Innovation in Scientific Multiteam Systems: Confluent & Countervailing Forces

Leslie A. DeChurch
Georgia Institute of Technology

Stephen J. Zaccaro
George Mason University

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Abstract

If necessity is the mother of innovation, the current economic crisis has rightly focused science and innovation policy on the critical role of ingenious ideas and their resulting applications to national competitiveness, wage and job growth, and long-term economic prosperity (Blank, 2012). An emerging interdisciplinary area of research, dubbed the Science of Team Science, poses interesting and important questions about how to best organize scientists' effort to maximize the likelihood that innovation will result. Scientific collectives are often referred to as "science teams" but are best understood as multiteam systems (MTSs). MTSs describe organizational forms consisting of multiple teams who work toward different team goals, but share at least one distal system level goal (Zaccaro, Marks, & DeChurch, 2012). It is not uncommon for science "teams" to consist of scientists drawn from multiple laboratories. Many of the challenges that arise do so because of concurrent and competing pressures, tension we capture introducing the notion of confluent and countervailing forces. Because of these complex forces, it is important to understand scientific teams through the lens of multiteam systems theory. This paper will present a systematic overview of the multiteam perspective with an emphasis on its application to understanding the performance determinants of MTSs. We organize our review around two emerging themes of this work – that of confluent and countervailing forces. Confluent forces are sets of teamwork processes and properties that combine across levels of analysis and jointly enable collective performance (e.g., within- and between-team coordination additively predict MTS performance). In contrast, countervailing forces are combinations of teamwork processes and properties that operate differently at different levels of analysis (e.g., team cohesion benefits team performance but compromises information sharing between teams). We conclude with a set of research priorities needed to advance knowledge and inform practice in team science.

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The year 1859 was an important one for science. Darwin published his "Origin of Species," fundamentally shifting the way natural scientists view evolution. Darwin spent decades observing nature and living with his family in relative isolation from the scholarly community. The year 2003 was also an important one for science. Researchers concluded a 13-year international, interdisciplinary effort to map DNA. The Origin of Species, published in 1859 had one author (Darwin, 1859). A landmark paper from the Human Genome Project (HGP) published in Nature in 2008 had 46 authors (McKernan et al., 2009).

If necessity is the mother of innovation, the current economic crisis has rightly focused science and innovation policy on the critical role of ingenious ideas and their resulting applications to national competitiveness, wage and job growth, and long-term economic prosperity (Blank, 2012). An emerging interdisciplinary area of research, dubbed the Science of Team Science, poses interesting and important questions about how to best organize scientists' effort to maximize the likelihood that innovation will result. Research in this area provides conflicting evidence about the capacity for scientific collectives (i.e., teams, centers) to seed grand innovations. On the one hand, sociological research convincingly argues for the "dominance of teams [as compared to solo authors] in the production of knowledge," particularly in the production of "high-impact" knowledge (Wutchy, Jones, & Uzzi, 2007, p. 1036). On the other hand, research shows many teams- the ones most prized for their diverse and distributed "dream teams"- are especially prone to underachieving across a variety of metrics ranging from publications to patents to the eventual commercialization of their creative outputs (Cummings &

Kiesler, 2005).

Taken together, these findings suggest two things. First, when teams succeed, they do so brilliantly, exceeding the creative impact of their solo scientist counterparts. Second, the reality is that many scientific teams fail. Given that scientific teams, as compared to solo scientists, are far more intellectually equipped to solve complex problems, there is something in the interaction of scientists as part of teams that explains this sub-optimization, and that furthermore, holds the key to lowering the "infant mortality rate" of scientific collaborations. This paper presents an overarching framework for understanding the confluent and countervailing forces that shape the eventual outcomes of scientific collectives. We use this framework to organize prior work detailing the effects of collective processes and states occurring both within and between teams on their resulting outcomes.

Scientific collectives are often referred to as "science teams" but are best understood as multiteam systems (MTSs). MTSs describe organizational forms consisting of multiple teams who work toward different team goals, but share at least one distal system level goal (Zaccaro, Marks, & DeChurch, 2012). It is not uncommon for science "teams" to consist of scientists drawn from multiple laboratories. Many of the challenges that arise do so because of both confluent and countervailing forces resulting from concurrent pressures to both cooperate and compete. For this reason, it is important to understand scientific teams through the lens of multiteam systems theory.

Another advantage of the MTS paradigm for the science of team science is that it serves as a boundary object needed to integrate two areas of research critical to the field of team science: research on ***team effectiveness*** largely conducted within psychology, organizational behavior, and communication, with research on ***social networks and complexity science***. MTSs have been defined as:

> "a relatively new unit of inquiry in the organizational sciences that refers to networks of teams where members work toward both proximal team goals and distal system goals (Zaccaro, Marks, & DeChurch, 2012). This hierarchical arrangement of goals calls for patterned activity within and across teams such that team members are tightly coupled, and the members of distinct teams are more loosely coupled. MTS research seeks to explain the performance of the overall network, as opposed to the effectiveness of individuals (Cross & Cummings, 2004) or of individual teams (Sparrowe, Liden, Wayne, & Kraimer, 2001). MTSs can also be viewed as a specific type of social network, one where every network member is interdependent in some way towards the accomplishment of a network-level purpose (DeChurch, Contractor, Murase, & Wax, 2013, p.3)."

Whereas research on MTS has been thus far rooted in more traditional social sciences, Psychology and Organizational Behavior, this form can also be understood through the lens of complexity theory. In fact, complexity theory (Anderson, 1999; Holland, 1992; Lansing, 2003) offers many useful insights about multilevel influences and nonlinearity (Uzzi, 2008), which can be fruitfully applied to understanding MTSs. Conversely, the MTS lens sets up important boundaries of teams and systems of teams, and elaborates theoretical mechanisms that govern individuals' behavior as they operate within and across these boundaries. Explicating these conceptual drivers is a necessary first step in applying complexity theory to the study of MTS. We explore these connections in more detail after introducing the concept of MTS as it has been examined thus far.

The Nature of Multiteam Systems

Descriptions of MTSs and their core concepts have been described in detail by other researchers (DeChurch & Mathieu, 2009; Marks, et al., 2004; Mathieu, et al. 2001; Zaccaro, et al., 2012), and we refer readers to those sources. In this paper we will briefly summarize key concepts from these prior works. Mathieu, et al. (2001) defined MTSs as:

> "Two or more teams that interface directly and interdependently in response to environmental contingencies toward the accomplishment of collective goals. MTS boundaries are defined by virtue of the fact that all teams within the system, while pursuing different proximal goals, share at least one common distal goal; and in doing so exhibit input, process and outcome interdependence with at least on other team in the system (p. 290)."

