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Developing a Typology for Mission-Oriented Innovation Policies

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Contents

Abstract

The goal to address broader societal problems by mission-oriented research and innovation policy has brought new demands for the governance and implementation to the forefront and led to a great diversity of missions. By developing a typology for the classification of different types of missions, this working paper can serve as a first step for studying the impact of the twelve missions of the German Hightech Strategy (HTS). Combining existent literature with insights from the governance structures, we identify four types of missions - two subtypes of transformer and accelerator missions each. Thereby, we provide a more fine-grained understanding of the different demands and challenges inherent to different missions and thus provide the opportunity for systematic comparison and a reflection on the varying requirements for assessing the impact of mission-oriented policies.

1 Introduction

The orientation of science and innovation policy has changed considerably in the past decades. Whereas the initial focus was on fueling economic growth by the commercialization of scientific insights without considerable interference by the state (see Arnold et al. 2018, p. 3), a more active and guiding role of the state has gained importance recently (Schot and Steinmueller 2018). In contrast to the earlier types of mission-oriented policies, current innovation policies are characterized by attempts to closer align policy with tackling the grand societal challenges (Robinson and Mazzucato 2019).[1] Considering the current and ongoing challenges of human kind such as pollution, climate change or demographic change, there are high hopes that new innovative ideas, processes and products will not only address but also solve these problems (directionality). The rising interest of policy makers to foster education, research and science that leads to solutions for these pressing problems corresponds with this development and has been labelled as the 'new mission for science and technology policy' following the so-called Maastricht Memorandum (Soete and Arundel 1993).

To this end, over the past ten to 15 years, several countries have introduced "innovation policy strategies" like the German *Hightech-Strategy* (BMBF 2006) or the British *Innovation and Research Strategy for Growth* (BIS 2011). During the past legislative periods the focus of these policy strategies changed from fostering single technological fields or disciplines[2] to support adequate solutions for the above-mentioned challenges by formulating comprehensive missions like "fighting cancer" or "preserving biological diversity" (BMBF 2018). According to Kuittinen et al. (2018b, ii) these new mission-oriented policies are characterized as "ambitious, exploratory and ground-breaking in nature, often cross-disciplinary, targeting a concrete problem/challenge, with a large impact and a well-defined timeframe" (similar Mazzucato 2018).

Designing innovation policies for this new type of missions aiming to address societal challenges instead of simply supporting single technological fields has multiple implications for the study and evaluation of innovation policy. This becomes clear when Larrue (2019, p. 9) proposes a "concept of mission-orientation constructed as a composite of different elements identified mainly deductively. It refers to the objective of the policy (societal challenges), its content (a co-ordinated bundle of instruments) and some implementation characteristics (goals and timeframe)." This re-orientation towards

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[1] For changes in the discourse and the shift from a perception of problems towards challenges see Kaldewey 2018; Kallerud et al. 2013.

[2] The very first version of the German High-Tech Strategy contained 17 different sub-strategies targeting selected technologies and disciplines like medical technology, information and communication technology or microsystems technology BMBF 2006.

societal goals requires conceptualizing innovation policy in a broader and crosscutting way, taking into consideration a significantly wider range of actor groups and stakeholders, understanding the potential impacts of these policies in different sectors and application areas, and introducing new governance arrangements. In consequence, mission-oriented policies challenge existing institutional settings for implementing innovation policy and call for a better integration of different policy instruments to achieve the aspired goals, as e.g. proposed in the German and British large-scale national strategies. Imposing grand challenges and missions as a major rationale for policy-making by a top-down organized process, however, will not necessarily lead to any real transformative innovation, but may also lead to subsuming previous research under new headlines like putting "old wine into new bottles" (Daimer et al. 2012, p. 223). Moreover, the far-reaching goals also require new approaches for measurement and evaluation (Amanatidou et al. 2014), as the impact of missions cannot be easily grasped with traditional evaluation techniques, and there are no established approaches yet (Weber and Polt 2014, p. 9).

In the following, we develop a new typology addressing the diversity of missions with regard to policy goals, inherent challenges and - in contrast to most previous literature - emphasize the importance of governance structures. The purpose of this typology is twofold: First, given the growing number, diversity, and relevance of mission-oriented policies, it aims at providing orientation to analysts and policy-makers on the key distinguishing characteristics of contemporary missions, thereby facilitating systematic comparisons and policy learning. Second, as the typology is developed in the context of a research project aiming to support the ongoing implementation of the missions of the current German Hightech Strategy (HTS)[3] by providing (among other aspects) an impact measurement concept, the typology will be used to select three to four different types from the twelve HTS missions. In the next steps of the project, there will be an in-depth investigation of the selected missions, particularly with regard to the mission goals and the measures and instruments used to reach these goals. The typology therefore serves as a tool for selection of relevant missions, while meanwhile deriving expectations about the different types of challenges being inherent different types of mission in order to develop a framework for impact assessment.

To arrive at a sound typology with distinct and – from a policy perspective – meaningful types, the paper starts with a summary and a critical assessment of mission typologies currently being offered by the literature. Based on the review, the requirements for a comprehensive and useful mission typology are outlined (sec. 2). Drawing on the insights of the review and taking into account the requirements identified, the typology is

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[3] https://www.hightech-strategie.de/de/hightech-strategie-2025-1726.html.

developed and the different types as well as their relationships are discussed (sec. 3). In section 4, we apply this typology to the 12 missions of the HTS, discuss problems encountered during this step and reflect on which missions should be selected based on the typology. The final section 5 summarizes the key insights presented in the paper and proposes areas for further investigation.

2 Review and critical assessment of existing mission typologies

2.1 Existing approaches

Given the turn towards a stronger mission orientation, there is a growing diversity of innovation policies and individual missions with regard to their scope, goals, and ambitions (Kuittinen et al. 2018b, p. 32; Larrue 2019). For instance, the German Hightech Strategy 2025 with a strong focus on the policy areas of research and technology comprises missions ranging from the introduction of a certain technological solution in the health sector, over further investments in research to fight cancer to addressing large societal problems like carbon dioxide emissions or a transformation of the mobility sector (BMBF 2018). The current British Industrial Strategy (BIS 2011) serves as another example in this respect. Here, the guiding principle is the identification of four Grand Challenges that correspondent with broad, cross-sectoral missions. On the one hand, this approach led to formulating complex and aggregated policy ambitions like tackling the Grand Challenge of an "Ageing society" by the corresponding mission: "Ensure that people can enjoy at least 5 extra healthy, independent years of life by 2035, while narrowing the gap between the experience of the richest and poorest". On the other hand, the UK strategy also contains missions that seem rather straightforward in scope and scale. The challenge of "Clean Growth", for instance, will be tackled by two missions: "at least halve the energy use of new buildings by 2030" and "establish the world’s first net-zero carbon industrial cluster by 2040 and at least 1 low-carbon cluster by 2030".[4]

Recent approaches to classify mission-oriented policies mostly exhibit a dichotomous understanding. Whereas some authors emphasize the scope of underlying problems as the main dimension of conflicts, others have more strongly focused on the anticipated solutions and goals of missions. Only recently, the role and process of implementation has increasingly attracted the attention of researchers. Therefore, the debate about the classification of mission-oriented policies provides multiple, but related starting points.

Firstly, mission-oriented policies can be understood by the underlying challenges which are the prerequisite for the formulation of a challenge-based approach (Mazzucato 2018). Georghiou et al. (2018: 5) distinguish between two types of challenges: Type A missions with "potentially solvable" challenges that can be translated into specific/verifiable goals (e.g. developing a vaccine for Ebola) and Type B whose complex

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[4] https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions.

character makes finding a solution complicated (e.g. Nixon's war on cancer). The understanding of challenges is thereby linked to concepts like those of "wicked problems" (Rittel and Webber 1973) or the distinction between simple, complex and complicated problems (Glouberman and Zimmerman 2002).

