From Field Consensus to Fragmentation: How Means-ends Decoupling Hinders Progress on Grand Challenges

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ABSTRACT

Grand challenges are complex problems with far-reaching societal implications that lack a clear technical solution. To make progress on grand challenges, many different communities need to collaborate over an extended period of time in complex organizational fields. However, institutional scholars have primarily focused on how communities form consensus on a grand challenge’s initial goals during the earliest stages of field emergence. There is little exposition of how various communities collaborate after initial field goals have been set and substantive solutions need to be pursued. With an in-depth study of the nanotechnology field, we show how disparate communities created alignment on field level goals during the early phase of field emergence. In a later phase, however, these same communities shifted to local action to the neglect of prior shared goals. This process decoupled the means and ends pursued by the participating communities producing field fragmentation. Our research shows how early consensus around a field’s goals and the means to achieve these goals diverged over time. We contribute a more precise understanding of field dynamics and explain the mechanisms and conditions that can generate means-end decoupling. We conclude by discussing how field fragmentation and institutional complexity affects progress on grand challenges.
INTRODUCTION

Many grand challenges like curing cancer, combating climate change and reducing poverty face the world today (Howard-Grenville, Buckle, Hoskins, & George, 2014; Kates & Dasgupta, 2007). Government, private and non-profit organizations pour billions of dollars per year into initiatives designed to address some of these grand challenges. Grand challenges share a number of key features: they lack a clear technical solution and encompass incomplete, contradictory, or changing requirements (Churchman, 1967; Rittel & Webber, 1973). It is often difficult to evaluate solutions due to the complex web of interdependencies involved in grand challenges. Determining how changes to one part of the system shape other parts of the system may be difficult to determine a priori. Thus, many diverse participants are needed to contribute to new technical or social innovations and address grand challenges at the field level. Yet, many of these initiatives fall short of achieving their initial goals. Why?

Research on field emergence can shed some light on this question. Organizational fields are a set of organizations “that partake of a common meaning system and whose participants interact more frequently and fatefuly with one another than with actors outside the field” (Scott, 2000: 56). Many scholars have examined how disparate actors craft shared goals at the field level in the face of grand challenges (Lawrence & Phillips, 2004; Lounsbury, Ventresca & Hirsch, 2003; Maguire, Hardy & Lawrence, 2004; Mair & Hehenberger, 2014; Weber, Heinze & DeSoucey 2008; Wry, Lounsbury & Glynn, 2011). Lounsbury et al. (2003) show how activists assumed a different frame to transform recycling from a waste activity to a mainstream commercial activity – achieving great environmental benefit in the process. Maguire et al. (2004) detail the struggles that HIV/AIDS patients engaged in to create a common field around HIV/AIDS treatment in order to foster societal acceptance and stimulate increases in funding. Weber et al. (2008) explain how members of the grass-fed movement used rhetorical strategies to create an appreciation of and thus a market for grass-fed beef to advance ecological sustainability. However, this research tends to focus on how field participants use
framing and rhetorical strategies to generate consensus and mobilize participation and resources in the earliest stages of field formation. In doing so, they overlook the processes through which fields start to deviate or decouple from their founding goals.

There are many ways in which a field’s goals evolve. This process can happen through explicit rhetoric as the contested process through which the use of DDT changed from acceptable to unacceptable (Maguire & Hardy, 2009). Or, alternatively, the goals of a field can drift over time in ways that are less noticed. Sometimes, managers and leaders seemingly adopt mandated rules or policies but fail to adopt them in practice (“symbolic adoption”) (March, 1962; Meyer & Rowan, 1977; Tilcsik, 2010). Recently scholars have begun to study means-ends decoupling, which occurs when rules or policies are adopted and followed but are only loosely tied to an organization’s ends or goals (“symbolic implementation”). This can happen, when an organization’s focus on measurement and evaluation distracts them from activities that align with stated goals (Bromley & Powell, 2012). However, there has been little examination of how means-ends decoupling unfolds or the conditions that are more or less likely to trigger it.

This is an important omission, particularly when considering emerging fields, because in many fields, the early establishment of consensus does not necessarily last. In the early stages of field formation, there is excitement and momentum around shared goals. However, the momentum that propels cooperation in a field’s early stages may dissipate as the field matures. As fields evolve and a more diverse body of participants begin contributing to the field, and the field moves beyond rhetoric toward action, the scope of the field’s goals broaden and consensus may be more difficult to achieve. For example, in the early days of satellite radio, competitors cooperated to increase the legitimacy of the field, but in later stages, they competed (Navis & Glynn, 2010). To make progress on a grand challenge, diverse field participants contributing vital knowledge and resources need to cooperate on common goals, but each may have their own logic, goals and means for achieving grand field level goals (DiMaggio & Powell, 1983; Greenwood, Diaz, Li, & Lorente, 2010).
Fields consist of communities and distinct communities may approach a grand challenge from different vantage points (O’Mahony & Lakhani, 2011; Smets, Morris & Greenwood, 2012; Thornton, Ocasio & Lounsbury, 2012; Van Maanen & Barley, 1984), which can either cohere or fragment these participants’ ability to work toward collective goals. For example, the field of modern architecture evolved as multiple communities with different interests shaped the values and material practices that ‘modern architects’ espoused (Jones, Maoret, Massa & Svejenova, 2012). Community interests provide organizing principles, which drive community goals, as well as the means appropriate to achieve those ends (Friedland & Alford, 1991). Alignment among these interests cannot be taken for granted and disparate community interests may compete when the demands they impose are not easily reconciled. In other words, fields can vary with regards to the diversity of communities and the diversity of the goals and means these communities adhere to in order to reach those goals (Greenwood et al., 2010; Pache & Santos, 2010).

When a field has multiple communities with potentially competing interests, creating and maintaining the consensus and coordination necessary to advance a grand challenge can become a challenge. This is particularly problematic when field participants need to transition from rhetoric about goals to the concrete actions needed to achieve those goals. Yet, how collaboration among multiple communities on specific endeavors might generate means-end decoupling after initial consensus on field level goals has been established is under explored. Addressing this question is important if we want to explain why field level efforts to address grand challenges advance or fall short of their aims. To address this gap, we examined the nanotechnology field dedicated to the grand challenge of creating “the ability to manipulate matter at the atomic and molecular level… [generating advances such as] shrinking all of the information at the Library of Congress into a device the size of a sugar cube” (President Clinton, January 21, 2000). If the grand challenge for the field of nanotechnology sounds ambiguous, it
was in that the aim was to create a fundamental capability that could have relevance to many social and commercial applications.

We identify two phases to the evolution of the nanotechnology field. During the first phase, three communities (futurists, government officials and service providers) generated common ends and converged on the field’s goal: to facilitate atom-by-atom control and manipulation at the nano-scale. However, after consensus was reached, these founding communities transitioned from rhetoric to action; and shifted their attention to advancing the means for achieving their common goal. In the second phase of the field’s evolution, two additional communities (scientists and entrepreneurs) became involved in the field. With five communities in the field, reaching consensus on common field level goals became more challenging. As each community turned their attention to local actions, they became more focused on the means to achieve local goals rather than on field level goals - neglecting the field’s collective goals. The field, thus, underwent the process of means-end decoupling, transitioning from consensus to fragmentation - where communities lacked agreement on common goals and the means to reach them.

Our research details the mechanisms that drive means-ends decoupling at the field level. In doing so, we move beyond rhetorical explanations of the emergence of field consensus to identify some of the challenges fields face as they mature and specify the conditions that lead to fragmentation. Because progress on grand challenges requires a long time horizon, the initial stages of field formation are unlikely to be adequate to make progress and a longer time horizon of field level cooperation may be necessary. Means-ends decoupling is one potential threat to advancing progress on grand challenges, because this process generates misalignment among a field participants’ means and ends, thus fracturing the field. By examining how a field transitions from crafting common field goals to one means-end decoupling we identify the conditions under which fields are likely to experience either field consensus or fragmentation and explain how this affects the coordination needed to address grand challenges.
**THE MEANS-ENDS DECOUPLING OF ORGANIZATIONAL FIELDS**

**Field Emergence: Making Progress Towards Grand Challenges**

For a new organizational field to emerge, diverse communities need to recognize that they are engaged in the same issue (Hoffman, 1999; Fligstein & McAdam, 2012). This assertion is supported by studies that have shown that for fields to emerge, it is important for communities to use rhetorical strategies to convince others of the value of their shared vantage point. McGuire, Hardy and Lawrence (2004) detail, for example, the activities of institutional entrepreneurs in Canada in mobilizing support for HIV/AIDS, thereby creating the initial foundations of the field of HIV/AIDS. Phillips and Lawrence (2004) show how a change in rhetoric around whales from creatures of destruction to friendly foes aided the emergence of the Canadian whale watching industry. Focusing on rhetoric, but at a more detailed level, Etzion and Ferraro (2010) emphasize how the use of analogies in financial accounting facilitated the legitimization of the field of sustainability accounting by uniting diverse stakeholders around a common framework. In a similar vein, Jones et al. (2012) detail the slow process of meaning construction that went into shaping the field of modern architecture and Weber et al. (2008) identify how participants used opposing meaning pairs to change the connotations of “grass fed beef”. Overall, these studies help explain how disparate actors leverage rhetorical strategies to collaborate on the creation of a new field.

By focusing on these rhetorical strategies, the literature on field emergence has emphasized how consensus can be reached across disparate actors to form a new field. DiMaggio (1991) shows, for example, how philanthropists, museums workers, and museum visitors engaged in vivid contestation over the museum reform movement by making comparisons to already established fields like libraries, departments stores, or symphony orchestras before they settled on a new understanding of the museum. Likewise, both Navis and Glynn (2010) and Kennedy (2008) show, in two different industries, that entrants to a new field
established their legitimacy by initially referencing their competitors so that external
stakeholders would view the emerging field as addressing a coherent set of issues.

However, what is missing from these studies is an understanding of what happens after
consensus on the goals of the field is established. How are goals maintained as the field initiates
the means necessary to achieve grand challenges? How does the growth of new participants
entering the field affect the ability to make progress on common goals? A focus on only the
establishment of consensus is problematic, because many fields evolve to become
heterogeneous and fragmented and as a result become increasingly complex (Greenwood et al.,
2010). This can no doubt affect a field’s ability to coordinate on grand challenges. While field
complexity is in vogue, the existing literature cannot explain how alignment among field actors
becomes preserved or fractured.

