Who gets what, when, and how? An analysis of stakeholder interests and conflicts in and around Big Science

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4. Big Science, Big Trouble? Understanding Conflict in and around Big Science Projects and Networks

Chapter four was published as Anna-Lena Rüland (2023) "Big Science, Big Trouble? Understanding Conflict in and Around Big Science Projects and Networks" in *Minerva.*[6] By proposing a model of conflict emergence in and around Big Science as well as providing a proof of concept for its validity, chapter four helps explain how conflicts arise between and among stakeholders as they pursue their respective interests in large scientific collaborations. In doing so, the chapter attends to the thesis' second research objective of deepening our understanding of how conflicts arise between and among Big Science stakeholders. The chapter contributes a holistic perspective of conflict emergence at the state and/or community level and thus combines the two levels of analysis that were examined separately in chapter two and three.

4.1. Introduction

Recently, interest in Big Science has surged, among other things because it is increasingly seen as a means to help address some of the grand challenges of our time (Börner et al., 2021). In the pertinent literature, the term Big Science usually refers to large-scale technical projects that

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are "physically bound to a single infrastructural site" (Hallonsten, 2016: 19), serve clearly defined ends, and are operated by big teams of scientists and/or engineers (Hallonsten, 2020: 631). However, since not all large-scale science installations are physically bound to a single site, this article introduces the term Big Science network to describe massive science projects which are geographically dispersed and provide infrastructures, resources, or services for top-level research.

For political and scientific stakeholders, both types of Big Science depict a significant and long-term economic investment (Brown and Malone, 2004: 114) that has the potential to enhance or harm their prestige (Williams and Mauduit, 2020; Office of Technology Assessment, 1995; Krige, 2013; McCray, 2010; Riordan et al., 2015) and ability to define science and policy agendas for the coming years. Both from a policy and scholarly perspective, understanding conflicts in Big Science is of utmost importance. Conflicts over sites, resources, scientific objectives, and/or credit have the potential to disrupt or completely derail these undertakings. A failure to adequately address conflicts in and around Big Science projects and networks, such as SKA, ITER, ESS, HBP, or TMT, could cost taxpayers millions of euros and cause serious damage to the public perception of large-scale science collaboration. While the literature on science collaboration and Big Science has investigated conflict causes, it has neglected to outline which specific mechanisms connect conflict cause and outbreak. This study addresses this blind spot by developing a model which explains how conflicts emerge in Big Science projects and networks by drawing on the scholarship on strategic action fields (SAFs). The model holds that five interlinked mechanisms—attribution of threat or opportunity, mobilization of resources, coalition-building, boundary deactivation, and innovative action—drive conflict emergence in and around Big Science. To provide a proof of concept for the model's validity, it is applied to three typical, yet most-different, cases of Big Science, namely ITER, HBP, and TMT.

By opening the black box between conflict cause and outbreak, the model adds value to existing scholarship on science collaboration, which is generally less interested in conflicts as such than in their effects on knowledge creation (Knorr Cetina, 1999; Traweek, 2009) or the longevity of scientific cooperation (Ulnicane, 2015). Understanding which mechanisms fuel conflict, however, is vital for conflict prevention and mitigation. The model proposed here can contribute to both since some of its mechanisms are observable and can therefore function as early warning signs to science managers.

The remainder of this article is structured as follows: First, in section 4.2., I develop a model that helps explain which mechanisms link conflict cause and outbreak in Big Science. I review the interdisciplinary literature on science collaboration and Big Science to identify major conflict causes in scientific projects. Using insights from SAF scholarship, I then propose mechanisms that connect conflict cause and outbreak. In section 4.3., I detail the methods which I use to apply the model to three case studies in section 4.4., 4.5., and 4.6. Next, in section 4.7., I discuss the findings of the case study analysis. Finally, in section 4.8., I conclude by pointing out the study's implications for management, limitations, and future avenues for research.

4.2. Towards a Mechanism-Based Model of Conflict Emergence in Big Science

In this study, the term conflict refers to open as opposed to latent or surface conflict. It is defined as a *visible* struggle between at least two parties that either perceive or have mutually exclusive goals and experience strong interference from others in achieving said goals (Hocker and Wilmot, 1978: 9; Fisher et al., 2000). In Big Science, conflict can occur at three different levels. It may develop at the interpersonal (micro) level, at the group (meso) level and/or at the state (macro) level. In this article, I will focus on the latter two because conflicts at the meso and macro level have the biggest potential to impact public support and perception of Big Science as well as its success. As Shrum et al. (2001) argue in their seminal study on trust and conflict in science collaboration, it is less likely that interpersonal conflict affects a collaboration as a whole (p. 689). If big parts of a local community reject and protest Big Science, however, public support for it may dwindle. A project or network may similarly fail if an entire group of scientists or managerial staff decides to leave a collaboration in the aftermath of conflict. Finally, a Big Science collaboration may never materialize if conflict erodes high-level political support.

To propose a model that connects conflict cause and outbreak in Big Science via a chain of mechanisms, it is necessary to first identify potential conflict causes. It is essential to consult literature on science collaboration *and* Big Science on this issue because Big Science collaborations are essentially conventional research projects made big on three dimensions, namely "organizations, machines, and politics" (Cramer et al., 2020: 10).

4.2.1. Conflict Causes in Science Collaborations and Big Science

At the meso level, conflicts in science collaboration and Big Science are most likely to arise over issues concerning funding, management, and organization, work and task division, research objectives, access to scientific resources and instruments as well as the distribution of scientific rewards (Knorr Cetina, 1999; Shrum et al., 2001; Traweek, 2009; Vasconcellos, 1990; D'Ippolito and Rüling, 2019; Cook-Deegan, 1994; Riordan et al., 2015) (see also Table 1 in the Appendix). At the macro level, issues concerning siting, financial contributions, scientific access, and procurement are seen to be the main conflict causes (Åberg, 2021; Krige, 2013; McCray, 2010; Williams and Mauduit, 2020; Arnoux and Jacquinot, 2006; Claessens, 2020) (see also Table 2 in the Appendix). According to Hallonsten (2014), all of these issues are most likely to create conflict between states, their representatives and/or funding agencies during the planning phase of a Big Science project or network, as this stage is generally considered the "trickiest" (p. 35). However, most of these conflicts, whether they develop at the meso or macro level, tend to be on the surface or remain latent. Reflecting this, the literature on science collaboration and Big Science rarely uses the term "conflict." Instead, it speaks of "tensions," "divisions," or "disagreements" in and around science collaboration and Big Science. For instance, in the case of the Human Genome Project (HGP), Hilgartner (1995) states that some critics of the HGP were "concerned" about "resource allocation" and "questioned whether the data produced by sequencing entire genomes would in fact be useful" (p. 303). In a similar vein, Mahfoud (2021) underlines that there were "disagreements between computational neuroscientists" before HBP had been selected as a European Future and Emerging Technology (FET) flagship (p. 333). The disagreements that Mahfoud describes specifically concerned the question of "what structural details could be excluded from neuron models without affecting the functional output" (p. 333). In the case of ITER, McCray (2010) stresses that there were "disagreements" over ITER's location. He shows how ITER site proposals from Canada, Spain, France, and Japan led to tensions between these contenders.