Secondly and closely related to this perspective, there is a number of attempts that categorize policies based on mission characteristics, i.e. the defined goals. Kuittinen et al. (2018a, 2018b) distinguish between accelerator missions, which have a narrowly defined scientific/technological focus, and broader transformer missions aiming at a transformation of existing systems and often addressing societal problems (see also Hekkert n.d.). A similar understanding can be also found in Robinson and Mazzucato (2019), who distinguish between traditional (Type 1) and challenge-driven (Type 2) mission-oriented policies, where the latter is characterized by a greater diffusion of responsibilities and the expectations for changes affecting also societal behavior. Related to the idea that policies tend to be located in a continuum between these ideal types (Kuittinen et al. 2018a, pp. ii–iii), there have been further reflections about the degree of mission orientation (Mazzucato 2018; Kuittinen et al. 2018a), i.e. the existence of gradual differences. The main characteristics of mission-oriented policies comprise the call for missions being oriented towards problems of wider societal relevance and have a cross-disciplinary and cross-sectoral/-actoral approach. Taking these demands as a baseline one could argue that higher mission-orientation should be more prevalent for transformer missions, as described by Polt et al. (2019), compared to more narrowly defined accelerator or science missions.

Building on an inductive approach and the insights of over 100 case studies, Polt et al. (2019) extend this typology further. Observing differences with regard to the motivation (aspirational vs. problem-driven), the intention (understanding vs. solution), the definition of a target/the scope (well- vs. ill defined), and the means (technological vs. socio-institutional), they empirically identify four types of missions:

i. science missions (e.g. US Cancer Moonshot - fundamental/basic research with high uncertainty)
ii. technological missions (e.g. Concorde, Apollo mission - specific goal with a strong focus on technological/scientific solutions)
iii. transformative missions (e.g. German Energiewende - aiming at systemic change)
iv. umbrella missions (e.g. German High Tech Strategy - comprehensive long-term policy frame)

While these concepts rest on the assumption that the type of challenge and the mission are closely linked with each other, Wanzenböck et al. (2019) seek to disentangle these dimensions and highlight the different modes of interaction between them. Similar to Patton (2011), they argue that both problems and solutions can exhibit varying degrees of complexity, creating different ideal types of constellations in a 2x2 problem-solution matrix. The more views on both the problem and the possible solution diverge, the harder it will be to achieve the desired outcomes. What sets Wanzenböck et al. (2019) apart from the so far discussed typologies is a dynamic instead of a static perspective. They assume that constellations can change over time, e.g. through public debate or new technological developments, shifting the situation more towards an alignment of views on the problem/solution.[5] Therefore, they outline several policy pathways that can lead to the desirable state of alignment: a (1) problem-led, experimental, (2) an open, fundamental research knowledge creation, and (3) hybrid, co-evolutionary pathway. However, while pinpointing to the potential dynamics of the process, the time horizon - depending on the perspective - might reach beyond the goal of a mission and rather capture challenges at different states of alignment.

Finally, some authors have broadened the perspective by highlighting that besides complexity as an inherent characteristic of problems and/or solutions, mission-oriented policies can vary with regard to their implementation requirements. Larrue (2019) develops a framework that serves a twofold goal: Firstly, classifying policies on a meta-level with regard to the main purpose of a policy (characteristics of different initiatives, not missions) and its integration into the overall policy framework. In consequence he distinguishes between a focus of the policy on outlining a general conception, (e.g., German High-Tech Strategy), the priority of policy-coordination (e.g., German Energiewende) or the active link to the implementation level (e.g., DARPA in the US). Secondly, in order to systematically analyze mission-oriented policies, he provides a comprehensive check list of potential factors to be analyzed which can be grouped into three main categories: strategic orientation, policy co-ordination and policy implementation. This perspective implies that the diversity of missions might not only be captured by the underlying challenges and missions, but also by the resulting requirements how to coordinate and manage the realization of missions and thus pay more attention to governance and implementation. In particular, this focus can contribute to overcoming the inherent challenges in the evaluation of mission-oriented policies (see above), by better understanding the dynamics and processes within a mission.

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[5] At the same time, they do not discuss the hypothetical case of disalignment and an increasing contestation of a solution, assuming that seemingly problems only can converge towards alignment or remain locked-in at the status quo.

Against the background of this current reflection on mission orientation, one has to acknowledge the tradition in STI-studies of analyzing fundamental shifts in technological areas or disciplinary fields from an ex-post perspective as well. This strand of research on transition pathways (see, for example, Köhler et al. 2019, for a detailed review), can yield insights into the dynamics of innovation processes (see, for example, Geels 2002; Geels et al. 2016; Geels and Schot 2007). However, it does not allow a more pronounced understanding of mission characteristics and - in particular - the role of governance structures (Arnold et al. 2018, p. 37). Relying on an ex-post perspective it exhibits an implicit preference for "successful" cases, being primarily interested in explaining changes instead of a reproduction of systems (cf. Geels and Schot 2007, p. 406). While Geels and co-authors reject the criticism of pursuing an overall structuralist approach and offer refined pathways incorporating a stronger role of agency (2007; 2016), their focus is primarily on the process of innovation of single products rather than the implementation of policies.

The perspective of Geels and Schot is in so far broader, as they assume that policy coordination is the result of the convergence of opinions during transition processes and downplay the role of specific policies for achieving this goal. This perspective becomes particularly clear when Geels and Schot (2007, p. 402) argue that "[i]n our view, no transition is planned and coordinated" from the outset" (p. 1502 [Smith et al. 2005]). And every transition becomes coordinated at some point through the alignment of visions and activities of different groups". From this perspective, mission-oriented policies are located at a different conceptual level, as they constitute a part of a transition process and should only gain relevance once there is consensus on a given goal. Whereas missions are clearly embedded in a deliberate political strategy aimed at achieving a certain outcome and require an active coordination, transition pathways describe the overall process.[6]

2.2 Demands for a new typology of missions

To provide a useful starting point for a better understanding of mission-oriented innovation policy, there is further need for capturing the diversity of missions in a typology with regard to the inherent challenges, goals and governance requirements. The arguments tie in with the observation of Cherp et al. (2018, p.187) who argue that there is a lacking consensus on how to integrate different perspectives into a uniform framework. Aiming to strive forward towards an uniform framework, we therefore argue that a typology should address the following two main challenges: (1) overcome the

[6] For a call for a stronger integration of politics in the understanding of innovation processes see also Meadowcroft (2009).

vagueness with regard to the level of analysis and outline a typology based on individual missions, and (2) bridge the gap in current research by bringing together the understanding of challenges (problems/solutions) with the role of actors and the governance of missions.

2.2.1 Conceptualizing the level of analysis

Firstly, many of the conceptions are rather ambivalent with regard to the level of analysis and are seemingly more closely related to the strategic policy level than to specific missions. This becomes most visible with regard to the "umbrella missions" as understood by Polt et al. (2019), which refer to policies comprising a number of individual missions (like the German High-Tech Strategy) and therefore might be on a different conceptual level than the remaining types of missions. In consequence, several science missions, for instance, could be part of an "umbrella mission". The diversity of goals makes it not only harder to assess the impact of mission-oriented policy, but also creates conceptual obstacles, as types might not necessarily “travel” across different analytical levels.

For a more systematic perspective on mission-oriented policies, it is therefore necessary to clarify the level of analysis before proceeding to the development of a typology. Keeping in mind the goal of performing an impact assessment in later steps, the mission level appears to be the natural level of analysis, as it can open the “black box” of larger strategic programs and prepare the ground for unpacking the diversity within larger policies in a more systematic way. While missions can be considered as the groundwork for mission-oriented innovation policies, their connection to challenges and overall policies is not straightforward. Missions, as the intermediary level between overarching strategies and single policy instruments, are supposed to be translations of challenges into solvable problems (Mazzucato 2018b, pp. 811–812; Robinson and Mazzucato 2019, p. 936), thus can also address only a subset of a challenge or can be linked to other missions and overall policy strategies in different ways.[7] Firstly, a single challenge can be addressed by multiple missions, so that missions and the main goal related to a challenge are not necessarily identical (see European Commission - Directorate-General for Research and Innovation 2017, p. 15). Secondly, missions can address challenges at different levels of granularity, thus putting emphasis on different aspects of a challenge (Larrue 2019, pp. 20–21). Finally, several missions can be subsumed in one - more or less coherent - policy strategy, addressing multiple challenges (like in the German HTS).

