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Technology Roadmaps, Innovation Journeys, and Nanoworld: A Spatio-temporal Consolidation of the EC Nanotechnology Policy

ABSTRACT: *Technology roadmaps have become an essential part of the European Commission's (EC) nanotechnology policy strategies. They represent socio-technical landscapes and evolving pathways, suggesting the underlying or otherwise supportive metaphorical patterns and narrative structures. For the same reason, however, roadmaps are problematic assemblages: they can simplify and distort reality, and filter things that don't fit. The presented study combines cognitive linguistics with narratology to scrutinise the European Commission's nanotechnology roadmapping as a discursive formation. It targets the systematic metaphors in approximately two-hundred news and reports on nanotechnology, compiled ad hoc from the CORDIS database (between the years 1999–2015). It is argued that the identified metaphors correspond to a discourse topology of 'locations', 'events', and their structures, especially as regards to the dilemma of 'path dependence', overcoming 'knowledge gaps', and reaching 'nanoworld'. These are accompanied by a narrative climax of developing mature science policy model, in the arrangement of actions and roles for the European governments, science (nanotechnology), policy, and the public. The study demonstrates how systematic metaphors engage all the actors in the narrative of 'innovation journey' to form stabilised structures of meaning, that is, spatio-temporal consolidation of nanotechnology policy. It is imperative to continuously assess the context of such consolidation, being less overt but not necessarily less effective, in privileging some meanings, interests, and practices over the others, thereby excluding other political alternatives.*

KEYWORDS: Nanotechnology policy; the European Commission (CORDIS); technology roadmaps; policy assessment; metaphor analysis.

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INTRODUCTION

Nanotechnology is a set of technologies that enables manipulation, study or exploitation of very small (typically less than 100 nanometres) structures and systems. While its rapidly expanding set of applications in electronics, food, medicine, and energy production captures the imagination of various audiences and continues to be contested as well, nanotechnology has developed into something more. During the past decade or so, it has become incorporated into strategic policies that seek to redefine what the nation or community is, and what it stands for (cf. Amato, 1999; Nordmann, 2007).[2]

In particular, the European Commission (EC) aims to implement nanotechnology as a pan-European research priority, and to develop a specifically European approach (Commission, 2005). It aspires to coordinate actions at different levels of performance, between research institutes and universities, small to large corporations, suppliers, industries, and trade associations, nation-states and international bodies. In this sense, it emphasises how the governance of 'nano' ought to be based on collaboration, the best scientific evidence and available practice (Commission, 2010a; see also Schummer, 2004; Gilad, 2010; Stokes, 2013). The EC nanotechnology

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2 For example, the National Nanotechnology Initiative (NNI) in the United States, or the Converging Technologies for the European Knowledge Society (CTEKS) in the European Union, both represent ambitious strategies, aiming at designing futures for whole societies to be rebuilt 'atom by atom' (Amato, 1999; Nordmann, 2007; in reference to Feynman's 1959 lecture).

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policy in a multi-actors and long-range strategic planning targets the emerging infrastructures (*ESFRI roadmap*), and frameworks for innovation (*Horizon 2020 roadmap*), and also, nanotechnology projects, such as: *NanoRoadSME* (2006), *NanoRoadMap* (2006), *FramingNano* (2008–2010), *Nanolandscapes* (2011), *NanoCode* and the *European Commission Code of Conduct* (2010–2012), *ObservatoryNano* (2012), or *NANOfutures: Integrated Research and Innovation Roadmap* (2012), among others. These activities not only give an indication of a general revival of technology roadmaps, in their traditional form, they are used as tools in top-down technology management, and are now moving in new political contexts. They show how words, images, and patterns of discourse exhibit their own set of dynamic and have special importance in the EC nanotechnology policy. They point at certain consolidation of 'a strong and unified Europe', which is not, as Sheila Jasanoff (2005, pp. 77–93) argues, merely arbitrary linguistic choice but a strategy. It is a systematic use of language to define problems that the European institutions could then position themselves to address in order to legitimise their political existence.

The objective of this study is to focus on character and effects of consolidation of the EC nanotechnology policy and to determine what information could be obtained from performing metaphor analysis in the roadmapping discourse. In contrast to studies focusing on explicit technology roadmaps (cf. Phaal et al., 2004 and 2009; Kostoff & Schaller, 2001; Verbong & Geels, 2010; McDowall, 2012), this study deals with roadmapping as a metaphorical pattern and narrative structure (Rip, 2012; Berker & Throndsen, 2017). I suggest studying roadmapping discourse in the institutional setting, where relative consensus about nanotechnology has been reached. For this purpose, I assembled *ad hoc* corpus (N = 200) from the Community Research and Development Information Service (CORDIS) from news and reports on 'nanotechnology' (keyword) development. Methodologically, I propose a systematic corpus-based approach that sharpens its analytical focus on variations in metaphorical concepts (Lakoff, 1993) and translates these concepts into narrative schema (Greimas, 1983 and 1987).[3] By combining two analytical models of systematic metaphor, either as a topological or narrative variation, I will argue how these can explain the character and dynamic of the spatio-temporal consolidation of the EC nanotechnology policy. The results of the analysis are confronted with selected policy documents to further address their embedding in discursive and social practices.

The article begins with an overview of the scholarship on technology roadmaps, followed by a discussion within the perspective of metaphor studies that can enrich understanding roadmapping concept in the political context. I place the research problem on the interface of CORDIS database and discuss its character and suitability for corpus compilation. I provide more detailed information on data and methodology of the study. Next, I present the main findings with a recovered topology and narrative dimension of the EC nanotechnology roadmapping. Discussion on metaphors and their systematicity in the context of the EC policy documents then brings the character, durability, and effects of the consolidation more into focus. Finally, I provide some concluding remarks concerning the nanotechnology policy assessment and implications for future research.