This does not mean, however, that open conflict does not develop in Big Science projects and networks. In the case of ITER, HGP, HBP, and TMT open conflict did in fact arise. It only did so, however, once a decision affecting or concerning a major project or network component (i.e. siting, scientific approach, or management) had been taken or was about to be made. For example, in the case of HGP, open conflict erupted when US commercial actors decided to directly challenge the HGP's open science strategy by starting a genome sequencing effort with the objective of patenting genes (Lambright, 2002: 20 ff.). In the case of HBP, open conflict emerged once the HBP leadership had decided to exclude the subproject on cognitive architectures from HBP's core funding (Mahfoud, 2021: 334). With regards to ITER's site, McCray's study shows that open conflict arose in 2003 when two site finalists were left and a decision concerning the reactor site was imminent (Claessens, 2020; McCray, 2010). Media reporting on TMT likewise indicates that open conflict between the international TMT consortium, consisting of US, Chinese, and Japanese research institutions as well as Canadian and Indian quasi-governmental agencies, and parts of the local and Native Hawaiian population was brought about by the consortium's decision to build TMT on Mauna Kea, Hawai'i Island (Overbye, 2016; Feder, 2019). Based on these insights from the science collaboration and Big Science literature, I therefore argue that the *immediate* cause of open conflict in and around Big Science is an imminent or executed decision that affects or concerns a major project or network component.

4.2.2. Opening the Black Box between Conflict Cause and Outbreak

Descriptions and explanations of why conflicts arise in Big Science are abundant in the pertinent literature. The specific mechanisms that link conflict cause and outbreak, however, remain opaque. There are two reasons for this. First, in the literature on science collaboration, conflictual episodes are typically only mentioned insofar as they are seen as an obstacle that scientific communities need to overcome to cooperate more effectively or to create new knowledge (Galison, 1997; Knorr Cetina, 1999; Ulnicane, 2015). Second, in the literature on Big Science, there is a general lack of "systematic comparative analyses" (Rüffin, 2020: 41-42) and of theory-building, including on critical phenomena such as conflict emergence.

A strand of scholarship able to open the black box of conflict emergence is that on SAFs. This type of scholarship is, among other things, concerned with the question of how contention arises in SAFs. SAFs are meso level social orders, in which different social actors vie for power. Building on social movement and institutional theory as well as Gidden's (1984) theory on structuration and Bourdieu's (1975) concept of the field (Kauppinen et al., 2017: 798), SAF theory identifies three interlinked mechanisms that are responsible for the onset of contention in SAFs (Fligstein and McAdam, 2012: 20). It is assumed that contention emerges if actors in a SAF:

1. Define an action as a threat to, or opportunity for, the realization of their interests (Fligstein and McAdam, 2012: 20);

2. Mobilize their resources, and
3. Use innovative forms of action to defend or push their agenda.

Initially, SAF scholarship focused on the analysis of social movement-like episodes of contention, such as the emergence of the civil rights movement in the US (Fligstein and McAdam, 2012: 115 ff.). More recent studies, however, have demonstrated that SAF theory also lends itself to the analysis of contentious episodes that have less in common with social movements, for instance developments in science policy. Even though Big Science is a high-stake science policy area, insights from the SAF scholarship have not yet been used to analyze phenomena in Big Science projects or networks. However, scholars have applied SAF theory to study more recent macro and meso level developments in science policy, such as the emergence of the European Research Area (Kauppinen et al., 2017) or the move of US academic science toward the market (Berman, 2014). Some of these scholars have contributed to the existing scholarship on SAFs by proposing additional mechanisms that set off contention in meso level social orders. For instance, in their study, Kauppinen et al. (2017) argue that the original mechanisms put forward in the SAF scholarship should be complemented by additional ones, among them coalition formation and boundary deactivation. Kauppinen et al. (2017) see coalition formation as "a mechanism through which [actors] are brought together" (p. 806). They understand boundary deactivation to be a mechanism that renders a boundary less salient "as an organizer of social relations on either side of it, of social relations across it, or of shared representations on either side" (Tilly, 2004: 223). Coupled with the existing mechanisms in the scholarship on SAFs, coalition formation and boundary deactivation contribute to a more nuanced understanding of contention in SAFs, including in science policy.

Given that Big Science projects and networks often bring several hundred if not thousands of people together to collaborate on a common scientific objective and are embedded in local communities (Börner et al., 2021), this study views them as SAFs. Mechanisms which SAF scholarship has identified as drivers of contention are therefore hypothesized to also play a role in conflict emergence in Big Science. Building on the above review of conflict causes in science collaboration and Big Science, this study moreover assumes that a(n) (imminent) decision affecting or concerning a major project or network component causes conflict in Big Science projects and networks. Taking these two assumptions as a starting point, it is possible to propose a mechanism-based model of conflict emergence in Big Science.

Central to the model on offer here are five mechanisms—attribution of threat or opportunity, resource mobilization, coalition building, boundary deactivation, and innovative action (compare Figure 1). They are seen to work as a link between conflict cause (imminent or executed decision affecting a major project or network component) and outcome (conflict outbreak). Drawing on SAF scholarship, the model contends that a(n) (imminent) decision affecting or concerning a major project or network component typically leads to two reactions among stakeholders. Either they perceive it as a threat, for example because stakeholders feel it jeopardizes their interests, or they consider it an opportunity to push their agenda, most likely at the expense of another stakeholder. This does not mean, however, that every threat or opportunity will lead to conflict. In fact, a certain level of jockeying for power is to be expected in and around Big Science without it necessarily leading to open conflict. A threat or opportunity will set off a range of mechanisms that eventually lead to open conflict if a threat is perceived as "existential" or an opportunity is considered "too good to pass." What I mean by this is that in both cases the risks of a wait-and-see approach far outweigh the costs of taking action. Whenever this is the case, stakeholders are likely to mobilize their social, political, or economic resources to defend or push their respective agenda. The mobilization of resources, in turn—particularly the activation of social networks—facilitates coalition-building. Such coalition-building is crucial for stakeholders who perceive a threat to or opportunity for their interests because the more actors they can rally behind their cause, the likelier it will be taken notice of and acted upon. In some cases, this may also require them to find allies outside their own field. To do so, stakeholder may have to deactivate boundaries between fields with different norms, routines, and purposes. For example, scientists may lobby high-level policymakers to push their cause. Boundary deactivation frees actors of some normative constraints of their own field, which may facilitate innovative action. Such innovative action consists of disruptive tactics, where disruptiveness implies that a chosen tactic breaks with previous conventions within a particular field or creates moments of genuine surprise. Typically, the more disruptive the tactics, the more attention they will generate for the actors using them. Attention, particularly from a broad and diverse audience, in turn, is crucial because it creates a stage that actors can use to argue their case. In doing so, they may employ tactics ranging from framing, publicly naming and shaming to withholding agreed upon project or network funds. Ultimately, such tactics accelerate the emergence of open conflict because they enable actors to actively interfere with another actor's objectives.

It should be noted that this process is not necessarily a linear one. Actors may, for example, fail to build a strong coalition, which may then require them to “fall back” on a previous mechanism. If coalition building has proven fruitless, for instance, actors may have to activate resources that they had not mobilized before.

The model depicted in Figure 1 is a condensed and simplified depiction of the mechanisms that connect conflict cause and outbreak. This strategy limits the model in the sense that it is unlikely to capture the empirical reality of conflict in all its nuances and messiness. For example, it may fail to uncover incremental mechanisms that lay in between the five proposed mechanisms. Yet condensation and simplification are needed to propose a model that is applicable beyond a single case.