The lack of attention to what happens after initial consensus on field goals has been
achieved is particularly problematic if our goal is to understand how to achieve grand
challenges, because many efforts to achieve grand challenges fail. For example, while 154 of
the world’s countries reached consensus on climate change in 1992 through the United Nations
Framework Convention on Climate (UNFCCC), over 20 years later little progress has been
made towards this goal. Several countries are becoming dissatisfied with the lack of progress
and some countries (like Canada) have decided to withdraw from the Kyoto protocol, which in
1997, established binding emissions targets. However, current theories of field emergence can
not account for what happened after the field initially achieved consensus (Howard-Grenville et
al. 2014). How did this field move from consensus to fragmentation?

To answer questions like these, we need to examine all of the different types of
participants engaged in a field. Fields consist of multiple communities—“voluntary collection[s]
of actors whose interests overlap and whose actions are partially influenced by this perception”
(O’Mahony & Lakhani, 2011: 7; see also DiMaggio & Powell, 1983). That is, fields consist of
multiple communities each with disparate interests for participating in a common field (Glynn,
The interests of each community shape both their goals and the means they use to pursue those goals. Pache and Santos (2010: 459) state that conflicting interests may influence communities “at the ideological level, prescribing which goals are legitimate to pursue, or they might exert pressures at the functional level, requiring organizations to adopt appropriate means or courses of action.” For example, many fields involve entrepreneurs driven by wealth creation (Thornton, 2004); scientists driven by making scientific progress (Gieryn, 1983) and government officials interested in the functioning and wealth of the state (Friedland & Alford, 1991). These three communities may share some common interests, but also maintain divergent goals. To understand how fields develop beyond the initial consensus that drives field emergence, we need to examine how the goals and means of disparate communities become aligned or misaligned.

Although diverse communities might have achieved consensus on a general goal for the field, their views on the appropriate means to advance the field might differ. For example, in Hoffman’s (1999) study of environmentalism within the chemical industry, the interests of the non-governmental organizations (NGOs) and the chemical industry differed dramatically in that NGOs emphasized that “the continued use of [DDT] and other synthetic chemicals would disrupt the “web of life,” posing a hazard to all living organisms, including humans”, whereas the chemical industry adhered to the “accepted belief… that engineering advances improved the quality of life for all humankind” (Hoffman, 1999: 360). Communities within a common field can navigate their diverging interests, by cooperating on limited shared goals, while preserving distinct local goals. For example, O’Mahony and Bechky (2008) showed how hackers in open source communities cooperated with titans of the software industry on commercializing open source software even though their views on intellectual property fundamentally differed. The shared interest in commercializing open source software was strong enough to support a defined space for collaboration that allowed both parties to maintain divergent interests.
The existence of multiple communities with different interests can make coordination on field level goals more challenging by creating plurality as to the appropriate means and ends for a field. For example, Dunn and Jones (2010) showed how medical education, while aligned on the field goal of enhancing medical understanding, encompassed an inherent tension between a focus on care and a focus on science. Powell and Sandholtz (2012) showed how the early biotechnology field was focused on generating human therapeutics based on genetic engineering, while incorporating communities focused on progressing science and communities interested in wealth creation. Jay (2013) details how both for-profit and non-profit organizations collaborated on environmental initiatives despite maintaining differing interests. The challenge for any field hoping to make progress on a grand challenge is to figure out how to maintain convergence on a common goal.

**Means-end Decoupling and Field Evolution**

Even when disparate contributors to a field are enthusiastic about a new idea, over time, a disconnect between the rhetoric field participants display and their adherence to the new practice might arise. For example, although many managers claimed that they had implemented Total Quality Management (TQM), they were often quite selective as to which practices they implemented (Zbaracki, 1998). The result was a disconnect between the official policies of TQM and the practices individual organizations engaged in. This pattern is characteristic of policy-practice decoupling where the policies and rules that an organization claims to adhere to and the actual practices of the organization become disconnected or decoupled (Bromley & Powell, 2012). Weick (1976) contends that one of the reasons policy-practice decoupling happens is to facilitate coordination. Often abstract policies are difficult to implement in a complex organization and a loose coupling of policies and practices facilitates localized coordination. This is particularly the case in uncertain or complex environments where it is difficult for managers to foresee the consequences of a particular policy implementation.
In contrast to policy-practice decoupling which entails symbolic adoption of practices, means-end decoupling is the symbolic implementation of practices. Means-ends decoupling unfolds over time as organizations shift their focus from goals to engage on the implementation processes needed to reach those goals. “A focus on information and procedure rather than directly on ultimate goals is at the core of means-ends decoupling” (Bromley & Powell, 2012: 26). When means-ends decoupling happens, the degree to which means are coupled to goals is unexamined and the means become ends in themselves leading to goal drift or goal displacement. Means-end decoupling has often been observed within organizations that have a social goal (Bromley & Powell, 2012). While these organizations set out to achieve a societal goal, the means they employ can divert attention from those goals. For example, the introduction of rationalistic procedures can foster goal displacement as leaders pursuit of power and influence supersedes their societal interests (Michels, 1966; Osterman, 2006; Piven & Cloward, 1977; Voss & Sherman, 2000).

Means-end decoupling need not be deliberate. Even when leaders are not power-seeking, attention toward organizational maintenance can sway the organization away from their initial goals, creating goal displacement. For example, Selznick (1949) showed how the Tennessee Valley Authority (TVA)’s efforts to gain legitimacy and attain resources led it to adopt policies that subverted its founding goals. Instead of being responsive to community interests, the agency became beholden to a small, powerful group of agrarian landholders. Nor is this a unique problem. Over attention to procedure can threaten the values that cultural agencies (Glynn & Lounsbury, 2005; Townley, 2002), universities (Kraatz, Ventresca & Deng, 2010), and other nonprofit organizations (Hwang & Powell, 2009) like museums are founded upon. While a museum might be founded with the goal of enhancing the cultural awareness of local communities, their goals over time may drift toward their own survival. The goal of cultural awareness through exhibitions is displaced by the goal of running cafes and giftshops.
Suffice it to say, the goals that organizations initially establish and the means they engage in to achieve those goals are not static over time. This can make coordination among disparate participants on common goals at the field level challenging. If multiple organizations from disparate communities are all contributing toward a common field goal, maintaining convergence on a common goal may require some vigilance. Drawing on an in-depth study of the nanotechnology field over a twenty-year period, we show that during the earliest period of field emergence, field participants generated common ends for the field, whereas later, as the field diversified, participants shifted to local forms of action to the neglect of shared goals. We identify the specific mechanisms underlying means-ends decoupling and show how this phenomena increased fragmentation of the field, inhibiting progress on a grand challenge.

METHODS

Setting: The Emerging Nanotechnology Field

We chose to study the nanotechnology field because it is an example of a grand challenge with ubiquitous applications for science, health and society that attracted diverse field participants. However, the nanotechnology field has not achieved many of the original goals established by its founding participants. The choice of the nanotechnology field was informed by Garfinkel’s (1967) advice to choose areas of investigation where the phenomenon of interest occurs in abundance. Pache and Santos (2010) argue that fields are most likely to fragment when they are moderately centralized, because they (unlike ones that are very centralized) are not governed by a single entity that guides interactions but they (unlike ones that are weakly centralized) still need to coordinate and interact with each other. We identified nanotechnology as a moderately centralized field in which participating communities had to interact in order to collaborate on joint activities. The field was, however, not fully centralized because no community – not even the powerful government – excerpted full control over the field (unlike for example the military (see Pache & Santos, 2010)).
As with most other fields, nanotechnology did not have a specific date of birth. Depending on the criteria chosen, scholars can point to slightly different dates to mark its inception. Science at the nano-scale began in the 1950s, but some of the major breakthroughs came in the 1980s, with the invention of the atomic force microscope. In contrast, the ontological foundations of nanotechnology were laid by Eric Drexler, a MIT PhD student who became a technological visionary primarily concerned with developing the field of nanotechnology (Granqvist, Grodal & Woolley, 2013; Granqvist & Laurila, 2011; Kaplan & Radin, 2011; Kennedy, Lo & Lounsbury, 2010). We call the group that grew around Eric Drexler the “futurist” community. We examine the nanotechnology field since its beginning up to the year 2005. While the first article in our data set is from 1953, very little activity occurred until 30 years later. Starting in the 1980s, when the futurist community was the only community involved in the field, we investigate how four other communities (government officials, service providers, entrepreneurs and scientists), with vastly different goals, means and interests came to be a part of the nanotechnology field. We describe these five distinct communities in more detail below.

Data Collection

The first author used theoretical sampling rather than representational sampling to guide data collection. Data collection began with a broad theoretical notion to study the emergence of complexity within organizational fields. As the first author collected data, the theoretical notion of interest became more focused and so did data collection efforts. While we present these phases of data collection chronologically, some events overlapped.

Phase 1: Ethnographic observations. The first author began data collection by conducting ethnographic observations at conferences and networking events. Conferences and networking events are field-configuring events where participants come together to negotiate the meaning of a field (Garud, 2008; Zilber, 2012). The conferences and networking events that
the first author attended were focused on the commercialization of nanotechnology and tended to attract multiple communities. During ethnographic observations, the first author recorded presentations and took notes on the activities and conversations of participants and elaborated on these field notes after each conference. During this process, we identified five different communities involved in the nanotechnology field, although they did not all enter the field at the same time. See Table 1 for an overview of the five communities and their general goals and means. The general goal of the futurist community was to stimulate the safe development of the nanotechnology field. In contrast, the general goal of the other communities was not specific to nanotechnology. The government’s general goal was to increase U.S. competitiveness in science and technology and the goal of the service providers was to stimulate demand for their services. The goals of the entrepreneurs and scientists were to make progress on product development and their scientific activities respectively.

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**Phase 2: Interviews.** The next phase in data collection was to conduct interviews with representatives from each community. Initially, the first author contacted participants to interview by selecting representatives from each community identified at field-configuring conferences and networking events. The first author then used snowball sampling to identify additional informants. Archival resources also helped identify informants. Efforts were made to ensure that informants interviewed had been involved in the nanotechnology field at all phases of its emergence even though they might not presently be involved in the field. In total, the first author conducted 77 interviews (13 with futurists, 11 with government officials, 18 with service providers, 24 with entrepreneurs and 11 with scientists). Table 2 depicts an overview of how these interviews are distributed across the communities.

