia, 2003), become a black box, in which the conversion and transformation of knowledge, old or new, assume a mystical status that is not governed by any rules of reason or any organizational mechanisms. Thus, these frameworks circumvent two variables related to exogenous and endogenous determinants from imitation to innovation, which allow Japanese firms to build a group's directed quest for and the absorptive capacity to create, convert and transform knowledge for innovation (Vogel, 1979). In this regard, the very nature of exogenous determinants in affecting endogenous knowledge creation, conversion, and transformation remains unexplained. In challenging these longstanding frameworks, a central theme persistent throughout our analysis is the linkage of knowledge creation, conversion and transformation between the individual as a primary actor and the role of the firm in integrating specialist knowledge for the production of new goods and services. In this case, discursive practice approach, which places emphasis on language and text, we argue, has the potential to extend our understanding of knowledge creation, conversion and transformation in practice.

A discursive approach to knowledge creation, conversion and transformation

The notion that our social world is a construction of meaning has led to the contemporary turn to the discursive practice approach in accounting for social life (Fairclough, 1992; Hardy and Phillips, 1999). Drawing on the interpretive paradigm (Thorne, 2016; Rabinow, 1987), a discursive practice approach deploy language and the constructive effect of text to produce, maintain, and transform the constellation of social relations, localized patterned activities and practices in everyday organizing (Foucault, 1977). As a system of possibility, discourse allows us to produce statements for testing and making it a field of knowledge through identifying truth or falseness (Foucault, 1977; Philp, 1985; Dreyfus and Rabinow, 1982). In the context of knowledge creation, conversion and transformation for innovation, discursive practices, we argue, places special emphasis on speech acts: 'what space experts say and when and how they are speaking as experts' in an effort not only to think and produce meanings of space technologies, but also to construct the body of conscious mind and emotional life of subjects they seek to govern (Foucault, 1977). Thus, discourse as used here is neither a theory nor a variable. Rather, discourse becomes the rule-governed system in which space experts construct, legitimate, and re-affirm status relations of knowledge in practice (Leclercq-Vandelannoitte, 2011; Philp, 2000). The resulting effect of space knowledge produced by discourse is disciplinary power that creates control over the 'objects the professionals claim to know. In other words, imbued with the discursive formations of innovation, choices for control--forms of rationality expressed in certain ways of talking about an innovation topic or restricting other ways of talking--reflect knowledges that are collected over time into different disciplines of science and technologies and deal with the construction and representation of practices (Foucault, 1977; Keenan, 1987; Philp, 2000). Central to this conceptualization of discourse is a special asymmetric relationship: knowledge as a watershed of innovation is to exercise and self-reinforce professional domination of technologies; and organizational control is to practice disciplinary knowledge for shaping resources and routines (Leclercq-Vandelannoitte, 2011; Riad, 2005).

The construction of this asymmetric knowledge produces same decisions (what people say) and action (what they do), which become a technique of the exercise of power for innovation. What people say as innovation knowledge determined by their status in an organization affects what other people do. The hierarchy of saying and doing suggests that the inscription of knowledge reflects the division of labor served as a self-reinforcing mechanism of disciplinary power. There is no power relation without the correlative constitution of a field of knowledge, nor is there knowledge that does not presuppose and constitute at the same time power relations (Foucault, 1979; Putman and Cooren 2004). Throughout the stages of creation, conversion and transformation, knowledge inscribed in the space industry, we argue, is disciplinary power, which frames organizational structures and business choices, which in turn get and imposed on the industry. The self-reinforcing mechanism of professional domination is knowledge. The dynamic interplay of knowledge and power through the discursive processes of innovation produce organizations, rules, and regulations, which in turn reinforce the mechanism of knowledge creation, conversion and transformation. In this dynamic process, the discursive practices, a specific set of norms, rules, and orientations, play a crucial role of legitimizing the shared meaning of knowledge and power between those subjected to power and those in power that defines the boundary of power relationships, but does not transcend it (Philp, 2000; Castlls, 2009). Power is an expression of technological knowledge through communication. In analyzing the discursive processes of knowledge creation from imitation to innovation, we synthesize insights of discursive processes of knowledge-creation, conversion and transformation to examine degrees of progress towards knowledge-based innovation in the Chinese space industry (Nonaka and Takeuchi, 1995; Krogh *et al.*, 2000; Leclercq-Vandelannoitte, 2011). In doing this, we go beyond the impasse of the knowledge creation frameworks to draw on the discourse; a set of language and practices—oral, written, and gestural texts, to delineate what constitutes knowledge creation in practice. Our discursive approach, therefore, emphasizes what can be described as a series of rules aimed at organizing and producing specific innovation relations between disciplines (bodies of technological knowledge) and disciplinary practices (forms of management control) at a particular historical moment of knowledge creation, conversion and transformation. In the next section, we present our research methodology.