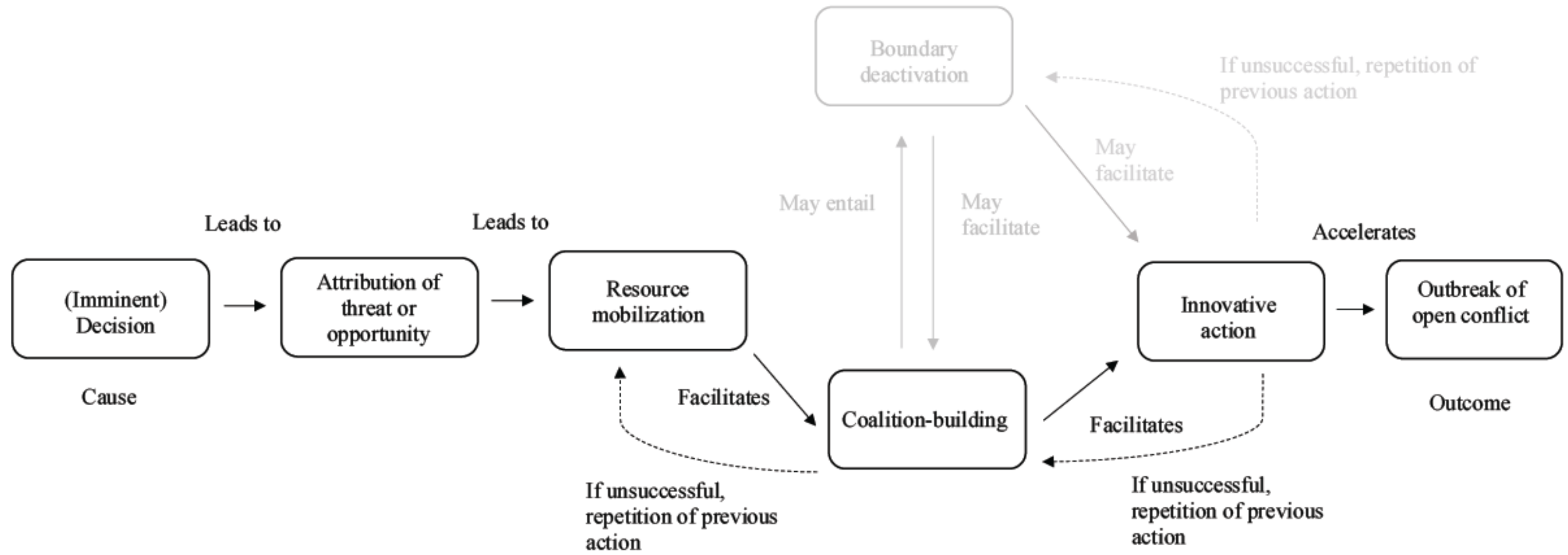

Figure 1: Model of conflict emergence

4.3. Methods and Data

This paper uses theory-testing process tracing to examine whether the proposed mechanism-based model holds in three typical, yet most-different, cases. Theory-testing process tracing lends itself for this purpose as its objective is to assess "whether hypothesized mechanisms are to be found between cause and outcome" (Beach and Brun Pedersen, 2013: 146). Checking whether such mechanisms are present necessitates two basic steps. First, it is important to specify which mechanisms plausibly link cause and outcome, for example by developing a model based on insights from the theoretical and empirical literature, as was done in section 2. Second, it is necessary to operationalize these mechanisms. To do so, mechanisms need to be rendered measurable, for instance by specifying their observable manifestations (compare Figure 2). This allows us to "examine the empirical fingerprints that the mechanisms should have left in the empirical material" (Beach and Pedersen, 2016: 93). By tracing these "fingerprints," we gain a more in-depth understanding of how cause and outcome are connected.

The objective of theory-testing process tracing is to examine whether hypothesized mechanisms exist in a small number of cases (Beach and Pedersen, 2016: 319). In the theory-testing variant of process tracing, several criteria guide case selection. First, only such cases where both cause and outcome are present can be considered (Beach and Brun Pedersen, 2013: 147). Second, in theory-testing process tracing, it is useful to choose cases that are at least partly documented in the literature as this allows "to move research to a context in which it is (…) possible to observe the workings of the mechanisms in (…) empirical detail" (Beach and Pedersen, 2016: 324). Third, to draw cautious generalizations, it is useful to select typical, yet most-different, cases from a relatively homogeneous population. A case is considered typical if it is representative of a broader set of cases (Gerring, 2007: 91). Two cases are most-different if they differ on all dimensions aside from cause and outcome (Gerring, 2009: 672).