STUDYING TECHNOLOGY ROADMAPS IN POLICY DISCOURSE

Technology roadmaps have been commonly used in industry, government, and academia (cf. Barker & Smith 1995; Kostoff & Schaller, 2001; Phaal et al., 2004), and have gone through constant evolution (Phaal et al., 2009). Despite their variability reflecting different contexts of use, there is a key gap in the discussion on technology roadmaps in political contexts (Berker & Throndsen, 2017). Sociology of expectations has been closing the gap by paying special attention to technology roadmaps as there is the ideologically anchored notion that technology will continue to offer possibilities for progress (cf. McGee, 1980; Van Lente, 2000). Technology roadmaps emerge as 'protected spaces' and are thus shaped by the requirements for protection, and some boundary maintenance (Van Lente, ibid). There is always a variation in the expectations between different kinds of actors: basic researchers, entrepreneurs, potential end users, and so on (Brown & Michael, 2003). Technology roadmaps have been described as a process of developing consensus, and even as an authority over these heterogeneous actors (Kostoff & Schaller 2001; Phaal et al., 2004). If technology roadmaps are to be successful, the same consensual process and boundary maintenance must develop in the European governance context. There, a

3 The metaphor analysis here follows the Greek etymology of the word 'metaphor': to transfer or bear, in this case meaning from one context to another. Conceptual metaphors involve transfer as set of correspondences between semantic domains (Semino, 2008, p. 226). In principle, the narrative schema usually obtained by means of modalisations in 'being' and 'doing' is here adjusted to the notion of '(conceptual) metaphorisations' and their variations. Probing into the locations, events, actors, and related structures of signification, metaphors can reinforce the structure of representation (cf. Greimas & Courtés, 1979, pp. 247–49).

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multitude of heterogeneous actors results in increasing coordination difficulties, and which also force and condense diverse logics and vocabulary, especially economic incentives and instrumental rationality with value-oriented responsible development and innovation.

Technology Roadmaps as Systematic Metaphors in Discourse

A perspective from middle-range is provided by Berker and Throndsen (2017), who perceive roadmap as a product of negotiation of the future, where the resulting 'story' is a compromise between different anticipations. In other words, actors (also institutions) need to establish at least some rudimentary storyline to be able to provide a sense of direction (Berker & Throndsen, 2017, p. 215). What is usually mapped is not only innovation landscape but rather a series of events that unfold between more or less clearly defined points in time (cf. Phaal et al., 2009). Arie Rip, who studied technology roadmaps as patterns of innovation journeys, sees roadmaps through similar dynamics of innovation and that can be understood in terms of 'generative metaphors' (cf. Rip, 2006, pp. 349–350; Rip, 2012, p. 167), powerful 'frames' that represent a specific problem, and also, as solution to this problem (in Schön, 1979 and 1993, pp. 144–147). Based on this theoretical background, we can assume that technology roadmapping exists more or less implicitly as a metaphorical (narrative) pattern of 'locations', 'events', and 'actors', and discursive formation (Foucault, 1972, p. 31) – and that can altogether have an influence on institutional arrangements.

This is a perspective reminiscent of a much older dictum '*the map is not the territory*' (Korzybski, 1933), and whereby deconstruction goes further to bring the issue of how the language represents place and future into much sharper focus.[4] We have heard many times from different scholarly sources claiming that metaphors are only a rhetorical veneer in a given language register, with their own character and logic. The cognitive linguistics research goes more in-depth describing roadmaps as systems of conceptual metaphors, such as JOURNEY, used across many languages, applied to multitudes of experiences and processes (Lakoff, 1993, pp. 219–229). Similarly, the MAP is all wide-scope domain that is conventionally applied to a very large variety of experiences (Semino, 2008, pp. 109–117), or that the PATH scheme tends to be used, as Paul Chilton has pointed out, in order to represent '*policies, plans, national history and grand ideas like "progress"*' (Chilton, 2004, p. 204). Finding the boundaries of the technology roadmapping is something that might prove difficult on these cultural-cognitive grounds.

Even so, it is important to get a grip on the complexity and contingency. One has to still search and explain the reasons behind the amount of discursive and political coordination. In other words, places and futures grounded in metaphors can offer cues for action, be exploited for performing specific (political) tasks and achieving goals. At the *conceptual level*, metaphors can evince a tendency to interpret new information so that it becomes compatible with our existing theories (cf. Merton, 1948; Van Lente & Rip, 1998; Rip, 2012). Just as systematic metaphors, narratives connect events and experiences that were disconnected to become interconnected and planned, displaying coherence, integrity, fullness, and closure (Gottweis, 1998, pp. 33–37). At the *story level*, metaphors can create a particular scenario about what did, can, or should happen to emergent technologies.

Technology Roadmapping as Situated Practice: CORDIS Database

The study presupposes we can analytically extract systematic metaphors in their social contexts as long as we manage to argue that institutionalisation of such contexts occurred (cf. Cameron, 1999; Chilton & Ilyin, 1993; Chilton & Schäffner, 2002; Mussolff, 2004; Charteris-Black, 2011). The Community Research and Development Information Service (CORDIS), primary information repository of the European Commission (EC) has a specific value in targeting roadmapping discourse in the EC's institutional setting. The repository complies with the guidelines of the Publications Office of the European Union, on behalf of the European Commission's Research Directorates-General and Agencies. It contains data from different actors on the EU-funded projects in execution. Also, the science editors and journalists prepare the content by writing research reports, news, or make interviews, for the sake of maintaining different story-lines. The CORDIS is therefore not only a repository for research projects, it is also a science policy medium with specific editorial and political agenda, a representation of specific goals, desires, and interests. Even when actors submit information

4 '*A map is not the territory it represents, but, if correct, it has a similar structure to the territory, which accounts for its usefulness*' (Korzybski, 1933, p. 58).

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about projects (contracts are signed), it's a form of ideological compliance: '*The project leaders justify their focus referring to the European Commission's articulated demands*' (Åm, 2013, p. 13). The consensus about nanotechnology development in CORDIS, emergent from the interaction between researcher, engineer, and policy-maker, is thus taken as a reference to roadmapping discourse.