Research methodology

Our choice of the Chinese space industry as a research setting is based on two major reasons. First, China's space industry embodies the innovation efforts and performance of its state-owned organizations in high technology industries (Hu *et al*, 2005; Altenburg *et al*, 2008). The nature of state ownership suggests that its innovation drivers and processes differ from those of conventional models, theories, and approaches, partly because its products are customized in design for the sole end-user and partly because production is in small batches, if not a single item. Second, it is even more complicated. The space industry exemplifies how the 'socialist' system stimulates knowledge creation that, in turn, improves innovation in competitive industries (Li, 2011).

Considering the paucity of research on knowledge creation and innovation in the Chinese space industry, we adopt an exploratory research design and qualitative methodology devoted to exploring the causal connection between knowledge creation and innovation, a phenomenon where the boundaries between theory and practice are not clearly defined or explained (Creswall, 2013; Marchall and Rossman, 2010; Tellis, 1997). Our focus is on the relationship among duplicative imitation, knowledge conversion, and innovation, each marked by critical points in the discursive processes of knowledge creation. Data are collected on the history and structure of the space industry, innovation, key events, main actors, and their contributions to the development of core technologies. The data collection set for our inquiry has three categories of materials and sources: private letters, semi-structured interviews, and internal documents, which capture the distinct way of knowledge creation and product innovation.

[Insert table 1 about here]

The primary data consist of 37 private and hand-written meeting minutes in the form of letters sent to senior defense scientists and bureaucrats by Qian Xuesen from 1956 to 2000. As a tool of discourse, the minutes documented issues related to organizational structures, product designs, innovation priorities, manufacturing, testing, 'brain-storming'-workshops, and technical hurdles, which became the platform for informal debates on technical and management solutions. As a leading space scientist in both the United States and China, Qian has personally designed or managed all the key space programs. In this informal setting, the letters provide sufficient traces and evidence of the inner circle in managing knowledge creation, knowledge integration, and knowledge utilization in respect of imitation and innovation for improving product quality, performance, and reliability. Certainly, there has been a change in research priorities since the 1950s, but there is nothing new about the pattern of and approach to knowledge-creation and innovation as the letters show.

We supplemented this with five semi-structured interviews and five follow-up interviews with former senior managers in the industry to gain additional contextual insights into the choices of knowledge-creation and innovation advocated in the private letters. All our interviewees were managers in the Chinese space industry during the 1960s and 1970s. They are all now 'retired', but still involved in some university teaching activities. Our interviews which lasted a minimum of two hours each covered issues related to the interviewees understanding and interpretation of the organizational learning, knowledge sharing, technology management, and supply chain that characterized the Chinese space industry in which they worked. Following Corley and Gioia (2004) referents for understanding collective experience of change, our questions and discussions in general centered on the central processes of organizing in the industry, how it felt working in those settings, and the aspiration and the industry-wide shared vision of the future. We drilled further down into the formal and informal processes the industry used to respond to 'new' challenges, disseminate know-hows, new ideas, and critical knowledge that was deemed to potentially strengthen (or impede) their own survival, growth, and success.

The first round of interviews took place between April and May 2010, whereas the follow-up interviews were held between April and May 2012. In the first round of interviews, we focus on the linkage of imitation and innovation, such as, licensing, learning, knowledge conversion, and technical challenges, faced by managers, research centers, suppliers, associated institutions, and the end-user from day one. The second round of interviews targets the crucial issues of discursive practices, including knowledge access channels, knowledge construction and deconstruction, and knowledge sharing within the space industry. The interviews gain further understandings of the challenges as well as the solutions for handling the anomalies (Moustaks, 2011).

In addition, we collect six issues of *Developments in the manned spacecraft projects* (2010), the internal bulletin of the Manned Spacecraft Office (MSO), which offer the rich organizational insights into latest developments in space technologies and research priorities as well as proposed imitation and innovation targets for reference to the spacecraft program. The documents show the discursive processes of constructing and deconstructing knowledge and innovation for increasing returns (Bangongshi, 2010). Equally important, they also reflect the extent to that knowledge and innovation concerns are aggregated into the framework used in this study.

