Master thesis

Knowledge Dynamics and Governance of International Research Programs

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Abstract

This study focuses on the organization of large-scale research collaborations, more specifically, International Research Programs (IRPs). A framework has been developed to investigate the landscape and organization of IRPs. The main goal of this study was to explore the interrelation between governance (in terms of scientific planning and funding) and knowledge dynamics of a research area. Knowledge dynamics are conceptualized using Bonaccorsi's search regime and Whitley's categorization of types of fields. Three cases have been analyzed: CERN, the Census of Marine Life (CoML) and the International Human Dimensions Program (IHDP). The cases show that the level of technical and cognitive complementarity largely determines the shape of the organization of the IRP. For each of the three IRPs, an integrator can be assigned that brings and holds the program together. Essential for the success of IRPs are key-actors in the program's network. These key-actors are internationally recognized research managers that can translate and negotiate between different arenas and understand both governance and knowledge dynamics. The interrelation between knowledge dynamics and governance is in particular tangible within scientific (steering) committees of a program. The empirical data shows that international research programs are heterogeneous, which supports the notion that for governance arrangements one size does not fit all.

Summary

This study has been pioneering work on the organization of large-scale research collaborations, more specifically, International Research Programs (IRPs). As there is no overall institutional framework for the internationalization of research, governance patterns may evolve closely in relation to knowledge dynamics of a research area. A framework has been developed to explore the interrelation between governance (in terms of scientific planning and funding), knowledge dynamics of a research area, and the characteristics of the organization of international research programs.

Knowledge dynamics of research areas are conceptualized using Whitley's approach of addressing research fields in terms of technical and strategic task uncertainty, and functional and strategic dependencies between researchers, as well as the more recent conceptualization of Bonaccorsi in terms of search regimes. Governance of research is conceptualized in terms of research programming, funding of research, and the aggregation of local results. Wagner's theory of international collaboration is used to distinguish IRPs characteristics of centralization versus decentralization as well as bottom-up versus top-down aspects.

Three cases have been analyzed. Their selection is based on their distinctive research areas and organization characteristics. All three cases are based on interviews and document analyses, as well as secondary sources on historical development of the programs, and research areas.

The first case is CERN as an example of Big Science. Costs of equipment are the main driver for internationalization. Formal governance is structured by intergovernmental arrangements. Within the program, institutionalization consists of shared decision-making, which aligns research dynamics and governance.

The second case is the Census of Marine Life (CoML), a large international marine biology (taxonomy) program, initiated by individual researchers and driven by the opportunities of data exchange, including the development of new databases. Its governance seems rather informal and structured by sets of work packages and opportunities for project funding.

The third case is the International Human Dimensions Program on global environmental change (IHDP), organized by the ICSU to complement natural science programs on global change. This program in social sciences shows typical characteristics in knowledge dynamics of the research area like high task uncertainty and low dependency. The link with international policy making on climate change may induce specific governance patterns, and is the major drive for international collaboration in research.

A new image of big science and international research collaboration is not so much focused on research facilities but rather on the networks that are the backbone of collaboration, and that reinforce international research programs. The interrelation between knowledge dynamics and governance in particular tangible in the scientific (steering) committees of a program, for example, indicating how (changing) research areas affect institutionalization of internationalization, and the other way around. This is the arena where success factors over time can be found. The cases show that the level of technical and cognitive complementarity largely determines the shape of the organization of the IRP. For each of the three IRPs, an integrator can be assigned that brings and holds the program together. This integrator can be related to the research area (internal), like sharing costs for equipment, or governance aspects (external) like access of project funding or research policy. Essential for the success of IRPs are key-actors in the program's network. These key-actors are internationally recognized research managers that can translate and negotiate between different arenas and understand both governance and knowledge dynamics. The empirical data shows that international research programs are heterogeneous, which supports the notion that for governance arrangements one size does not fit all.

Note

The results presented in this report are based on a study performed in the period October 2009-July 2010. Since then, situations have evolved or changed in the studied international research programs. For example, the Higgs particle has been detected July 2012. However, the changed situations do not affect the analysis of the empirical data presented in this report.