This definition points to three defining and distinguishing features of MTSs: (a) they are composed of at least two coupled component teams; (b) component teams are organized into a goal hierarchy, in which they may or may not share particular proximal goals, but all teams share the same distal goal; and (c) interactions within the MTS are driven by various degrees of task interdependencies among component teams. Indeed, perhaps the major difference between MTSs and other forms of team-based organizations is that while in most organizations, teams are only nominally or loosely coupled with their outputs pooled, in MTSs teams are linked in stronger patterns of reciprocal and intensive interdependence (Thompson; 1967; Tesluk, Mathieu, Zaccaro, & Marks, 1997; Zaccaro, et al., 2012).

Zaccaro, et al., (2012) offered a fairly generic input-process-output model of multiteam system effectiveness. They posited three sets of MTS attributes as inputs into MTS processes; compositional attributes, linkage attributes, and developmental attributes. Table 1 lists the several dimensions within each set of attributes. Compositional attributes refer to "the overall demographic features of the MTS, as well as the relative characteristics of component teams" (Zaccaro, et al., 2012, p. 13). They include qualities such as the size of the MTS, the number of its individual and team members, where the teams derived from, and their diversity on several dimensions.

This dimension has been focal in the emerging field of team science. For example, Cummings and Kiesler (2003) studied the impact of two compositional attributes, functional diversity and geographic dispersion, on a range of scientific team outcomes including ideation, training, and outreach. Their findings suggest that having members from different disciplines is not as disruptive to science team output as is their geographic dispersion. Another example in science teams compositional attributes was conducted by Guimera, Uzzi, Spiro, and Amaral (2005) who investigated the size, proportion of newcomers, and number of repeat collaborations as predictors of creative team performance in both artistic and scientific teams.

These two examples highlight the relevance of compositional attributes to understanding scientific teams, though extant research on science teams has not examined the composition of scientific MTSs, per se. These findings can be usefully applied to understanding both (a) the composition of scientific *teams* who operate with high internal interdependence, and (b) the component teams operating within scientific MTSs. Future research is needed that extends these findings to explore the composition of MTSs consisting of multiple interdependent teams.

Linkage attributes refer to the "linking mechanisms that connect component teams" (Zaccaro, et al., 2012, p. 18), and include such features as the degree of interdependence among component teams, the power arrangements among such teams, and communication structures within the MTS. Research on scientific teams has begun to explore the linkage attributes that connect different subsets of work that is performed in large scientific collectives. Though not a study of MTSs per se, Balakrishnan, Kiesler, Cummings, and Zadeh (2011) studied the researchers engaged in 52 projects and categorized their work processes as either co-acting, coordinated, or integrated. This is a useful distinction for understanding how distinct component teams within a scientific MTS coordinate their work. A newly funded NSF project (DeChurch, Zaccaro, and Kanfer, 2013) will directly test the implications of these linkage attributes identified by Balakrishnan et al. on the innovation of scientific teams and systems of teams.

The last set of MTS attributes pertains to the "developmental dynamics and patterns" (Zaccaro, et al., 2012, p. 20) that characterize the formation and growth of the MTS. These attributes include such factors as whether the MTS is appointed or self-organizes from multiteam interactions, the expected duration of the MTS, and the transitivity of membership within and across the MTS. Prior research on scientific teams has investigated factors relevant to MTS development. For example, Guimera et al. (2005) studied repeat collaborations, which would determine the ability for a system of teams to work together seamlessly relying on norms already in place from prior projects.

Cummings and Kiesler (2008) find that although multi-university collaborations suffer from coordination "process losses" due to the increased effort required to effectively work together across geographic distance, they also found prior collaboration among the researchers mitigated the harmful effects of distance.

Using this taxonomy and the work of Cummings and Kiesler (2008), we offer Table 2. Table 2 summarizes four ideal types of scientific multiteam systems based on two of the most critical compositional attributes from the MTS taxonomy: boundary status and functional diversity. The boundary status dimension describes the number of embedding organizations from which MTS component teams are drawn from. MTSs contained within a single organization have a number of advantages stemming from this common superordinate identity and operating environment that bode well for their success. Conversely, MTSs whose teams are nested within different organizations face the challenges of integrating across different operating environments.

The second important dimension of MTSs is the functional diversity of component teams. Hall and her colleagues (2008) described this feature of scientific collectives as the degree to which the scientific problem calls for integration across multiple disciplines. Functional diversity presents both opportunities in the way of innovative capacity and integration, but also incurs the threats of conflict and an overall lack of coherence.

Table 2 provides examples of scientific MTSs characterizing the points along the continua of boundary status and functional diversity. MTSs who are bound within a single organization and single discipline (i.e., low functional diversity) are often found within research agencies. For example, NASA employs many scientific MTSs comprised of teams of similarly disciplined scientists each of whom works on a subset of scientific problem. MTSs can also exhibit high functional diversity while operating within a single embedding organization. Many university-based centers and institutes fall into this MTS category. MTSs often span the boundaries of multiple organizations. Scientific MTSs whose teams are drawn from multiple organizations but who work within one or a few closely related disciplines include many scientific-industry partnerships. In these cases scientific teams often have similar background, but partner across organizations from academia and industry. A final MTS type includes those whose component teams are not only drawn from different organizations but also from different disciplines. Multi-university and multidisciplinary research groups fall into this category. These MTSs face the challenges presented by functional diversity and differing embedding organizations.

Impact of MTS Attributes on Processes & Outcomes

The compositional, linkage, and developmental attributes of MTSs were proposed by Zaccaro, et al. (2012) as influencing MTS outcomes through their effects on MTS interaction processes. MTS success rests on effective processes and interactions occurring both within and among component teams (Marks, et al., 2005). Marks, Mathieu, and Zaccaro (2001) delineated several processes that can occur within teams as they accomplish tasks. These included transition, action, and interpersonal processes. Transition processes typically occur within planning phases of team performance episodes, and include such activities as mission analysis, goal specification, strategy formulation, and action planning. Action processes typically occur during execution phases of team performance episodes, and include progress monitoring, systems monitoring, team back up behavior, and coordination. Interpersonal processes can occur within and outside team performance episodes and include activities such as conflict management, fostering of team motivation, and regulation of team member affect.