[Insert table 2 about here]

Our data analysis follows three steps: First, we engage in a form of open coding by re-reading the textual data to identify their relevance and connexions of the discursive processes with what was heard and seen in the field. We then examine the sequence of programs over time to identify the origins of underlying discursive forces, principles, and effects, which shape the core competence of the space industry. Second, we probe the data to identify the discursive processes of recurrent comparative phrases, which were noted, highlighted and used to develop our provisional categories and first-order codes (Glaser, 1967; Corley and Gioia, 2004). Finally, in comparison with the literature on knowledge creation and innovation, we focus on the structures and the emerging themes of discourse on knowledge creation and sharing as a vital source of innovation from imitation in the Chinese space industry. Our case evidence in general suggest that the Chinese space industry, over time, from a closed to an open innovation model of innovation, in which the initial stage of closed innovation helped the organization to build the requisite absorptive capacity (Cohen and Levinthal, 1990), to be leveraged in the subsequent open innovation stage. In the next section, we present the very fine details of our findings

Knowledge creation as a primer of imitation

The discursive assemblages of processes of knowledge creation served as a tool of imitation to learn, copy, and produce duplicative missiles within the organizational context. In so doing, we identify underlying forces, aspects, and effects of organizational discourse related to short-range and medium-range missile programs in defining and interpreting the meanings of discourse emerging from the key events, incidents, and challenges faced by the space industry (Chen and Shapiro, 2009; Porter, 1998; Grant and Baden-Fuller, 2004). A senior program manager described the early imitation efforts of the industry:

> The most significant event in the program was the licensing agreement of 1956, which gave our space industry secured access to Soviet state-of-art missile technologies. The resulting knowledge spillovers, in turn, boosted our understanding of and efforts to integrate Soviet knowledge in missile design, components, and skills to produce identical products (Interview I, 2010).

In the end, the discursive processes of duplicative, the activities directed towards external knowledge acquisition and sharing, added value to the capacity creation, and fostered the development of a basic knowledge base (Mahmood and Rufin, 2005; Bolton, 1993), via learning-by-watching. Moreover, the licensing agreement allowed the Chinese scientists to have direct access to Soviet technologies and rare know-how on missile production, which served as a precursor to shoring their competences and accumulating viable technological capabilities. Although there was no formal research and development (R&D) strategy, the industry constructed its own distinct system integration through external knowledge acquisition, learning, and sharing, which required and contributed to reverse engineering (Berger et al., 2012), and blind copying of others expertise (Brown and Duguid, 1991). In building such a capability, discourse on Soviet missile production, in particular, became the driver to learning, sharing, and the transfer of borrowed know-how and technologies.

The licensing agreement as the knowledge access channel allowed the space industry to push for learning-by-watching through the observation of how Soviet engineers trained their counterparts in building missiles, by which knowledge took on significance. In exploring knowledge potentials, the interface between Soviet knowledge and the Chinese settings sparked an organizational process of knowledge-creation and discursive practices focused on assimilation efforts to learn, to integrate systems, and to produce needed products (Xie, 1992; Qian, 2007).

The licensing of ballistic missile technologies conceived of as historically conditioned was dominated by systematic designs and rational deliberations, rather than by chance. With the formal request by China for the blueprint of missiles, the Soviet Union delivered two P-1 samples and parts, the Soviet products of the German V-2 liquid fuel short-range ballistic missiles, to Beijing for training purposes in late 1956. The licensing agreement constituted the 5th Research Academy, which made its efforts to develop its missile knowledge base of imitation. For one of our interviewees, the imitation activities simply served as vehicles of learning:

> During the course of knowledge, if not capability building, there was no whatsoever R&D and it was simply copying or reverse engineering. The learning processes placed special emphasis on disassembling and assembling the missiles as a way to learn and understand the basic structure of design. The engineers spent enormous time to measure all the parts and to test the components of the materials (Interview III, 2010).

In assimilating data, the 5th Research Academy organized knowledge-diffusion seminars, such as, the introduction to missiles, missile guidance principles, aerodynamics, engine, aerospace structure, control systems, and computer technologies to share knowledge gained through learning and observation. The heated debates on technologies and learning among engineers resulted in new knowledge, explicit and tacit, which was then incorporated into the product development strategy (Qian, 2007). As some knowledge was not disclosed in the licensing agreement, Chinese duplicative imitation efforts involved the purposive identification and gaining of tacit knowledge and unavailable technological information designed to reduce uncertainty associated with reverse engineering.