Given the current state of knowledge and the above discussion, I have placed the following research questions in the focus. The first question is exploratory, and the second one is more performance-based, aiming at the potential consequences by relating a metaphor to the real world:

- *Are the systematic metaphors, representing roadmapping discourse in CORDIS database, resonating with nanotechnology policy, that is, systematic in projecting 'political (means, ends, actions, plans, actors, etc.) is physical (paths, locations, events, maps, travellers, etc.)', either as the conceptual (Lakoff) or narrative (Greimas) variation?*
- *And if so, why are observed metaphors used, that is, are there any particular consequences of these concepts and structures that extend beyond linguistic analysis (from discourse to social practice), in terms of actor's qualifying roles, performance modes, mobilisation of resources, eligibility conditions, and so on?*

METHODOLOGY AND DATA

There are different methods available in metaphor analysis, even though studies of political discourse increasingly rely on corpus-based approaches (cf. Chilton & Ilyin, 1993; Chilton & Schäffner, 2002; Chilton, 2004; Musolff, 2004; Charteris-Black, 2004 and 2011). The corpus-based approaches are ideally suited to investigate the use of conventional metaphorical expressions, and particularly, their systematicity and structures. However, a close reading of text passages is necessary for determining metaphoricity (Wikberg, 2007), and which sets several limitations on corpus annotation and its validity, as well as on the size of the corpus.

The specialised corpus for this study was compiled *ad hoc*, searching for texts on 'nanotechnology' (keyword) in the 'news' section of the CORDIS database. There was no further specification in the request, such as 'technology roadmap', as discourse is wider than a topic. The other criteria were searching within the years 1999–2015, that would exceed the period of a particular framework programme. As the initial corpus was considerably large, randomizing the sample reduced its size to approx. 200 articles. Each article in CORDIS has a 'record number' or RCN – thus it can be traced back (see also the reference section of this study). The articles in the collection are from two categories of sources:

- reports on the EU-funded research projects from experts that provided them, or from science editors (based on each report summary)
- news written by journalists on current research and innovation activities, including project interviews, trending science news, reporting on events, funding opportunities.

All data were coded in accordance with the corpus linguistics approach to conceptual metaphor (see Semino, 2008, pp. 191–216). In the first phase of the analysis, I conducted open coding for metaphorical candidates to obtain the conceptual metaphors, that is, variations in 'political is physical' (see also 'metaphor keys' in Charteris-Black, 2004). I also used axial coding of the conceptual metaphors to obtain the appropriate dimension of these codes. In both phases, the coding process was assisted by *Atlas.ti*, a software for qualitative analysis. This enabled generating topology and narrative structure of the relatively large sample of discourse in question. Metaphor analysis focused on separating literal utterances (words, sentences) from conceptual domain level (concepts), traditionally marked in capital letters and searching for their systematicity. In literature focusing on ROADMAP metaphor, the most frequent are the systematic metaphors with background concepts for JOURNEY (cf. Lakoff & Johnson, 1980, pp. 44–46, pp. 89–91); PATH (Chilton, 2004, p. 204); and MAP (Semino, 2008, pp. 109–117), among others. Probably the most coherent model, however, is offered by George Lakoff (1993, pp. 206–229), introducing metaphorical *topos* as systematic transfer from 'physical' semantic domain (also in Table 1).

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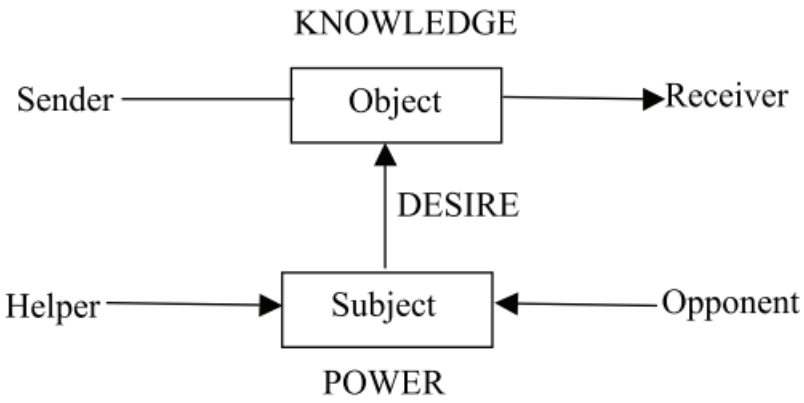
Tab. 1: Location Event-Structure model.

POLITICAL	*is* PHYSICAL
Means	*are* paths (for achieving purpose)
Purposes	*are* (desired) destinations
Actions/changes	*are* movements (to or from locations)
Actors	*are* travellers
Inability to act	*is* the inability to move
Difficulties	*are* impediments to motion
External events	*are* (moving) objects
Long-term, purposeful activities	*are* journeys

Source: adapted from Lakoff (1993, pp. 219–229)

Fig. 1: The actantial model, adapted from Greimas (1983).



Source: Kwiat (2008, p. 44)

The list of elementary metaphors is not pre-set, or exhaustive. It indicates complex topologies with internal logic, and which can contain richer and more culture-specific knowledge about travellers, vehicles, modes of travel, impediments to travel and so on (Semino, 2008, p. 92). In particular, stories are told about actors, 'heroes' who pass series of trials, accomplish great deeds; or just small stories about actors realizing something (cf. Rip, 2012, p. 160; Mordini, 2007). This is well established in Greimas's (1983) actantial model with six metaphorical actors (actants), which form the three pairs or oppositions: *Subject* versus *Object*, *Sender* versus *Receiver*, and *Helper* versus *Opponent* (also in Figure 1). These oppositions generate three types of relations: desire, which is felt by the subject for the object; knowledge, constituted by communication between sender and receiver; and power, realised through the agonistic struggle between helper and opponent.