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[7] A single strategy might be driven by the interplay of different goals of different missions, creating additional obstacles for understanding the impact of policies due to the complementary character of missions. In consequence, it can be difficult to disentangle individual contributions at an aggregate level.

Moreover, different types of missions may differ systematically in their orientation. Griniece and Sorokins (2018), for instance, report from a survey among stakeholders in R&I policy that not all criteria for mission-oriented policy suggested by Mazzucato (2018) can be equally applied to all missions.

2.2.2 The role of governance and actors for the implementation of mission-oriented policies

The focus on the scope of necessary transformations (Kuittinen et al. 2018a; Polt et al. 2019) or the complexity of solutions (Wanzenböck et al. 2019) only indirectly links to the actor constellations and challenges arising from the implementation of mission-oriented policies that have been emphasized recently (see, for example, Grillitsch et al. 2019; Larrue 2019). The directionality coming along with mission-orientation imposes a more active role of the state in coordinating and formulating goals, bringing together different groups of actors at different levels and creating the need for new means of cooperation(Weber and Rohracher 2012; Mazzucato 2018; Robinson and Mazzucato 2019, p. 938; Boon and Edler 2018; Arnold et al. 2018, p. 56).[8] At the same time, the directionality should fuel the emergence of conflicts between different actors with their distinct own preferences which do not necessarily coincide with the goals formulated in the outline of the policy, thereby entailing higher degrees of politicization of innovation policy. In consequence, mission-oriented policies require a systemic policy-making approaches that allows for coordination of different parts of the internal policy system and engages them in discursive processes (reflexive and transformative governance) and leads to the implementation of systemic policy instruments to affect actors outside the policy sphere (Smits and Kuhlmann 2004). This has been also reflected in frameworks trying to conceptualize the types of transformations by highlighting the role of coordination as one core dimension (Berkhout et al. 2004; Grin et al. 2010)

Given the importance of *governance of change* to achieve the aspired comprehensive changes of some missions, a typology should account for the distinct goals and specific governance-modi. The complexity for governance can arise along two lines, requiring a critical reflection on the role and performance of public and private actors, who should bring about the desired change connected to the missions (Edler et al. 2003; Braun 2008; Lindner 2012; Matthews 2012; Flanagan et al. 2011). The first perspective ought to take on the "view" of internal governance arrangements since "missions", according to their

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[8] The example presented by USAID (2018, p. 3-4) demonstrates well that complexity might not be necessarily limited to the technological solution. For instance, the science part in a vaccination program might be of limited complexity, while the logistic of distributing the vaccination can be the larger challenge and for instance requires the cooperation of multiple actors in a difficult environment.

crosscutting nature, might fall into the shared responsibility of several ministries as well as several departments in the involved ministries (greater demands for internal coordination within state administration).

Secondly, the realization of policies depends on the interplay and cooperation of multiple public and external stakeholders from industry, science and society. The challenge in this context is to ensure an efficient coordination among all these actors and use the available policy instruments in a way that they serve the desired outcomes. Again, a greater number of involved actor groups and a great variety of policy instruments increases the level of complexity for policy coordination and should be hence reflected in the mission typology.

3 Towards a new typology of missions

This section outlines a novel approach for understanding the variation of mission-oriented policies by suggesting a typology that addresses the aforementioned problems. It explicitly focuses on the level of different individual missions that can be subsumed in a larger policy frame, such as the German High-Tech Strategy, and outlines the fundamentals and suggested operationalization for a classification of missions types.

While the typology shares some commonalities with the findings of the inductive approach of Polt et al. (2019), it extends it in several important ways. Firstly, it suggests a more fine-grained distinction in case of transformer missions. Missions might not only vary with regard to the question whether they require a socio-technical transformation or not (Schot and Steinmueller 2018, p. 1562), but also the scope of socio-technical transition can vary between different types of missions. Secondly, it seeks to go beyond the dichotomy of the state correcting vs. creating markets by taking a closer look at the type of involvement of state actors - a blank spot in innovation research. Thereby it seeks to disentangle the varying degrees of complexity when it comes to the “governance of change”, analyzing the interplay of different private and public actors.

In particular, we distinguish differences between types of missions along three dimensions:

i. the problem-structure of a mission: type of failure, anticipated means, and the orientation towards a given goal or finding a solution
ii. the role of external governance: the interplay of public and non-public actors and the instruments used to achieve this
iii. the internal dimension of governance: the coordination of a mission within public actors

The proposed typology consists of four (ideal) types of missions, which are nested into the two main categories of transformer and accelerator missions (see also Table 1 for an overview). The differences between the main categories of transformer and accelerator missions, which are well established in the literature, can be found in the structure of the underlying problem (type of failure addressed) and the complexity of the anticipated solution. In each of these main categories, one can distinguish two sub-categories, reflecting the existing heterogeneity of missions. Especially these sub-types require the incorporation of an internal and external perspective of governance, to fully grasp the existing variation. Whereas the differences between transformer subtypes are rather gradual differences, the difference in case of accelerator missions are rather by kind.

Table 1: Characteristics of different types of missions

	Accelerator Mission		Transformer Mission	
	Type 1 (A1)	Type 2 (A2)	Type 1 (T1)	Type 2 (T2)
Type of problem	Market failure	Market + structural failure	Transformational system failure	Transformational system failure
Type of solution	Scientific innovation	Technological/ regulatory change	Transformation of system	Transformation of system (behavior)
Problem vs. goal oriented	Problem-oriented	Goal-oriented	Goal-oriented	Problem-oriented
Complexity external coord.	Low	Medium	High	Very high
Complexity Internal coord	Low	Medium	High	Very high

3.1 Accelerator vs. transformer missions

The first difference between missions is their overall character as an accelerator or transformer mission, thus a differentiation according to the main purpose of a mission. Inspired by the notion of Wanzenböck et al. (2019), who argue that the extent of complexity of a mission arises from both the type of challenge and the possible solutions, this typology assumes that the main differences between accelerators and transformers can be found along two dimensions: the character of the underlying challenge being addressed and the goal of a mission (see Table 1).

First of all, missions vary with regard to the type of failure they aim to address. Following Weber and Rohracher (2012), innovation policies can aim to fix different types of failures: market failures (e.g. information asymmetries, externalities of expenditures), structural system failures (e.g. lack of infrastructure, capacity, formal rules), and transformational system failures (e.g. lack of vision on project, difficulty to learn about public demand, need for policy coordination), which Daimer et al. (2012) subsume under the headline of orientation failure. With increasing complexity of the challenge additional types of failure gain importance, complementing "lower level" types like market failure and therefore impose additional requirements for state interventions (Weber and Rohracher 2012, p. 1042). This understanding of failure closely links to the scope of the underlying challenges. Whereas in case of accelerator missions, the main target of interventions is to overcome market or structural institutional failures, the failure is more comprehensive in case of transformer missions. These are directed towards overcoming more substantial problems such as the difficulty to determine public demand and steer the direction of the innovation process.