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Insert Table 1 about here
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Phase 3: Archival research. To track the development of the field over time, the first author conducted extensive archival research. First, the first author collected an extensive archival dataset by identifying documents pertaining to the central events that occurred during the emergence of the nanotechnology field. This archival material covers the first scientific articles written by Eric Drexler, which established a possible path for the development of nanotechnology; all the reports released by the Presidents Council of Science and Technology; and important books written on the topic like Eric Drexler’s popular (1986) book *The Engines of Creation: The Coming Era of Nanotechnology*.

Second, in addition to historical materials, the first author collected a systematic dataset for each of the five communities by identifying a data-source in which community members conversed about the emerging field of nanotechnology. For the futurists, this was their monthly newsletter, *The Foresight Update*; for government officials, it was congressional hearings; for service providers, it was the business press; for the entrepreneurial community it was press releases and, for the scientific community, it was the journal *Science*. To identify relevant articles from each data source, the first author developed a list of search words related to nanoscience. As a point of departure from the Foresight Institute, a list of search words developed by the Fraunhofer institute were also used. Additional search terms based on prior collected data were also added to the list. Furthermore, the first author consulted experts in the field to obtain their assessment of the field’s evolution. The final list of search terms used is located in Appendix 1. These search terms helped identify articles relating to each of the five communities totaling 9,011 articles over the period 1984-2005. The first author also collected 3,762 articles from the top 50 US Newspapers to contextualize the evolution of the field. See Table 2 for a detailed overview of the archival data.
Data Analysis

We coded the data using a grounded theory approach (Lofland & Lofland, 1995). Our analysis started broad and became more focused over time. During data collection, evidence of means-end decoupling within the nanotechnology field began to emerge. As data analysis progressed, our analysis tackled more specific questions to explain how means-end decoupling had arisen. After the first author collected all the data, we uploaded the ethnographic observations and interviews in Atlas.TI and began open coding. We arranged all the archival material chronologically to obtain an in-depth understanding of the temporal development of the field. Based on this temporal ordering, our analysis proceeded in five steps: 1) Identifying the field’s shift from initial consensus on field level goals to fragmentation; 2) identifying two distinct processes: “generating common ends” and “means-end decoupling”; 3) specifying the mechanisms that contributed to generating common ends; 4) identifying the mechanisms that contributed to means-end decoupling; and 5) identifying the conditions that triggered the transition between generating common ends and means-end decoupling. Figure 1 provides an overview of our coding process.

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Insert Figure 1 about here
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Step 1: Identifying the shift from consensus to fragmentation. The first step in our data analysis was open coding. During this coding process, we realized that in the beginning of the field the founding communities crafted shared goals, however, these goals were never met, and the field had become fragmented with regards to the goals that the different communities strove towards. For example, we coded the statement “much of the ‘nanotechnology’ funding that we give out is focused on water issues” as an activity that was no longer aligned with the initial goal of achieving the grand challenges of atom-by-atom control. We also coded statements from conference organizers like “we invite firms [to present at the conference] who have
activities at the nano-scale” as evidence of a shift away from the goal of the grand challenge. Nearly all biotechnology, chemistry and materials science at the time would fall under the rubric of having “some aspect [that] is below 100 nanometer”.

Step 2: Identifying two processes “generating common ends” and “means-end decoupling”. We compared and contrasted across the five communities to understand how field fragmentation developed. This led us to identify two processes: “generating common ends” and “means-end decoupling”. “Generating common ends” occurred when participants indicated that the founding communities were focused on common overall goal for the field like “we and the government both wanted to see nanotechnology develop”. In contrast, “means-end decoupling” statements were focused on how to manage the day-to-day activities associated with the field, even though these might not be aligned with the field’s original grand challenge. For example, a statement like “most of our time is spent making decisions about who to fund based on who carries out the best science” was coded as evidence of means-end decoupling.

Step 3: Identifying the mechanisms that contributed to generating common ends. In the next step of analysis, we examined the coded text associated with generating common ends. We identified two mechanisms: “crafting field goals” and “coordinating collectively” which contributed to generating common ends. We labeled participants’ actions as “crafting field goals” if community members made statements like “we were trying to develop a roadmap for nanotechnology”. We coded statements like “we invited people within many different backgrounds -- scientists, people from government and business people” as instances of “coordinating collectively”.

Step 4: Identifying the mechanisms that contributed to means-end decoupling. In the next step of data coding, we examined statements related to means-end decoupling to tease out the mechanisms that contributed to this process. We identified three mechanisms that constituted means-ends decoupling: “translating goals into action”, “coordinating locally” and “neglecting field goals”. If the participants or passages in the archival data discussed how they
collaborated with other communities, we coded them as instantiations of “translating goals into action”. We labeled the coded text as “coordinating locally” if the data described coordinating with one or two communities only. Lastly, we recognized a lack of evidence – that participants during this second phase neglected to maintain the original goal of the field. We coded statements in which participants describe the lack of coordination around the initial goals of the grand challenge as “neglecting field goals”.

**Step 5: Identifying the conditions that triggered the process from field consensus to fragmentation.** In the final step of data analysis, we revisited the data to identify the underlying conditions that set the means-ends decoupling process in motion, triggering the transition from consensus to fragmentation. In comparing and contrasting the two field processes we identified three conditions that fostered means-end decoupling: 1) Introduction of new resources; 2) the need to integrate with existing institutionalized practices; and 3) increased diversity of field participants.

**FROM FIELD CONSENSUS TO FRAGMENTATION: MEANS-END DECOUPLING WITHIN THE NANOTECHNOLOGY FIELD (1986-2005)**

We explain how the nanotechnology field transitioned from consensus on field goals, to a fragmented field where a growing number of communities shifted to focus on local action. A field becomes fragmented when there are many constituents who lack agreement on common goals and the means to reach them. During an initial period of field consensus, from around 1986 until the announcement of the National Nanotechnology Initiative (NNI) in 2000, three different communities became involved with the nanotechnology field and oriented around the common goal of making progress on creating new techniques to control matter at the atomic and molecular level. After the initiation of the National Nanotechnology Initiative, in 2001, until 2005, two more communities entered the field. With five communities participating in the development of the field, communities began to diverge with regards to both their goals for the field as well as the means to reach those goals.
We argue that the transition from field level consensus to fragmentation can be explained through the process of means-end decoupling. Although this construct is discussed in the literature (Bromley & Powell, 2012), the drivers that underlie means-end decoupling are not well understood. Our research identifies the specific mechanisms and processes by which means-end decoupling takes place at the field level.


During the 1980s and 1990s, three different communities became involved in nanotechnology – each with their own set of interests: Futurists, government officials and service providers, but they all coordinated on common field goals. Figure 2 shows how communities’ interest in the field evolved between 1986 and 2000 by indicating the degree to which articles on nanotechnology appeared within each community.

The futurist community was the first and only community crafting goals for the nanotechnology field in the 1980s. During the late 1990s, government officials and service providers became interested in nanotechnology as well and all three communities began to orient around a grand challenge for the field of nanotechnology: Advancing atom-by-atom controlled manipulation at the nano-scale. This was a broad but ambitious goal that could transform production of all material things. We identified two mechanisms that fostered the generation of common ends at this time: 1) crafting field goals and 2) coordinating collectively. Table 3 presents additional examples of these two mechanisms.
Crafting Field Goals

The first mechanism that fostered field consensus on the grand challenge for nanotechnology was the creation of common goals for the field despite different communities’ divergent interests. The emergence of the nanotechnology field in the 1980s and 1990s was characterized by the gradual involvement of new communities. While the futurists initiated the field and were focused on developing nanotechnology for the sake of nanotechnology, government officials and service providers became interested in the field when they realized that the growth of nanotechnology could be complementary to their existing goals. Government officials were interested in enhancing investments to advance science and technology and saw how they could benefit from the field’s emergence. Service providers were interested in creating a new market for professional services in nanotechnology and wanted to legitimize the market. Thus, these three communities crafted field goals, working to align their respective community goals with the goals of the field to create a common vision they could rally behind. We explain how each community converged on goals for the field in the order in which they engaged with the field.

The futurists. The idea of creating a new organizational field around nanotechnology emerged in the 1980s and was the brainchild of futurist Eric Drexler. He popularized his vision of nanotechnology in his 1986 book *The Engines of Creation: The Coming Era of Nanotechnology*, which we take as the beginning of field formation. This book speculated that the future of technology would be bottom-up molecular manufacturing, where goods like calculators and computers would be produced by precisely assembling individual atoms into desired structures. Drexler envisioned the creation of desktop manufacturing systems using only a raw material like crude oil that would build things on demand atom-by-atom, and nano-robots that would flow around the bloodstream and remove plaque. The futurist community wanted to develop a field that would aid humanity and prevent any negative consequences that
could arise from nanotechnology. In the first issue of the *Foresight Update*, the futurists discussed their goals for the emerging nanotechnology field:

If we face great challenges as a civilization, shouldn't we organize in some way to meet them? In the coming months and years, the approach of nanotechnology and artificial intelligence will raise a host of issues, with technical, economic, political, and ethical dimensions. We will need networks of informed individuals and forums for discussion. We will need organizations able to influence public policy, including international policy. How to proceed is less obvious. Organizations can take many forms, and our experience in other broad, technology-oriented organizations suggested many pitfalls. (*Foresight Update*, 15 June 2012: 1)

The community of futurists was clear in their desire to influence public policy and set out to ensure that other communities in the field shared this vision. However, they were less certain about the means to achieve those goals. One of the main activities futurists engaged in was mobilizing other communities around the goal of developing a technological field focused on nano-robots and desktop manufacturing systems. This vision resonated with both government officials and service providers.