The actants above may combine. For example, there can be a duality of roles, in which one desires something and receives something from the other who sends it, for example, trust, recognition, legitimisation, funding, and so on. Helper and opponent may similarly combine with subject, being at once the conscious will yet also the unconscious resistance to act in fulfilling a desire. Conversely, a single actant may be instantiated with more than one actor, for example, a multiplicity of helpers (Kwiat, 2008, pp. 44–45). This multiplicity of roles then corresponds to different modalisations of actor's desires, competences and confrontations (cf. Greimas, 1987, pp. 140–147). The modalisations are also formed by temporality of passing through three events, also tests, or formal stages (in Greimas, 1966, pp. 38–44): qualifying event (*Épreuve qualifiante*); main event (*Épreuve principale*); glorifying event (*Épreuve glorifiante*). These events, just as actors, are conceptual metaphors that can be used in this study for the representation of discourse formation. The metaphors are taken for elements in narrative grammar and thus set in place by the various components

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of the discursive semantics (cf. 'figurative discourses' in Greimas & Courtés, 1982, p. 134). Even though Greimas's analysis is traditionally conducted on a different level of abstraction (i.e., elementary words, like modality verbs) that must be envisaged to describe signification, the proposed approach does not violate his transpositional model. As has become an accepted practice in cognitive linguistics, upper case is reserved to represent concepts underlying particular expressions. Words or phrases that were selected from CORDIS for the focus of discussion are in italics, or placed in single speech marks; once they are definitively classified as metaphors, they are shown in 'target is source' forms.

METAPHORICAL CONVENTIONALITY AND CREATIVITY IN LAKOFF'S AND GREIMAS'S MODEL

This section presents the empirical observations from the CORDIS database, which draws on the analytical models outlined above. The quotations were selected to show how the CORDIS (EC's) nanotechnology policy metaphors, and in Lakoff (1993) terms, 'locations' and 'events' are used systematically and creatively in order to structure and sustain rich inference patterns. In addition, Greimas's (1983) actantial model is adjusted to uncover 'events' as actions of different 'actors' in different narrative roles. An overview of the topology, as well as narrative dimension is presented at the end of the section.

LOCATION(s): Lisbon, ERA, and Nanoworld

The references to nanotechnology in the early period involved the descriptions of policies, and of hypothetical development scenarios. When the expert group's foresight report had made six recommendations for '*a research agenda "beyond the Lisbon strategy" [...] to analyse the evolution paths of key technologies […]',* it had concluded that '*we need to think beyond Lisbon*' (CORDIS, 2005a), as if the strategy was a place on a map. The European Commission highlighted the economic and social importance of nanotechnology related to *'(...) an open and diverse European Research Area [ERA] (...) crucial in the quest to minimise and eliminate the various barriers and disincentives to researcher mobility that currently exists in Europe*' (CORDIS, 2000a). The above utterances or statements relied on some fairly conventional mappings of the (geographical) AREA source domain to represent purposeful, goal-oriented activity, and where there are 'barriers' as impediments to research and development. Years later, the 22nd thematic supplement was published by the Commission, entitled '*Exploring the nano-world – Leading EU research in nanosciences and nanotechnologies*' (2006), and defined nanoworld as '*a vibrant new research area linked to the convergence of existing scientific disciplines*' (CORDIS, 2006a). The document has established a connection between 'convergence' and 'nanoworld', representing (future) DESTINATION.

Altogether, Lisbon Agenda (Strategy), the European Research Area, and Nanoworld are LOCATIONS in a state of mutual endorsement. Their relationship is addressed through the so-called '*nano-enabled social, economic and value chains*' (CORDIS, 2013a), representing metaphors for a common work of transforming the multitudes of futures into connected PATHWAYS. Nanotechnology development should enable '*countries to move towards energy self-sufficiency*' and when '*the benefits of economic growth will become that much more accessible*' (CORDIS, 2005b). The pathways were also established when the 'European Technology Platforms' set as its objective achieving MILESTONES, for example, in the sustainable and competitive construction sector by 2030, where: '*A pathway to each of the ultimate objectives for 2030 is included in the document, with stepping stone goals for 2010 and 2020*' (CORDIS, 2004d). Such examples are not separated from a wider range of expressions whose meanings relate to different events.

EVENTS(s): Reaching Frontier and Obtaining Valuables

If 'nanoworld' has been identified as a metaphor for destination, it opens up to representations for actions leading to obtaining the VALUABLES, such as '*economic growth, population health, the environment, Europe's transport, energy production, safety assessment*, etc.', an event which begins as '*society needs-driven research*' (CORDIS, 2003a; CORDIS, 2004a; CORDIS, 2005c). In one of the CORDIS reports, the Irish government minister speaks of a MISSION: '*to advance the frontiers of nanosciences where physics, chemistry, and biology converge* (...) *It is in the nano-world that discoveries will be made and technologies developed[,] which are likely to change our lives in the coming decades*' (CORDIS, 2005d). These activities correspond to various '*calls for proposals*' (CORDIS, 2000a),

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and where the EC ensures their evaluation, and co-finances those who are successful. Since the creation of the European Research Council (ERC), a 'frontier research', or 'curiosity-driven research', aims at topics determined by the researchers themselves. When the EU Science and Research Commissioner Janez Potocnik was defending the European Research Council (ERC) budget for the 7th Framework Programme (2007–2013), he argued: '*[ERC] should not simply be understood as a funding mechanism for "basic research" in the traditional sense of the term [...] the term frontier research, rather than basic research, to make a clear distinction for the ERC's role, and to give the ERC a 21st century connotation, as opposed to one captive to the dynamics of research in the mid-20th century*' (CORDIS, 2006b). The next era of exploration has been announced to see the European Union at the 'forefront of research' (CORDIS, 2009a). As soon as the frontier is reached by the scientific community, '*it leaves behind routine, activities filled out by all the EU member states, industry and private enterprises*' (CORDIS, 2002a).

Reaching the FRONTIER not only gives the image of metaphorical boundaries, it manifests to push forward together. It represents the opportunity for true 'Innovation Union' and 'Joint Technology Initiatives' (CORDIS, 2007a), creating 'synergies' (CORDIS, 2006b; CORDIS, 2009b; CORDIS, 2013b), and reaching necessary 'critical masses' (CORDIS, 2012). There is a sort of urgency in developing consent for nanotechnology policy, whereas, '*[...] a kind of European nanotechnology initiatives are required to stay in the race with the US and Asia*' (CORDIS, 2003b). It is argued that the '*European Governments are determined not to miss the boat on the next "nano" revolution*' (CORDIS, 2005e). The metaphor of the RACE(ing) here extends to the 'European Union as a SHIP', reaching the nano-revolution as its destination. It evokes a fascinating series of events, making it seem as if every European government was participating in a marvellous adventure, or CONQUEST.