Secondly and closely related to the type of challenge, also the solution of the problem might vary in its complexity. While generally more complex problems also make more complex interventions necessary (see also Walton 2016, p. 414), missions might attach varying importance to the role of scientific progress vis-a-vis the other dimensions. Whereas in accelerator missions, changes primarily affect the area of science and/or technology and can involve changes in the institutional setting (laws, regulations, etc.), the level of change is more comprehensive for transformer missions. Goals of transformer missions cannot be achieved only by technological/scientific progress but imply a substantial transformation of the overall system and its structure, including the societal sphere, institutions and behavior of actors. Accordingly, they complement the neo-classical canon of input and output additionality to remedy market failure by aiming at behavioral change and additionality. Following an exploratory definition of Gök and Edler (2012, p. 307) "a policy [addressing behavioral change] is only successful if it increases the capacities of agents that are crucial for innovation activity and performance (cognitive, networking, etc.) and by doing so leads to persistent effects". Transformer missions are hence substantially broader in their goals and take a broader variety of stakeholders into consideration. Therefore, they require the application of a more diverse set of policy-instruments to reach these goals.

This distinction between transformer and accelerator mission closely ties in with the well-established perspective of missions as a dichotomy which can be found for many authors (Robinson and Mazzucato 2019; Kuittinen et al. 2018a; Kuittinen et al. 2018b; Hekkert n.d.). Instead of breaking with this perspective, this typology rather argues that it is necessary to differentiate missions beyond this dichotomy and take into consideration the role of governance and anticipated pathways of reaching mission goals including the role of the applied policy instruments and their mix.

3.2 Accelerator Type 1 and Type 2

Accelerator missions can be understood as missions that seek to find an answer to a challenge with a limited scope (e.g. Moonshot, research in one particular field), but do not aim for a comprehensive system change. Despite this uniformity at the aggregate level, one can delineate two different sub-types of accelerator missions that reveal varying characteristics along a number of dimensions:

i. the type of failure forming the foundation for the mission
ii. the complexity of the anticipated solution
iii. the definition of steps how to achieve the goal postulated in the mission
iv. the complexity of internal and external governance to manage the mission

While being rather clearly delineated from transformer missions, accelerator missions internally differ with regard to the type of failure they address as well as the anticipated complexity of the solution. Accelerator Type 1 (A1) missions primarily seek to overcome a market failure and rely on scientific and/or technological innovation in order to address the challenge. In contrast, the constellation in Type 2 (A2) is often more complex, as the failure is not only rooted in information asymmetries or the lacking externalities of costs/benefits, but also requires structural adjustments, e.g. in the regulatory dimension. In consequence, accelerator Type 2 mission goals typically cannot be accomplished by technological or scientific solutions alone, but need to be accompanied by a broader set of measures and a more complex policy-mix in order to make these insights applicable to a wider range of areas.

Whereas these two dimensions already allow for a distinction of subtypes of accelerator missions, the additional dimensions reveal further insights into the implementation structures. Type 1 missions (A1) tend to be aligned with fundamental research, having two implications. Firstly, there is less certainty of the final product, so that the mission is rather defined by the problem (dealing with a certain illness, etc.) than by the means and solution how to achieve it. Secondly, the focus on research activities limits the demands for governing a change process, as both the number of involved groups and the diversity of policy instruments (financing research activities) is rather low.

In contrast, A2 missions have a different focus as there exists an already defined solution, the main challenge therefore is the pathway to achieve the goal. In consequence, the process is less open with regard to the type of solution and the choice of technology.[9] At the same time, it emphasizes the spill-over/application of scientific/technological insights to a broader range of actors what increases the importance of governing the process. On the one hand, state actors need to be actively involved in the implementation process of the mission beyond financing, e.g. by coordinating different groups or actors or adjusting legislation in line with the desired outcomes.

3.3 Transformer Type 1 and Type 2

Transformer missions aim to achieve a comprehensive change affecting the system as a whole and therefore are not limited to scientific progress and regulatory changes. In contrast to the previously discussed accelerator types A1 and A2, which differ along different dimensions, the sub-types of transformer missions (T1, T2) rather differ in degree than by kind. Therefore, they can be considered as ideal types of a continuum

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[9] This deviates from the idea that mission-orientation implies an openness to different solutions and technology (Dachs et al. 2015, p. 11).

placing missions at different levels of complexity with regard to the goal and the role of governance.

Transformer type 1 missions (T1) are comparatively more narrow in their scope in two ways. Firstly, T1 missions should emphasize the solution over the goal to address the problem, thus possess a clearly defined agenda what part of a challenge to address by which means. Secondly, despite high levels of complexity for coordination and governance, the changes might be smaller compared to transformer type 2 missions. While the crosscutting character of the mission affects a wider group of actors, these are rather located at a low level of the innovation chain, thus do not directly affect final users. In consequence, they can be managed more easily, as both the range of public and private actors is less comprehensive and they are less likely to be exposed to interaction effects with other fields. Moreover, the achievement of mission goals is also (partly) linked to improvements in efficiency, thus does not strive for a full overhaul of the existent system. An example could be missions that aim for systemic change in production systems, but neither do directly affect end users, nor do substantial disadvantage some actors, as the solutions have a strong efficiency-improving component.

In contrast, T2 missions have the highest level of complexity. Given the considerable scope of the challenge and the absence of a promising solution, they are primarily problem-driven and rather present a framework of possible goals. However, they do not offer yet a specific solution, so that there might be multiple avenues for addressing the problem. They require an active state intervention and are particular prone to interaction effects as they are embedded in a multi-actor setting providing solutions closer to the final users and thus require also considerable behavioral changes. Moreover, they have stronger redistributive effects compared to T1 missions, as changes may affect actors unevenly and impose costs only on some of them. For instance, altering the existing practices of mobility may shift power and resources between different sectors and means of transportation. Given the existence of potential interaction effects with other policies, the crosscutting character results in a larger number of state actors involved. This subsequently increases the risk of institutional conflicts, deadlocks in negotiation and imposes a higher need for coordination among involved actors.

3.4 Discussion of typology

This typology suggests a framework that distinguishes between transformer and accelerator missions and at a second level differentiates between subtypes in each of the categories. Table 1 summarizes the key characteristics of the four mission types that were discussed in greater detail in the previous sub-sections. While providing a starting point for the classification of diverse types of missions, there is a number of aspects that deserve further attention.

First of all, the framework is not perfectly symmetrical, in particular with regard to the differences within the categories of transformers and accelerator missions. Whereas in the case of accelerator missions there seems to be a rather consistent picture with regard to the different dimensions pointing to a rather systematic cut-off point, the differences in case of transformers are of a rather gradual character. In consequence, T1 and T2 appear even more strongly as ideal types within a continuum, suggesting that T2 might be more vague and ambiguous by comprising more complex and far-reaching challenges. This is also an alternative understanding to the term "umbrella missions" used by Polt et al. (2019). Instead of subsuming multiple missions under the auspices of one policy, umbrella missions might be understood as rather widely defined goals with a low level of specification of means to achieve the formulated goal and instead are oriented towards the problem, or as stated in the Lund Declaration in 2009 the “grand challenges of our time”.[10]

Secondly, missions might be in total received as a continuum with regard to their complexity. This ties in with arguments of previous research which perceived its classification as ideal types, acknowledging that real-world cases can be found in-between the two poles described (Kuittinen et al. 2018b, p. 32). This understanding of a continuum about the complexity of change and its governance may be even expanded to the overall typology of mission types. While the uncertainty about finding a solution might be higher in Type A1 compared to A2, the overall complexity due to the depth of transformation and the internal and external governance requirements tend to increase over A1 and A2, to T1 and T2 as an endpoint.[11]

Thirdly, despite problems of clearly delineating T1 and T2, the introduction of the two sub-types is a useful analytical perspective, as it offers a differentiation within the category of transformer mission. Instead of considering transformer missions as a uniform category of missions with rather bold and broad goals, it seeks to understand the differences with regard to structure and its distinct challenges within this category. As discussed beforehand, the main difference can be found in the increasing complexity of governance structures, tying in with the recent trend in the analysis of mission-oriented

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[10] As stated during the Swedish Presidency of the European Union in July 2009: The Lund Declaration - Europe must focus on the Grand Challenges of our time, online: https://era.gv.at/object/document/130, accessed 12.09.2019, p.1.