These processes are particularly important to scientific teams, as they are among the most powerful predictors of team creativity. A recent meta-analysis (Hulsheger, Anderson, & Salgado, 2009) cumulating more than 30 years of research on the antecedents to team creativity and innovation found processes were more potent predictors of creative output than were wither compositional or structural drivers. The most impactful process variables were: support for innovation, vision, task orientation, and eternal communication.

The finding that processes are more potent predictors of innovation than are initial conditions (e.g., composition and structure) presents an interesting dilemma for the science of team science. Far more research on scientific teams has focused on composition and structure than on process, and so it's worth considering the reasons behind this difference in research attention. Two possible explanations are data availability and ease of policy application. The data on the characteristics of who's in a team are readily available through archival records. Conversely, data on the nature of the interactions among members, i.e., processes, are much harder to obtain and have traditionally required surveys or direct observation and coding. Advancements in harnessing digital traces is one of the most promising methodological developments for understanding scientific collectives. Another appeal of studying composition is the direct application to policy. For example, if we find that multidisciplinary teams are ultimately more innovative, we can advise policy makers to foster the creation of such teams when awarding funds for research, or when building teams to tackle particular problems.

Processes can also be a powerful leverage point, and this represents an important area in need of future work. Hulsheger et al.'s (2009) finding that processes are stronger predictors ought to encourage future research and policy makers to more carefully consider the important role of these processes as leverage points for innovation.

Several MTS researchers have extended this team framework to describe the interaction processes that connect component teams within MTSs (i.e., between team processes). For example, Marks et al. (2005) found between-team transition and action processes contributed significantly to the prediction of MTS performance beyond team action processes. In another vein, DeChurch et al. (2011) used a historiometric analysis of MTSs engaged in either responses to natural disasters, or postwar stability, support, transition, and reconstruction efforts to identify transition and action leadership processes that occur within and between component teams in an MTS. These and other studies (Davison, Hollenbeck, Barnes, Sleesman, & Ilgen, 2012; Lanaj, Hollenbeck, Ilgen, Barnes, & Harmon, 2012), highlight the necessity of examining MTS effectiveness in terms of multi-level processes.

Marks, et al. (2001) distinguished team processes from team emergent states. The latter refer to "properties of the team that are typically dynamic in nature and vary as a function of team context, inputs, processes, and outcomes" (Marks, et al., 2001, p. 357). Emergent states evolve through team interactions as members complete multiple performance episodes within specific team contexts. Marks et al. (2001; see also DeChurch and Mesmer-Magnus, 2010) defined several categories of emergent states, including affective, cognitive, and motivational states. Affective states include trust and cohesion; cognitive states include shared mental models and transactive memory; motivational states include collective efficacy and goal states.

Marks, et al (2001) referred to emergent states that exist within teams. However, in MTSs, such states can exist between components teams as well as characterize the MTS as a whole. For example, Jimenez-Rodriguez (2012) measured MTS efficacy by asking team members to indicate how confident they were that their team and another team could achieve its goals. She also asked members to evaluate the perceived competence of the MTS as a whole in achieving its goals. Jimenez-Rodriguez assessed MTS trust by examining between-team perceptions of "willingness...to be vulnerable to the actions of [the other] party" (Mayer, Davis, & Schoorman, 1995; p.712). She also included in her study measures of shared mental models and transactive memory systems, using the MTS as the referent. Thus, in her study she examined the affective and motivational states that can emerge between two component teams in an MTS, as well as the motivational and cognitive states that can emerge across the entire MTS. DiRosa (2013) and Rentsch and Staniewicz (2012) provide additional insight into the nature of MTS cohesion and shared cognition, respectively. Taken together, this work indicates that just as combinations of within and between team processes have critical implications for overall MTS effectiveness, so do within team and between team emergent states.

Entitativity in Multiteam Systems

Mathieu, et al., (2001) and Zaccaro, et al. (20012) detailed several differences between MTSs and other collectives such as traditional organizations, team-based organizations, matrix organizations, task forces, subassemblies, distributed teams, and top management teams. Their arguments help establish MTS as a distinct and unique entity.

However, another key issue not covered in those contributions is whether each component team in an MTS can be considered as distinct from each other team, i.e., as a separate entity from all of the others, as they work interdependently toward systems goals. If component teams cannot be considered as clearly discrete from one another, than the so-called MTS can merely be consider as just a larger team. This aspect of component teams, called their degree of "entitavitity' (Cartwright, 1958), has been examined in the group dynamics literature in terms of the factors that distinguish a purely nominal collection of people from those that are perceived as -- and function as -- a group. These factors include common fate, similarity, proximity, and boundary reinforcement (Campbell, 1958; Forysth, 2006; Faraj & Yan, 2009). While these elements have been applied to define the existence of a group or team as a separate and discrete entity, they can also be used to determine the distinctiveness of component teams from each other within MTSs.

Common fate was considered by Campbell (1958) as perhaps the most fundamental defining element of groups as entities. This element refers to the degree of commonality in the performance processes and outcomes experienced by team members. According to Campbell, common fate can be detected in the covariation of team member activities and outcomes; entitativity is evidenced by higher covariation within teams than across teams. In MTSs goal hierarchies can create degrees of common fate, or covariation of goal activity and outcome, between different teams working together to accomplish a proximal goal; however, each team still has its own distinct activities and outcomes that distinguish it from other teams in the MTS.

For example, an MTS having the goal of understanding human elements of cyber-security may be composed of separate teams of psychologists and computer scientists. While each team may work in close collaboration with the other, each still enacts its own set of functional activities with outcomes and deliverables that are different from those of the other team. There remains a definable commonality in activities and outcomes that is greater within component teams than between component teams in an MTS, even in one with a highly integrated and interdependent goal hierarchy. Such distinctions contribute to the boundaries among component teams, and thus to the definition of an MTS. We underscore that the distinctiveness of component teams is a defining characteristic of MTSs, and one that differentiates them from individual teams.

While Campbell (1958) placed greater weight on common fate as a way to detect entitativity than on similarity and proximity, he noted that the latter provide additional diagnostic information. *Similarity* refers to common qualities or characteristics possessed by team members. Thus members may display greater similarity in demographic backgrounds, values, and functional expertise among themselves relative to other teams in the MTS. For example, in the aforementioned cyber-security science team, members of each functional group (i.e., psychologists, computer scientists) retain their own disciplinary frames of reference, language, and procedures, making them distinct from members of the other group. The richness of the MTS and its distal outcome is in the integration of these different perspectives, but such integration does not collapse the boundaries between the component teams.