Reaching the destination requires undertaking the most testing of journeys, one that involves complex NAVIGATION. These activities include a series of multi-stakeholder dialogues defined as 'horizon scanning' and 'steering committees' (CORDIS, 2006d; CORDIS, 2007d). For example, '*the role of observatory* [on nanotechnologies] *would be to present reliable, complete and responsible science-based and economic expert analysis across different technology sectors and establish a dialogue with decision makers and others*' (CORDIS, 2008). The EC aims to define these relevant activities in the 'industrial roadmaps' (CORDIS, 2002b; CORDIS, 2005f; CORDIS, 2005g; CORDIS, 2006f; CORDIS, 2006g; CORDIS, 2013c). Whereas the responsibility for any research infrastructure remains mainly with the EU Member States, *'a roadmap produced by the European Strategy Forum on Research Infrastructures (ESFRI) identified a pan-European infrastructure for nanostructures and nanoelectronics as a priority facility*' (CORDIS, 2007e). Obtaining the knowledge of socio-technical landscape represents the activities needed to create a MAP that '*does not just chart, unlocks and formulates meaning; it forms bridges between here and there, between disparate ideas that we did not know were previously connected*' (CORDIS, 2015).

DRIVERs, GAPs, BRIDGEs, and STREAMs: Problems and Solutions on the Journey

Many of the references to locations and events involve descriptions of problems and solutions and create specific hypothetical scenarios. Nanoscience (nanotechnology) is expected to be '*one of the vital technological drivers for transforming the EU into a true Innovation Union*' (CORDIS, 2014), it should enable actors to engage in '*strategic relationships that drive their business successfully forward*' (CORDIS, 2015). Not only does the metaphor of a driver establish PATHWAY DEPENDENCY (with 'businesses as passengers'), nanoscience / nanotechnology as DRIVER is framed as a powerful protagonist: '*Nanotechnology is at an early stage but it's the driving force of the future*' (CORDIS, 2000a). It is argued '*[...] nanosciences and nanotechnologies have the potential to drive growth and jobs in Europe, and their development and use should not be delayed, unbalanced or left to chance*' (CORDIS, 2007b), or that '*[...] there is a huge market for this field, which is also driving more research*' (CORDIS, 2007c).

Nanoscience (nanotechnology) is also playing an antagonistic role in its representation of a RUNAWAY, that is, moving without control, when there is an '*innovation running ahead of regulation*', or too slow, when there is a '*lack of knowledge that led some participants to call for a moratorium on certain aspects of nanotechnology use and research*' (CORDIS, 2003c). It is concluded as necessary '*to track, evaluate and accept or reject new nanotechnologies, backed by an international convention on the evaluation of new technologies*' (CORDIS, 2004c). The European Commission takes decisions to mainstream safety concerns: '*the most immediate priority is to prevent those who have the most to gain – big business – from beating the regulation race*' (CORDIS, 2003c). This also suggests, (big) business is a runner or racer that does not always follow the regulations.

In '*No Knowledge, No Future, Says Potocnik*' (CORDIS, 2005i), the Commissioner insisted that '*building the Europe of knowledge requires resources*' and the Joint European Technology Initiatives (JTIs) are *'champions for knowledge for growth*'. The JTIs between

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industry and member states here thus represent HEROic alliances. Nano-scientists work with engineers on 'nano-switch', a system that '[BRIDGEs] *biological and nano- worlds*' (CORDIS, 2003d; CORDIS, 2006c). Policy makers point out that '*[...] the EU has the tools in place to avoid what has been known as the "European Paradox" – the phenomenon by which Europe invests in research, but then fails to transfer the results into products, and instead imports the resulting technologies from elsewhere. We have the tools to change the paradigm and to make a jump of quality [...]*' (CORDIS, 2007f). The European paradox as (knowledge) GAP captures difficult terrain of the innovation landscape. It requires Europe to make a radical move on the innovation journey – a 'jump of quality'. There are gaps between science and market, different innovation phases, and also 'nano-divide' (CORDIS, 2005h, in ref. to North-South divide), representing the exclusion of certain groups from innovation outcomes.

The CORDIS reports on the importance of STREAMs when designing a pathway to nanoworld and reaching the public: '*we know how to anticipate this technological revolution, prepare the discoveries upstream and transform the trials downstream, by making all the actors in this field work in perfect synergy*' (CORDIS, 2004e).[5] There are lessons learned from GMO's: '*[...] citizens should be involved upstream*' (CORDIS, 2006e). For this to happen, '*foresight and social sciences must try to build bridges between demand pulled technological fields (agri-food, manufacturing, environment) and supply-pushed areas (nano- and biotechnologies, IT and cognitive sciences)*' (CORDIS, 2005d). The public is represented as the '*measurer of all things and* GUARDIAN [capital letters added] *of the world*' (CORDIS, 2003e), while role of the social scientist is to '*examine the barriers to public acceptance of nanotechnologies (...) as trust can also be lost when the results of risk evaluation assessments are not consistent*' (CORDIS, ibid.) The metaphor for public trust as VALUABLE or CONTAINER appears in an article entitled '*Trust and communication: keys to public acceptance of nanotechnology*' (CORDIS, 2007g), and also, in '*Communication and risk assessment: keys to unleashing nano-potential*' (CORDIS, 2006e). These metaphors denote trust as a valuable object over which final trial is won, or lost.