Chinese imitation required considerable absorptive capability to integrate systems in an effort to transform industry-specific knowledge into firm specific knowledge (Bolton, 1993). In so doing, the 5th Research Academy set up departments, namely, missile design, aerodynamics, control systems, aerospace structures, engine, propellants, electronic engineering, computer technologies, and technical physics in converting knowledge into missile products. The challenge they faced was that knowledge was neither shared equally among the new departments nor easily imitated across them. Learning through the discursive processes of knowledge creation continued and underpinned the development of special expertise. Another senior program manager on the distinct ways to increase the stocks of knowledge through cooperative arrangements observed that:

> With the licensed production of P-2, the Soviet Union later initiated technological aid programs including the provision of missile samples, whole technical documentation, and launching site blueprints, sending their engineers to train Chinese engineers, and inviting them to learn missile technologies in the Soviet Union (Interview V, 2010).

The dynamic interaction of knowledge creation and technological capability building facilitated the development of the licensed copy of Soviet missiles (DF-1). In this regard, one interviewee defined Chinese innovation in the DF-1 program as 'home-made alcohol for fuel and liquid oxygen as an oxidizer' (Interview I, 2010).

With the initial breakthrough in duplicative imitation, the industry launched a more creative imitation program of DF-2 by simply doubling the size of DF-1. The test failed spectacularly, and the follow-up investigation reported that:

> The major problems were two-folds: the aero-elastic effects on the aerodynamic performance of the spinning missile and the structural defects associated with the aluminum skin, the ring frames, and the engine, which led to the mechanical failure (Interview V, 2010).

Besides the designing and defect problems, the industry faced other technical challenges related to wind/gun tunnels, repetitively fired two-stage coaxial plasma engines, welding and joining solutions, remote control devices, and high precision bearings (Qian, 2007). The technical challenges suggested misunderstanding inherent in knowledge creation during the process of duplicative imitation, but also heavy dependence on Soviet explicit knowledge and the lack of absorptive capability to handle tacit knowledge during the processes of duplicative imitation.

On the one hand, our data evidence suggests that effort by the Chinese to access, acquire, and diffuse Soviet knowledge affected organizational learning and knowledge-creation within the industry-specific context. A senior program manager explained the priorities of duplicative imitation initiative:

> We wanted to be efficient in our duplicative efforts so we asked engineers to try to share the Soviet explicit knowledge they have accumulated in all key areas of product design, engines,

control units, electronic components, fuels, technical physics, production processes, and organizational structures (Interview, 2010).

Of particular importance to such efforts was the focus on engineering cybernetics, the science of control and communication in complex machine systems (Qian, 2007). Cybernetics for the Chinese space industry was more about what Qian (1964) described as 'the qualitative aspects of the interrelations among the various components of a system and the synthetic behavior of the complete mechanism, which had direct engineering applications in designing guided systems'. What was novel in this process was the attempt to link engineering cybernetics with knowledge creation, knowledge utilization, and project management through discourse (Xie, 1992).

Although Soviet explicit, formal, and expert knowledge to some extent was easy to understand and master, tacit knowledge, was hard to transfer and served as a barrier for the industry to create knowledge. The failed test of DF-2 showed that knowledge creation was not simply enlarging the size of the Soviet prototype, but developing the absorptive capability to assimilate and apply knowledge in quality and quantity to the programs (Nonaka and Takeuchi, 2000). In contrast to a scope of choices about product copying, prototype production, and testing, the absorptive capability involved a set of skills and expertise to manage the explicit and tacit components of transferred knowledge to modify Soviet knowledge (Mowery and Oxley, 1995; Luo *et al.*, 2011). Again, our data evidence suggests that discourse shaped the engineers' mind, their approaches to imitation, and conditioned their responses to the programs. As a tool of knowledge creation and diffusion, the discursive processes ultimately offset the absence of technical advice from Soviet engineers, who left for home because of the rapidly deteriorating relations with China. The discursive processes created and conveyed by the industry built and shared special knowledge for the imitation programs.

4.2 **Knowledge conversion as core competence**

Over time, the impasse surrounding the process of knowledge creation called into question the rationale of imitation as a justified practice for generating the fundamental knowledge required to operate effectively in such a technologically complex industry. Nevertheless, there was a widely held belief within the industry that, an imitation centric knowledge creation was necessary in the management of tacit and accumulated explicit knowledge that will drive and sustain the competitiveness of the Chinese space industry (Nonaka and von Krogh, 2009). Spin-on and spin-off as a necessary mechanism to address the structural challenges of knowledge sharing begun to gain tract in the industry but security concerns tend to slow down the process. As observed by an interviewee:

> Lack of competition, limited demand, and the security dimension of the programs decreased the willingness of knowledge exchange with the civilian sectors. There were fears that any attempt to adopt civilian technologies would disrupt the supply chain and the prevailing organizational routines (Interview, III, 2010).