Proximity refers to the temporal and spatial "adjacency" (Campbell, 1958, p. 22) of team members as they conduct team work. While this factor carries less weight than common fate and similarity in defining entities, especially when team members use technology to connect over long distances and time periods, it can contribute to perceptions of grouping and team boundaries. For example, in two studies to be described later in this paper (Asencio et al., 2012; 2013) MTSs were created linking teams of ecology, psychology, and business students, respectively, around a scientific innovation goal hierarchy. Each team also had separate as well as integrated deliverables. The teams were not only distinguished by their separate outcomes (common fate), functional differences (similarity), but also by their geographic separation (proximity), with one team in France, another in Virginia, and a third in Georgia. Thus, while in this example the MTS as a whole consisted of as few as 9-10 members, multiple factors contributed to the perceived entitativity of three distinct teams, even as they were quite interdependent in their accomplishment of the overall goal hierarchy.

Teams foster entitativity by engaging in boundary management activities, especially boundary reinforcement (Faraj & Yan, 2009). Faraj and Yan (2009, p. 907) defined boundary reinforcement as referring to "the ways in which a team internally sets and reclaims its boundaries by increasing member awareness of boundaries and sharpening team identity." As common fate, similarity, and proximity factors operate to foster a perception of a team as a distinct identity, team members engage in activities that decrease the permeability of team boundaries, demarking who is "inside' the team and who is outside. This phenomenon is well known in the inter-team conflict literature (Hewstone, Rubin, & Willis, 2002), exemplified by the classic "Robbers Cave" study (Sherif, Harvey, White, Hood, & Sherif, 1961/1988), in which boys were randomly assigned to two separate groups. Once assigned, they engaged a multiple activities to increase the perceived differentiation between the two groups, including adopting separate team names, team flags and team-specific clothing. Each team sought to foster a separate and distinct identity.

In MTSs, similar, albeit more subtle processes can occur to maintain component team distinctiveness even as they work together on integrated goals. For example, in science MTSs, members of component teams from different scientific disciplines may reinforce team boundaries by championing their own frames of reference and methods in discussions about how collective tasks are to be accomplished. They may speak in the jargon of their own discipline, and reinterpret contributions of other science component teams in their own language. One may see joking and serious references to how "we" do science versus how "they" do what they do. These and related activities serve to increase the boundary strength and differentiation among component teams in an MTS.

These four factors of common fate, similarity, proximity, and boundary reinforcement contribute to the perception of component teams as separate entities even as they are coupled together in an MTS. If the entitativeness of component teams within an MTS are not firmly established, then the structure and uniqueness of the MTS itself is in doubt. This may be especially true in relatively small MTSs with small numbers of component teams. Prior research has used MTSs composed of 4 persons arranged into 2 teams (Marks, DeChurch, Mathieu, Panzer, & Alonzo, 2005), 6 persons in 3 teams (DeChurch & Marks, 2006), 4 persons plus simulated team members in 3 teams (Jimenez-Rodriguez, 2012), and 14 persons in 3 teams (Davison et al., 2012; Lanaj et al., 2012). In very small MTSs (e.g., Marks et al., 2005), one might legitimately question whether the collective of focus is truly an MTS rather than a team. The answer to this question lies in the degree to which component team members (a) share common activities and outcomes that are more similar within teams than with the other component teams, (b) share greater within team than between team similarities in demographic attributes and functional background, (c) work more closely in temporal and spatial proximity than members of other teams, and (d) engage in boundary reinforcement.

Thus, imagine a collection of 2 plant ecologists, 2 marine biologists, and 2 oceanographers brought together to explore the effects of oil spills in a marine environment. This relatively small aggregate would still be considered an MTS if each component team is responsible for accomplishing specific subgoals using activities defined by their particular functional area, and different from those of the others. This distinctiveness would also be enhanced as the scientists within each team come from similar professional backgrounds, but differ from those in the other teams, and as each team works in separate lab spaces. Finally, the different discipline-based language and frames of reference adopted within each team will reinforce the strength of team distinctiveness, and thus the identification of this collection as an MTS, despite its relatively small size of 6 total members.

Entitativity and MTS Characteristics

Several of the MTS characteristics listed in Table 1 can influence of the perceived entitativity of component teams in an MTS. For example, boundary status, where teams come from different organizations rather than a single organization, is likely to enhance within team similarity and boundary reinforcement. Also, as teams differ respectively in terms of functional diversity and cultural diversity, greater intra-team similarity relative to other teams in the MTS will foster stronger perceptions of component team entitativity.

Geographic dispersion, where component teams are distributed, will prime proximity cues in perceptions if teams as entities.

Among linkage attributes, hierarchical arrangement and power distribution can contribute to component team entitativity. Teams will be perceived as more distinct from one another as they vary in terms of (a) overall MTS responsibilities, and (b) amount of power and influence they possess within the MTS. Regarding MTS developmental attributes, MTSs can vary in terms of whether they evolve from collections of individuals who subsequently form component teams, or they are formed by bringing together already intact teams. The latter mode of MTS development is likely to foster greater perceptions of component team entitativity.

Component Team Entitativity and Boundary Forces within MTSs

Our analysis of component team entitativity is intended to address the question of when a collection of individuals formed into subgroupings constitutes a true MTS versus simply a larger group or organization. We have emphasized those factors that sharpen the boundaries between component teams and therefore the perception of an organization form composed of tightly coupled, but still distinct, teams. We contend that these factors carry weight even when MTSs are small in overall size and/or when MTS goal hierarchies foster highly interdependence interactions and collaborations across the component teams. An interesting aspect of component team entitativity, though, is that the stronger the boundary strength and reinforcement activities of such teams are, the more they will give rise to countervailing forces between team and MTS dynamics. Conversely, confluent forces increase in strength as teams engage in greater boundary spanning activities (Ancona & Caldwell, 1988; Faraj & Yan, 2009) across the MTS. In the remainder of this paper, we detail the nature of such confluence and countervailing forces within MTSs.

Multilevel Forces in Multiteam Systems

Table 3 provides a schematic for thinking about four areas of research with findings that bear on collective performance; the relationships examined in each of these areas is depicted in Figure 1. The top half of the table details two research areas with findings on the consequences of the interactions that occur among the members of teams. The bottom half of the table details two research areas with findings that bear on the consequences of the interactions that commence between the members of distinct teams.

