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Co-creating and directing Innovation Ecosystems? NASA's changing approach to public-private partnerships in low-earth orbit

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ABSTRACT

U.S. public activities in space directed via NASA are undergoing change. While NASA has historically been able to drive market creation, through its procurement policy (which is much weaker in Europe), the past decade has seen a visible shift in US space policy, away from NASA-directed developments in low-Earth orbit (LEO) towards an ecosystem with a mix of private, not-for-profit, and public actors in LEO. This has fundamentally changed NASA's role from an orchestrating/directing role, to a more 'facilitating' one driven by commercialization needs. This shift in mission and approach has ramifications for the LEO ecosystem as well as NASA's innovation policy, which has previously centred on clearly defined "mission-oriented" objectives, such as putting a man on the moon or creating the shuttle fleet. Such objectives required 'active' innovation policy whereby NASA both funded and 'directed' the innovation, within its walls and with its partners. The emerging multi-actor ecosystem approach has involved a more open-ended objective that does not have a unified nor clearly defined endgame. In this situation, NASA's ability to shape activities in a direction in line with its mission will depend on its relationships with other members in the system. The rise of new actors in the space eco-system, and new relationships between them, presents interesting challenges for innovation policy informed by an Innovation System approach. In this paper, we critique the market failure approach of public intervention in markets and describe further work to be done in the innovation systems literature - more focus on the interactions between agents (and the type of agents) as complimentary to the dominant focus on funding programmes in innovation systems. In this paper, we present the evolving processes of NASA's engagement in building a low-earth orbit economy to draw out case specific insights into a public agency shifting its mission to incorporate approaches to facilitate the market creation policy. The paper focuses on the way that NASA structures its new innovation policy, away from a classical supply side oriented R&D investment through NASA itself, towards a policy of orchestration and combination of instruments rather. We close the paper with a reflection on the ramifications of NASA's approach to building a sustainable low-Earth orbit economic ecosystem.

1. Introduction

Historically, NASA's mission-oriented programs for innovation have been driven by security concerns and by the need for maintaining technical leadership over other nations.[1] The situation is now shifting. NASA is attempting to create new markets that fuel a sustainable Earth-LEO economy, or, as Sam Scimemi, director of the ISS, put it, to "sustain economic activity in LEO enabled by human spaceflight, driven by private investments, creating value through commercial supply and demand" where the "destiny of LEO beyond ISS is in the hands of private industry outside the government box."

A recent report from NASA's office of the chief technologist, the drive towards a self-sustained "low-earth-orbit ecosystem" has been positioned as a desirable objective for NASA's human spaceflight policy and linking to its larger aims of deeper exploration of the solar system (see Emerging Space report pp4). The report comes after a wave of mission shifts and space policy directives which emphasis that the private sector should be given more power and be supported to stimulate space services. There is also evidence of actual activities stemming from these policy changes, for example the first fully commercial launches of cargo to the international space station by SpaceX and Orbital-ATK, along with other commercial service providers onboard the ISS such as microgravity experiment services (NanoRacks) and in-

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[1] In this paper, when we describe NASA policies, we focus on those related to human spaceflight and operations in low-Earth orbit (LEO). This is not the full scope of NASA's activities, of course, which also include deep-space scientific missions, aeronautics, planetary landers, etc. For full details, see www.nasa.gov.

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orbit 3D printing virtually controlled by the private firm Made-In-Space (where NASA does not own the onboard printer).

There is a growing emphasis and action on stimulating/creating a low-earth-orbit economy, where markets will produce economic benefits for the US as well as a low-earth-orbit industry that can provide services for NASA when needed. However, there are also indications that the way the shift towards an ecosystem approach is being actioned by NASA is leading away from a "market creation" approach, to something resembling a "fixing market failure" approach (Mazzucato, 2015a, 2015b). Indeed, at first glance, it seems that NASA has moved from a role as dominant director of innovation and development with active mission-oriented polices (Foray et al., 2012) towards more diffusion-based policies (Chiang, 1991) where their role is to support the creation of the right conditions for markets to emerge (a standard market failure approach). This support role focuses on catalysing an "innovation ecosystem" with a mix of private, not-for-profit, and public actors in LEO.

In this paper, in line with the focus of this special issue, we take an innovation ecosystem approach to understand (a) the changing population of the low-earth-orbit ecosystem, (b) the forms and functions of the relationships that connect between members of this population and (c) use these findings to understand the changing relationship between NASA and low-earth-orbit human spaceflight activities. Innovation ecosystems require different types of policies. Vertical policies are more directional and 'active' focusing on directing change. Horizontal policies are more focused on the background or framework conditions necessary for innovation, allowing the direction to be set by the private sector. While both horizontal and vertical policies are required, it can be said that horizontal policies are more about 'facilitating' innovation in the private sector, while vertical policies embody a more active role for the public sector in directing change not only facilitating it, often through missions which require actively creating and shaping markets—not only fixing them (Mazzucato, 2015a, 2015b). We shall return to this in the conclusions.