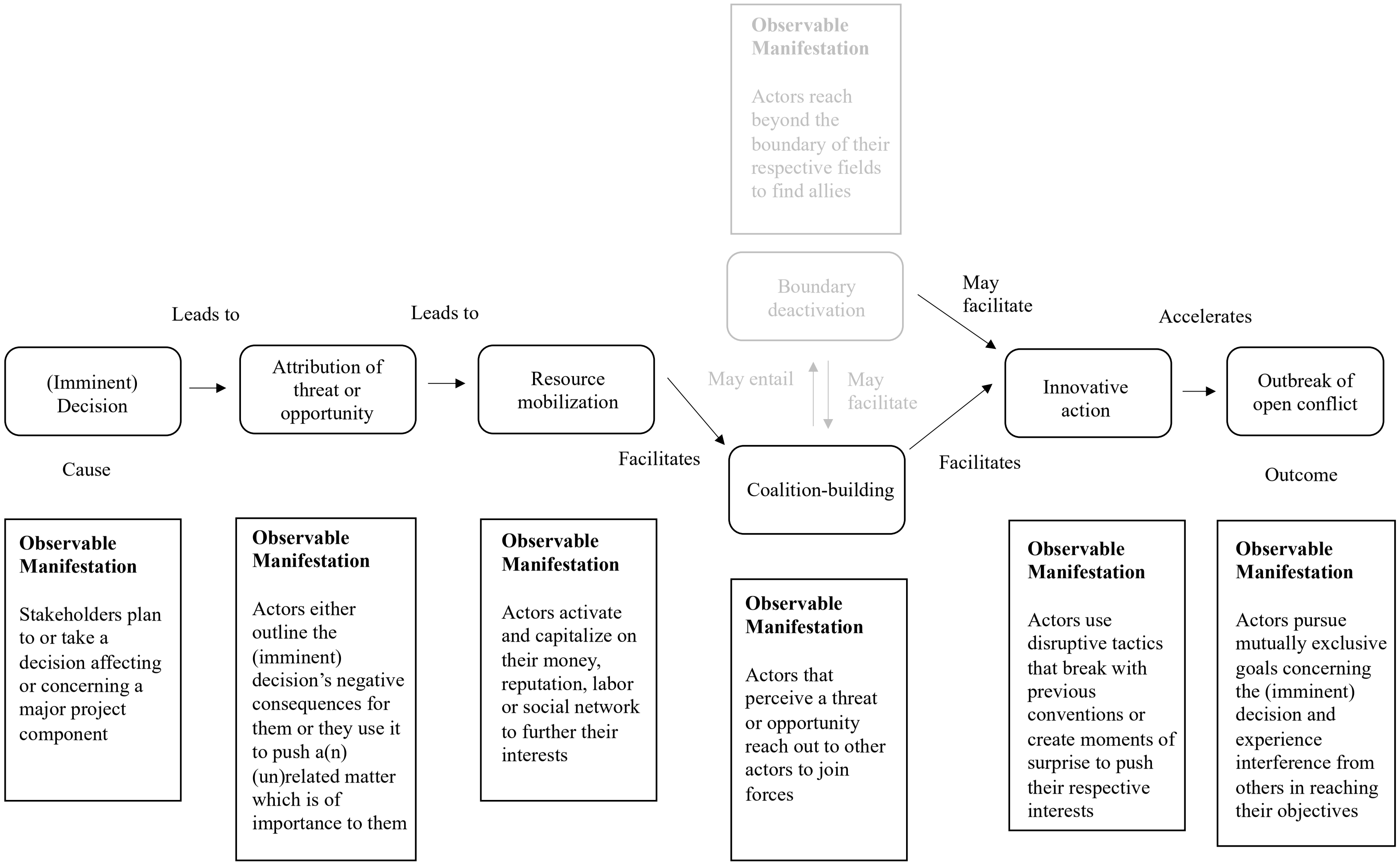

Figure 2: Operationalized model of conflict emergence

These criteria apply to ITER, HBP, and TMT. First, all three cases have lived through at least one episode of open conflict. In line with an embedded case study design, I focus on one particular instance of conflict within all cases (Yin, 2003). For each case, I selected an instance of "archetypal" conflict. With archetypal conflicts I mean such conflicts that can be traced back to a cause that the literature has identified as one of the most common conflict causes in science collaborations. Concentrating on one instance of archetypal conflict helps focus the case study inquiry (Yin, 2003: 45) and could potentially generate useful findings for practitioners because although these conflicts appear time and again, policymakers and managers seem to struggle to anticipate or to adequately address these conflicts before they escalate. In the case of ITER and TMT, I focus on site conflicts. In the case of HBP, I concentrate on the conflict that ensued over the network's funds, scientific approach, and management after one of its subprojects had been excluded from HBP core funding. Second, ITER, HBP, and TMT, including the conflictual episodes embedded in the cases, are sufficiently documented in the academic and/or grey literature. Drawing on insights from this literature, it is possible to trace the workings of the hypothesized mechanisms. Finally, choosing ITER, HBP, and TMT as case studies makes sense because they depict typical, yet most different, cases from the rather restricted population of Big Science projects and networks. Generally, Big Science can be divided into two main subtypes (compare Table 6). Big Science projects are "bound to a single infrastructural site" (Hallonsten 2016: 19) because they need one or several physical instrument(s) (i.e. a reactor) to attain their scientific objective. Big Science networks, in contrast, are geographically distributed projects that do not need such a physical instrument to attain their research objective. Thus, Big Science most commonly differs on two dimensions: its degree of centrality (high or low) and whether it needs a physical instrument to attain its objective (yes or no). ITER and TMT depict typical cases of a Big Science project, which is bound to a specific site and needs an instrument to obtain its objective. HBP, in contrast, is a typical case of a Big Science network. It does not need a physical facility to achieve its objective of building a digital research infrastructure for neuroscientists and is decentralized, as more than 150 institutes across Europe are part of it. At the same time, ITER, TMT, and HBP are most-different cases. They differ on all dimensions (e.g. funding, governance, objective) aside from cause and outcome.

Table 6: Big Science subtypes

Degree of Centralization		In Need of Physical Instrument?	
		No	Yes
	High		ITER, TMT
	Low	HBP	

For the two in-depth case studies of conflict in ITER and HBP, a variety of independent sources, such as academic papers, newspaper articles, and government records, formed the basis for theory-testing process tracing (for an overview see Table 3 in the Appendix). These non-reactive sources were complemented by 25 semi-structured expert interviews which were conducted between April and July 2021 via Microsoft Teams. Each interview was recorded, manually transcribed, and analyzed using MAXQDA. 25 interviews were conducted with scientists, science managers, or policymakers that are or were at some point involved in ITER or HBP (see Table 7) and guided by an interview guideline.[7] Questions that were included in this guideline touched on three main themes. A first set of questions concerned the interviewee's personal background and role in ITER or HBP. A second block of questions targeted a specific conflictual episode in ITER or HBP, which had previously been identified from the academic and grey literature. Questions included in this second block focused on the conflict sources, parties, settlements, and outcomes. Finally, a third group of questions concentrated on potential conflict mitigation strategies for Big Science projects and networks. In contrast to the in-depth case studies of conflict in ITER and HBP, the cursory analysis of conflict around TMT is mainly informed by three interviews that were conducted with Native Hawaiians between October and November 2022.

[7] Interviews were conducted in English, German, or French. Quotes (in italic) from interview transcripts were translated by the author. Twenty-four of the interviews were conducted specifically for this article; one interview was conducted as part of a European Research Council-funded project. This interview was kindly made available for this article by the project's Principal Investigator.

Table 7: Overview of interviews conducted for chapter four

Interviewee Code	Project	Affiliation*	Length of Recording
INT01	HBP	European Commission	36 minutes
INT02	HBP	HBP Management	51 minutes
INT03	HBP	HBP Mediation Committee	46 minutes
INT04	HBP	HBP Steering Committee	87 minutes
INT05	HBP	HBP Leadership	116 minutes
INT06	HBP	HBP Leadership	31 minutes
INT07	HBP	HBP Management	81 minutes
INT08	HBP	HBP Mediation Committee	40 minutes
INT09	HBP	HBP Mediation Committee	29 minutes
INT10	HBP	HBP Advisory Board	74 minutes
INT11	HBP	European Commission	76 minutes
INT12	ITER	Fusion for Energy	56 minutes
INT13	ITER	Max-Planck-Institute for Plasma Physics	70 minutes
INT14	ITER	ITER International Organization	71 minutes
INT15	ITER	ITER Council	56 minutes
INT16	ITER	European Commission	70 minutes
INT17	ITER	Fusion for Energy	84 minutes
INT18	ITER	ITER International Organization	45 minutes
INT19	ITER	ITER Japan Home Team	50 minutes
INT20	ITER	Max-Planck-Institute for Plasma Physics	Written communication
INT21	ITER	Fusion for Energy	72 minutes
INT22	ITER	ITER International Organization	57 minutes
INT23	ITER	European Commission	63 minutes
INT24	ITER	European Commission	101 minutes
INT25	ITER	ITER International Organization	73 minutes
INT26	TMT	Local Community	131 minutes
INT27	TMT	Local Community	49 minutes
INT28	TMT	Local Community	45 minutes

**Past or present*

4.4. Case Study I: HBP

4.4.1. Background

HBP is a five hundred million-euro Big Science network at the intersection of neuroscience and ICT which the European Commission (EC) selected as a flagship in the FET competition in 2013. From the very beginning of this competition, HBP was presented as an innovative project which would bring the two fields of neuroscience and ICT together (European Commission, 2011). Prior to the inception of HBP, European research at the intersection of neuroscience and ICT was organized in multiple "blue-sky"-type projects of small to moderate size. Henry Markram—one of the main proponents of HBP and later the project's scientific director—considered this approach inadequate for the advancement of the two fields. He tried to persuade his colleagues to pursue *"one big approach"* (INT04). For Markram, this approach meant building "a single, unified model" of the brain (Mahfoud, 2021: 323). Not all his colleagues, however, welcomed this proposal. Some of them were interviewed for this study and stated that they valued *"diversity in interdisciplinarity"* (INT04), which for them meant that researchers follow different research questions and approaches in several smaller projects. Yet, despite this initial skepticism towards Markram's vision, in 2011, the EC Directorate General Communications Networks, Content, and Technology (DG Connect) awarded him with one million euros in the FET preselection phase to create a proof of concept for HBP (INT01).