Metaphor Topology and Narrative Structure: Innovation Journey

The above metaphors correspond to Lakoff's (1993) model in terms of LOCATIONS (Lisbon, ERA, Nanoworld, pathways), EVENTS (journeys, leaps, driving, bridging, streaming, passing trials), and other related structures of the socio-technical landscape (ships, observatories, bridges, maps, valuables), including ACTORS (heroes, travellers, observers, and guardians). The topology of these metaphors can be listed as the following:

- Lisbon Agenda/ERA/Nanoworld is Location (Departure/Convergence/Destination)
- Growing Economy, Public Health, and so on, are Valuables (Objects in Nanoworld)
- Public Trust is Valuable/Container (Object)
- Innovation is Journey/Race/Conquest (Distance/Speed/Reward), and in particular,
- Nanotechnology Development is Pathway/Jump (Evolutionary/Radical)
- Development Phases are Milestones (Feasibility and Traceability of Opportunities/Threats)
- European Union is Ship, and
- Collective Action is Synergy, Reaching Frontier, or Critical Mass
- The European Commission is Sender (Calls for Proposals)
- European Governments, Joint Technology Initiatives (Partnerships) are Heroes (Crew)
- Nanoscience/Nanotechnology is Helper (Society- and Curiosity- Driven), and also,
- Nanoscience/Nanotechnology is Opponent (Avoiding Regulation and Competition)
- Public is Receiver/Guardian (Receives Valuables/Gives Trust) and represents
- Challenge is Upstream (Delivering Discoveries)/Downstream (Transforming Trials)
- Knowledge is Vision (Building Observatory, Map), and also,
- Decision-Making is Direction-Giving (Knowledge of the Landscape)
- Crisis/European Paradox is Gap (Lower Ground)
- Solutions are Paths/Leaps/Bridges (Upper or Middle Ground)

5 For example, the European Research Council's 'Synergy Grant' is rhetorically related to the upstream: '*channelling funds into the most promising new fields with a degree of flexibility not always possible in other funding schemes*' (CORDIS, 2006b).

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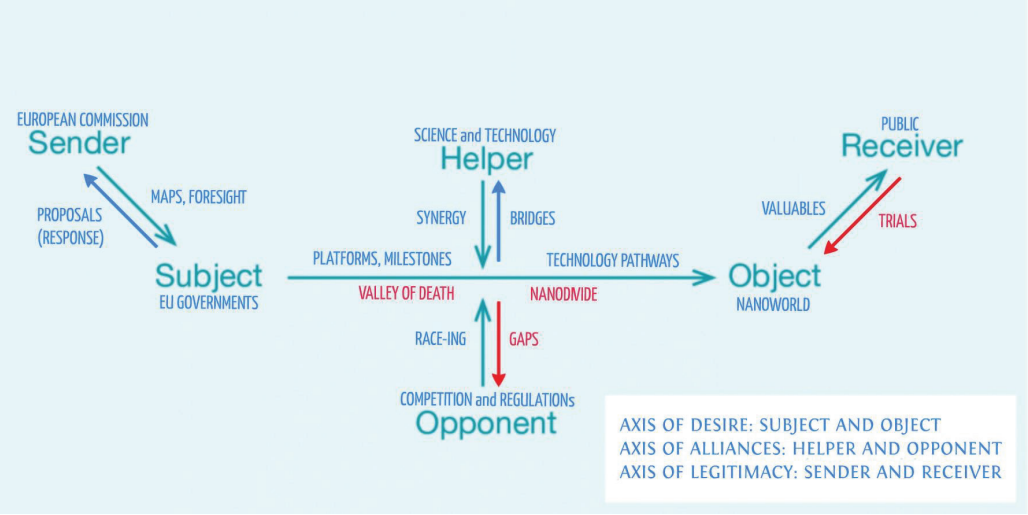
The narrative structure is formed on the line between the subject and object, described as (heroic) journey to the nanoworld (Axis of desire); Sender and receiver are connected as the EC (sender) sends heroes and public (receiver) prepares their trials (Axis of legitimacy). A specific opposition is between helper and opponent (Axis of alliances). It is represented by the ambiguous character of science and technology: competition and regulation *versus* synergy and value, or economic chains. The story-line could be as follows: *heroes hear the call and board the EU ship, set out for the nanoworld; they are confronted by adversaries (big business/industry), and aided by experts (drivers, observers, cartographers) in their challenges; they consult observatory (experts), acquire a better knowledge of the (future) territory; navigate across valleys, build bridges, and finally, face (public) trials; the stepping stones, or milestones indicate that objectives can be reached; valuables are presented to the public, in terms of nanotechnology solutions for ecology, energy, quality of life, and so on; if successful in passing public trials, heroes receive trust and their journey is at an end* (also in Figure 2).

Fig. 2: Narrative structure, adapted from Greimas (1983) to the EC nanotechnology policy.



Source: compiled by the author

In the diagram above, the narrative structure has three phases (from left, and middle, to right): qualifying event (*Épreuve qualifiante*), main event (*Épreuve principale*), and glorifying event (*Épreuve glorifiante*). The arrows indicate specific modality of actions: the EC proposes the EU governments to undertake a journey to the nanoworld, in order for them to return with powerful artefacts, and to pass the series of trials (manipulation: having-to-do). The governments set out on innovation journey (performance), their success depends on helpers and the intervention of competition / regulation, and new abilities (competence: knowing-how-to-do and being-able-to-do); altogether, they arrive at a destination with the objects (performance); this is a location where heroes pass series of trials (manipulation: having to do); unlocking access to the public is focused on public's power or attribute in its possession, that is, granting trust, or mistrust (reward / sanction).

SPATIO-TEMPORAL CONSOLIDATION OF THE EC NANOTECHNOLOGY POLICY (DISCUSSION)

All the examples above involve highly conventional ways of metaphorically describing goals as 'destinations', actions as 'steps', and positive change or success as 'moving forward' and 'progress', negative change as 'going down' and into 'gap' (cf. Semino, 2008, p. 110). In the given institutional setting, however, they arguably outline unique patterns and topologies that resonate with nanotechnology policy-making (research Q1). It will be argued that these structures have particular consequences in the overall form and coherence of the EC nanotechnology policy, and with implications for discursive technology assessment (research Q2).