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Table of content

Acronyms and abbreviations

Alice	A Large Ion Collider Experiment
ATLAS	A Toroidal LHC ApparatuS
CERN	the European organization for nuclear research
CMarZ	Census of Marine Zooplankton
CMS	Compact Muon Solenoid
CoML	Census of Marine Life
Cordis	Community Research and Development Information Service
EC	European Commission
ERA	European Research Area
ERC	European Research Council
ESF	European Science Foundation
ESG	Earth system governance project of IHDP
ESSP	Earth System Science Partnership
EU	European Union
FOM	Stichting voor Fundamenteel Onderzoek der Materie
FP7	7th Framework Programme for research (European Commission)
HEP	High Energy Physics
ICoMM	International Census of Marine Microbes
ICSU	International Council of Science
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Dimensions Program of global environmental change
IRP	International Research Program
ISSC	International Social Science Council
IT-IHDP	Industrial Transformation project of IHDP
LHC	large hadron collider
NIOZ	Nationaal Instituut Oceaan en Zeeonderzoek
NWO	Netherlands organisation for scientific research (Dutch research council)
OBIS	Ocean Biogeographic Information System
POGO	Partnership for Observation of the Global Oceans
SC	Scientific Commitee
SCOR	Scientific Committee Ocean Research
SSC	Scientific Steering Committee
UNU	United Nations University
VI	VernieuwingsImpuls NWO
WCRP	World Climate Research Programme

1 Introduction

1.1 International research programs in context

Collaboration in scientific research takes place at different levels (f.e within a university or collaborative research projects or research programs). Global exchange and circulation of local knowledge and practices (including artifacts, texts, people) are important elements of science. Researchers are part of communities and commonly, scientific collaborations exceed national boundaries. These international collaborations can take many forms; one of these organizational forms is a research program.

A very visible and often used example of a big collaboration research program is CERN (the European organization for nuclear research). CERN's research today mainly contains experiments around the Large Hadron Collider (LHC) that is located near Geneva. More than 8000 people from over 60 countries (20 member states) collaborate within this research program. However not all large scaled programs share a facility like CERN.

The nature of these international programs has received scarcely attention in scholarly research (only some research on CERN). Furthermore, policy makers are developing policy arrangements to shape and steer large-scale programs.[1] So far, they commonly approach the landscape of international research programs as being homogeneous but there does not exist a theoretical framework based on empirical data that substantiates this. It seems likely that the landscape is rather heterogeneous and that, concerning policy measures, one size does not fit all.

Firstly, this thesis can be seen as pioneering work on developing a theoretical framework that reflects dynamics of the landscape of international research programs. Secondly, another element of this exploration is that it provides an empirical body of three case studies to support this framework.

Hence, this thesis will focus on *international research programs and their characteristics*. As indicated before, a systematic overview is lacking and furthermore it seems desirable to investigate the possibilities for steering of global science. To realize this aim, it is essential to indicate the *characteristics and dynamics* of these collaborations. Firstly, this thesis will focus on whether the dynamics of international research programs depend on characteristics of a research field. The concept knowledge dynamics refers to the characteristics and dynamics of the knowledge fields[2] For example, a field's dependence on technological equipment or on the use of specific models. These characteristics of a field are dynamic as they evolve historically. Secondly, there are few attempts of conceptualizations of internationalization. There are several conceptualizations of differences between research fields. This project focuses on the internationalization of science by developing a framework and exploring three cases of international research programs (within different research areas and their dynamics) to find empirical support for this framework.

The leading question of this thesis will be:

"What is the interrelation between the ***knowledge dynamics*** *of a* ***research field****,* ***governance,*** *and the* ***characteristics of international research programs****?"*

[1] For example, these governance issues are on the OECD agenda.

[2] Research fields is a commonly used term that is closely related to terms like research area, discipline or even search regime.