The unusual commitment to military knowledge and imitation by the industry also exacerbated the technical problems, related to the expected transition from imitation to innovation, which threatened program survival. A senior program manager highlighted the conundrum facing the industry

> Without access to advanced civilian technologies, the knowledge creation bottlenecks in materials, engines, control systems, computer technologies, and guidance devices forced the industry to scale back the programs, rather than to leapfrog into the innovative spacecraft programs introduced in the 1970s (Interview III, 2010).

Responding to endogenous reform and the exogenous shocks of the technological revolution, our data evidence suggest that the evolving discursive processes of knowledge conversion gave special attention to shared dual-use knowledge as a crucial indicator to measure how and the extent to that dual-use tacit and explicit knowledge increased innovation, not imitation (Qian, 2007). In an effort to maximize the innovation potential of the industry, the discursive processes encouraged knowledge exchange with the civilian sectors by soliciting and incorporating civilian input into the prevailing military-organizational context. This enabled the industry to attract substantial FDI and access to foreign technologies (Qian, 2007). Discourse on transfiguring civilian knowledge gave the industry a chance to identify, collect, digest, and disseminate the latest technologies critical to the future space innovation programs.

The new approach to knowledge conversion followed the models of the US Strategic Defense Initiatives (SDI) of Star Wars and the European Eureka Plan, as their innovation practices created sound representations of technological capability-building (Qian, 2007; Xie, 1992). One senior program manager offered insight into knowledge sharing as a new project management model:

> For the Chinese space industry, external knowledge sources in innovation, by all accounts, provided an urgent need to deconstruct the old model of knowledge creation by focusing on knowledge sharing with the civilian sectors (Interview II, 2010).

The discursive processes of 'share-ness' and 'recognition' for knowledge spillovers prompted an assessment of its in-house R&D. The lessons learned demonstrated that a simple model of product imitation could not do justice to the subtleties of missile and spacecraft innovation, which relied on cooperation with complex systems industries. According to data, the key to dual-use knowledge creation and knowledge spillovers was how to define civilian technologies. With increasing access to foreign technologies, efficiency, profits, and markets were the indicators to measure civilian innovation and competitiveness. In the Chinese space industry, there was increasing resistance to the ill designed products that undermined organizational efforts to optimize resources for developing quality and reliable products (Qian, 2007). By contrast, the underperformance of dual-use knowledge threatened the sustainability of space innovation. With the exogenous shocks of developments in space and information technologies, increasingly resilient and expansive dual-use knowledge cast doubt on the poorly defined innovation programs (Qian, 2007). A senior program manager explicated how the new approach to knowledge creation serves as a solution for innovation:

> Despite constraints on the knowledge choices, the industry's actors demonstrated their desires to acquire new knowledge and agreed on dual-use knowledge sharing through cooperative arrangements (Interview II, 2010).

Our data evidence suggests that the discursive processes constructed and defined dual-use knowledge for innovation, with the objective of improving product performance, capacity, and reliability. With the endorsement by the government as both the regulator and the end-user to form the civilian-military alliance, the new innovation priorities of building launch vehicles, spacecraft, and a space station were to leverage dual-use technologies (Qian, 2007). Yet, dual-use technologies raised another question about the scope of action in justifying these programs. On the organizational front, the discursive processes of knowledge conversion were embedded within the context of Chinese technological development, which had been splitting the industries since the 1950s. This business model still shaped today's perception of and approach to innovation. The design of the civilian-military alliance placed emphasis on the civilian sector, which enjoyed advanced foreign technology transfers that would add value to space innovation. The opposition to this spin-on was the space industry in favor of the spin-off method downplaying the relevance of the proposal to the innovation programs. Take for example the satellite innovation program that spun off the battery technology to the civilian sectors and space engineering cybernetics to analyze and project China's population growth, a pure non-military issue (Greenhalh, 2005; Qian, 2007). Compared to the missile imitation programs, the proposed dual-use option underestimated the management issues, such as, knowledge creation, program management, and institutionalized cooperation, which were the backbone of Chinese innovation (Qian, 2007). The narrowly-defined approach also overlooked the practices of international cooperation in the space industry (Qian, 2007). As for technologies, it failed to identify any technologies essential to the space innovation programs (Qian, 2007). In short, the discursive processes implied that the spin-on model of knowledge conversion was elusive, unfocused, and hard to provide any value for innovation.