Together with his two main campaigners, Karlheinz Meier and Richard Frackowiak, Markram invested a great deal of energy to find as many allies in the neuroscience community for HBP as possible (INT06). To get renowned colleagues on board, he presented HBP as an inclusive project which would be able to accommodate the whole bandwidth of the fragmented neuroscience field (Hummel, 2015). HBP proponents also mobilized considerable resources to get this message across to the FET selection committee in the proof of concept. A professional writer and marketing specialist were hired to support scientists in the writing process (INT04; INT07). In addition, the EPFL hosted some of the scientists it considered key for the HBP for several months and ensured they could work on the flagship proposal uninterrupted (INT04). As a result, these scientists were able to write an extremely dense roadmap for HBP, which ultimately convinced the FET selection committee (INT08).

The approach Markram was planning to pursue in HBP not only persuaded the FET selection committee; it also inspired many of his fellow neuroscience colleagues. A former HBP advisory board member who was interviewed for this paper said that many of them were convinced that the HBP would "*usher in a new age of neuroscience research*" (INT10). At the same time, some scientists in the European neuroscience community were skeptical that HBP would attain its ambitious goal of simulating the brain, particularly within the comparably short timeframe (10 years) it would receive funding from the EC. Others considered its scientific focus "overly narrow" (Horgan, 2013). Ultimately, both groups of critics were concerned that the HBP would turn out to be "a waste of public money" (own translation; Schnabel and Rauner, 2013). Their concerns grew even stronger once it was announced that the EC would only contribute half of the originally pledged one billion euro for the flagships (Schnabel and Rauner, 2013). Previous studies have shown that such concerns related to the costs of Big Science undertakings are prone to arise among researchers that work in the prospective project's or network's field (see: Arnoux and Jacquinot, 2006; Lambright, 2002; Newton and Slesnick, 1990; Riordan et al., 2015). Sometimes, they can even accelerate the demise of a Big Science project (Ellis, 2019). Yet, in case of HBP, conflicts over funding issues remained largely latent, at least until the HBP leadership decided to remove the neuroscience subproject from HBP core funding, triggering open conflict.

4.4.2. The Emergence of Conflict

The decision to exclude the neuroscience subproject from HBP core funding was first taken by the HBP leadership in March 2014 (Destexhe, 2021: 2) and then officially announced in a Framework Proposal Agreement for a second round of EC funding in June 2014 (Neurofuture.eu, 2014). For HBP neuroscience researchers, it depicted a financial threat because it effectively meant that they lost access to HBP grant money. Neuroscientists inside and outside HBP also saw the decision as an epistemological threat. Since the HBP leadership presented the project as the "*future way of conducting neuroscience research*" (INT08), being excluded from HBP led neuroscientists to believe that they would have less of an impact on the future of their research field. Thus, for them, the very "*definition of what neuroscience is and what it means*" was at stake (INT07).

In July 2014, a month after the decision to exclude the neuroscience subproject from HBP core funding was announced, neuroscientists from across Europe and Israel clearly expressed this view in an open message to the EC—which has come to be known as "the open letter" (Mahfoud, 2021). In this message, they criticized the quality and implementation of HBP as well as "the lack of flexibility and openness of the consortium" (Neurofuture.eu, 2014). This latter point of criticism stemmed from the fact that during the HBP's ramp-up phase, Markam and his colleagues, Meier and Frackowiak, formed the project's Executive Committee, filled most of the instrumental positions of the HBP governance bodies, and controlled the Board of Directors, which depended on their votes to reach a two-thirds majority to take decisions (Marquardt, 2015: 8). Similar to early critics of HBP, the authors of the open message moreover suggested that the money allocated to HBP might be better spent on "individual investigator-driven grants" (Neurofuture.eu, 2014), implying that the EC's support of a single neuroscience flagship could threaten the funding of "much needed," more diverse European neuroscience research (Neurofuture.eu, 2014).

Despite such strong criticism, policymakers from DG Connect continued to support the HBP leadership in the immediate aftermath of the letter's publication. In a blogpost from July 2014, the Director General of DG Connect specified that there is "no single roadmap for understanding the brain" and that a certain level of contention in a "ground-breaking" project like the HBP is to be welcomed (Madelin, 2014). The EC hence perceived the decision to exclude the neuroscience subproject from the core funding as legitimate. A former high-ranking EC decision-maker who was interviewed for this article clarified that when *"the consortium leaders said, 'we need to put more resources here,' (...) we [the EC] said 'we trust you'"* (INT01). When the authors of the open message learned of the EC's reaction and realized that they would not receive any support from EU decisionmakers, they mobilized their professional network to further push their cause. Particularly French scientists capitalized on the good and close relations they had with the heads of major national research organizations (INT07). The latter had similar interests and objectives as the neuroscientists. Both wanted to prevent their research institutes from being excluded from a major initiative like HBP and EU research funds from being wasted on a mismanaged Big Science network. Joining forces, they reached across the boundary of the scientific field to lobby French and European politicians to induce change in HBP (INT07). Despite this coalition's lobbying effort, *"(...) the advantage [wa]s [still] with the defenders [the HBP leadership]"* because the EC continued to side with them. The EC mainly defended the HBP executive committee because if it *"[had said that] 'Yes, the attack is right,' they [would have had] to find a new consortium leadership"* (INT01).

However, backed by renowned and powerful heads of major national research organizations, neuroscientists intensified their protest against HBP through disruptive tactics. They pushed their criticism of HBP and its leadership by framing the flagship as a network that pursued a fundamentally flawed scientific approach and had been "oversold" to policymakers (Kelly, 2014). Neuroscientists voiced such harsh critique in popular science magazines and mainstream media outlets (INT03), therewith breaking with the practice of debating scientific controversies within the confines of the academe. An EU project officer and a HBP science manager who were interviewed for this paper confirmed that the tactics employed by HBP critics disrupted the entire network. According to the high-ranking HBP science manager they *"created an internal (...) and (...) external crisis"* in the network because *"its legitimacy (...)*

and leadership [were] questioned" (INT02). In the EC, in turn, no one was surprised to see Markram's scientific vision under attack. Yet policy officers responsible for HBP in DG Connect were taken aback "*by the method[s] these neuroscientists were ready to use to push their case"* (INT11). Within a few weeks, these "methods" accelerated the emergence of open conflict during which the HBP leadership and its critics pursued mutually exclusive goals concerning the decision to bar the neuroscience subproject from HBP core funding (for a graphic overview of conflict emergence see Figure 3). While Markram et al. were reluctant to reintegrate the subproject, their critics demanded just that. The latter strongly interfered with Markam et al.'s objective of reorganizing HBP funds by publicly naming and shaming the HBP leadership for its scientific and governance approach.