**Governed officials.** In the early 1990s, government officials with the U.S. President’s Council of Advisors on Science and Technology (PCAST) were looking to convince Congress to increase funding for science and engineering to enhance US competitiveness in science based industries. When they heard the futurists’ vision of a nanotechnology field, they saw an opportunity to generate support in Congress for increases in science funding. The futurists’ ideas about nanotechnology were compatible with politicians’ desire to appear as leaders and builders of the next scientific revolution. A government white paper on nanotechnology highlights some of the questions under consideration at this time:

What if we could build things the way nature does – atom by atom and molecule by molecule?...Cover an airplane with paint containing nanoscale pigment particles that instantly reconfigure, chameleon-like, to mimic the aircraft’s surroundings...How about bricks and other building materials that can sense weather conditions and then respond by altering their inner structures to be more or less permeable to air and humidity?... And how about synthetic anti-body-like nano-scale drugs or devices that might seek out and destroy malignant cells wherever they might be in the body? (IWEG, 1999: 2).
Congressional aid, Eric Warming, explained how the congressman he worked for, Brad Balling, became a point person for nanotechnology within the US government:

…Part of my responsibility was to come up with areas where Brad could try to take the lead - things that he could do. So that’s where I identified nanotechnology as something for him to do – a place for him to go

The goals of government officials aligned well with the futurists’ goals of securing funding to advance general scientific and technological progress and further the nation’s intellectual leadership. A member of PCAST, Tom Kalil, elaborated on his reason to push nanotechnology as part of the government’s agenda:

I was very interested in increasing support for the physical sciences and engineering and ensuring U.S. leadership in an emerging technology in which global leadership was up for grabs......... I thought the initiative model had been one way in which I’d been successful in getting high-level support, interest and visibility for a particular area of research. I was confident enough that nanoscale science was such a broad area that it was appropriate for the government to emphasize that in its investment strategy. (Small Time Magazine, March 4th, 2005)

From Tom’s perspective, one of the government’s major roles was to ensure the nation’s long-term competitiveness and he, among others, thought could happen by increasing funding for science and engineering. He saw nanotechnology as an opportunity to create a new government initiative that could generate more funding for science and technology in general. Thus, there was clear alignment on the goals for the nanotechnology field between the community of futurists and the community of government officials.

Service providers. Service providers are professionals (e.g. lawyers, venture capitalists, and journalists) aiming to provide services and increase information about the field of nanotechnology. Service providers saw opportunities to join and stimulate the growth of the nanotechnology field to capitalize on this emerging market by starting conference organizations and trade magazines. Louise Hansen, the CEO, of the trade magazine NanoNews, described the role she envisioned for NanoNews when the field was in its infancy:
We were established to provide a community voice to an industry segment that had no community at the time, or business community. And so the idea was to really give some coherence to the discussion, and develop a dialogue or a place where people could really see how these emerging technologies are making an impact and so our role wasn't just to be an observer of it, but to really develop a community that recognized the commercial importance of the technologies. And I think when we first started, a lot of our role was to make people aware that the technologies had commercial potentials.

At this time, the goal of *NanoNews* was aligned with the goals of both the futurist and the community of government officials as they all aimed to build a common field to advance the capability to “shape the world atom by atom”. At this time, these field goals could be pursued in tandem without conflicting with the goals each community had for their members.

Service providers, like venture capitalists, were excited about developing a nanotechnology field and lobbied the government in the hope of increasing the government’s involvement in the field. Venture capitalists thought a government initiative could help them fund the commercialization process from discovery to product creation and ignite a new commercial space. Chick Vennum, a high-ranking official from UniTech (a top research university) and prior member of PCAST, described the role of the venture capitalist community at this time:

…If we look at UniTech, I can think of a few venture capitalists who were very excited very early on about this area and even talked it up and were around here probing for ideas. I particularly had in my mind, Carl Henning, from New York, who now is totally specialized in this area.

Service providers like patent lawyers were also excited about the prospect of a new field, which could help create a new lucrative area of patent-litigation.

[Nanotechnology] is now and will continue to be a very lucrative area for patent lawyers. Right now we're doing some of the basic technology transfer from universities and the startups and writing some of the early patent applications but it won’t be long before there’s a lot of litigation in nanotechnology, which is an area where I'm very interested in trying to litigate some of these patents. ……[……]…….I'm looking at the long term - if I get in early, I understand the field and I get my name known and the firm’s name known then when
somebody’s looking for a patent firm to handle their litigation we’ll have been around for a long time and be sort of the household name in nanotechnology. One of many, obviously, we're not the only firm getting involved. We're one of the few firms in Los Angeles and even in California that’s spearheading nanotechnology at this point. So getting in early is good.

To facilitate the development of the field and increase their knowledge of nanotechnology, many patent lawyers attended early nanotechnology conferences and meetings where they took part in discussing the goals of the field with both the communities of futurists and government officials. The community of service providers were interested in creating a market for nanotechnology expertise and thus their goals were aligned with the other two communities to create a common field that could attract both government and venture capital funding and further scientific as well as commercial growth of nanotechnology applications.

**Scientists.** The futurists had made early attempts to involve scientists within the nanotechnology field as they thought the scientific community ought to be the most interested in seeing the nanotechnology field develop. They recognized that scientific expertise was needed to actually make progress on their grand vision. Indeed, Eric Drexler, saw himself primarily as a scientist, and thus knew that the involvement of other scientists was necessary for the field of nanotechnology to mature. However, the futurists were largely unsuccessful in this endeavor, as the logic of science espoused by most scientists was not well aligned with the goals of the nanotechnology field at this time (see also Kaplan & Radin, 2011). To most scientists, the goals of the nanotechnology field sounded like science fiction and were far removed from serious scientific endeavors. One scientist, Matt Klinger, explained this position.

Most people think [Drexler] is kind of crazy….I think scientists generally have a negative view [of the futurists]… [Scientists] have a very rigid view of the way things should be done, and [Drexler] doesn't do it that way. Scientists are very, very critical people. Criticizing people is kind of what scientist do. He [Drexler] is an easy target. He gets a lot of criticisms geared toward him. I have to say, I have heard ranting and raving over how it's basically criminal for us not to freeze people just before they die, because surely, with nanotechnology, we would be able to thaw out a frozen body and repair whatever it was thought to have died from, and it's basically murder not to freeze someone who is about to die. To hear something that extreme, it does make you think, “Wow, this guy really is off the deep end”.
Entrepreneurs. Entrepreneurs, were more interested in the nano grand challenge than the scientific community, but were still skeptical about the short-term commercial application of these ideas. The entrepreneurial community was focused on near-term economic gain and the visions promoted by the other three communities at this time seemed a long time into the future. In particular, entrepreneurs thought that the futurist’s ideas were at odds with a quick technological development. Below is a quote from Carl Wanger, who expresses a view of the futurists commonly held in the entrepreneurial community:

[The futurists] are probably good at writing novels. Maybe they should just worry about their science fiction novels. I don't get those guys. … They have such a bizarre thinking.

Thus, few scientists or entrepreneurs participated in crafting field goals during the 1980s and 1990s. While the futurists tried to involve these two communities, most scientists and entrepreneurs considered the grand challenge of achieving atom-by-atom control over matter too far into the future to warrant their involvement. However, both the government and service providers were on board with the futurists. An interagency governmental working group reported that:

The emerging fields of nanoscience and nanoengineering are leading to unprecedented understanding and control over the fundamental building blocks of all physical things. This is likely to change the way almost everything—from vaccines to computers to automobiles tires to objects not yet imagined is designed and made. (IWGN, 1999: 1)

For the scientists, bold language such as this conflicted with values of scientific purity and peer review (Gieryn, 1983), where statements needed to be justified by drawing on existing scientific knowledge. There was no clear scientific path to explain how these grand challenges could be achieved. Scientists and entrepreneurs therefore explicitly rejected the goals espoused by futurists, government officials and service providers and were only peripherally engaged in creating the goals associated with nanotechnology during the field’s early stages.
Coordinating Collectively

An additional mechanism that fostered field level consensus on the grand challenge for nanotechnology was the communities’ willingness to coordinate collectively on common field goals. During the 1980s and 1990s, the futurists, government officials and service provider communities all coordinated collectively with each other by interacting directly with each other to craft field level goals. Collective coordination was achieved through nanotechnology specific conferences that included all three communities. The futurist community organized an annual conference where representatives from all three communities were invited to participate.

From the late 1980s until year 2000, the Foresight conference was the convening place where people met to discuss the goals of the nanotechnology field. The first Foresight conference, held in 1989, was a field-configuring event (see Garud, 2008), where community members collectively negotiated the goals of the field. At this conference, field participants collectively defined nanotechnology as the “thorough control of the structure of matter” and set the goal for the field as “understanding and building structures, devices, and systems on the scale of molecules” (Foresight Update 7, 1989: 1). The Foresight conference was the one gathering place for everyone interested in nanotechnology, as there was no other place for people interested in nanotechnology to congregate. As one of the early futurists, Catherine Patti explains:

People were talking about it [nanotechnology] mainly starting in our conferences starting in 1989. That was the place that you came to talk about these things. There were not really anywhere else to go. There were not any other nanotechnology conference until after the year 2000. I think that the other conference series started in the year 2001 and 2002. But prior to that there were not anywhere else to go other than our conferences to talk about nanotechnology. There were nowhere else.

Only a few entrepreneurs and scientists were present at the 1989 conference (or earlier) as these two communities were focused on their current goals of advancing the products and the science
relevant in the here and now: they both viewed the nanotechnology field as too future oriented and thus less relevant to them.

Collective coordination also happened through the futurists’ newsletter, *The Foresight Update*, which was the primary forum where the three communities debated the state of the field. The newsletter helped coordinate activities and showed new participants how to become involved. For example, an editorial in the 1987 *Foresight Update* stated:

Many of the letters we've received ask "How can I help?" Enabling many people to cooperate in preparing for future technologies is the purpose of our Institute. At this early stage the question of how to help breaks into two parts: (1) How can I help FI [The Foresight Institute] get rolling? and (2) What role can I play once the startup stage is over and the organization is in action?

After the government community became involved in the field, they became conveners, organizing meetings that invited all of the communities. However, these hearings were dominated by the futurists, government officials, and service providers. From the early 1980s to the year 2000, three communities: futurists, government officials and service providers generated common ends on the lofty but ambiguous grand challenge of “shaping the world atom by atom”. Although each community had very different interests, they still managed to organize around common field goals and coordinate collectively in the same forums.

**MEANS-END DECOUPLING (2001-2005)**

We identified three distinct triggers that set the means-ends decoupling process in motion. First, there was the introduction of new resources through the allocation of funds to the National Nanotechnology Initiative - a government initiative tasked with funneling hundreds of millions of dollars into nanotechnology research. Second, to make progress on the means to achieve the grand challenge, field founders needed to figure out how to integrate the field’s goal with existing practices in highly institutionalized environments like academic science. For example, government officials realized that to attract scientists and entrepreneurs to the field,
they needed to craft funding proposals in ways that were consistent with scientists existing language and work practices. Third, the allocation of new resources to the field attracted more diverse participants who had not been part of collective coordination on field goals.