Area 1 describes the vast and mature literature on intact teams (see exemplar reviews Kozlowski & Ilgen, 2006; Mathieu et al., 2007). Much of this literature has recently been meta-analyzed and shows the effects of internal team transition, action, and interpersonal processes (DeChurch, Mesmer-Magnus, & Doty, in press; LePine et al., 2008; Mesmer-Magnus & DeChurch, 2009;) as well as motivational (Gully et al., 2002; Mullen & Cooper, 1994; Stajkovik et al., 2009) and cognitive (DeChurch & Mesmer-Magnus, 2010) emergent states on team performance. Stokols et al.'s (2008) ecology of team science describes this literature under the heading of: "Social Psychology and Management Research on the Effectiveness of Teams (p. S99)." Area 1 findings are a valuable source of findings about the types of interactions that are needed for teams to function effectively. Given the maturity of this research area and size of the empirical record, this is a fruitful literature for underpinning policy recommendations for team science.

An important caveat about the application of Area 1 findings to team science is that these findings are best applied to teams whose work is best served by working closely internally with little to moderate interaction with members outside the team or discipline. Many of the collective endeavors of team science are *innovation* enterprises designed to tackle grand challenges necessitating an interdisciplinary perspective. As noted by Hall et al. (2008):

> "Team science can be conducted within a single, focused discipline, or can span different disciplines. The degree of variation across disciplines, as well as the breadth of levels of analysis (from cells to society), can affect the size and complexity of a given team. As such, the degree of complexity of a given problem that a team tackles can, in turn, influence the breadth and degree of the integration of disciplinary knowledge needed to explain or solve that problem (p. S243)."

What Hall and colleagues describe as the "complexity of a given team" distinguishes whether the science team should be understood as a team or as an MTS. If the former, then findings from Area 1 can be appropriately applied to understanding the inner functioning of these science teams, and to the development of evidence-based recommendations for policy. On the other hand, as complexity increases, science teams are better understood as MTSs, and findings from Area 3 research used to underpin policy.

In scientific teams where teams are closely linked to other teams, Area 3 findings are more appropriate to inform policy and design interventions. The linkage or interdependence can arise from shared resources, common goals, and/or supplementary skill sets. When interdependence between teams is high, as is often the case in research centers and institutes and many large-scale scientific endeavors, Area 3 findings hold that these so-called science teams are better understood as scientific multiteam systems. This burgeoning research area demonstrates that "conventional wisdom regarding effective coordination in traditional teams and large organizations does not always transfer to multiteam systems (Davison et al., 2012, p. 808)." An example of this was provided by Davison and his colleagues who showed that a robust finding from the teams literature (i.e., Area 1) that coordination among members shows a positive linear relation to team performance, does not apply in MTSs. Rather, direct mutual adjustment can actually be detrimental. Lanaj et al. (2012) provide further compelling evidence that team prescriptions may have harmful side effects when given to MTSs. Lanaj and her colleagues found decentralized planning, i.e., having multiple members all contributing their ideas to the problem is harmful to MTS performance because it increases risk taking and impedes coordination.

Areas 1 and 4 both address the problem of collective performance by looking at predictors at the same level of analysis of the criteria of interest. Area 1 looks at team processes as predictors of team performance. Area 4 looks at multiteam processes as predictors of MTS performance. We highlight two additional but less investigated approaches to the problem of collective performance that focus on multilevel determinants (Kozlowski & Klein, 2001). Both of these are the areas where the notion of countervailance comes into play. The popular meaning of countervailance is that two forces compensate for one another, or one force overcomes the effect of another. We elaborate on this definition applying it to MTSs in the next section. Area 2 describes research that examines the impact of team processes on MTS outcomes. An example of a finding that fits this cell is Davison et al.'s observation that different teams fill different roles in the MTS, and that the patterns of processes enacted by teams matters.

This is an example of what Kozlowski and Klein (2001) define as a compilational form of emergence. Meaning the predictor of collective performance is rooted in team interactions, but takes on meaning as a pattern at the MTS level. Many of the examples of emergence that have been applied to teams characterize individuals thoughts, feelings, and actions as building blocks to a "team" pattern of thoughts, feelings, and/or interactions. The team pattern is said to emerge, and to subsequently explain variation in team performance. In the case of multiteam systems, the building blocks of emergence are the teams.

The remaining quadrant, Area 3, describes research examining the MTS as the context that affects the functioning of individual teams. For example, Asencio et al. (2013) examined the communication networks within and between scientific teams operating as a part of a 4-team MTS. She found between-team communication shows an inverted-U shaped relationship with the formation of team identity. Interpreted through the lens of social identity and social comparison theory (Tajfel, 1978), a team that has a moderate number of between team boundary ties to other teams is aware of the boundary of the team, and these interactions with "different" others improves ones evaluation of the team. However, as the density of between-team ties increases past this threshold, the team identity is lost, coming at a substantial cost to the coherence of the functional work performed within it.

Confluent Forces in MTSs

Early research on multiteam systems examined what we define as confluent forces (i.e., Table 3, Area 3 research). The popular definition of confluence is flowing together, and we use this definition to describe the multilevel forces that emerge at the team and between team levels of analysis and jointly determine the effectiveness of MTSs. Studies by Marks et al. (2005) and Davison et al. (2012) are exemplar of “confluence thinking” about MTSs. Both studies demonstrate that MTS performance requires high quality interaction processes occurring within each of the component teams and also between the members of distinct teams. These studies show that while both within- and between-team processes are important determinants of MTS performance, between-team action processes like coordination, mutual adjustment, and backup behavior explain incremental variance in MTS performance. Thus, confluent forces are sets of teamwork processes and properties that combine across levels of analysis and jointly enable collective performance (e.g., within- and between-team coordination additively predict MTS performance). Stated differently, confluent forces describe processes that are necessary but not sufficient at a given level of emergence.

Empirical findings have begun to accumulate demonstrating confluence effects in MTSs. In addition to the earlier example of confluence with team and MTS action processes, DeChurch and Marks (2006) find confluence with leadership. Building on research that shows functional leadership that fosters both direction setting and coordinating predicts team performance (Kozlowski et al., 1996; Zaccaro, Rittman, & Marks, 2002), DeChurch and Marks experimentally manipulate leadership within MTSs finding that leadership targeted at direction setting and coordination *between* teams is associated with greater MTS performance than leadership which targets these functions at integrating the activities within component teams.