[11] This perspective might gain additional support from attempts to employ factor analysis for eliminating irrelevant dimensions. The analysis found that most factors were loading on one dimension only (see discussion below).

policies to pay more attention to the implementation and role of governance (Larrue 2019; Grillitsch et al. 2019). This step might be particularly relevant against the background of attempts to better understand the impact of mission-oriented innovation policies as it can help to better map relevant missions, open up the way for a more systematic comparison, and link the evaluation of missions closer to their key characteristics.

Finally, we explored the importance of a wider range of empirically possible dimensions. Relying on a large variety of possible dimensions identified in the literature and preliminary assessments for the 12 German HTS missions, we experimented with exploratory (baysian) factor analysis as a way for identifying relevant dimensions.[12] The results of this analysis, however, do not indicate a systematic problem with the selection of main categories in our typology. While there are four dimensions standing out as a second strand in analysis, there are some problems connected to the following categories:

- contestation on whether an issue is a real problem
- uncertainty about the effects of non-activity
- redistributive consequences of an intervention by regulation
- consensus on the existence of a specific solution

While some of the dimensions are already subsumed in other measures (redistribution), especially contestation appears to be prone to wrong assessments, when missions only address a subset of a challenge and might be exposed to interaction effects. At the same time, the fact that most of these dimensions are closely linked to the interplay of different actors supports the claim that the governance structures are a crucial element for understanding the dynamics and challenges of mission-oriented policies.

3.5 Operationalization of dimensions

Building on the typology developed in the previous sections, the following paragraphs provide a step towards the application of the typology to the 12 HTS missions. In particular, we outline an operationalization for the relevant dimensions and discuss sub-components for the governance dimensions. In most cases, given the lack of quantifiable data, the subsequent analysis will rely on qualitative assessment, providing a usually dichotomous distinction between different options. Table 2 provides an overview of the

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[12] Factor analysis is a statistical approach that to identify potentially crosscutting dimensions and exclude irrelevant dimensions/identify dimensions with a similar direction. Using a total of 25 potential dimensions identified in the literature we run a Bayesian Exploratory Factor Analysis with the BayesFM package in R (Conti et al. 2014). This allows to treat both the number of latent factors and allocation of manifest variables to the factors as not fixed.

relevant sub-dimensions to be included, the character of the variable (binary, index) and the relation to other literature.

Given the absence of a natural threshold, a qualitative assessment can distinguish between high and low levels for individual dimensions. The first two dimensions primarily describe the structure of the challenge and possible solutions to it. Firstly, the type of failure and thus the underlying scope of problem shapes the need for intervention and gives insights into the complexity of the problem. Following Weber and Rohracher (2012), it assumes that a transformational system failure implies a higher level of complexity compared to market or structural system failures alone. Therefore, only those missions that are motivated by a failure that is deeply rooted in the existent system structure will be classified as a transformational system failure. The second dimension refers to the anticipated solution of the problem and is more closely linked to the mission as such. The main question to delineate the type of the solution is whether the anticipated change is driven by scientific/technological progress and regulatory adjustments only, or whether the mission requires a deeper transformation reaching beyond these dimensions and affecting the institutional setting and the behavior of actors in the field.

Beyond this distinction between accelerator and transformation missions, the previous sections have outlined three additional dimensions. First of all, there is the question whether the mission is primarily developed based on the perception of a problem, or whether it already provides the solution to a problem, shifting the focus on the steps towards achieving this goal. A problem-orientation implies that the type of challenge is acknowledged and one aims for the improvement of the situation, however, without being able to provide yet a solution how to achieve this

Secondly, the role of external coordination can be understood as the interplay of public and private actors and the means used to achieve the desired outcomes (equally weighted), thus the question about agency (actors) and policy instruments. Whereas the former indicates the range of potential stakeholders in the realization of the mission goals and thus gives a hint about the possible interdependencies, the second sheds light on the capability of the state to steer and manage the outcomes, by relying on appropriate policy instruments. To capture the range of potential actors, we use an additive index of key players (state, research/science, economy, society understood as citizens and formal organizations representing relevant non-economic groups). As key players we define those actors that can be considered as necessary for achieving the mission goal. In order to understand the interplay of actors and specifically the role of the state, we consider the following dimensions of state activity as relevant:

i. Informing: supporting the acceptance of technological advancements that address missions or/and facilitate behavioral change among citizen by providing information and persuasive efforts
ii. Financing: providing a substantial share of financing in order to ensure the realization of the mission
iii. Regulating: adjusting existing regulations to new developments and set a legal frame for its implementation,
iv. Coordinating: coordination of the interplay of different actors and actively creating new (institutional) structures for the realization of the mission
v. Redistributing: the potential importance for the state to overcome redistributive consequences in order to ensure the realization of the mission

Table 2: Dimension of typology and operationalization

Dimension	Operationalization	Type of variable	Level of analysis	Related Literature
Type of problem	Type of failure (transformative vs. non-transformative)	Binary	Challenge	Weber/Rohracher 2012, Wanzenböck et al 2019
Type of solution	Change in behavior necessary vs. scientific innovation/ regulation (behavioral additionality)	Binary	Mission	Gök/Edler 2012; Hekkert n.d., p. 13; Wanzenböck et al. 2019, Polt et al. 2019
Problem- vs. goal-oriented	Mission entails a clearly defined goal	Binary	Mission	Polt et al. 2019
External coordination	Cross-sectoral diversity (state, science, economy, society)	Additive index	Mission/ Challenge	
	Dimensions of state activity (financing, regulating, coordination, redistribution, information)	Additive index	Mission/ Challenge	Larrue et al. 2019, p. 13; Lowi 1972; Hufnagl 2010
Internal coordination	Dimensions of internal interaction (number/type of actors involved, governance architecture/leadership)	Additive index	Mission	Larrue 2019

The final dimension deals with the internal challenges of governance within the state that can act as a constraining factor to the governance of change. The more complex the governance of mission-oriented policies within state actors, the harder it will be to effectively get involved in the realization of the mission goals and successfully fulfill its role in the interaction with other actors. Again, complexity of internal coordination is measured by an additive index, capturing different sources increasing the efforts for coordination:

i. Horizontal coordination: number of ministries (departments) involved in coordination of policy (low: <3 ministries, medium: 3-4 ministries; high: >4 ministries)
ii. Vertical coordination: number of actors across different levels (national, regional, local, subordinated agencies) involved in coordination of policy
iii. Division of responsibility: Management of mission in the hand of a lead coordinator vs. the existence of multiple centers of coordination?

3.6 From different types of missions to different types of problems

The typology identifies four main types of missions that vary with regard to the complexity of problem/solution (seeking), the orientation of the mission, and the complexity of governance with regard to public and non-public actors. The implementation of each of these types of missions faces distinct challenges, with rising levels of complexity (these challenges are likely to add up when moving from accelerator to transformer missions and from type 1 to type 2):

- Accelerator Type 1 (A1): Relying primarily on further scientific progress, the main challenges are linked to the uncertainty of outcomes, the creation of appropriate incentive structures and an effective management of investments.
- Accelerator Type 2 (A2): In contrast to A1, accelerator type 2 missions require a higher level of coordination and state involvement as they also need to overcome structural failures. Scientific/technological progress itself is not sufficient, but these insights need to be made applicable/translated for a broader range of users/contexts.
- Transformer Type 1 (T1): In comparison to accelerator missions the key challenge is achieving a comprehensive transformation. This adds one additional level of complexity, as it broadens the range of involved stakeholders and might require also changes in the behavior of actors. Among the key challenges are the long required time horizon, the "translation" between different disciplines and sectors and the interplay between different fields.
- Transformer Type 2 (T2): Being rather similar in its character to T1 with regard to the scope of challenge and the possible solutions, T2 missions are the most challenging due to their complex governance structure, the high degree of interdepedency with other fields, and the potential (redistributive) conflicts between actors. In consequence, the interplay of actors might be particularly prone to conflicts, making the transformation process slow-paced, hard to predict,

and closely linked to comprehensive negotiation processes that require a massive coordination both with private and public actors.