Both scientists and entrepreneurs became engaged in the field when their goals of obtaining funding to run their labs, students and employees began to align with the goals of government and service providers to fund science at the nano-scale. However, these two new communities did not necessarily share the prior overall goal shared by field founders. As one scientist, Sam Weiwei, explained:

It's kind of like rock music. You know, some artists came out, it was an album, and it's just kind of spread like wildfire. I think that initiative [NNI] had that effect. Some people reluctantly others more willingly. John [my colleague] jumped onto the bandwagon. In my case it's completely neutral. I don't care as long as the work is interesting it doesn't matter [what field you are in].

When the three founding communities shifted from crafting the grand challenge to the actual means of achieving this goal, they needed the engagement of scientists doing real science in this area and of entrepreneurs taking on the actual risk of commercial development. However, the goals of these two communities were not the ones espoused by the three founding communities. This chasm between means and goals widened through a process of means-ends decoupling which helped fragment the field and distance most communities from the field’s founding goals. We found that the process of means-end decoupling depended on three mechanisms: 1) translating goals into action, 2) coordinating locally, and 3) neglecting field level goals. Table 4 provides additional data on each mechanism.

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Translating Goals into Action

The first mechanism, which contributed to means-end decoupling, was the shift among all communities from crafting common field goals to coordinating around the means or
activities necessary to actually make scientific and technological progress in nanotechnology. After Congress passed the NNI, government officials in each federal agency had to figure out which proposals to fund. At this time, few scientific projects were close to building desktop manufacturing systems or robots made with atom-by-atom precision. Thus, government agencies allocated funds to research projects at the nano-scale with immediate goals that were more readily accomplishable and more likely to be appreciated by mainstream scientists than the goals articulated by the three founding communities.

Venture capitalists were excited about the grand goals for nanotechnology as laid out by the futurists, but when it came to allocating their investments, they sought growth companies that would yield a reasonable return within a short time span. Thus, they adopted their funding patterns to more immediate goals, much like government officials. For example, William Peterson, a prominent venture capitalist described how he had initially been taken with the vision of nanotechnology presented by the futurists:

This was back in 1997 or 1998 - this was before nanotechnology was this big thing. All of these people were taking about Drexler’s idea of building things atom-by-atom so …we started discussing it here [at the VC firm], and one of the things that was apparent is that once you move matter from the analog domain to the digital domain then you can actually start manipulating it in a fashion that we are used to.

It was the grand challenge of creating robotic systems atom-by-atom that initially captivated venture capitalists and led them to participate in the nanotechnology field, but they focused on funding applications far removed from this original vision. William Peterson continued explaining how his venture capital firm ended up investing during the first couple of years of the new millennium:

So, we should start looking at it [nanotechnology]. And then it begs the question what do we invest in? Because we are not going to invest in Eric Drexler's little machines and little subversibles. We are going to invest in something that fits our investment framework. So, what we set out to do is look for businesses that would get to revenue within one to two-years and then get to profitability within three to four-years and then have some kind of exit that we could get to maybe within four to six-years and that fits within our criteria. The place that we saw
opportunity was in tools for nanotechnology, so the picks and the shovels that
will build the groundwork for all of this, and also very rudimentary components,
very very simple things….. But for the most part the stuff that we’ve looked at
investing in are some [nano] materials, some firms that use carbon nano-tubes or
[nano] powders or whatever. Both process tools for making nanotech stuff and
metrology tools for measuring were key.

While venture capitalists were fascinated by the field’s grand founding goals, the
means that they employed to achieve the vision had to fall within their existing mode of doing
business, where returns on investment accrued within a limited time frame. The futurists
disagreed with both the venture capitalists and government officials about the means for
achieving the nanotechnology vision. Instead of funneling monies into existing research, the
futurists wanted the government to spend money on “proof of concept” of molecular
manufacturing – that is documenting that creating technologies atom-by-atom was possible.
Originally, the NNI included funds earmarked for this specific purpose. However, during the
legislative process, these provisions were removed from the legislation - an action that
infuriated the futurists. One prominent futurist marveled at how this was possible:

In this latest bill on nanotechnology that was passed in December of ’03 we had
gotten a National Academy of Sciences study of molecular manufacturing, and
we were very pleased about that. It was all fine it was in there. But the problem
is that at the very last second, very, very soon before the vote - in the last minute
it was changed and nearly nobody in the whole process knew about it. It
changed from molecular manufacturing to molecular self-assembly ….which is
a meaningless term, because it is already done all the time.

As government officials began making funding decisions, service providers began
creating investment funds and organizing their own nanotechnology conferences independent
of the futurists. These convening events started to draw scientists and entrepreneurs into the
nanotechnology field, but they were not asked to agree with the founders’ overall vision of the
nanotechnology field. Rather, both the scientific and entrepreneurial communities began
presenting their current research at nanotechnology conferences and networking events that
were not hosted by the futurists. While both scientists and entrepreneurs remained wary of the
overall goal of the nanotechnology field, participating in these new conferences provided
visibility and connections to stakeholders as well as resources that they would otherwise not have access too.

**Coordinating Locally**

The second mechanism, which facilitated means-ends decoupling, was a shift from the founding communities collectively coordinating in common forums to select communities engaging in local coordination. Rather than all three communities working together directly with each other to determine common goals, actions to pursue field goals became negotiated and integrated within just one or two communities at a time. For example, venture capitalists would find entrepreneurial firms to invest in that suited their vision without adhering to the overall goals of the field. However, they still claimed that they invested in “nanotechnology”. Likewise, federal government agencies like the National Institute of Health (NIH), the National Science Foundation (NSF), the Environmental Protection Agency (EPA) and the Defense Advance Research Project Agency (DARPA) allocated funds to the scientific community under the goal of promoting nanotechnology. However, the funders within these agencies were primarily focused on funding the best science whether or not those proposals were aligned with the field goals for nanotechnology or not. One EPA official, Dr. Balunski, explained how her department chose which proposals to fund:

> We choose the best science - that's really what's happening. We choose the quality research projects and, of course, we can't fund them all. We are sitting on 157 right now that maybe about 30% passes peer-review so that means we will probably get about 50 out of there, and we can probably fund about half of those. Remember what we are looking at are the implications, so we are not really looking at nanotechnology. We're really looking at the implications of nano materials - specifically manufacturing nano materials—not something that's just done in the research lab; it's something that people or the environment could come in contact with.

Dr. Balunski’s strategy for allocating funds to the scientific community was not to follow the exact guidelines of what was defined as “nanotechnology”. Her main concern was
to fund the best science as defined by the existing peer review process grounded in the current standards of what constituted quality science. That is, who got funded was negotiated locally between government officials and the scientists participating in the peer review process. Of the proposals funded, some might support the goals for nanotechnology agreed upon previously and others might not. The EPA’s main concern was ensuring the safety of people and the environment, not whether the proposals funded aligned with the vision of nanotechnology as agreed upon by the three founding communities. This meant that most of the proposals funded with monies from the National Nanotechnology Initiative were not allocated to research projects aligned with the field’s prior vision to produce desktop manufacturing systems or nanobots, but rather to research projects investigating more mundane and near-term scientific questions like how nano-materials interact with water.

The shift to local action between select communities fostered decoupling between the goals originally espoused for the field and the actual activities participants later carried out. This disconnect was possible because even though the three founding communities were initially aligned on their goals for the field, they were not necessarily aligned with regards to the means to carry them out. The process of means-ends decoupling initiated as each community began to diverge on the best course of action to accomplish espoused field goals.

**Neglecting Field Goals**

The third mechanism contributing to means-ends decoupling was goals neglect – where communities stopped attending to the field goals once agreed upon to the neglect of the field’s grand founding goals. Empirically, identifying patterns of actions that do not take place is more difficult than identifying actions that take place. However, we found evidence that the lack of goal maintenance contributed to goal neglect. Using a sports metaphor government official, Phil Bond, for example suggested that actually advancing science was “more important” than crafting a common goal:
Deciding upon a goal for nanotechnology will be “helpful” said Under Secretary of Commerce for Technology Phil Bond. But in the end, he said, its more important for the nanotechnology industry to ‘do our blocking and tackling’ (July 9, 2003, Solid State Technology)

While early in the field, communities spent considerable effort building consensus around field goals, this activity received less attention once communities began focusing on means and pursuing local action. The lack of attention to field goals meant that the goals the different communities associated with nanotechnology began to drift toward each community’s more immediate goals. Four out of five communities’ goals for the field of nanotechnology drifted from the field’s founding goals between 1986 and 2005 towards more immediate goals. The only community to remain steadfast to the grand vision previously articulated for nanotechnology was the futurists.

While the futurists still saw the goal of the nanotechnology field as the creation of atom-by-atom control to build microscopic assembler robots, this was no longer true for government and service provider communities. Most government officials were content as long as monies were furthering scientific research on nanotechnology materials and tools. Service providers were content as long as there was demand for their services. One futurist, Sam Mallort, complained about how the other communities no longer wanted to engage in discussions about the overall goal of nanotechnology:

[We don’t have the same goals now]. A very simple example. If you're a group that openly talks about the potential downsides of nanotechnology and how we need to really address them – like, for instance, we bring out the Foresight Guidelines, which are in their fourth revision. Some people say, "Oh, well, we don’t want to scare these poor little legislators so let's not [show them this]. We don't want them to think about this. We want them only to think about allocating money that I can go get a grant for. Let's have them think about that so let's just not discuss any of this scary stuff, let's discuss how many billions are going to be allocated so my buddies can get grants that say 'nano' on them.

What Sam explains is that, whereas early in the field’s formation, the three founding communities crafted consensus on the overall goals for nanotechnology, these same
communities were no longer in agreement. While the futurists clung to the field’s founding goals, the government and service provider communities broadened their goals to accommodate the goals of scientists and entrepreneurs. These two founding communities became reluctant to discuss field goals for nanotechnology out of concern that it would disrupt the current focus on scientific and entrepreneurial activities – where progress on near term activities was actually being made. Figure 3 shows the field’s shift from a focus on the grand goal towards more immediate goals.

Field Fragmentation

We consider a field to be fragmented when there are many constituents who lack agreement on common goals and on the means to reach them. Table 7a provides evidence of fragmentation within the nanotechnology field across the five communities with regards to the goals of the field and Table 7b shows fragmentation across the five communities with regards to the means.