1.2 International Research Program (IRP)

A research program is not the same as a research project. Projects usually have time-scale of 4/5 years while programs last longer and thus have a more *structural character*. A program can exist of several research projects that have a more determined timescale. We use the heuristic International Research Programs (IRPs) to define a formalized collaboration between researchers or institutions that exceeds national borders. Scientific planning is an important aspect of IRPs. A research program often has a management structure, including a scientific (steering) committee that keeps track of the activities within the program and the program's budget.

The international research programs that have been selected for this study are:

- CERN,
- Census of Marine Life (CoML) and the
- International Human Dimensions Program of global environmental change (IHDP).

Each of the IRPs will be introduced in the next paragraphs. An argumentation why these cases are studied can be found elsewhere is this report (Paragraph 3.2).

1.2.1 CERN

In 1954, the convention CERN was established. Nowadays CERN is a collaboration of over 580 universities and institutes (80 countries of which 20 European member states). (CERN 2010) At the facility[3] CERN, near Geneva (Switzerland), the Large Hadron Collider (LHC) is located, which is the current accelerator of CERN. This 27km long particle accelerator contains four detectors, each of them housing a big experiment (project) studying particle collisions (fundamental physics). The research area is usually indicated as "High Energy Physics" (HEP) or "particle physics". March 2010, for the first time collisions took place at an energy level that is high enough (7 TeV) to provide data that can proof the existence of the Higgs particle (projects: ATLAS and CMS). In theoretical models (Standard Model) the Higgs particle plays an important role in explaining why particles have mass. LHC offers the necessary experiment that can proof its existence. This research is fundamental research that is (primarily) not aimed at application. Nevertheless, at CERN the Worldwide Web was developed and without its contribution to research and development of big superconducting magnets the MRI scanners we use nowadays would not have been the same or even non-existent.

1.2.2 Census of Marine Life (CoML)

The second case is Census of Marine Life (CoML) that aims to get insight in what lives in the oceans and "explain the diversity, distribution, and abundance of marine life in the oceans; past, present and future". (CoML 2010) This is a broad research goal and contains aspects of biodiversity research as well as pure taxonomy; a discipline that has changed with the introduction of molecular biology and genetic bar-coding techniques. CoML is an ambitious quest that started in 1999 with an initial basic funding by the Sloan Foundation (US) for 10 years. CoML is distributed and does not have one central facility but has regional nodes that hold the network together. Through CoML, researchers have been able to participate in collaborative marine biology expeditions.

1.2.3 International Human Dimensions Program of Global environmental change (IHDP)

The International Human Dimensions Program of Global environmental change (IHDP) is a broad network program of social environmental sciences that "works toward understanding and addressing

[3] Note that CERN can indicate the convention as well as the facility. CERN the convention is the allience of 20 memberstates, CERN the institute/facility is located near Geneva.

the effects of individuals and societies on global environmental change, and how such global changes, in turn, affect humans." (IHDP 2010) Different social scientists (political scientists, anthropologists, sociologists and environmental scientists) are contributing to this network program that is sponsored by the United Nations University (UNU), ICSU (International Council for Science) and ISSC (International Social Science Council) The Scientific Committee of IHDP has formulated several research subprograms such as the Earth System Governance project and the Industrial Transformation project. IHDP is part of the umbrella ESSP (Earth System Science Partnership) that links the different programs on global change[4], for example by formulating joint projects. (ESSP 2009)

[4] These global change programs that are parallel to IHDP, are more affiliated with the natural sciences (IGBP, Diversitas, WCRP). These programs on global change have a longer history, and for a long time human dimensions of global change did not receive scientific attention on this global scale.

2 Conceptualization

2.1 Science system

As an introduction, I will briefly sketch how the science system as a whole can be approached as a backbone for this study. This study focuses on the organizational forms of science, which fits in a tradition of *studying organizational structures, performance and strategies*. Scientists are member of a research discipline and their choices, aims and ambitions can be derived from that membership of a scientific community that is mostly content-wise driven (research area with norms and values). (Callon 2001) Bedrock of the rewarding structure of the 'science system' is making knowledge available through publications. This model emphasizes the element of *science as a competitive enterprise*. (Callon 2001) Scholars of this tradition have argued that the science system can be seen as a complex adaptive system; others apply the notion of organizational evolution theory. This is a meso level approach, which as we will see is most relevant for this study.