In enhancing competitive advantage, Qian mapped out the spin-off of the specific military technologies to the civilian sector as a concrete example to counter the ambiguous term dual-use knowledge for innovation (Qian, 2007). The spin-off approach covered a variety of innovative technologies--using satellite and optical fiber communication technologies to set up a competitive IT industry, the system of vocational, adult, and higher education across the country, TV networks, and the sensor grids for monitoring weather, ocean, natural resources, and natural disasters (Qian, 2007). On the other hand, a spin-on focus should be on innovative technologies--artificial intelligence, remote control, biotech, material science, and high-temperature super-conductor, in which the space industry must take lead (Qian, 2007). The goal of this knowledge conversion was, as data suggested, to produce the new weapon systems the end-user needed, but also to reflect that the industry required a considerable amount of specialized dual-use knowledge to build core competence. The discursive processes of knowledge conversion in the alliance attributed to a delicate option of integrating the civilian and the military with attention to the civilian sector (Qian, 2007; Song, 1999). To the space industry, the destruction of military knowledge creation made its innovation programs clearly viable.

Innovation through knowledge transformation

The discursive processes of knowledge transformation constitute innovation in spacecraft through the interaction among partners, suppliers, regulators, and the end-user (Qian, 2007). The interaction, as noted in interviews, demonstrated that the space industry appreciated product complexity, technical advances, and complex forms of specialized knowledge, which the scale and scope of the integration mission required. The challenges of modifying and transforming knowledge across the boundaries created by specialized knowledge domains reflected changes in the industry, where competition for efficiency, profits, and market shares was to measure the spacecraft programs. Therefore, there was increasing resistance to the duplicative imitation programs, which had undermined the organizational efforts to optimize the resources for developing high quality customized products (Qian, 2007). The innovation priorities outlined in the space program blue print stated: 1) before 2002, China would launch two unmanned spacecraft and one manned spacecraft; 2) in 2007, it would master sophisticated docking technology and launch a space laboratory; and 3) it would build a 20-ton space station similar to the NASA-led space station to conduct scientific research (White Paper, 2006).

What mattered was the organizational push for knowledge transformation in innovation, though the designs and the development stages were elusive (Qian, 2007; Zhu, 2003). The bottom line was to make the innovation programs sustainable by creating the synergy of civilian and military knowledge, technologies, rules, and practices. Innovation knowledge was contested, refined, and reconstructed in managing a source of novelty through the discursive processes of product designs based on the US, European, and Russian models (Bulletin I & II, 2010; Zhu, 2003). The proposed designs echoing latest technological developments in the space industry were plagued with complex systems and logistic demands--global communication, observation, meteorology, and remote control networks and fleets required to be deployed in the Atlantic and the Pacific to monitor the spacecraft (Qian, 2007). Similar to the duplicative imitation programs, a solution for managing them was licensing or a strategic alliance with foreign firms, who would offer a unique and complementary source of competitive advantage, such as, know-how and advanced technologies (Qian, 2007). Without it, the partners and the suppliers could not achieve the performance targets required by the spacecraft programs.

During the discursive processes, a frustrating issue was how to define the conceptual terms 'advanced' and 'inferior' as a justification for core competence in innovation. In other words, the purpose of innovation was to build a Chinese, not a Russian or US spacecraft, a goal that polarized the program management team (Bulletin V & VI, 2010; Zhang, 2008). The question represented the clear-cut demarcation of knowledge that each partner or supplier held. Once these definitions were on the table, different solutions could be compared and contrasted, tradeoffs could be made, and agreements on novel knowledge and technologies could be reached (Miller et al, 1995; Carlile and Rebentisch, 2003). In relation to the spacecraft innovation, for example, an interviewee observed that:

> Although the proposed design of spacecraft reflected knowledge assets in practice, the US space shuttle represented cutting-edge technologies, and the command of them would give the industry a solid membership in the space club. Nevertheless, the technical hurdles and the financial costs faced by the industry would have been beyond reach in the 1990s and for upcoming decades. By comparison, the Russian spacecraft seemed outdated, but it was reliable with a simple structure (Interview II, 2012).

The low-risk spacecraft vis-à-vis the highly sophisticated US space shuttles would fit into the Chinese approach to knowledge creation practices, with emphasis on mature technologies. Our data evidence suggests that, the deep concern over the technologies underlined the disappointment with the proposed research design. If cost was a primary issue, there were other ways to develop the programs by focusing on tailored batches of civilian supersonic shuttles for air transport or using virtual reality technologies to conduct unmanned space missions in the context of military and civilian knowledge conversion that would reduce research, production, and maintenance costs (Qian, 2007). As one senior program manager concluded:

> If the goal was to gain membership to the exclusive space club and to reserve the power to speak on space related issues in the world, it was a rational choice to use the spacecraft as a short cut to send astronauts into space (Interview II, 2012).