By 2005, of the ten possible pairwise relationships among the five communities with regards to their goals for the nanotechnology field, six were misaligned, two mixed, and only two aligned. Even though their goals had shifted, the government’s goals still aligned with the service providers and the service providers’ goals now aligned with entrepreneurs in growing a commercialized version of nanotechnology. Entrepreneurs were only partially aligned with the government. When examining the ten possible pairwise relationships with regards to the means of the five communities, four were misaligned, two mixed, and four aligned. The government’s means aligned with service providers and scientists; while the service providers means aligned
with entrepreneurs. Of note, the founders of the field and initial articulators of the grand vision, the futurists, were not aligned on the means pursued by any other community. While there was initially consensus on common ends in the early stages of field formation, the field had fragmented by the end of 2005. Our analysis indicates that the process of means-ends decoupling was responsible for this shift.

**From Consensus to Fragmentation – Means-end Decoupling within Organizational Fields**

This paper offers one explanation of why grand challenges have difficulty achieving their stated goals by unpacking the process through which initial consensus on field goals becomes disrupted and fragmented once a field converges on a common grand challenge. The theoretical model in Figure 4 depicts a generalizable model for how the process of means-ends decoupling unfolds.

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Insert Figure 4 about here
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Initially communities engage in the process of generating common ends to help field participants realize the interests they hold in common early in the field’s formation. Two mechanisms support this process: crafting goals for the field as a whole and coordinating collectively with all founding communities in the same venues at the same time. These two mechanisms help produce general consensus on the goals of the field, but this consensus does not necessarily endure.

Three triggers help set the process of means-ends decoupling in motion. First, the introduction of new resources devoted to a field’s grand challenge marks a point of transition in a field’s evolution, because, with money in hand, the field’s participants begin to consider how to use those funds to achieve the field’s goal. Second, translating grand goals into actions requires integrating these goals with existing institutionalized practices. In our case, this occurred within scientific and entrepreneurial communities where new advances can actually
take shape. The need to coordinate within existing institutionalized work contexts hinders focus on the field’s goal as these work contexts are set up to achieve more immediate goals rather than the field’s grand challenge. Third, the introduction of new resources attracts more participants to join the field, expanding the diversity of participants in the field. In our case, the founding communities courted new participants who had the necessary skills to progress science and technology to achieve the grand challenge but this also introduced new interests within the field and made consensus more difficult to achieve.

As shown in Figure 4, the process of means-ends decoupling depends on the presence of three mechanisms that reinforce each other. The first is translating goals into action, where community members shift from a focus on goals to a focus on means. After the initial goals of the field are formed, communities begin to work on how to translate these goals into action and, to do so goals may shift away from the field goals originally articulated. This shift is likely to be towards more immediate rather than grand goals.

Second, communities begin coordinating locally with select members of the field rather than collectively with all constituents of the field together at the same time. Thus, the process of translating goals to action proceeds without the robust dialogue characterizing the field’s earlier formation. Communities begin to pursue local actions embedded in established and localized practice which helps lure their attention away from the field’s grand vision articulated earlier.

Third, when all communities become more preoccupied with local means rather than with collective ends, they begin to neglect field goals to the detriment of progress toward the field’s grand challenge. These three mechanisms reinforce each other to produce a process where gradually the means become the focus, rather than the ends. As field participants shift their attention and their goals, their alignment among the goals and the means to achieve those goals begins to fracture. Thus, the process of means-ends decoupling not only draws field participants’ attention away from the field’s grand challenge, it also introduces new sources of misalignment in the field creating field complexity.
DISCUSSION

Our research began by examining why grand challenges fall short of their stated goals. This is not just a practical problem, but a question with consequences for policy and theory that institutional theorists can help answer. While institutional theorists have examined how early communities reach consensus on an emerging field’s goals (e.g. Maguire, Hardy & Lawrence, 2004; Mair & Hehenberger, 2014), less attention has been paid to understanding what happens when communities transition from the rhetoric of crafting goals to engaging in the activities that will accomplish these goals. This is problematic, because if we want to understand how to make progress on grand challenges, we not only need to understand how goals are set, but how real progress towards these grand challenges are made.

Lessons from the Kyoto protocol in 1997 teach us that consensus on a field goal (like binding emissions targets) is not enough to constitute progress toward a grand challenge. Grand challenges require lengthy periods of time for progress to happen and thus, we need to understand how a field’s goals evolve as fields mature. Mature fields display a high degree of heterogeneity and fragmentation (Greenwood et al., 2011), which can inhibit progress on grand challenges. However, little research explains how this happens. Bromley and Powell (2012) explain what means-ends decoupling is and how it can undermine the good intentions of organizations, but little research has examined the mechanisms behind this process at the field level. Without understanding what stands in the way of grand challenges, scholars and policy makers are helpless to eradicate barriers to progress.

Our research uncovers the mechanisms behind the process of means-end decoupling and shows how initial consensus on common goals became fragmented over time to the neglect of the grand challenge. In doing so, this paper makes several contributions. First, we contribute a theoretical explanation of why grand challenges are difficult to achieve. Second, we add to theories of field emergence by explaining how the initial consensus that establishes a new field
becomes fragmented through the process of means-end decoupling. Third, we identify the mechanisms that facilitate means-end decoupling as well as the triggers that set the process in motion. Lastly, our findings reveal endogenous sources of institutional complexity.

**Making Headway on Grand Challenges: How Do Organizational Fields Evolve from Consensus to Fragmentation?**

Grand challenges involve making progress on some of the world's most pressing problems like combating global warming (Howard-Grenville et al., 2014), addressing world poverty (Kates & Dasgupta, 2007), or developing cures for deadly diseases (Daar et al., 2007). Advancing these grand challenges, by definition, necessitates inventing new to the world solutions or technologies (Churchman, 1967; Rittel & Webber, 1973), which benefit from the contributions of diverse participants. Management scholars have made little leeway in applying organizational theory to explain why grand challenges are difficult to achieve. This paper takes a step in this direction.

The existing literature on field emergence can explain how field founders create consensus on the meaning and goals of nascent fields (Lawrence & Phillips, 2004; Lounsbury et al., 2003; Weber et al., 2008; Wry et al., 2011). However, this literature says less about what happens after consensus has formed. Fields change and as they evolve, so do their participants, goals and the means to achieve those goals. For example, Wry et al. (2011) theorize about the process through which initial field participants mobilize and the strategies they use to increase participation within the field without inducing too much heterogeneity. However, this theory assumes that a field’s founding communities can control who joins the field. Few fields are bounded and can be orchestrated in that manner. Second, this theory does not take into account the ways in which the dynamics of the field might change once consensus has been reached on field goals. As fields grow, their members are likely to become more diverse and with this
growth in constituents, their goals and means broaden in turn. What affects a field’s ability to sustain consensus on a grand challenge or vision over time?

This paper refines this literature by highlighting the dynamics, which take place after a field’s grand challenges or goals have formed and participants shift to focus on the actual activities aimed at advancing the field. As this happens, grand goals transform and become more immediate goals that can only take shape within existing institutional structures. What our research suggests is that grand goals are difficult to shoehorn into existing work practices. For ideas to become embedded in local understandings, they must be adapted to the specific context (Bechky, 2003). While translation is necessary for local coordination to occur (Carlile, 2004), if all field participants are allowed to accomplish their own local translations, then without collective coordination, it is easy to see how the goals of the field can drift. When people work on breakthrough innovations, differing interpretations of a single grand idea can persist, and without active coordination of the ultimate goal, the end result can drift or become incoherent (Seidel & O’Mahony, 2014).

Our research provides an eagle eye but comprehensive view of how the interactions of a variety of constituents founding a field shape its evolution. Most studies of field emergence have focused on only one or two types of participants (Lawrence & Phillips, 2004; Maguire et al., 2004; Weber et al., 2008). These studies have not investigated how coordination is achieved among multiple communities that retain divergent interests. Yet, most fields are composed of many disparate types of contributors and in fact, this is a key condition for creating a locus of innovation (Powell, Koput & Smith-Doerr, 1996), which is necessary for progress to be made on a grand challenge. By examining the shifting participation of multiple communities at the same time, we show how initial differences are overcome to support collaboration (e.g. Bechky & O’Mahony, 2008) as well as what subjugates these relationships to fracture. While new communities with new skills are necessary for a field to continue to grow, their inclusion can change the course of the field’s evolution. The inclusion of divergent interests can successfully
broaden the boundaries of a field (e.g. Jones et al., 2012) or fragment the field and foster its collapse. Our research identifies some of the conditions that may trigger the latter – which should be of interest to policymakers and organizational theorists alike.

**Means-End Decoupling within Emerging Fields**

Classic theories of decoupling have viewed decoupling as the loosening of the connective tissues that binds the formal and informal aspects of the organization (March, 1962; Tilcsik, 2010). If this was the case, in our study, field communities might have claimed to support nanotechnology, but yet not take any steps in that direction. However, an alternative form of decoupling can happen when organizations loose sight of their goals and become enamored with the means once associated with those goals (Bromley & Powell, 2012). When means-ends decoupling happens, the means become a focus of attention, even though there is “scant evidence…to show that these activities are linked to organizational effectiveness or outcomes” (Bromley and Powell, 2012:14). This form of decoupling has received less attention, but is no less pernicious in its effect. Bromley and Powell outline some of the symptoms of means-ends decoupling, but not the mechanisms that underlie it. Our research identifies both the mechanisms that foster consensus as well as the mechanisms that fracture it.

Another important debate in the literature on decoupling is the extent to which institutional pressures derive from within organizational systems or are imposed from the outside. Meyer and Rowan (1977) proposed that decoupling happens as organizations conform to rationalization pressures in the environment. Our research suggests an endogenous explanation where communities’ interests and how they navigate conflicting institutional demands are gradually disposed towards means-end decoupling. This paper examines an endogenous process in which decoupling occurs not because of the relationship between a firm and its external environment, but rather from localized and distributed demands within the field itself. While much of the existing research on decoupling has focused on how organizations
signal compliance without changing their underlying practices (Tilcsik, 2010), more recent literature has investigated how organizations might not change their symbols, but alter their practices under the radar (Hsu & Grodal, 2015; Snellman, 2013).