Team charters are documents created by teams reflecting their plans for working together. The creation of a charter is a useful process for initiating a team and ensuring early successes. Research on teams well documents the tendency of teams to jump into their work too quickly shortchanging the planning process (DeChurch & Haas, 2008; Hackman, Brousseau, & Weiss, 1976; Weingart, 1992), and charters have been shown to be a useful intervention for ensuring the team engages in the needed goal setting, planning, and analysis of the task requisite to success (Marks, Mathieu, & Zaccaro, 2001; Mathieu & Rapp, 2009). Given the increased coordination costs faced by multidisciplinary and/or distributed scientific teams (Cummmings & Kiesler, 2003; Kiesler & Cummings, 2002; Olson & Olson, 2000), chartering would be even more essential to their successful launch. This idea was supported in a study by Asencio et al. (2012) who proposed MTS charters as a way to engage component teams to plan about their global, MTS goals and vision for the project, to plan their workflows, and to put early norms in place that will scaffold an MTS transactive memory system where distinct teams know where expertise lies in other teams, and teams have clear norms and expectations of one another.

Taken together, these findings support policy recommendations that designing interventions for scientific interventions first requires an accurate determination of whether the nature of the work is better suited to a single team, or to a multiteam system. If the latter, then the coupling between teams suggests that interventions need to bolster the processes that have been shown to improve these between team interactions.

Countervailing Forces in MTSs

Countervailing forces are combinations of teamwork processes and properties that operate differently at different levels of analysis (e.g., team cohesion benefits team performance but compromises information sharing between teams). A countervailing force occurs when a process or emergent state has both positive and negative consequences. We define four illustrative types of countervailance, described in Table 4 and depicted in Figure 2. The four types of countervailance can be distinguished along two dimensions. The first dimension is the *level of origin* of the process or emergent state. In MTSs, impactful processes and states can originate at the team level or at the MTS level. For example, a process like coordination reflects the timing and sequencing of interdependent actions, and can emerge as a meaningful construct at both the team and MTS level. *Team* coordination characterizes the timing and sequencing of interactions among the members of a given science team. This same process can emerge at the MTS level, describing the timing and sequencing of interactions "between-teams," the quality of the handoffs among the members of distinct teams.

The second distinguishing dimension of countervailing forces is the nature of the local versus global consequences. This dimension captures the core notion of countervailance where forces, or multilevel processes, counteract one another. We use these four types as illustrations of how forces arising at different levels of analysis, i.e., the team or system, exhibit countervailance. Across types of countervailance, the local (i.e., team level) consequences of a focal process differ from the global (i.e., system level) consequences of that process. Local consequences include the performance and viability of the component teams. Scientific component teams might include individual labs or programs where relatively small groups of individuals pursue shared goals requiring close interaction. Global consequences refer to the performance and viability of the MTS as a whole, describing the extent to which the MTS reaches the goal for which it forms.

The notion of countervailance is pervasive in complexity science. A number of interesting studies have applied complexity thinking to understand the creative output of scientific teams (Guimera, Uzzi, Spiro, & Amaral, 2005; Uzzi, 2008; Uzzi & Spiro, 2008). Threaded in the core logic are notions of countervailance. As an example, Uzzi and Spiro (2008) linked the small world structure of collaboration networks to the creative output of Broadway musical teams. Interestingly, small world structures present two somewhat contradictory properties of social groups: high local clustering and short average path lengths. This unique combination of structural features is actually a solution to two countervailing forces in musical groups: a need for cohesion and a need for connectivity. The small world network enables both – local clustering enables cohesion whereas short average path lengths enable connectivity.

We characterize countervailance into four idealized types. Each of these types captures a specific set of forces that originate and/or manifest as consequences at different levels of analysis. Type I countervailance occurs when a focal process or state originates at the team level (e.g., team cohesion, team coordination, team trust) and is beneficial locally to the team, but harmful globally to the system. An example of Type 1 countervailance was described by Williams (2012) in emergency response MTSs:

> “The data suggest that identification is an important element as MTSs coordinate their activities, but there is a lack of system identification and

instead individuals rely on their strong identification with their profession, team, and organization when responding to emergencies that require multiple team coordination" (Williams, 2012, p. 71)."

DiRosa (2013) provides empirical evidence of Type I countervailence with team cohesion. An abundant literature documents the benefits of cohesion, the degree to which individuals are attracted to the team, for team performance and satisfaction (Mullen & Cooper, 1994). DiRosa measured the levels of cohesion within teams (i.e., platoons) operating as part of larger MTSs (i.e., battalions), and found that the readiness of the MTS was lowest when both team and MTS cohesion were both very high.

Another empirical example of Type I countervailance was reported by Asencio et al. (2013) with communication. Asencio and her colleagues found team communication benefits the formation of team identity, as has been found in prior research. However, team communication suppresses the formation of a multiteam identity, and in doing so, harms MTS viability.

Type II countervailance occurs when a team level process or state has harmful consequences at the team level, to performance or viability, but has benficial effects at he MTS level. An example of this type of countervailance might occur with team competition. Research on teams finds competitive handling of disagreements are harmful to group performance and satisfaction (DeChurch, Mesmer-Magnus, & Doty, in press). However, we might expect that competition within the team creates enough unrest where members are willing to engage with the ideas and suggestions of those outside the team, and be more receptive to the ideas coming from other-disciplined teams. In this case, the competive interactions occurring within teams create countervailing forces whereby the costs to decreased internal cohesion and performance are offset by benefits to cross-team information sharing and idea vetting.

Type III countervailance occurs when a cross-team level process (e.g., MTS identity) has consequences that are beneficial locally, to the team, but harful globally, to the system. An example of a Type III countervailing force was presented by Lanaj et al. (2012). Decentralized planning, the even involvement of multiple members of the team has been found to benefit team performance. However, Lanaj and her colleagues found decentralized planning that emerges at the MTS level, even participation in planning among all members of the MTS, is harmful to MTS performance. The nature of the countervailing forces can be understood by looking at the three mechanisms through which planning affects performance: aspirations, risk seeking, and coordination. Lanaj and her colleagues find decentralized planning has similar motivational benefits (i.e., aspiration effects) at both the team and MTS levels. When looking at the other two mechanisms, however, decentralized planning harms MTS performance by increasing risk taking and dampening coordination. Thus, the motivational benefits of decentralized planning are offset by MTS risk taking and between-team coordination breakdowns. While decentralized planning is harmful globally, decentralized planning is beneficial within teams as members are more engaged in contributing their unique perspectives to the task.