Put simply, the discursive processes of knowledge transformation served as a means to identify and validate the interface of knowledge, innovation, and the spacecraft programs.

The challenge associated with knowledge transformation was that the spacecraft design as a symbol of storage only served to self-reinforce learning effects designed to put values to the existing knowledge stocks in active use. In this respect, rapidly changing space technologies, although expensive, were mature and available to anyone interested in them and made space travel easier (Wang, 2008). Closer end user-producer engagement allowed the end-user to put its needs into designs, manufacture, and after-sale services, but the final decision made by the government as the sole end-user missed the issues of the spacecraft design and technologies, related to simple or full-size replicas of the Russian or US models. As argued by a senior program manager,

> Discourse on the technical designs continued in increasing, modifying, and transforming the various stocks of accumulated knowledge (Interview III, 2012).

One of the most important issues related to design, for example, was whether the scapecraft should be equipped with two or three sections—orbital, reentry, and service modules. To capitalize on the status as a space industry competitor, they decided to safely copy and launch the Gemini-style two-section spacecraft, on which the Chinese space agency had already done a lot of research. The subtle difficulty involved in this imitation strategy was summarized succinctly by an interviewee who argued that:

> As the spacecraft project was not a simple business mission as a crusade to foster innovation, copying the US or Soviet model of the 1960s at the expense of other choices would not reflect the Chinese current technological capability (Interview III, 2012).

On the other hand, the modified three-section design defined as 'advanced' and 'innovative' was too risky to finish all necessary manufacturing and testing within the limited time and budget, given that the industry had already endorsed the idea of building a functional spacecraft at the beginning of the project. While this earlier commitment escalated the risk associated with the project, senior program manager saw the innovation choice of spacecraft as a rational one:

> After seriously reassessing the technological capability in the skills to integrate hardware and software components into a fully coherent system, the know-how for research and production, and the detailed knowledge of supply chain management and quality control, a special deliberative panel of five senior engineers was set up for the final deliberation, with the compromised vote of 3 to 2 favored the Soyuz-TM-style three-section spacecraft (Interview III, 2012).

In the end, the Soyuz-TM spacecraft averted the imitation or inferior technology curse, it was deemed a 'success', suggesting that it was more advanced than the first generation of the Soviet one-man Vostok 1 and the US one-man Mercury-Atlas 6.

Our interview evidence points to the fact that, the discursive processes of knowledge transformation, in contrast to the literature of knowledge creation on firms in developed economies was critical to innovation in the space industry. The Chinese space engineers were well trained and shared a uniform set of norms, procedures, and rules. This stored knowledge affected their course of learning action for innovation from imitation and, in turn, attempts to digest, transform, and diffuse stored knowledge across the board afforded an incentive to adapt it to the local environments. As the innovation events showed, the discursive interaction of foreign knowledge and Chinese knowledge creation enhanced innovation in the spacecraft programs. With increasing novelty, discourse on cooperation among regulators, research centers, manufacturers, suppliers, and the end-user served as a dynamic mechanism to deal with innovation challenges. We argue that the discursive processes led to the consensus on technologies and product innovation. Describing the Chinese approach to innovation management, a senior program manager had this to say:

> The centralized program team consisted of a small group of leading engineers recognized across the industry in charge of (1) identifying new knowledge for innovation, (2) integrating this knowledge into local conditions for product designs and production, (3) setting innovation standards and rules, (4) supervising production to make sure all the parties to meet the innovation standards and targets (Interviews II, 2010 & 2012).

Clearly, knowledge transformation represents the unambiguous challenge confronted by the space engineers. Knowledge in the space industry is highly specialized and develops its own terminology, protocols, syntaxes, and rules, which reside with specialists (Carlile and Rebentisch, 2003). The absence of share-ness requires the engineers to establish a shared language and method through the discursive processes to interpret and trade off specialized knowledge for innovation. The practice put forward by the engineers was a cooperative approach through the discursive processes to define the meaning of innovation and knowledge transformation. In the organizational context, this cooperation mechanism provided new norms, frameworks, rules, and management methods to transform knowledge and to adapt it to in-house R&D and production. But the ways of discourse on cooperation were intangible to deal with emerging organizational challenges, namely, lack of competitive choices and transparency.