In the following section, we draw on the literature around systems of innovation to help us create an innovation ecosystem "lens" to probe into the changes that are occurring both within NASAs space policy regarding low-earth orbit, and the multi-actor activities (actual and planned) in low-earth orbit. Section 2 will also describe how we will use this meso-level model of the innovation ecosystem to help us connect the broader US human spaceflight policy (macro) with the individual activities of firms and other organizations in low-earth-orbit (micro). Section 3 will describe the emergence of US human spaceflight during NASA's first 5 decades of activity, detailing the nature of the bilateral relationships between NASA and other parties, where NASA is the central organizers of US human spaceflight in LEO. Section 4, will dig deeper into how this has shifted from a single actor space, to an emerging innovation ecosystem, detailing the new forms of relationships between NASA and other actors in LEO. Section 5 will explore the ramifications of the emerging ecosystem for US human spaceflight policy, particularly for LEO.

2. Models of actor ecologies in innovation

Innovation in technology-based sectors is rarely done by a single organization alone; these fields are characterized by complex organizational networks which address different aspects of innovation. In the literature on innovation in technology-based sectors, the complex division of labour has been modelled in terms of innovation chains (sometimes called value chains), networks and systems. While some of these concepts build on each other, they have their relative merits and limitations. Below we review, briefly, this literature to locate our ecosystem approach.

2.1. Value chains and networks

The concept of the value chain is used in strategic analysis: as a tool, it has been used for three decades now to analyse the firm, its major competitors, and their respective performances, to identify and address performance gaps (Peppard and Rylander, 2006, Porter, 2001). A value chain is 'the series of activities required to produce and deliver a product or service' (Porter, 2001:11). The chain is constituted around the activities required to produce it, from raw materials to the ultimate consumption of the finished product. Layers in a value chain have been described in terms of a sequence comprising suppliers, manufacturers, distributors, and consumers. For example, one of the more well-researched chains - the wireless communication (mobile phone) chain, includes equipment companies; infrastructure companies/network operators; Steinbock, 2003), which interact with a multitude of specialized companies (software intermediaries; financial intermediaries; content providers; resellers; cf. Peppard and Rylander, 2006); which in turn engage with the end customer (Li and Whalley, 2002). Scanlon (2009) includes a 'reverse supply chain', which re-connects the user with the original equipment manufacturer whenever phones are returned for repair or disposal. In semiconductor manufacturing, the main engineering and manufacturing tasks that involve integrated circuit (IC) design, (physical) manufacturing, and systems integration of these ICs (cf Lee & von Tunzelmann 2005), have over the past three decades become organizationally separated; different companies address different parts of the chain (design houses; mask houses; wafer companies; pure-play foundries; and back-end processing and electronic packaging. Within innovation chains we observe interactions both within the same layer ('horizontal' transactions) but also between layers ('vertical' ties), such as logistics management and contractual arrangements between buyers and suppliers (Lazzarini et al., 2001, cf. also Saliola and Zanfei, 2009, Omta et al., 2001). Both in terms of the actors (organizations and their relationships) and technologies, chains can be seen as dynamic: they undergo changes related to co-evolution of innovation, relationships between actors in the value network, services offered (cf the adoption of new functionalities), and customer relationships (Peppard and Rylander, 2006). The concept of value chains has come under scrutiny for certain limitations (cf Fransman, 2002), and alternatives have been proposed in various bodies of literature, such as network concepts which highlight cooperative rather than hierarchical behaviors in inter-firm relationships (cf Peppard and Rylander, 2006, Funk, 2009, Li and Whalley, 2002).

2.2. Innovation systems

Another strand of research on innovation actor ecologies, broadly as innovation systems analysis, integrates (extensive) quantitative analysis with testing of the impact of particular actors or instruments on the innovation process within the system and relative to other national systems (Lee & von Tunzelmann, 2005). Systems of innovation have been defined as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1995), or "the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge" (Lundvall, 1992, p. 2). Distinctions are made between a national, local, and sectoral innovation system (Malerba, 2002). Lee & von Tunzelmann (2005) describe a model of a national innovation system that comprises five actors (government, industry (firms), research institutes (public and private), foreign companies, and universities) (Lee & von Tunzelmann, 2005). Malerba (2002) distinguishes in his definition of a sectoral system of innovation and production, firm type organizations (users, producers and input suppliers) and non-firm organizations (e.g. universities, financial institutions, government agencies, trade-unions, or technical associations). A 'sectoral' innovation system would focus on an industry sector - such as telecom equipment and services (for case studies of each sector, cf. Malerba, 2002). Such an industry sector perspective broadens the firm- or supplier/assembler network-centric view of value chains to include development- and market-external actors, such as institutions assumed to be impacting on the dynamics of innovation. The assumption

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