Macro level study traditions like triple helix theory and mode 2 knowledge production are useful to keep in the back of your mind because they illuminate the broader landscape of science developing. Triple Helix theory argues that the three spheres 'government', 'industry' and 'academia' should be seen as interrelated and co-developing and they should not be treated as separate entities. (Etzkowitz and Leydesdorff 2000) An important notion is that alterations, or transformations, in one of the three spheres affect the complete system. Mode 2 knowledge production is an associated way of approaching the science system and its broader embedding in society via illuminating how science has become more context-driven, problem focused and interdisciplinary. (Gibbons, Limoges et al. 1994) Governance of science thus exceeds or transcends studying the science system, and includes taking in account what is happening in the other spheres. New theories on governance have been developed like network governance that help to encompass these elements of interconnectedness of different spheres. (Kersbergen and Waarden 2004; Young, Chambers et al. 2008) The notion of governance and regulation or steering of science will be discussed in this study, however not on a macro level. The focus of this thesis is on a meso level, while the above-mentioned notions provide some positioning of this meso research in macro structures and ideas.

2.2 International collaboration

Collaboration between scientists is a prominent element of scientific research. Sharing knowledge and skills are important for knowledge production. This circulation takes place at different levels, demand different forms of coordination and involves various motives. (Smith and Katz 2000; Heinze and Kuhlmann 2008; Wagner 2008; Vermeulen 2009) We can assume that collaboration in science goes beyond national borders. In this paragraph I will illuminate different aspects of collaboration.

2.2.1 Levels of collaboration

Since the character of collaboration is complex, Smith and Katz argue for different types of collaboration should be used as a heuristic to illuminate differences in *dynamics of structures, roles, objectives and modes of operation*.(Smith and Katz 2000) They elaborate on several elements of collaboration and for example distinguish three levels of collaboration: interpersonal, team and corporate.

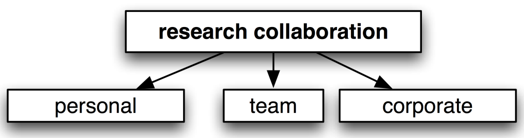

Figure 2.1: types of collaboration

The first, interpersonal, is a more *informal* collaboration like a person-to-person partnership. Governance control is weak and this form is the most occurring form of international collaboration activity. (Wagner 2008) Co-authorship is one of the quantitative indicators for these kind of partnerships. Corporate collaboration is the most *formal* type and examples of this kind are the big international research programs that will be the topic of this thesis. Team collaboration is in between these two levels that involves collaboration on a project scale but less informal as corporate structures, however more coordinated than interpersonal collaboration. Since this study focuses on collaboration in the form of international research programs, the focus will be on the more *formal aspects of collaboration*. All International research programs have this property of formal kind of collaboration but the scale of team or interpersonal collaboration within these programs can vary.

2.2.2 Types of collaboration

Dividing collaboration into these three categories helps us understanding the different levels of collaboration but does not help us yet to understand its nature. This nature also affects the type or shape of (possible) coordination. Corporate collaboration is structured in different ways with different institutional and organizational arrangements. Wagner therefore distinguishes different types by applying two dimensions. First, research collaborations can be rather *distributed or centralized*. This concerns the geographical location of the research. The second dimension is about the coordination of the collaboration divided in *a top-down or bottom-up character*.(Wagner 2008) Top-down organization of collaboration takes place when government officials set up a co-operation without research has taken place yet. This contrasts to bottom-up co-operation where the involvement of researchers involves individual scientists forming a network because a mix of different knowledge and skills is required to achieve a certain research goal. The latter is a collaboration that is driven and organized by individual scientists only. Using these two dimensions we can divide four types of research (Figure 2.2) that Wagner names: Megascience, Participatory, Geotic and Coordinated research collaboration.