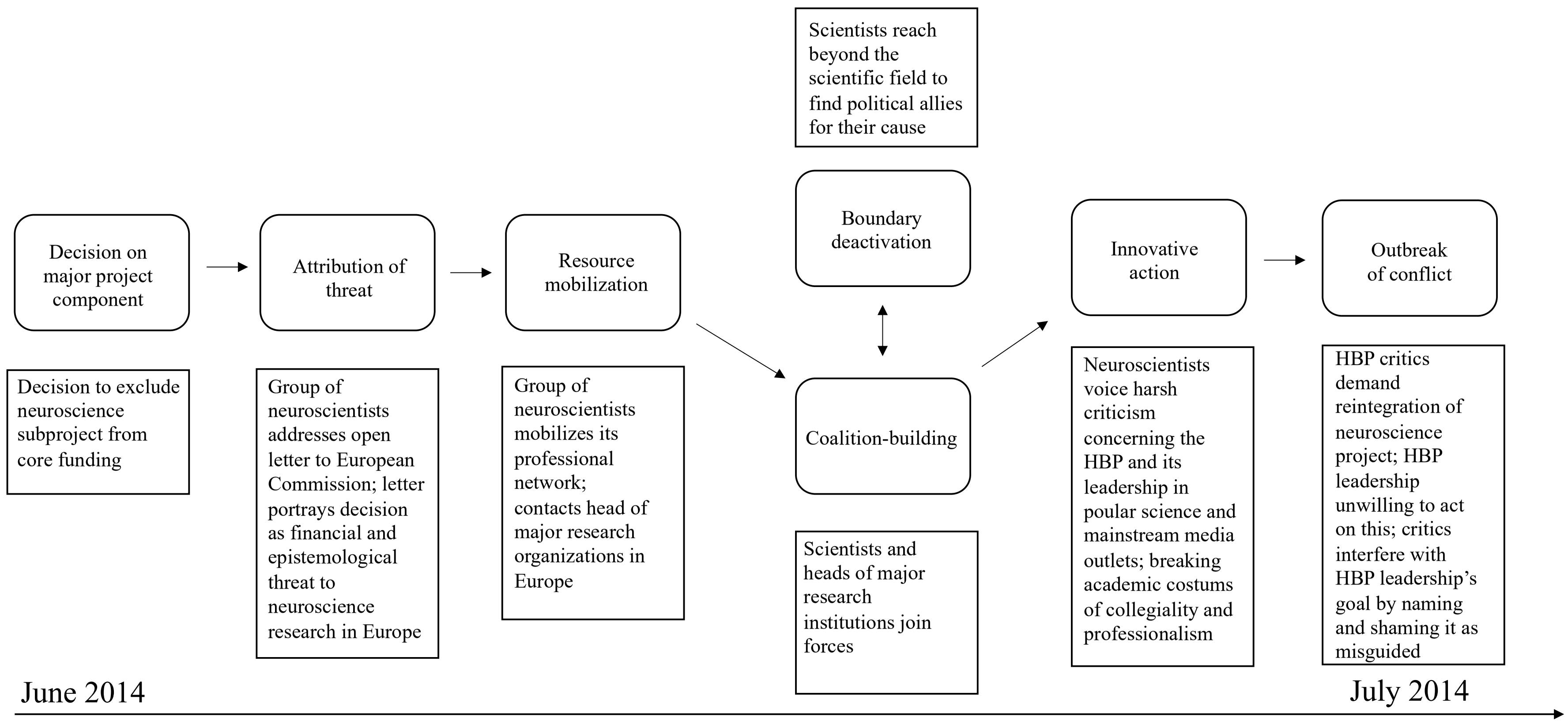

Figure 3: Model applied to HBP case study

4.5. Case Study II: ITER

4.5.1. Background

ITER is a controlled thermonuclear fusion experiment which aims to demonstrate the scientific viability of fusion as a future source of sustainable energy (European Commission, 2017). It was first proposed in the mid-1980s—at a time, when the need for more sophisticated, complex, and costlier instruments in fusion research spurred international collaboration (Broad, 1992). For instance, during the early 1980s, a team of scientists from across the world began to work on the so-called International Tokamak Reactor under the umbrella of the International Atomic Energy Agency (Claessens, 2020: 29). While Europe decided to join this collaborative effort (McCray, 2010: 291), the US were initially reluctant to support international cooperation in fusion research (McCray, 2010: 292).

In 1985, however, US Secretary of State, George Shultz, and Soviet science advisor, Evgeny Velikov, managed to add cooperation on nuclear fusion to the agenda of a high-level meeting between Reagan and Gorbachev which was to take place in Geneva. At the meeting's closure, the leaders issued a joint statement, in which they "emphasized the potential importance of (…) utilizing controlled thermonuclear fusion for peaceful purposes" and advocated for "the widest practicable development of international cooperation in obtaining this source of energy" (Reagan and Gorbachev, 1985). At the time, nuclear fusion depicted an ideal area of cooperation for political rivals like the US and the Soviet Union for two main reasons. First, an international fusion research community and "pathways for information exchange" were already in place (McCray, 2010: 293). Second, applications of fusion energy require several generations to materialize, mitigating security concerns regarding technology-sharing (INT19; Curli, 2024). Still, it took until 1988 for design work on ITER to begin. By then, the US and the Soviet Union had obtained support for the project from Japan and the European Atomic Energy Community (Arnoux and Jacquinot, 2006: 113).

4.5.2. The Emergence of Conflict

ITER is an extremely complex and technologically demanding project whose life cycle—from inception to full operationality—covers a long time span. Thus, it comes as no surprise that the project not only lived through one but several conflictual episodes. For example, during ITER's Conceptual Design Activities, latent conflict concerning the reactor's scientific specifications and its first director's management style emerged (Åberg, 2021). Later, during the Engineering

Design Activities (EDA), the question of where to build ITER created latent conflict among project partners. To ease tensions, ITER partners decided to split the engineering team across three sites and continents even though this made little sense from a project management point of view. Yet, because every country feared that the EDA location would have a competitive advantage in the final siting decision, this was the only solution all ITER partners could agree on (INT19).

Following the completion of the EDA in 2001 the siting issue re-emerged. Between 2001 and 2003, four countries—Canada, Japan, Spain, and France—signaled their willingness to host ITER. As during the EDA, the pending siting decision triggered latent conflict between ITER partners in general and the four site candidates in particular. Open conflict, meaning a visible struggle, between the ITER partners, however, only emerged after November 2003 when merely two site proposals, namely that of Japan and France, were still in the running. The US used this French–Japanese site duel as an opportunity to pursue its foreign policy agenda "by other means" (Krige, 2013). In particular, the country saw the site competition as a way to reward its ally Japan for supporting the US invasion of Iraq in March 2003.

Both international media outlets and EU policymakers suspected that this was the objective that the US were pursuing in the ITER site competition when it invited ministers from the project parties—which by then also included China and South Korea—to Reston, a suburb of Washington DC, in December 2003 (Claessens, 2020: 48). On the one hand, earlier that year, the US had implied that they preferred Spain's site over that of its direct European contender (Brumfiel and Butler, 2003). On the other hand, the meeting venue in Reston was swamped with US and Japanese journalists, while no European media outlets had been invited, indicating that the US and Japan were confident that they would be able to declare Japan ITER host at the end of the gathering (Claessens, 2020: 49). Spencer Abraham, State Secretary for Energy under the Bush administration, chaired the meeting at Reston. According to an EU official who was interviewed for this paper and present at the meeting in Reston, Abraham opened the gathering by stating that it was important to "move forward" and to "come to a decision" concerning ITER's siting (INT24). Abraham then proceeded to ask all parties present which ITER site they favored. China, Russia, and the EU preferred the French site, while the US and Japan were backing the Japanese site. South Korea, in turn, was undecided. As no consensus emerged, Abraham suspended the meeting and—according to the interviewed EU policymaker—leveraged his country's close economic and political ties to South Korea to convince it to join forces and support a Japanese site for ITER (INT24). This attempt to build a coalition for

Japan's proposal was successful as South Korea backed Tokyo's site bid during a second round of consultations, as did Japan and the US. The EU, Russia, and China, in contrast, favored the French site. To put an end to this stalemate, Russia suggested to open the negotiations by offering the candidate that would not obtain ITER a "consolation" prize in the form of a material research facility (INT24). Despite this conciliatory proposal, the parties were unable to come to an agreement at the meeting in Reston.