These different constellations of problems may also have implications with regard to the foreseen assessment on the impact of missions from the HTS. Arnold et al. (2018, 16, 54) argue the complexity of evaluation depends on the complexity of the problem. In a similar vein, Kuittinen et al. (2018a, p. 35) argue that "mission-oriented R&I initiatives should be evaluated against criteria adapted to their objectives and the problems they target", rejecting a one-size-fits-all approach. The call for differentiated perspectives is also backed by reports from the ASIRPA evaluation approach (Matt et al. 2017: 217), which find different development paths depending on the mode of coordination/instruments used.

Taking all these arguments together, one can assume that different mission types face different challenges and thus require different approaches for evaluation. Therefore, the focus on the impact in case of A1 could concentrate on different aspects coming closer to "traditional" summative evaluation, whereas a stronger transformation component requires an adjusted approach taking into account aspects of ex-ante evaluation schemes. In consequence, the implementation as well as the evaluation of transformative missions should pursue a broader focus with regard to impacts and pay particular attention to a critical assessment of the status quo. This might include the reverse thinking of ex-ante impact assessment which means one starts with the desired outcome and builds on a theory of change how the intervention can contribute to the aspired outcome at the macro- and at the micro-level (Daimer and Bührer 2019).

4 Empirical application of the typology to the German Hightech-Strategy (HTS 2025)

4.1 Empirical classification of HTS missions

Having outlined a general concept for the classification of individual missions in mission-oriented policies, this section applies the typology to the twelve missions of the German Hightech Strategy 2025. The missions are grouped into three main categories (societal challenge, future competencies, open innovation and venture culture), ranging from the challenge of health over regional development to sustainability. Relying on qualitative assessment that was cross-checked with members of the project team, each mission was coded for the aforementioned dimensions based on information provided in official program documents of the HTS 2025 (BMBF 2018, 2019; a detailed description justifying the coding of individual missions can be found in the appendix). Table 3 summarizes the coding and provides an overview of the classification into the four categories.[13]

Empirically, the HTS seemingly contains missions corresponding to each of the four ideal types formulated in the mission typology. Among accelerator missions, especially the research-oriented mission on Cancer appears as a Type 1, as its focus on science and research activity limits the challenges with regard to internal and external governance. In contrast, the more applied missions on intelligent medicine (2), battery cells (8), artificial intelligence (11), and carbon dioxide reduction in the industry (4) as accelerator Type 2 missions. The remaining transformer mission usually address more substantial types of failures and therefore require a more complex intervention, both with regard to the solution and the governance of involved public and private actors. However, even in these complex settings, there exists variation. As can be seen from Table 3, especially the missions on circular economy (5) and open knowledge (10) appear to exhibit a lower degree of complexity with regard to the coordination of private and public actors and the use of policy instruments. As discussed in the following section, however, not all mission neatly fit into a certain category, but exhibit sometimes hybrid characteristics or ambiguities due to the description of the mission.

[13] Note that due to data constraints, we did not include the dimensions on vertical coordination and the division of responsibility for the complexity of internal governance.

Table 3: Assessments for relevant dimensions (Index variables only display aggregated values of individual dimensions).

	Fighting cancer (1)	Intelligent medicine (2)	Battery cells (8)	Artificial intelligence (11)	CO2 emission industry (4)	Circular Economy (5)	Open knowledge (12)	Plastic waste (3)	Biodiversity (6)	Mobility (7)	Good life (9)	Technology for humans (10)
Type of failure (transformational system failure)	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Type of solution (behavorial change necessary)	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Orientation of mission (solution/application-oriented)	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
Complexity external governance (0-1)	0.55	0.65	0.58	0.68	0.68	0.78	0.8	0.9	1	1	1	1
Sectoral depth (Number of key actor groups involved) (0-1)	0.5	0.5	0.75	0.75	0.75	0.75	1	1	1	1	1	1
Range of policy instruments (0-1)	0.6	0.8	0.4	0.6	0.6	0.8	0.6	0.8	1	1	1	1
Complexity internal governance (0-1)	0	0	0	0.5	0.5	0.5	0	1	0.5	1	1	1
Depth of governance (0-1)	0	0	0	0.5	0.5	0.5	0	1	0.5	1	1	1
Type of Mission	**A1**	**A2**	**A2**	**A2**	**A2**	**T1**	**T1**	**T2**	**T2**	**T2**	**T2**	**T2**

The results of this classification are illustrated by the use of cluster analysis techniques. Figure 1 displays the dendrogram for a cluster analysis for the selected categories (average linkage, gower dissimilarity measure for mixed binary/continuous data).[14] Whereas the upper branch of the dendrogram indicates the existence of two subtypes of transformer missions with quite some difference to each other, especially the cancer mission (1) stands out among the accelerator missions. In all subtypes there is evidence for minor diversity, however, the overall differences are rather small in comparison to differences between subtypes, as can be seen from the length of the vertical lines in the dendrogram.

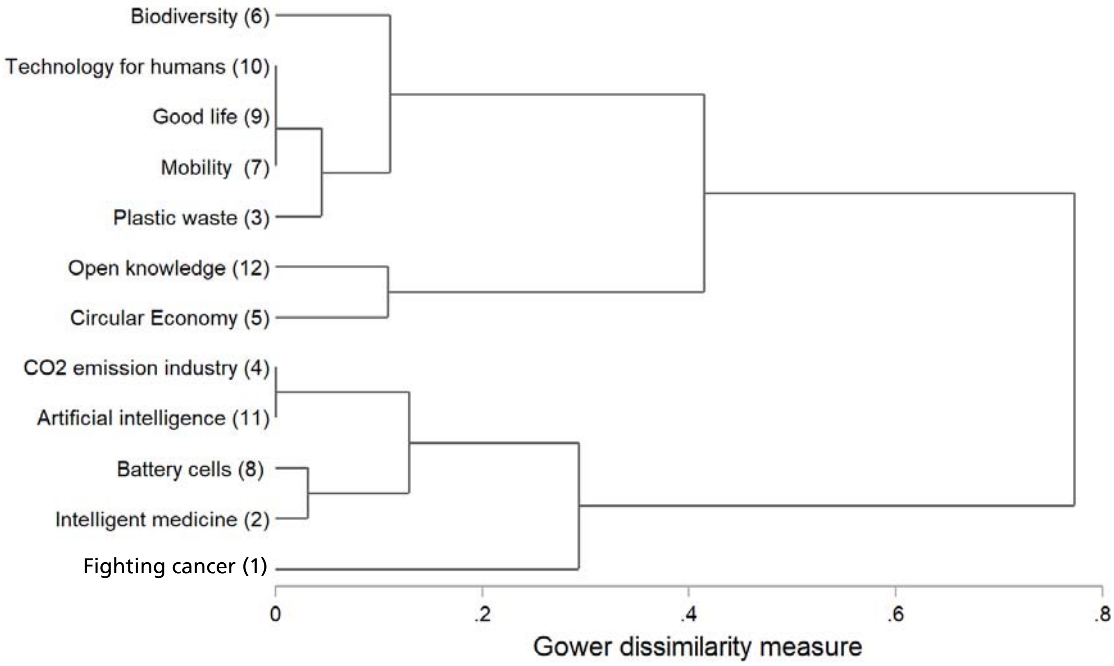

Figure 1: Cluster analysis for the twelve German HTS missions

4.2 Discussion of classification

The application of this new typology to the twelve missions of the German Hightech strategy demonstrated that the typology can be used to systematically classify real-world missions. What sets this new typology apart from previous research are in particular three points: the conceptual delineation between policies and missions, the emphasis on the actor constellations and governance as a factor for shaping the realization of mission goals, and the attempt to provide a more fine-grained differentiation between different types of transformer missions. The latter, so far, have usually been subsumed in a single

[14] The emerging cluster structure is highly similar when using a single/weighted linkage or different dissimilarity measures.

category, ignoring the existent variation between them. Instead, we argue that there might exist gradual differences within transformers missions that require further attention.