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Metaphors, Narratives and Nanotechnology Policy-Making

The roadmapping discourse arguably resonates with various models of nanotechnology policy. In Figure 2, the left region represents policy decisions, such as calls for proposals, that shape research priorities, and where consensus on journey is required (*policy-driven model*); the middle region is driven by research and knowledge directly applied to problem-solving, such as building bridges, synergies (*knowledge-driven model*); finally, the right region describes direct relationship between science and public (*enlightenment model*). The presence of various policy models might be a good indicator that a narrative structure recovered from the corpus can represent an entire discourse. It can also illustrate the efforts to find a unifying story-form model for the EC nanotechnology policy or even establish a form of social contract. Such a form of contract, it will be argued next, is based on systematic metaphors that engage all the actors in the narrative of 'innovation journey'.

Nanotechnology development, as a type of purposeful activity, is constructed (framed) as an innovation journey. The JOURNEY is not only goal-oriented to achieve some external objective, it is also an integrating force where common PATH appears as 'ours' (or European). Travellers have to adjust to their common pathway dependencies. Somewhat allegorically, the journey includes determination of governments, a curiosity of scientists, driven to explore more outside the main route (frontiers), or industries burdened by regulations, all together on a timely mission to nanoworld. Overcoming the GAPs is connected to creating synergies, and economic or value chains that raise bridges (Axis of alliances in Figure 2). This narrative scenario partly contrasts with the reality of mutual suspicion and mistrust, various interests, multiple directions (cf. Brown & Michael, 2003). The supporting characters are equally problematic. Does the 'observatory' generate information for the public, for the European Governments, for the Commission, or for the scientists and engineers? According to Heidrun Åm, the *ObservatoryNano* project (2008–2012) was marked by demands for factuality and evidence-gathering. In such moves of scientification, nanotechnology was articulated as a technical matter – in contrast to it being a potentially controversial, political matter (Åm, 2013). This ambivalent role makes 'observer' an ambiguous character – rather than independent and neutral. And further, if 'Europe is common SHIP', it is hoped that governments will not let it sink, and which means that everybody has to row, with the exception of passengers excluded from the travel. This is important, as SHIP metaphor sets up a specific 'in-out' opposition in relation to social groups (cf. CONTAINER scheme in Semino, 2008, pp. 95–97). For scientists arriving 'upstream', the public is constructed at a challenging location, where there are a series of tests (trials). The public awaits ship's arrival with gifts from the nanoworld, 'downstream' trials grant keys, or unlock public acceptance and trust. This would suggest high status of the public, but the situation is again more ambiguous.

There is a certain incongruity represented by the contrast between the existing low 'public awareness to nanotechnology' (EuroBarometer, 2010, p. 33) and the imaginary public that the nanotechnology policy metaphorically construes. While the scientists, engineers and the European governments are represented as a crew, the public is outside of the vessel. This suggests, crucially, that the public is excluded from the travel or anything that would imply steering innovation in decisive events (the middle region in Figure 2). Steering the innovation is the role reserved for experts and policy-makers. It might be an indicator that the EC doesn't have a genuine interest in the public opinion on nanotechnology, at least not in the sense of questioning the whole purpose of the travel. For example, the report on '*NanoGeoPolitics: ETC Group Surveys the Political Landscape*' (2005) by the Action Group on Erosion, Technology and Concentration (ETC), a Canada-based activist group, provides such a critical feedback in one of the three nanotechnology governance approaches that it says to be emerging: '*(1) Optimists – "technology is good" – Full speed ahead (with "responsible" drivers at the wheel); (2) Realists – "technology is neutral" – Invite a few of the passengers to suggest alternative routes (the "upstream" approach); (3) Sceptics – "technology is political" – Get out the map and let everyone decide if they want to take a trip and if car, bike or bus is the best way to go*' (ETC Group, 2005, p. 7). The ETC's third option to 'get out the map' is MORATORIUM. It contrasts with the Commission being convinced that: '*Apart from denying society the possible benefits, it* [moratorium] *may lead to the constitution of "technological paradises", i.e.[,] where research is carried out in zones without regulatory frameworks and is open to possible misuse*' (Commission, 2004). The non-technical solutions are replaced with 'technological paradises' to appear outlandish (cf. Nordmann, 2007), while at the same time the Commission evokes nanoworld as 'societal paradise'.

The resistance to nanotechnology is problematic as such, as we rather make necessary choices between different technological alternatives (cf. Edgerton, 2006, p. 9). Nanotechnology contributes as a multi-causal phenomenon, not only in the sense that a variety of factors influence nanotechnology development but also in the perhaps less obvious sense that there are multiple technology pathways. The concept of RACE and CONQUEST may still work to narrow down the options as the journey follows the fastest or most challenging pathway. These concepts anticipate no 'dead ends' or 'slow' development. One of the key findings from the analysis

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is that the 'nanoworld', traditionally perceived as nanoscale, is here represented as both a scale and a location in the future. There are multiple technology pathways and roads, but there is only one NANOWORLD. It exists as the conveyance of desire relayed through allegory (Axis of desire, in Figure 2) – 'true paradise'. It is a place where policy strategies for convergence can establish their credibility, to be able to talk 'back in time' authoritatively about the future actions (Axis of legitimacy, in Figure 2). Nanoworld represents 'racing against time', 'conquest', and 'responsible research and innovation'. It can give the steering committees permanent and important status. Just as when BRIDGE/STREAM strategies are justified through the reference to a GAP, the actors can be mobilised by the notion of such a transition. The 'European paradox' here represents such a functional setting, for example, when the support to nanotechnology from, '*(...) the European Institute of Innovation and Technology (EIT) will also help to address the "European paradox" [, implying] that excellent existing research is far from being harnessed to the full*' (Commission, 2011, p. 82).

Similarly, the European Research Council's FRONTIER research manifests destiny of scientists to push forward together and at all costs (cf. Ceccarelli, 2013), it creates a functional setting for mobilizing action. The Council claims that its '*grants operate on a "bottom-up" basis without predetermined priorities*' (Commission, 2017), in the case of the ERC Synergy grant, however, '*applications must demonstrate that the proposed research cannot be carried out by a single principal investigator working alone*' (Commission, 2017). This is where synergy is performative. Also, the '*Europe 2020 Flagship Initiative Innovation Union*' (2011) is a conventional use of the metaphor that represents real incentives of completing the '*free movement of knowledge and excellence*' (Commission, 2010c), to '*strengthen the innovation chain and boost levels of investment throughout the Union*' (Commission, 2010b, p. 30). This altogether suggests that roadmapping metaphors have certain capacities to mobilise resources, set eligibility conditions, and qualifying roles.