We must consider the extent to which decoupling was detrimental or beneficial to achieving the field’s grand challenge. Weick (1976), one of the first scholars to theorize about decoupling within organizations, put forward the notion that loose coupling was possibly beneficial for organizations, because it enabled grand ideas, which lacked specificity, to be implemented within existing complex work practices. Weick’s (1984) view was that some degree of decoupling was inevitable and perhaps even necessary for progress on abstract ideas to be made. His theory of ‘small wins’ accepted the idea that the translation from grand ideas to immediate goals could be helpful in enabling progress to occur. Weick understood that what makes grand challenges difficult is the problem of where to initiate solutioning and his theory of small wins advocates decomposing larger problems into small ones, that are more easily accomplished. This may be why means-ends decoupling is most likely to be prevalent when the effects of collective action are ambiguous or difficult to measure (Bromley & Powell, 2012: 26-27). With respect and consideration for Weick, our research suggests that while means-ends decoupling may have facilitated coordination among new participants to the field in the near term, over the period of observation, means-ends decoupling became detrimental to accomplishing the grand goal the field of nanotechnology set out to achieve.

The Creation of Heterogeneity and Complexity within Fields

Finally, our research helps explain how heterogeneity and complexity can arise within organizational fields. Scholars have studied institutional complexity after it has arisen (Battilana & Dorado, 2010; Kraatz & Block, 2008; Purdy & Gray, 2009; Smets et al., 2012) without understanding how the field became complex in the first place. The existing literature on institutional complexity has primarily emphasized the strategies firms use to manage
complexity (Battilana & Dorado, 2010; Jay, 2013; Pache & Santos, 2010). Our research shows that it is important for organizations to pay attention to the evolution of complexity within their institutional environment as it occurs. In contrast to the existing literature, we identify sources of complexity that occur endogenously rather than exogenously.

The introduction of new resources attracts diverse participants and the need to translate grand goals to immediate goals are some of the triggering conditions that can set means-end decoupling in motion and fragment the field. Future research would do well to examine how constituents to a field can preserve their common goal, as they translate goals into action and accommodate new members. The current literature on complexity tends to assume that the interests of participating members are given and unchanging over time (Besharov & Smith, 2014; Pache & Santos, 2010). However, our research suggests that community interests might evolve as the field changes. Future research might consider complexity as a dynamic construct which ebbs and flows as a function of a field’s community or constituent dynamics.

**Directions for Future Research**

This research takes an important step toward understanding why grand challenges are difficult to achieve by identifying means-end decoupling as the process, which can lead a field from initial consensus to fragmentation. Future research might dive deeper into examining the relationship between means-end decoupling and policy-practice decoupling. Are these separate phenomena or do they often work in unison and even might influence and stimulate each other? More work needs to be done to specify the boundary conditions which stimulate means-end decoupling and the actions which might be taken by field participants to avoid goal drift and keep the field on track. Future research might employ a comparative ethnographic or case study approach (e.g. Bechky & O’Mahony, forthcoming) on multiple fields focused on grand challenges to examine why some are more successful than others. It would be important to engage in theoretical sampling (see Eisenhardt, 1989) to include a robust sample of grand
challenges that vary in their nature of the challenge, resources and participants required, and time horizon for completion. Future research might also investigate how heterogeneity within communities, which was not addressed in this paper, affects collaboration across communities.

While we believe that our results are generalizable across a wide range of contexts, we identified a set of process triggers, which may make the evolution of means-end decoupling more likely. We would expect that fields where many resources are allocated; which need to integrate with existing institutionalized environments; and which involve multiple diverse participants are more likely to decouple their means from the goal of the grand challenge than fields lacking those conditions. Counter intuitively, it is possible that participants in pursuit of grand challenges, who avoid integrating with existing institutions may be more likely to succeed than participants that seek to “stand on the shoulders of giants”. But it is also possible, that these types of fields will also be less likely to gain the legitimacy required to acquire significant resources. In our research, we considered the community of government officials as an equal participant in an emerging field and explicated the role they played in introducing heterogeneity and creating field complexity. We would encourage institutional scholars to attend to the ongoing involvement of government officials in a field rather than just examine the effects of laws, statutes and programs on field participants.

Conclusively, this paper identifies why grand challenges are so hard to achieve by investigating how means-end decoupling shifts a field from consensus to fragmentation and hinders progress towards the fields original goal. We traced the evolution of five communities participation in an emerging field from its inception through its first two decades. At this point in time it is difficult to assess what type of progress on the nanotechnology grand challenge will ultimately be made, but future research should examine how fields focused on grand challenges change through their entire institutional life-cycle as the grand challenges they are working on will also no doubt evolve.
### TABLE 1
General Community Goals and Means

<table>
<thead>
<tr>
<th>General community goal</th>
<th>Futurists</th>
<th>Government officials</th>
<th>Service providers</th>
<th>Entrepreneurs</th>
<th>Scientists</th>
</tr>
</thead>
<tbody>
<tr>
<td>General community goal</td>
<td>Develop technological fields that aid humanity and saves them from the negative consequences of technology development.</td>
<td>Strengthen U.S. competitiveness through investments in science and technology.</td>
<td>Develop industry specific professional skills that can be sold as services at a high value.</td>
<td>Acquire capital and resources to create new markets with high growth potential.</td>
<td>Work within invisible colleges to generate new universal knowledge by subjecting scholarly work to academic peer review.</td>
</tr>
<tr>
<td>General community means</td>
<td>Organize conferences and write newsletters.</td>
<td>Generate government initiatives and fund scientific efforts.</td>
<td>Organize conference, publish trade magazines, provide consulting service and fund entrepreneurs.</td>
<td>Engage in product development activities.</td>
<td>Conduct scientific experiments.</td>
</tr>
<tr>
<td>Community’s interest in nanotechnology</td>
<td>“[Nanotechnology] is really going to happen at some point, and people deserve to know… And what we can do today is look at longer term issues, like control issues and things like that…The ideas really got out there to the general public…” (Catherine Zimmerman)</td>
<td>“A science and technology initiative…is a targeted increase in funding for a particular area of science and technology. …The [National Nanotechnology Initiative] is a mechanism for the United States government to set priorities….. I’m not proposing initiatives as the sole driver for increases in funding. But my experience was if I had some of these they would also engender support more broadly for increases in sciences and technology” (Tim Kilberg)</td>
<td>“[Nanotech] is going to be…a very lucrative area for patent lawyers…I know there are some companies that are poised to be suing – like right now….there just isn’t a lot of products on the market to be suing for. … But what I’m looking at in the long term is if I get in early…then when somebody’s looking for a patent firm to handle their litigation we’ll have been around for a long time and be sort of the household name in nanotechnology…” (Rob Peterson)</td>
<td>“I believe that we are using nano-engineered principles to get unique properties and performance and features that will allow us to do commercially valuable things with products in the energy sector…[.] I see us as a company with a strong intellectual property position focused on a specific vertical market that is energy using nano-engineered materials to accomplish certain performance characteristics” (Henrik Bergman)</td>
<td>“I think [funding] has changed what people call it. I think we saw a lot of people change the name of what they are working on. Now they say that they work on nanotechnology and all that really happened is the scale that we pattern accurately decreased and people changed names around to get funding. … Instead of people getting a normal NSF grant they got an NSF grant that had nanotechnology in the title” (Matt Mortensen)</td>
</tr>
</tbody>
</table>
TABLE 2
Overview of the Data

<table>
<thead>
<tr>
<th></th>
<th>Futurists</th>
<th>Government officials</th>
<th>Service providers</th>
<th>Entrepreneurs</th>
<th>Scientists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviews</td>
<td>13</td>
<td>11</td>
<td>18</td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td>(N = 77)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Articles analyzed</td>
<td>926</td>
<td>925</td>
<td>494</td>
<td>4,157</td>
<td>2509</td>
</tr>
<tr>
<td>quantitatively (N = 9,011)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Articles analyzed</td>
<td>204</td>
<td>142</td>
<td>189</td>
<td>170</td>
<td>233</td>
</tr>
<tr>
<td>qualitatively (N = 938)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional material:
- Historical documents covering the major events that took place during the development of the nanotechnology field.
- Newspaper articles from the top 50 U.S. Newspapers (total 3,762)

* The archival data listed above was supplemented with additional important documents pivotal in the development of nanotechnology.

* Many of the articles were only one or two paragraphs
# TABLE 3

<table>
<thead>
<tr>
<th>Mechanisms</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crafting common field goals</td>
<td>The process where multiple communities, who aspire to become part of a common field, create joint goals for the field.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>In the early part of field formation, community members met at the Foresight Conferences, which served as a field configuring events. During the 1990s government officials held workshops that included all the communities. For example, on June 22, 1999 the Committee on Science House of Representative held a panel to discuss the future of nanotechnology, which included representatives from scientists and futurists: “It is also appropriate for the Subcommittee to take a good look at the Federal Government's role in funding nanotechnology research, to discuss what can be done to help move this research from the lab to the marketplace, and to discuss where nanotechnology might be in 10, 20, 30 years from now……”. Later in the same hearing Ralph Merkle expanded: “I want to just say that this is an area where there are some differences in opinion about the particular routes to follow, but, nonetheless, agreement about the overall goals and objectives that we should be able to build, essentially, most of the structures that are consistent with physical law.”</td>
</tr>
<tr>
<td>Coordinating collectively</td>
<td>The process through which all the communities involved in a field participate in negotiating and determining field goals.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>During the early part of field formation, the three founding communities where involved in joint negotiations about the goals of the field. In particular, they coordinated collectively while present at the same conferences and meetings. One futurist explained how the Foresight Institute contributed to collective coordination: “One of the big contributions of Foresight has been along technical conferences. It was the first conference on nanotechnology. So it had scientists from all sorts of institutions, all sorts of places. Another thing that they did on an ongoing basis is they did publications – newsletters and little electronic newsletters, so hard copy and electronic variety of newsletters that just basically kept people up to speed on what was going on the cutting edge of nanotech”</td>
</tr>
</tbody>
</table>
### TABLE 4