However, this is not to claim that there are no problems with regard to this typology. In the following, we turn towards the existence of limitations and problems that could be associated with it. First of all, despite attempts to capture the underlying challenges, the classification is closely linked to the mission itself. On the one hand, missions may only address a subset of a challenge or adopt a narrow approach to it. This has been come most clear in the case of mission four (reduction of carbon dioxide in industry). The mission focuses itself on technological solution, without aiming for broader systemic changes. On the other hand, the assessment depends on the quality of the mission definition, i.e. how specific goals and means to achieve these goals are defined, what was a challenge in case of some rather vaguely and ambiguously defined missions (6, 9, 12). From this perspective, the incorporation of governance structures constitutes a major asset of this typology, as it brings in additional dimensions that can rely on additional quantifiable data. At the same time, the attributed values across dimensions appear to be highly correlated, thus increase the trust in the previously obtained values. In order to overcome the potential problems arising from a bias of mission descriptions, the empirical classification of missions and its dimensions underwent extensive discussion in the project team and were cross-checked - wherever possible - by external data.

Secondly, in many instances there is an empirical overlap of several of the key dimensions - a problem already described in the practical implementation of research in this area (Walz et al. 2017, p. 15). While complex problems in most instances results in missions with complex interventions, there are good reasons to rely on a broader conceptual framework. On the one hand, as argued beforehand missions may address only sub-parts of a challenge, making it necessary to take a closer look at the overall setting. Especially from a comparative perspective, this can be a crucial step to identify variation even among seemingly similar missions. On the other hand, the rather comprehensive approach is rooted in the foreseen impact assessment. As different types of missions might have different foci for evaluation (see section 3.6), it is necessary to capture potential variation from the very beginning, in order to provide an adequate framework for impact assessment.

Finally, the typology as such does not directly conceptualize the relationship between different missions within a strategy (like the HTS). Aiming to study several missions from a comparative perspective might therefore imply to broaden the horizon to understand how different missions are related to each other. To what extent do other missions affect the implementation of a mission? Such interdependencies may impose one additional layer of complexity also for evaluation, as the success of a mission might be affected by outcomes of other missions (Amanatidou et al. 2014, p. 425).

4.3 Thoughts on the selection of missions for in-depth investigation

The mission typology developed in this paper is a first step towards the measurement of impacts of mission-oriented research and innovation policy. By providing a fine-grained typology, it is possible to select individual missions for an in-depths study that can build on a framework that takes into consideration the specific challenges and pitfalls of each type. This section outlines some thoughts that might provide a starting point for the adequate selection of cases.

The selection might benefit from the reliance on two principles: the representativeness of missions for larger mission types and the interdependence between different missions. Firstly, missions selected should be typical/representative cases (see, e.g., Seawright and Gerring 2008) that exhibit a high degree of similarity to the ideal types described in section 3. From a comparative perspective typical cases are particularly beneficial as they allow maximizing the variation between cases under study and make selection less vulnerable to ambiguities in the project description (see section above for problematic cases). While missions can be located in a continuum between these ideal types, hybrid cases make it more difficult to investigate the with-in case dynamics and may limit the ability for more generalized conclusions. From this perspective, particularly the following missions might be promising:

- Accelerator Type 1: **Fighting cancer (1)** → Being the only example for an accelerator Type 1, fighting cancer is a paradigmatic example for a “classical” science mission, having a broadly defined goal and being exposed to high uncertainty about the outcomes. Moreover, the challenges for coordination are limited due to the prevalent focus on research activities.
- Accelerator Type 2: **Intelligent medicine (2) battery cells (8),** or **artificial intelligence (11).** Compared to the reduction of carbon dioxide (4), the aforementioned mission come closest to the principle of bringing knowledge into application. While especially intelligent medicine might be characterized by a clear final product, artificial intelligence might be interesting from the perspective of interactions between missions (see discussion below).
- Transformer Type 1: **Circular economy (5)** - A relatively strong focus on technological/scientific solutions and the supply side (producers) places mission 5 at the low end of transformer missions, as consumers only play an indirect role

for the realization of the mission. In contrast, the more fuzzy mission of open knowledge (12) appears to exhibit stronger tendencies towards Type 2, as behavioral changes play a more pronounced role.

- Transformer Type 2: Especially the mission on **mobility (7)** can be considered as a representative case for the fourth category. It entails highly transformative goals, a complex constellation of actors both from an internal and external perspective, and potential redistributive conflicts. Moreover, mobility can be considered to be located at the high end of the innovation chain, with mobility being affected by innovations in many related fields and even other missions of the HTF (like battery cells).

A second argument for the selection of mission could be the interdependency between mission that allows studying how outputs of different missions interact with each other and thereby control for dynamics beyond the case under study. This could, at least partly, ease the challenges for evaluation due to the interconnectedness of challenges (Amanatidou et al. 2014, p. 425). Keeping in mind the arguments made with regard to representative cases, the following considerations might be relevant:

- A focus on missions related to health (1, 2), sustainability/environmental protection (3, 4, 5, 6), or mobility (7, 8) would allow study missions embedded in a similar context with varying levels of ambitions and complexity and gain insights into the interplay of different missions.
- The mission of artificial intelligence (11) is not only a topical issue, but also exhibits multiple references to other missions (1, 2, 5, 6, 7, 10, 12). Therefore, when aiming to account for interaction effects between different missions, it might be a particularly compelling choice.

5 Conclusions

In this paper we present a novel analytical framework for the study of mission-oriented innovation and research policies. The key argument is that the turn towards a stronger directionality of these policies has also substantial implications for the role of the state. Accordingly, the study of mission-oriented policies needs to adjust its perspective and pay more attention to the governance, the implementation process, and actor constellations. Building on previous research and the distinction between transformer and accelerator missions, we develop a framework at the mission-level that distinguishes between four types of missions. Thereby, we aim to reflect for the varying degrees of complexity within missions and account for the different logics and goals of mission-oriented policies. Based on these insights, the typology can contribute to develop appropriate approaches to evaluate and measure the impact of mission-oriented innovation and research policies by accounting for mission-specific problems and characteristics.

We apply this typology to the twelve missions of the German *Hightech-Strategy 2025* and find that most missions can be clearly classified as one of the theoretically developed mission types. Based on this typology, we outline suggestions for the selection of adequate missions for an in-depth study, highlighting the benefits from a focus on representative cases. The selection of missions that relate to a shared challenge, like mobility, moreover might offer the opportunity for a better understanding of the internal dynamics, as outcomes of different missions might be interdependent.

Identifying different types of missions points to several implications for future research. Firstly, research should empirically test this mission typology by applying it to further cases, like the British *Innovation and Research Strategy for Growth*. Secondly, the comparison of different mission types can help to explore to what extent different challenges and governance structures shape the dynamics and outcomes of missions. Do the empirical findings confirm the theoretical expectation formulated in section 3.6 that we should observe different kinds of challenges in different types of missions?

Thirdly, it seems of utmost importance to analyze the connection between the formulated missions and the "ways and means" on how these missions should be accomplished or tackled, namely the policy instruments. Fostering innovation by applying policy instruments has always been a difficult task. However, given the complex setting of mission-oriented policies, it even becomes more challenging to correctly observe and examine the cause and effect relationship of policy actions and the desired outcomes. Shifting the perspective towards the role of governance may help to map the field more clearly. Especially the study of failed mission in this regard might be particularly revealing, in order to understand whether complex missions indeed fail due to their overall complexity and too high ambitions or because of problems at the implementation level. Thereby, this typology also can contribute to a better understanding on the context-specific role of policy-mixes (Rogge and Reichardt 2016) and the effectiveness of different policy instruments (Edler et al. 2016).