Discussion and conclusion

The existing literature on knowledge creation and conversion is exclusively based on the assumption that market forces and market efficiency are the fundamental primary drivers for innovation. In the self-organizing market economy, agents are likely to be rational optimizers, who maximize utility and profit over time. By comparison, the Chinese market economy remains 'socialist' in the public sector: the space industry is state-owned, extensive, and closed; and competition is a concern recently, although the economy is competitive in the private sector (Lin, 2012; Stiglitz and Yusuf, 2001). The dual nature of the Chinese economy suggests that planning and control is the defining feature of the customized space products in design and production for the sole end-user (Rawski, 1994; Lin, 2012).

The Chinese space industry over time, our study reveals has evolved from a state sponsored imitation program to a global competitor. The discursive processes of knowledge creation through developing oral, written, and gestural texts, we argue, drives innovation in the Chinese space industry. More precisely, the industry's transition from imitation to innovation involved the discursively constructed ensembles of in-house knowledge generation for specialization in the production of space products, which makes the late comer a vibrant competitor in the context of high complexity and uncertainty. Within the space industry-specific context, knowledge is created, shared, and utilized through discourse to construct and deconstruct believes and the actuality of skillful action (Nonaka *et al*, 2000; Nonaka and von Krogh, 2009). The discursive processes serve as competitive advantage and as the source of sustained innovation growth (Teece *et al*, 1997; Nelson and Winter, 1982; Nonaka and Takeuchi, 1996; Nonaka *et al*, 2000; Grant, 1996; Foucault, 1971). We are of the view that despite China's emergence as a leading competitor, its knowledge creation potential in the space industry is still evolving. Our finding suggests the construction and deconstruction of knowledge are by nature product-driven to meet the customized needs of the sole user, but not mass market consumers. The discursive processes among partners, suppliers, research centers, regulators, and the end-user attribute to new designs and prototypes in response to market demands and technical challenges. During these processes, licensing and open sources become the knowledge access channels, which affect and are affected by research priorities and production requirements. In managing the product specific bottlenecks, knowledge creation is the sole criterion to identify innovation choices and solutions and to measure the technological capability and knowledge base, which the industry chooses and commits. This approach justifies industrial adjustments for innovation.

First, the discursive processes of knowledge creation set the stage of copying the Russian missiles for the customized, rather than mass product market. The practices of duplicative imitation through the dynamic interplay of tacit and explicit knowledge determine the mission of the space industry. This distinct nature shows that the discursive processes define licensing and on-the-job-training as the source of knowledge. The industry-wide learning mechanisms justify imitation choices of managing prototype development, engineering, and production. The lesson learned from production is that imitation is not just enlarging the size of missiles, but developing creative thinking and doing in-house research, with the aim of integrating knowledge assets, copying, and management.

Second, knowledge conversion through the discursive processes is the key to maximize the utility of dual-use technologies from the civilian sectors that enjoy access to advanced technologies through

FDI, joint ventures, and licensing. Exchange on knowledge reflects the increasing demands on product performance, capacity, and reliability from the sole end-user and forces the industry to take proactive measures to seek dual-use technologies. As suggested by tour data evidence, knowledge conversion is negotiated through discourse prior to product development, because there is no a dominant approach to it. The mechanism of the organizational practices is to identify and legitimize civilian technologies to replace old ones that threaten program survival. In this respect, dual use technologies allow the partners, suppliers, research centers, regulators, and the end user to produce new products.

Third, the discursive processes of knowledge transformation enhance in-house R&D, production, and management. These processes for creative innovation are not simply to make tacit knowledge explicit or versa, but to redefine and transform specialized knowledge for generating collective knowledge (Nonaka and Takeuchi, 1995; Carlile and Rebentishi, 2003). With this collective knowledge, the space industry seeks technical and management solutions associated with performance, capacity, and reliability, but also consensus building in in-house R&D, innovation, and production. Knowledge transformation makes specialization shared across the space industry.

In sum, our case evidence suggests that other Chinese state-owned industries might have similar processes for managing knowledge creation and innovation to meet domestic needs. As this case illustrates, the rise of the Chinese space industry as a contender will drive foreign firms to be more innovative in order to maintain their dominant position. Their innovative ideas and technologies are in return digested and imitated by the Chinese firms in their effort to adding significant value to their own products. Following this logic, they actively seek a short cut by optimizing knowledge-creation, technologies, and resources for making their products competitive. In as much as their innovation catch-up strategy has given rise to a global champion, they have made history. The story of the Chinese space industry is therefore a witness to the quantum jump from imitation to innovation in a technologically complex industry. It does not just tell how the discursive processes of knowledge creation could potentially lead to the creation of advanced technologies. It tells history.

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