<table>
<thead>
<tr>
<th>Mechanisms</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
</table>
| Translating goals into   | Is the process through which participants begin to translate field level     | Government officials and venture capitalists funded entrepreneurs/scientists that did not comply with the original vision of nanotechnology, because few entrepreneurs/scientists did work related to the grand vision of atom-by-atom control. A government official explained: “[L]awmakers don't administrator things…the their pass legislation to fund a program and then it's carried out by other people. Now I haven't talked with these guys but I would be willing to bet you that there are some people who would be pretty surprised!” A scientist explained: “Well, if you understand the scientific peer review process, it's a very conservative process. Period. And I think the old open secret in the scientific community is that what you put your [grant] proposal in on is the stuff we've already done and when you get the grant, you bootleg the money on doing next thing so you can develop data and go onto the next proposal about stuff you've already done, right? It's the open secret about how things work”.
| actions                   | goals into actual doable activities.                                        |                                                                                                                                                                                                         |
| Coordinating locally     | Is the process through which communities coordinate decentrally without the | Venture capitalists coordinated with investors and companies as to which firms to invest in. Government officials coordinated with scientists as to which research proposals to fund. One government official explained how government agencies coordinated locally to fund nano-science within existing structures: “the memo goes out [from Congress] and says, "Here's a priority, but it doesn't say, "We're going to take $10 million from the Department of Defense and give it to EPA because we think EPA needs more money in nanotechnology." Really what it's saying to EPA and the Department of Defense is "Within your budget we want you to make these [nanotechnology] priority areas." So at the end of that process where the discussion goes back and forth between the agencies and the OMB [Office of Management and Budget]– at the end of all that what they finally have agreed then they say to the agency, “Okay, now go back and tell us how much of the existing programs is nanotechnology,” because almost none of them has a program that's called nanotechnology research. It's part of their program for clean water or their program for advanced sensors.”
|                           | involvement of all the communities in the field.                          |                                                                                                                                                                                                         |
| Neglecting field level   | Is the process through which the initial common goal of the field is no     | After the creation of the original goals there was no effort to bring all of the communities together to create a central vision for nanotechnology. One futurist explained: “It started to broaden and by the time we get to year 2000 then even though in the popular mind we are still talking about nano-robotics then by the time the NNI started…by the way this is like a founding coalition and…a very very very wide variety of folks got together …We were promised the little machines, and as far as [the public] knows they are getting them. Unfortunately it is not happening..' Another futurist explained: “The problem is that the money is not really going towards what Congress thought that it was going towards. It is being funneled into things that are much more near term.” Christine Peterson (2004:11-12) described how the government originally supported a grand vision of nanotechnology but over time funding was only allocated to near term applications. “A 1999 NNI promotional brochure likewise described and seemingly endorsed “Feynman’s vision of total nanoscale control,” terming it “the original nanotechnology vision”. Another NNI document explained, “the essence of nanotechnology is the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new molecular organization”. However, after the funding was allocated “NNI director Mihail Roco attempted to shut down inquiry by decreeting that “None of this exists... this is only science fiction...these aspects stay outside the development of nanotechnology as we intend it.”
<p>| goals                    | no longer maintained and communities’ goals become misaligned.              |                                                                                                                                                                                                         |</p>
<table>
<thead>
<tr>
<th>Community</th>
<th>Futurists</th>
<th>Government</th>
<th>Service providers</th>
<th>Entrepreneurs</th>
<th>Scientists</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Futurists</strong></td>
<td>Misaligned</td>
<td>Aligned</td>
<td>Misaligned/Aligned</td>
<td>Misaligned/Misaligned</td>
<td>Misaligned/Misaligned</td>
</tr>
<tr>
<td>The goal of the futurists was to create microscopic assembler robots, which conflicted with the government’s goal of just wanting to fund science at the nano-scale without emphasis on specific areas.</td>
<td>The goal of the service providers’ was to create a new field, which could stimulate demand for their services. They were not concerned with whether these presentations exerted precise control of matter at the nano-scale, which was the goal of the futurists.</td>
<td>The goals of the service providers’ was to create a new field. This goal was aligned with the government’s goal of creating a new nanotechnology field.</td>
<td>The goals of the entrepreneurs’ and the futurists’ conflicted. The entrepreneurs’ was focused on profit generation whereas the futurists’ emphasized responsible technological development. Furthermore, entrepreneurs had a short time horizon for the realization of nanotechnology, whereas the futurists took a much longer time perspective.</td>
<td>The scientists’ goals were misaligned with those of the futurists’ as the goals of scientists were to invent and publish rigorous scientific knowledge. The goals of the futurists were to develop an agenda for the long-term development of nanotechnology.</td>
<td></td>
</tr>
<tr>
<td><strong>Government</strong></td>
<td>Aligned</td>
<td>Misaligned/Misaligned</td>
<td>Misaligned/Aligned</td>
<td>Misaligned/Misaligned</td>
<td>Misaligned/Misaligned</td>
</tr>
<tr>
<td>The goal of the service providers’ was to create a new field. This goal was aligned with the government’s goal of creating a new nanotechnology field.</td>
<td>Entrepreneurs and government officials were aligned in their focus on creating a new field. However, entrepreneurs saw the creation of new commercial opportunities as the only goal of the field, whereas the agenda of the government was broader (e.g. education, minimizing pollution, stimulating underfunded geographical areas).</td>
<td>The government wanted to create scientific breakthroughs that created jobs and that the constituents would be interested in. Scientists wanted to investigate issues that had the highest scientific importance.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Service Providers</strong></td>
<td>Aligned/Misaligned</td>
<td>Misaligned/Misaligned</td>
<td>Misaligned/Aligned</td>
<td>Misaligned/Misaligned</td>
<td>Misaligned/Misaligned</td>
</tr>
<tr>
<td>The goals of the service providers’ and the entrepreneurs’ were aligned in their efforts to create a new field that would generate commercial services.</td>
<td>The goals of the service providers and the scientists were misaligned as the main goal of the service providers was to create a new field, whereas the goal of the scientists was to invent and publish rigorous scientific knowledge.</td>
<td>Scientists and entrepreneurs were aligned in their focus on creating short-term scientific breakthroughs. However, they were misaligned with regards to their emphasis on whether these breakthroughs needed to have a commercial potential or not.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

White boxes represent alignment in the communities’ goals. Grey boxes represent misalignment in the communities’ goals. Light grey boxes represent that part of the communities’ goals are aligned whereas others are misaligned.
TABLE 5b: Means Misalignment within the Nanotechnology Field (2001-2005)

<table>
<thead>
<tr>
<th>Community</th>
<th>Futurists</th>
<th>Government</th>
<th>Service Providers</th>
<th>Entrepreneurs</th>
<th>Scientists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Futurists</td>
<td>Misaligned</td>
<td>The futurists wanted to invest resources in testing the feasibility of the grand nanotechnology vision. Government officials wanted to invest money in funding the best science.</td>
<td>Service providers wanted to fund and write about companies that were already in existence. Futurists wanted to invest time and energy into testing the feasibility of microscopic robots.</td>
<td>Entrepreneurs wanted to invest in problems that might yield commercial products in the near future. Futurists wanted to invest in problems that would test the feasibility of their grand nanotechnology goal.</td>
<td>Misaligned</td>
</tr>
<tr>
<td>Government</td>
<td>Misaligned</td>
<td>The means of the government was aligned the service providers’ in that both emphasized the creation of interdisciplinary conferences and funding for a wide array of scientific and commercial enterprises.</td>
<td>Aligned/Misaligned</td>
<td>The government and the entrepreneurs were aligned in their means regarding the nanotechnology field as both wanted to fund commercial enterprises that might participate in the creation of a field. They were misaligned, because the government also wanted to fund scientific areas that might not have a near-term commercial potential.</td>
<td>Misaligned</td>
</tr>
<tr>
<td>Service providers</td>
<td>Aligned</td>
<td>The means that the service providers used to promote the nanotechnology field was to host conferences and write about companies that had the potential to become profitable within a short period of time. Entrepreneurs saw these conferences and articles as outlets, which could help them attract attention to their products.</td>
<td>Aligned/Misaligned</td>
<td>The means of the scientists and the service providers were aligned, because scientists benefited from being featured in the service providers’ conferences and articles. However, they were misaligned in that service providers would talk about the scientists’ work in ways that conflicted with the scientists’ emphasis of scientific purity.</td>
<td>Misaligned</td>
</tr>
</tbody>
</table>

White boxes represent that the means of the communities’ were aligned. Grey boxes represent misalignment in the means of the communities. Light grey boxes represent that the means of the communities were both aligned and misaligned.
FIGURE 1
The Coding Structure

Step 1:
Identifying fragmentation

Step 2:
Identifying two processes

- Identifying the shift from initial consensus on field level goals to fragmentation

Step 3:
Generating common ends

- Means - end decoupling
  - Crafting common goals
  - Coordinating collectively

Step 4:
Means-end decoupling

- Translating goals into action
- Coordinating locally
- Neglecting field goals

Step 5:
Identifying process triggers

- Identifying the conditions that triggered the transition between generating common ends and means-end decoupling
FIGURE 2
The Evolution of Community Interest in the Field of Nanotechnology (1985-2005)

The data for Figure 2 comes from the top 50 US Newspapers. The y-axis in Figure 2 measures the percentage of articles on nanoscience that mention “nanotechnology” or “nanotech”. Figure 2 thus illustrates when the five different communities began to refer to their nanoscience activities as nanotechnology.

Generating Common Ends (1986-2000)
Means-end Decoupling (2001-2005)
Figure 3 shows the percentage of articles within the top 50 US Newspapers, which focus on grand versus immediate goals for nanotechnology. Grand goals include references to: robot, or artificial intelligence. Immediate goals include references to: cosmetics, textiles, consumer electronics, batteries, golf balls, or pants.
FIGURE 4
Theoretical Model: From Consensus to Fragmentation – Means-end Decoupling within Organizational Fields

Generating Common Ends
- Crafting field goals
- Coordinating collectively

Field Consensus

Process Triggers
- Introduction of new resources
- Need to integrate with existing complex institutionalized practices
- Increased diversity of field participants

Means-ends Decoupling
- Translating goals into actions
- Neglecting field goals
- Coordinating locally

Field Fragmentation
REFERENCES


President Clinton, January 21, 2000. *President Clinton’s Address to Caltech on Science and Technology*. The White House. Office of the Press Secretary, Los Angeles, CA.


APPENDIX 1: Search Words Used to Identify Nano-science Articles

Nanotube, nanorod, buckyball, buckminsterfullere, fullerene, molecular manufacturing, molecular engineering, molecular self-assembly, quantum dot, nanodot, nanoscale, nanosensor, nanostructure, atomic force microscope, scanning force microscope, scanning tunneling microscope, nanobot, molecular robot, nanodevice, nanoparticle, nanopore, nanomotor, nanopowder, diamondoid, nanofabrication, nanoarray, nanocomputation, nanoengineering, nanocrystal, nanoelectronic, nanophotonic, nanochannel, nanoceramic, nanofabric, nano-imprint, nanolayer, nanosubstrat, nanowire, nanomachine, nanoswitches, nanocoating, nanocomposit, nanoconducting, nanomanipulator, nanomaterial, nanoarchitecture, nanobio, nanolithography, nanophase, nanosci, nanotech