Type IV countervailance occurs when the focal process or state originates at the MTS level, and the consequences of that process are harmful locally to the team but beneficial globally to the MTS. An example of Type IV countervailance was provided by Asencio et al. (2013) who found that very high amounts of between-team communication were harmful to the formation of team identity, but beneficial to the formation of system identity. Hence a multiteam process (i.e., communication) is harmful locally to teams, but beneficial globally to the system.

Much of the research on MTSs to invoke the countervailing forces we describe exhibit the form: “things you thought were good that are actually bad.” As the example with team conflict illustrates, there are likely additional processes of the form: “things you thought were bad that can actually be good.” We pose this as a particularly fruitful area of future research for multiteam systems in science where conflict and competition may stimulate a desire to “win” that while harmful locally, incurs benefits at the system level.

Research on MTS countervailance is currently too nascent to support evidence-based policy recommendations for team science, though the initial findings clearly point to the importance of considering the complex effects of team science interventions occurring at both the team and MTS level. This represents the most critical area in need of future research.

Implications and Future Research Needs

The findings from MTS research have much to say about the optimal design and development of scientific collectives. This paper has summarized two major themes in this work, and identified some important new directions. We can summarize these themes in meta-propositions. First, the notion of confluent forces launched MTS research with the initial observation that the dynamics occurring between teams are often more important to the ultimate success or failure of MTSs than are the dynamics occurring within them. Hence, the first meta-proposition is that:

Proposition 1. In multidisciplinary MTSs, overall MTS effectiveness is jointly determined by processes commencing both within and between teams.

An important implication for team science stemming from this first meta-proposition is that it is important to distinguish science teams from scientific MTSs. The optimal workflow for the two collectives differs, and so interventions aimed at maximizing investments in scientific collectives need to consider the extent to which the work is and should be performed by a team or a multiteam system. It is useful to distinguish multidisciplinary teams from multidisciplinary MTSs based on the four aspects of entitativity: common fate, similarity, proximity, and boundary reinforcement.

All four of these core aspects of entitativity are more easily created and maintained in smaller as compared to larger groups. However, the need for social groups to remain small is often at odds with the needs of science to be interdisciplinary. As was well articulated by Hall and her colleagues, "the degree of complexity of a given problem that a team tackles can, in turn, influence the breadth and degree of the integration of disciplinary knowledge needed to explain or solve that problem (p. S243)." Thus, the key decision rule to be applied when choosing to build science teams versus scientific MTSs should be the nature of the scientific problem at hand. The MTS lens is helpful in understanding how to build well-functioning collectives when creating small teams is simply not a good match to the nature of the problem.

More recently, research on MTSs has embraced the idea of unintended consequences, and begun to investigate the potential negative consequences of processes previously found to be beneficial in teams (e.g., decentralized planning, communication).

This line of thought suggests two additional meta-propositions in need of testing within scientific MTSs:

Proposition 2. In multidisciplinary MTSs, some interaction processes are beneficial locally (i.e., supporting team performance and viability) but harmful globally (i.e., undermining system performance and viability).

Proposition 3. In multidisciplinary MTSs, some interaction processes are harmful locally (i.e., undermining team performance and viability) but beneficial globally (i.e., supporting system performance and viability).

Science teams are formed to address the "inherent complexity of contemporary public, health, environmental, political, and policy challenges (Stokols, Misra, Moser, Hall, & Taylor, 2008)". Such teams typically exist as social entities for long periods of time. Often, science teams are comprised of experts from distinct fields, and team members collaborate across multiple geographical and organizational boundaries (Stokols et al., 2008). Science teams are conceptualized broadly as large-scale teams tasked with analyzing research questions about a particular phenomena (Hall, Feng, Moser, Stokols, & Taylor, 2008). Typically, the phenomenon or problem under study requires the unique knowledge and approaches brought to bear by the different disciplines. This paper has outlined a perspective and set of findings that underscore the need to differentiate scientific teams from scientific mutliteam systems, and to match interventions and evaluations to the appropriate set of evidence about the functioning of the collective. MTSs function differently than teams in many ways, and similarly in others.

A landmark paper from the Human Genome Project (HGP) published in Nature in 2008 had 46 authors (McKernan et al., 2009). Beyond the scientific merits of the HGP, the HGP was an organizational success, one built upon complex and iterative coordination and ideation among a great many distinct teams pursing both local and global goals. The HGP manuscript had 46 co-authors representing a small subset of those whose creative and other inputs ultimately yielded the success presented in the published article. Many of the prescriptions arising from the literature on small teams are at best untenable and at worst ruinous to the functioning of a collective this large. The HGP was a scientific multiteam system.

Table 1.

Dimensions of MTS Characteristics

Compositional Attributes

- *Number*: Number of component teams within the MTS
- *Size*: Total number of individual members across teams
- *Boundary status*: component teams come from single organization (internal) versus multiple organizations (cross-boundary)
    - *Organizational diversity*: In a cross-boundary MTS, the number of different organizations represented among the component teams
    - *Proportional membership*: In a cross-boundary MTS, the percentage of teams from different organizations
- *Functional diversity*: Degree of heterogeneity in the core purposes and missions of component teams
- *Geographic dispersion*: co-located or dispersed component teams
- *Cultural diversity*: degree to which component teams come from different nations/cultures
- *Motive structure*: degree of commitment of each component team to the MTS; the compatibility of team goals and MTS goals
- *Temporal orientation:* level of effort and temporal resources expected of each component team

Linkage Attributes

- *Interdependence*: degree of integrated coordination (e.g., input, process, outcome) among members of different component teams
- *Hierarchical arrangement*: ordering of teams according to levels of responsibility
- *Power distribution*: the relative influence of teams within the MTS
- *Communication:*
    - *Structure*: the typical patterns of interteam communication
    - *Modality*: the modes of communication (e.g., electronic, face-to-face, mixed) that occur across component teams)

Developmental Attributes

- *Genesis*: the initial formation of an MTS as either appointed or emergent
    - *Direction of development*: from emergent to formalized; an evolution from an early formal state
- *Tenure*: the anticipated duration of the MTS
- *Stage*: the stage of MTS development from newly formed to mature
- *Transformation of system composition*
    - *Membership constancy*: fluidity versus constancy of component teams as members
    - *Linkage constancy*: fluidity versus constancy of linkages among component teams

From: Zaccaro, S. J., Marks, M. A., & DeChurch, L. A. (2012). Multiteam systems: An introduction. In S. J. Zaccaro, M. A. Marks, & L. A. DeChurch (Eds), *Multiteam systems: An organization form for dynamic and complex environments* (pp. 3-32). New York: Routledge. Permission pending

Table 2.