Finally, the typology allows shedding light on the interplay between different missions and exploring interactions in larger policy frameworks. While multiple missions may address one challenge at the same time, their relation with each other may vary considerably (complementary, re-inforcing, conflicting). Mapping the different types of missions may be one step ahead to grasp the interplay of different missions theoretically and study their impacts from a broader perspective, by moving from the mission-level to the overall policy-level.

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Appendix: Description of HTS missions

Mission 1 (Fighting cancer)

Fighting cancer (Mission 1) can be considered as a clear case of an **accelerator type 1** mission. Being heavily reliant on further progress in science in order to develop new approaches to cure cancer, the main failure in the past is the limitation of financing, classifying it as an archetypical case of market failure. The mission is defined from the perspective of the problem (fighting cancer) and does not provide a clear pathway how to achieve this goal. While the most current report also highlights the goal to bring the insights to application, the focus is mainly on research, whereas insights from application are supposed to feedback into research activities. At the same time, the governance structure both internally and externally is of limited complexity. Neither does the role of the state go considerably beyond financing research, nor does the coordination appear to be crosscutting a wide range of public and private actors.

Mission 2 (Intelligent medicine)

The introduction of the electronic patient file can be classified as a case for an **accelerator type 2** mission. The main challenge connected to this mission is less based on finding new technological solutions, but rather implementing an already defined solution (electronic patient record) and thereby overcoming the prevailing transformational system failure. The role of the state is not limited to financing, but also includes regulatory and coordinative tasks, making both efforts for internal and external coordination necessary.

Mission 3 (Plastic waste)

The mission on plastic waste can be considered as a **transformer mission type 2**. Addressing a part of the grand challenge on sustainability, it seeks to engage in a large variety of areas (research, information, regulation, etc.) and strives for a change of societal behavior. Thus it does not limit the mission to finding technical solutions, but aims for a systemic change. The complexity of the endeavor is also reflected in the variety of national (and international) stakeholder resulting in highly diverse projects and the coordination of the mission across six ministries (BMBF, BMU, BMEL, BMJV, BMWi, BMZ).

Mission 4 (Zero emission CO2)

The mission aims at reducing carbon-dioxide emissions in the industry and is classified as an **accelerator type 2**. While addressing a complex problem, the emphasis in the mission is clearly on providing new technological solutions and their application at industrial level (BMBF 2019). Thus, the scope of the mission is much more narrow than the overall challenge, as can be seen from the lacking reference to regulatory means in current documents. The rather narrow understanding of the mission goal and focus on technological progress suggests also comparatively limited levels of internal and external complexity (though the collaboration of BMU and BMWi might imply competing interests). Depending on the reading of the mission and weight attached to the underlying challenge, a different classification might be possible.

Mission 5 (Circular economy)

Mission 5 with its focus on circular economy leans towards **transformer mission type 1.** While the underlying problem is complex and involves a wide variety of actors and cannot be understood by a market/structural failure only, it appears as rather narrowly defined for a transformer mission. Having outlined a clear, quantifiable goal (increase resource productivity by 30% until 2030), the mission strongly emphasizes the role of technological innovation and structural changes compared to a broader transformation. At the same time, this focus on innovation and increasing productivity/efficiency implies a lower level of contestation (redistributive questions) and a more limited scope of (public and state) actors, as the mission is primarily focused on the production/recycling process. At the same time, it can be considered at the low end of the innovation chain and thus being less exposed to interdependencies with efforts in related fields.

Mission 6 (Biodiversity)

Mission 6 falls into the category of a **transformer mission**, **leaning towards type 2**. The decline of biodiversity can be considered as a multi-faceted complex problem that is affected from a transitional failure requiring a comprehensive state intervention, addressing not only technological but also regulatory and behavioral dimensions. While the initial programming document emphasized the role of research, the current report includes regulatory activities. The constellation can be also considered as more problem-oriented and complex when thinking about its implications for anticipated activities like regulatory changes in the agricultural or housing/planning sector, making coordination more conflicting and complex both between public and private and within state actors (BMBF, BMEL, BMU).

Mission 7 (Mobility)

Much alike the mission related to carbon dioxide, mission 7 (mobility) can be considered as a **transformer mission type 2**. It addresses a fundamental challenge with transitional failure which cannot be solved by regulatory and technological means only. Presenting a bundle of measures it does not provide yet a solution to the problem, but departs from the observation that mobility is at the edge of a transformational process. It comprises a wide variety of stakeholders and has potential redistributive effects turning the issue into a highly contested debate. At the same time, the crosscutting character of this challenge also necessitates the cooperation of multiple state-actors imposing a high coordinative burden on the state in order to fulfil its role in steering the development process.

Mission 8 (Production of battery cells)

The production of battery cells can be considered as an **accelerator mission type 2.** Being placed at the intersection of scientific innovation and the application into the industrial domain it has a rather clearly defined final product. While the mission description highlights the role of research, the anticipated role of state behavior is not limited to financing of research, but requires a more active involvement in shaping a favorable environment for fueling the production of battery cells.

Mission 9 (Good life)

Like climate change and the related topic of mobility, mission 9 targets one of the big challenges, arising from demographic change and the widening gap between rural and urban communities. Therefore, it also qualifies as a **transformer mission type 2**, given the wicked structure of the challenge and the transformative character of a possible solution that requires a broad variety of instruments. Enlisting a number of problematic dimensions, the mission does not yet provide a solution and thus is more problem oriented. Furthermore, the multi-faceted character of this problem makes the coordination between public and state actors necessary and is likely to lead to contestation about the prioritization of measures (for instance about the geographical prioritization of support). A similar structure can be also found with regard to the internal governance of the mission, which crosscut several policy fields and therefore creates high demands for a successful coordination of different actors.

Mission 10 (Technology for humans)

Mission 10 targets a broad field of problems, making current technological developments available for social purposes. While resting on a notion of technological innovation, the scope of this mission is considerably broader aiming to reach into domains like the work environment. Instead of focusing on a single technology, it suggests a general approach, suggesting that it is best classified as a **transformer mission type 2**. Addressing a topic with broad societal implications, it pursues a problem-oriented approach, which rests on the insights of emerging challenges based on technological innovation. Following the rather vague mission description, the focus is more towards exploring the impacts of new technologies on the social sphere including behavioral change of citizens and the adjustment of existing regulations as a reaction to a changing environment. Coordination is highly dispersed between state actors (BMAS, BMFSJ, BMEL, BMWi, BMBF) and involves a wide range of different stakeholders, suggesting a highly complex coordination.

Mission 11 (Artificial intelligence)

Similar to mission 8, also mission 11 which aims to promote the development of artificial intelligence can be classified as an **accelerator mission type 2.** While highlighting the importance of research, the mission clearly links the goal to the application of insights and strengthening the German position in the emerging field. Again, governance is more complex compared to Type 1 missions, as it involves a wider range of potential actors (universities, enterprises, etc.) and cannot be achieved by a support of research activities only. Facilitating the emergence of new applications requires both the creation of favorable environments as well as higher regulatory and coordinative efforts and the dispersion of information to address emerging issues.

Mission 12 (Open knowledge)

The mission aims at creating new avenues for open knowledge (12) and has the characteristic traits of a **transformer mission, leaning towards type 1**. It deals with a problem that is not a mere market- or structural failure, but has deeper roots that require an overall transformation of existent processes of knowledge exchange and innovation. Having already defined a focus on open access/science/data/innovation the mission has moved from a mere problem description towards a solution-oriented approach with a feasible technical solution. What limits its complexity with regard to the governance is mainly the fact that the level of contestation might be rather limited, as it complements existing strands (what can be also seen by the combination of existing instruments used) without replacing them completely. The outreach might be also limited in so far, as the coordination is supposed to be carried out by two ministries only, suggesting that the topic is not treated as crosscutting a wide variety of policy fields and ministerial responsibilities.