Thus, to further advance their preferred course of action—a Japanese ITER site—the US finally reverted to disruptive tactics. During a visit to Japan in early 2004, Secretary of Energy Abraham broke with long-established diplomatic conventions by publicly and strongly supporting Japan's site bid for ITER. As Japan had recently dispatched a battalion of non-combat troops to southern Iraq (Watts, 2003), he first thanked Tokyo for its "aid in the fight against terrorism in the (…) wake of September 11" in a luncheon address in January 2004 (US Department of Energy, 2004). He then went on to underline how "proud" he was to say that the US[A] strongly supported building ITER in Japan," which "from a technical standpoint" had "offered the superior site" (US Department of Energy, 2004). These public statements considerably disrupted the ITER site negotiations as they deepened the rift between those that supported a French site and those that did not—so much so that the French government promptly threatened to construct the reactor by itself after Abraham's visit to Japan (Buck, 2004). The US's Secretary of Energy's statements in Japan also accelerated the emergence of open conflict because they highlighted the goal incompatibility between the US and Japan on the one hand and the EU and France on the other (for an overview of conflict emergence see Figure 4). In addition, they demonstrated that the US were willing to interfere with the ITER siting competition to further its own foreign policy goals. France's reaction to Abraham's comments, in turn, showed that French decisionmakers were likewise willing to interfere with the US agenda.

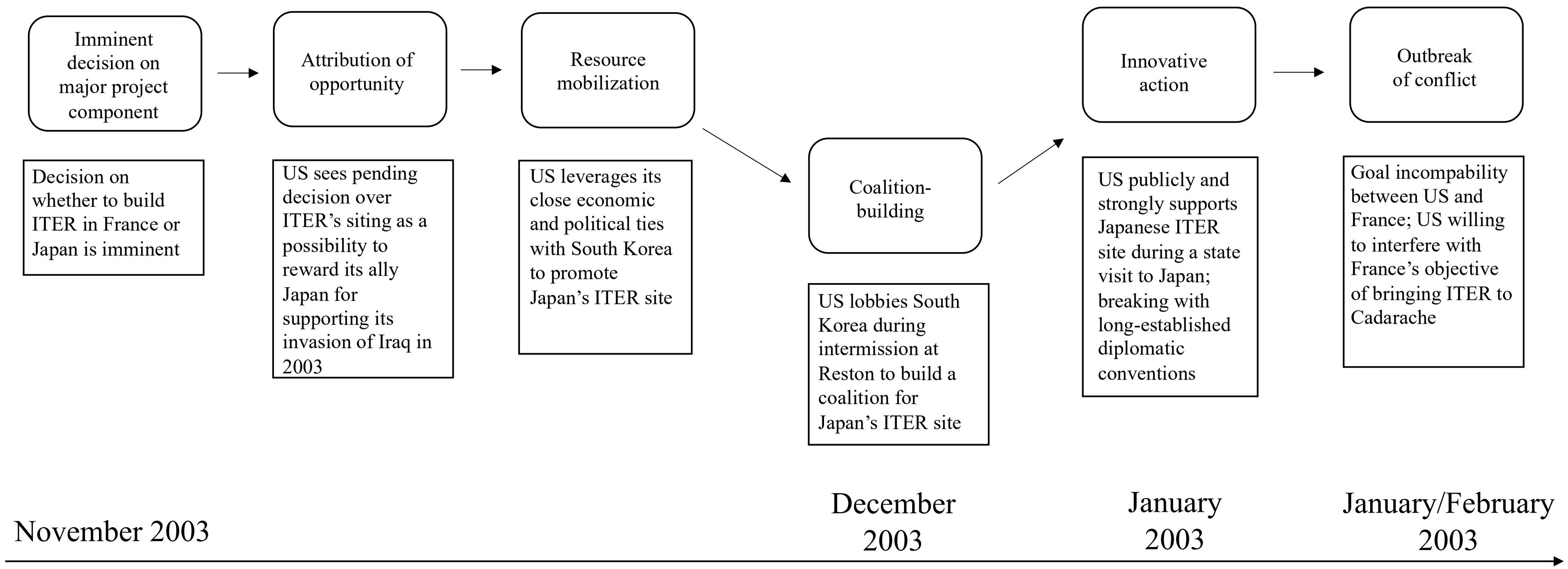

Figure 4: Model applied to ITER case study

4.6. Case Study III: TMT

While a third in-depth case study is beyond the scope of this paper, a cursory investigation of another conflictual episode around another Big Science collaboration, such as TMT, can provide further, even if only anecdotal, evidence for the model's validity. In addition to what was stated in the methods section, TMT is an interesting case study for two more reasons. First, the same cause triggered conflict on several occasions, which allows us to apply the model to several instances of conflict. Second, in the case of TMT, conflict spanned the macro and the meso level as TMT's partners, an international consortium consisting of US, Chinese, and Japanese research institutions as well as Canadian and Indian quasi-governmental agencies, and parts of the local and Native Hawaiian population were divided over the question of whether Mauna Kea can be considered an appropriate site for a large-scale telescope. Latent conflict between those two groups first emerged in 2011. At this point in time, UH set the administrative process of obtaining the necessary permits for building TMT in motion (KAHEA, 2016). Holding a 65 year "master lease" for a substantial part of Mauna Kea's summit region, UH had—at least until a stewardship reform in 2022—considerable decision power over the mountain's stewardship and the prerogative to apply for the permits on behalf of the TMT consortium. Several Native Hawaiians that opposed further development on Mauna Kea's sacred and "ceded" lands[8] filed legal challenges and lawsuits to prevent UH from obtaining permits for TMT. These legal battles went through several instances in the state judicial system and dragged on for several years (INT26).

In 2014, the TMT consortium's decision to proceed with a groundbreaking ceremony despite the ongoing legal battles triggered open conflict between project supporters and opponents. Opposition came from environmentalists that rejected TMT because of its potentially detrimental impact on Mauna Kea's ecosystem as well as from parts of the local and Native Hawaiian community. For the latter, the construction of TMT on sacred and ceded lands threatened to restrict access to cultural sites on the mountain and to infringe on indigenous land rights. In addition, TMT was seen to add to previous mismanagement of the mountain and to bring few direct socio-economic benefits to the local community. On the day of the TMT

[8] Ceded lands are Crown and government lands which were ceded to the US when the country annexed the islands of Hawai'i through Joint House Resolution 259. "Not all [in Hawai'i] accept the resolution as a valid means of annexation" and they argue that "Native Hawaiians retain rightful claims to these lands," see Uyeda C (2021) Mountains, Telescopes, and Broken Promises: The Dignity Taking of Hawaii's Ceded Lands. *Asian American Law Journal* 28: 65. https://doi.org/10.15779/Z38CC0TV0T.

groundbreaking, some Native Hawaiians made use of their local community bonds to gather a group for a ceremonial prayer vigil at the base of Mauna Kea. Parts of the group went up to the summit in a spontaneous effort to halt the TMT groundbreaking ceremony (INT26). Through innovative tactics, including blocking the road leading to the groundbreaking site and interrupting the event through chants (INT26), the group genuinely surprised the TMT consortium, which was expecting legal objections, but not non-violent direct action (INT26). The protests eventually led to a situation where the TMT consortium and Native Hawaiian TMT opponents were pursuing mutually exclusive goals. While the latter wanted to prevent the TMT from being built on Mauna Kea, TMT's funders wanted to go ahead with the groundbreaking. Due to the interference of TMT opponents, however, the TMT consortium could not proceed.