Types of Scientific Multiteam Systems based on Boundary Status and Functional Diversity

	MTS Boundary Status	
	Single Organization	Multiple Embedding Organizations
MTS Functional Diversity – Teams Drawn From:		
Single Discipline	Multiple teams (labs) from a single or very closely related discipline(s) working on particular aspects of a larger scientific problem; all teams work within the same organization ***Examples***: Internal scientific collectives found within agencies such as NIH, NASA, DoD	Multiple teams (labs) from a single or very closely related discipline(s) working on particular aspects of a larger scientific problem; teams are working at a minimum of two organizations ***Examples***: Partnerships between agencies such as NIH, NASA, DoD; collaborations between academia and industry
Multiple Disciplines	Multiple teams (labs) from different disciplines working on particular aspects of a larger scientific problem; all teams work within the same organization ***Examples***: Centers and Institutes at Universities	Multiple teams (labs) from different disciplines working on particular aspects of a larger scientific problem; teams are working at a minimum of two organizations ***Examples***: Research teams from multiple universities who work on collaborative grants

Table 3.

Focal Research Areas on Teams and Multiteam Systems

	Consequence Level of Analysis: Team Level	Consequence Level of Analysis: MTS Level
	Team Level Predictors (Processes & Emergent States)	
Team-Level Process	**Research Area 1:** Extant research on small teams linking team process to team outcomes (single-level)	**Research Area 2:** Impact of team processes on MTS outcomes
Exemplar Studies	See reviews by Kozlowski & Ilgen, 2006; Mathieu et al., 2007	Asencio et al., 2013
Research Maturity; Fit with Framework	Mature; Extensively meta-analyzed	Nascent; Countervailance Types I and II
	MTS Level Predictors (Processes & Emergent States)	
MTS-Level Process	**Research Area 3:** Impact of MTS process on team outcomes	**Research Area 4:** Extant research on MTS linking between-team processes to multiteam outcomes (single level)
Exemplar Studies	Asencio et al., 2013	Marks et al., 2005; DeChurch & Marks, 2006; Davison et al., 2012
Research Maturity; Fit with Framework	Nascent; Countervailance Types III and IV	Developing; Steady stream of primary empirical studies; Confluence

Table 4.

Four Types of Countervailance in Multiteam Systems (Research in Areas 2 & 3)

Level of Origin of the Process or State	**Consequences are beneficial locally but harmful globally**	**Consequences are harmful locally but beneficial globally**
Manifests at the team level	Type I	Type II
Manifests at the MTS level	Type III	Type IV

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Figure 1.

Focal Relationships Examined within Four Areas of Research on Teams and Multiteam Systems

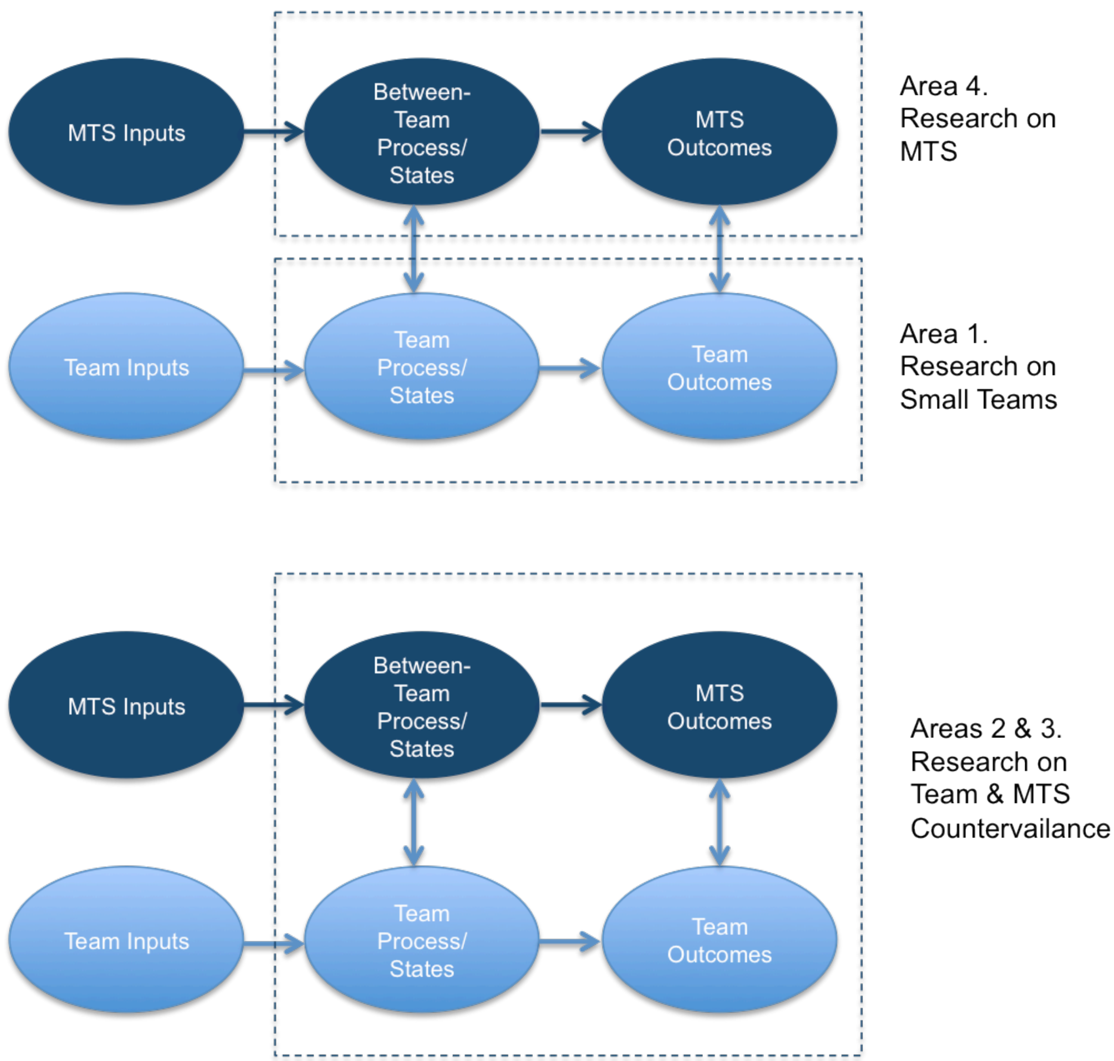

Figure 2.

Illustration of the Relationships Involved in Type I - IV Countervailance