Nanotechnology Policy Assessment and Two Forms of Bias

Although the knowledge of topology and narrative structure might serve as an effective blueprint for nanotechnology policy-making (and grant applications), it arguably poses a problem for nanotechnology policy assessment, and respectively, discursive and argumentative technology assessment. The nanotechnology development modelled as pathway (journey) has embedded a variant of the *confirmation bias.* If problems described as the 'European paradox' persist, or even continue to worsen, the prediction is confirmed. If the situation improves, the experts can attribute it to their decisions based on policy model. Either way, the model works – it predicts difficult years ahead, asks citizens to 'tighten their belts', and then promises to improve situation after this 'difficult stage' of the 'journeying', 'bridging', 'steering' and 'streaming'. Change requires time. Disasters, such as opening 'valley(s) of death' and passages through the underworld, are part of the larger plan and must take place. Any deterioration of the situation becomes a confirmation of the prophecy and any improvement as an answer to the requirement (cf. Merton, 1948). The paradox has a certain inevitability to it, and may actually work as endless mobilisation resource through promise-requirement cycles (cf. Van Lente & Rip, 1998; Rip, 2012).[6] The duration is rather open unless the 'milestones' are clear and verifiable. By way of these articulations, legitimacy as a chain of significance has been successfully established between the science (society-driven), industry (science-driven), and society (technology-driven). Any complex problem can be re-framed and reduced to a problem of an imaginary geography that can legitimise and strengthen policies – except that it may not solve the paradox.

We should ask: who is the sender, what are the intentions and what is hidden? The omitted elements might be more relevant than the elements featured in the roadmap. The concept of innovation JOURNEY does not embrace non-nanotechnological solutions, and it is also important to see that the relationship between 'nanoworld' and LOCATION is arbitrary. Other conceptual metaphors can bear different meanings, such as CONTAINER ('Pandora's box'), or ANIMAL (cf. 'Prey' in M. Crichton's [2003] novel). Accordingly, the objective is not only to render metaphors that are relative and context specific but also to resist effects of the narrative (closure), to disentangle what is constructed as both promise and requirement. The storyline advances through metaphors for events into developing a mature science policy model for nanotechnology, a reaction to policy frustration with the 'European paradox' and 'nano-divide(s)'. These provide the story with *catharsis* (drawing a map / building a bridge), just as in similar science policy narratives constituted on the model of 'tragedy' (Aristotle), or 'hero's journey' (Campbell, 1949). The EC technology roadmaps have a privileged

6 Here I invite the reader to review further any of the numerous examples of projects supported by the European Commission's policy (framework) programmes addressing the 'Valley of Death' between academic research and the uptake of innovation by companies.

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position, in a sense that they integrate what Hidemi Suganami (1996) considers a good causal narrative. The hero, who wants to arrive in the nanoworld, must become more knowing and thus able, accepts ROADMAP (policy) as a powerful artefact or attribute. This *story bias* redirects our attention, from causes that arise from scientific research and obstacles that science policy confronts, to consequences that are made collective, and that may not be entirely reflected by the public.

CONCLUSIONS

In this study, I attempted to identify the metaphors of roadmapping discourse with regard to their metaphorical patterns and related narrative structure. I identified metaphors for 'locations' and 'events' that are being used to describe the future development of a field of nanotechnology, but also society at large. In this sense, metaphors have engaged all the actors in a narrative of 'innovation journey', in their 'path dependence', difficulties overcoming 'knowledge gaps', and reaching the 'nanoworld'. The investigated metaphors thus have positive connotations within the roadmapping discourse formation in question as they transform unknown concepts of place and future into a clear organisational identity and image. The systematic metaphors are plausible tools for harmonisation through concepts that connect nanotechnology policy with science, industry and public domain, yet they evoke much deeper dilemmas. Technology roadmaps may seem responsive to the variety of issues. However, they as much form the basis for certain issues, such as the 'European paradox'. The study here also confirms that metaphors have certain capacities in mobilising resources, defining qualifying roles and establishing eligibility conditions. This is illustrated by the unifying story-form of the nanotechnology policy, conveyed by the allegory of 'innovation journey', and that may even work to establish a form of social contract between all the actors.

The identified metaphors consolidate the nanotechnology policy, characterised by spatial (topology) and temporal (narrative) patterning. The effects of the consolidation appear in two kinds of underlying biases: *confirmation bias,* that is, problems and solutions are of the same conceptual or semantic domain, and together, can form promise-requirement cycle; and *story bias*, that is, the established connection between elements of a story and filtering out other elements. It is imperative to continuously assess the context of the spatio-temporal consolidation of nanotechnology discourse. The chain of significations can be broken, especially in terms of assessing alternative concepts and story-lines. Rather than using metaphors as an *explanans* for further adjustment of policies, they have to be rather an *explanandum*, something we have to explain and constantly contextualise. We have to pay just as much attention to what is concealed as to what is revealed because what is concealed may privilege some meanings, interests, and activities over the others – regulation that is less overt but not necessarily less effective. In this sense, the research yielded an interesting finding of the public being placed at the final location on the map, where it doesn't have any means ('pathways') to negotiate nanotechnology development. Public's 'only' attribute is trust. Trust is very important in modern societies (Giddens), but reflexivity is its fundamental feature, especially when the knowledge of the world starts altering that world.

And while this study aims to raise reflexivity towards the processes in which roadmapping discourse becomes grounded and stabilised, and even establishes performance regimes, it is important to make a note on the limits of this study. The position of cognitive linguistics is clearer in a sense that these are the metaphors 'we live (and make politics) by'. The study might thus be taken as an occasion for metaphor theory to be updated with empirical material that has been recognised as driving this still evolving field. Related to that, I also see possible choices for future research in investigating metaphors and narratives in interviews with relevant actors and in ethnographic detail, applicable to studying the causes, progression, and effects of technology roadmapping.

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