In 2015, the construction of TMT was scheduled to go forward, once again triggering open conflict between project supporters and opponents. This time, however, the threat to indigenous land rights and cultural practices seemed even more palpable because construction material was supposed to go up the mountain. Native Hawaiians in opposition of TMT, who refer to themselves as kiaʻi (protectors), activated their dense community network and asked other community members to come up the mountain to protest and stop TMT's construction on two occasions. Deactivating the boundary between local politics and the world of entertainment, kiaʻi also used familial ties to celebrities with connections to Hawaiʻi to build a strong coalition for the protection of Mauna Kea's sacred lands (INT27). These celebrities engaged in innovative action by campaigning for the protection of Mauna Kea through social media (Scheuring, 2015), generating nationwide attention for the controversy and supporting kiaʻi that blocked Mauna Kea's access road twice throughout 2015 to interfere with TMT's construction.

In 2019, when most legal challenges concerning TMT's permits had been decided in court and the TMT consortium tried to proceed with moving heavy construction equipment to the summit, the same mechanisms as in 2015 induced conflict emergence. This time, however, kiaʻi were able to rely on more resources and bigger networks from previous protests. Previous social media campaigning, for instance, helped kiaʻi to connect with and receive support from other indigenous movements across the globe, thus building transnational coalitions for indigenous land struggles (Case, 2021). In addition, they made use of disruptive tactics by forming front lines that were spearheaded by kupuna (elders), a group that is usually expected to be on the protest sidelines (INT28). Through these tactics, kiaʻi interfered with the TMT consortium's goal to begin constructing the telescope on Mauna Kea for a third time.

4.7. Discussion

The objective of this study was to provide a better understanding of conflicts in and around Big Science projects and networks. To do so, this study proposes a mechanism-based model of conflict emergence in Big Science that is applicable beyond a single case. The model holds that five interlinked mechanisms—attribution of threat or opportunity, mobilization of resources, coalition-building, boundary deactivation, and innovative action—fuel conflict emergence in Big Science. It adds value to the scholarship on science collaboration which typically only mentions conflicts insofar as they are seen as an obstacle for effective scientific cooperation or knowledge generation (Galison, 1997; Knorr Cetina, 1999; Ulnicane, 2015). In addition, it contributes to the literature on Big Science which generally lacks "systematic comparative analyses" and theory-building (Rüffin, 2020: 41-42).

A comparison of the case studies under investigation in this study indicates that there are three aspects in which conflict emergence differs and one aspect in which it does not. First, it seems that actors involved in conflicts at the macro level rely more heavily on their political and economic resources, while actors caught up in conflicts at the meso level are more prone to mobilize their social capital. For instance, in the case of ITER, where conflict developed at the macro level, the US mainly capitalized on their reputation as a world power as well as their strong economic entanglement with South Korea to convince the country to support Japan's ITER site bid. In the case of HBP and TMT, actors at the meso level used their dense social network to push their agenda.

Second, it could be argued that a conflict triggered by an imminent decision needs more time to emerge than a conflict caused by a decision which has already been executed or is in the process of being executed. In the case of ITER, conflict emerged after several months, while in the case of HBP and TMT open conflict emerged within a few weeks or days. In the case of the TMT groundbreaking, conflict even emerged on the spot, which explains why a time-consuming mechanism like coalition-building does not hold here. Reactions to an executed decision might be stronger than to an imminent one because reversing a decision that has already been taken is, or at least often seems, more daunting than revoking one that may or may not be settled in the near future.

Third, boundary deactivation seems to play a greater role for actors at the meso than at the macro level. Contrary to what happened in the ITER case study, actors in HBP and TMT reached across field boundaries to build strong coalitions for their cause. In the case of HBP, it is particularly noteworthy that by forging coalitions with policymakers, scientists managed to deactivate the boundary between the meso and macro level. This does not mean, however, that it cannot also prove strategic for actors at the macro level, for example politicians, to build coalitions with actors from another field. Policymakers wanting to cut the costs of a project or network might, for example, build a coalition with a scientific community that is in favor of using a cheaper technology. When a Big Science project with potential safety concerns is proposed, politicians may further deactivate boundaries between local and national politics to build coalitions with those parts of the local community that are in favor of the project to promote its realization.

Finally, while the specific tactics chosen by the actors in the case studies may differ on a case-by-case basis, all of them are characterized by a high degree of disruptiveness. Every tactic either breaks with previous conventions in a specific field or creates moments of surprise. In the case of ITER, Energy Secretary Abraham's remarks in Japan were disruptive because they broke with diplomatic practices. Typically, a project party that has no intentions of being project host does not interfere with the site competition by openly and publicly endorsing one site over another. In the case of HBP, the highly critical, harsh, and publicly voiced statements of some neuroscientists proved disruptive because they broke with academic traditions. Lastly, in the case of TMT, protestors' roadblocks, interruptions during groundbreaking, makeup of frontlines, and Hawaiian celebrity's social media involvement genuinely surprised the TMT consortium (INT26).

4.8. Conclusion, Implications for Management, and Limitations

Conflicts are prone to emerge in and around Big Science projects and networks because like other meso level social orders these undertakings bring a plethora of different actors with potentially conflicting goals and expectations together for a long period of time. Understanding which general mechanisms drive conflict in and around Big Science projects and networks is highly relevant, both from a policy and academic perspective, because a failure to address conflicts in and around these extremely expensive science undertakings can cause serious damage to the public perception of large-scale science collaboration. Given that many of today's grand challenges possess a pronounced scientific dimension and thus need to be addressed through international research (Parikh, 2021), public acceptance of and confidence in Big Science is all the more essential. The model on offer in this study is a first attempt at theorizing conflict emergence in Big Science, which is an important step in preventing and mitigating destabilizing processes in and around Big Science.

In this regard, there are two key take-away messages for Big Science managers. First, to be able to distinguish between surface and open conflict, managers have to develop a deep understanding of the expectations and interests with which different stakeholders join or perceive a collaboration. Only then will they be able to assess whether a decision that affects or concerns a major project or network component is likely to be perceived as a threat or opportunity. Organizing regular meetings with different stakeholder groups, especially at the beginning of a collaboration, is one way to achieve a better understanding of their expectations and interests. Such meetings are particularly essential if Big Science touches on topics that have major ethical, security, or health implications and/or if projects or networks encroach on sites that have symbolic, religious, or cultural value for historically marginalized groups. Native Hawaiians that oppose TMT's construction, for example, have repeatedly underlined that TMT promoters did not sufficiently acknowledge their grievances and concerns (Ku'iwalu, 2020). As stakeholders' expectations and interests are likely to change over time, regular check-ins with stakeholder groups should also remain a priority past the "storming phase" of a collaboration. Second, if Big Science managers notice that coalitions between different stakeholder groups form after a decision affecting a major project or network component has been made or is imminent, they should intervene and initiate a mediation process. At this stage, it might already prove useful to invite a third neutral party to lead said process because such a neutral third party is more likely to have the necessary standing and moral authority to uncover the grievances and hopes of those involved in the emerging conflict. Managing this phase of conflict emergence is also critical because if stakeholders cross boundaries to push their agenda, the emerging conflict might spill over into another field. If actors from an additional field get involved in an emerging conflict, in turn, it might prove even harder to mitigate or resolve it.

Further research on conflicts in Big Science could generate additional insights for project management. For instance, by shifting the focus from conflict emergence to conflict settlement, Big Science stakeholders could learn valuable lessons for effective conflict mediation. Additional research on conflicts in and around Big Science is further needed to refine and potentially extend the model on offer in this article. In doing so, future studies would benefit from a more diverse sample of interview partners, which balances voices from East and West, small and big project contributors as well as project proponents and critics. Although this study aimed for such a diverse sample, interview partners for the ITER and HBP case studies were largely recruited from major Western European laboratories and research institutions.