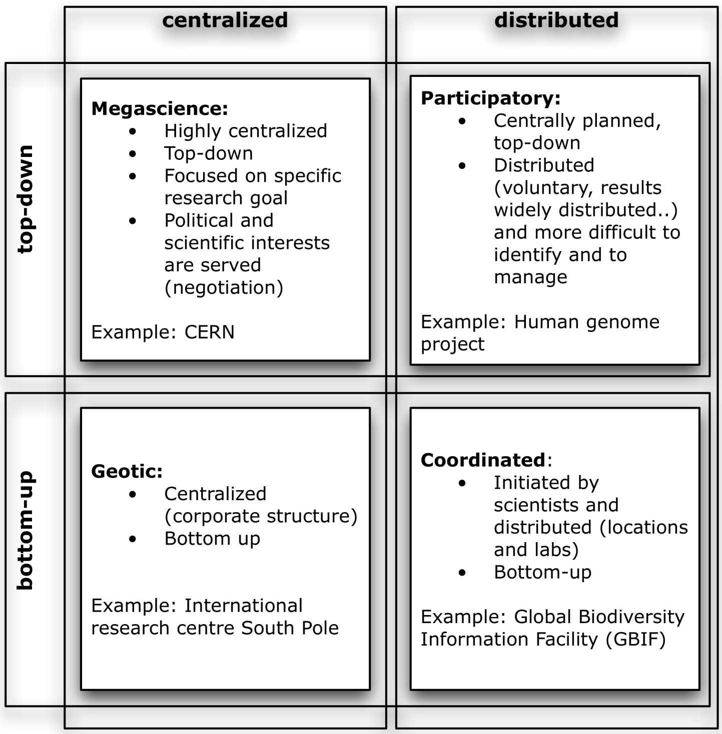

Figure 2.2: Wagner's types of collaboration

2.2.3 Motives

Ways of conceptualizing collaboration as described above help answering the question what kind of collaborations can occur but do not give us particular insight *why* collaborations take a specific form. To understand the nature of specific collaborations and the arising of research programs, motives for co-operation is an aspect to be taken into account. These motives can play at all three levels of collaboration. Heinze and Kuhlmann (2008) looked at collaboration in nanotechnology to attain insight in these structures and motives for researchers to work together. Motives they found included: expanding research capacity, improving research capabilities, realizing institutional complementarities and enhancing visibility for scientists and companies in the field. More generic motives like curiosity and knowledge advancement were also identified. (Smith and Katz 2000; Heinze and Kuhlmann 2008) These motives can be driven from the research itself, on the knowledge or material needed to execute research, or on the institutional and governance aspects that might enable only certain kinds of collaboration.

2.2.4 Dynamic approach

So far, the collaboration and characteristics of international research programs have been approached quite statically. But when analyzing international research programs we have to take into account the process of how programs come into being, and once they are constituted, how they change over time. These processes are affected by many elements. This study is guided by a notion of a dynamic landscape of IRPs. An analytical distinction can be made between knowledge dynamics of a research area and governance dynamics (or the coordination of research). This approach can be used to analyze dynamics of collaborations or research programs. These dynamics will be illuminated in the next paragraph (2.3).

2.2.5 How to find International Research Programs

We must note that collaboration, and also the international research programs this research focuses on, are sometimes not as visible and easy to detect as we might expect. Of course, very visible are *centralized facilities* like CERN. When collaboration takes a *network form* they can be more difficult to identify whether they have a structural character. This is one of the conclusions of a quick scan of the landscape of IRPs that I have executed for the Rathenau Institute as an orientation. This scan and the first attempt of developing a database with basic information of IRPs and their relations can be found in Appendix A. We have encountered several difficulties in the process of developing this database, such as the large diversity of organization structures, divergence in methods of calculating budgets (within a program) and lacking available information on websites (transparency).

Hence, the way to look for formal collaboration is not straightforward and a search can start from a specific research area or theme, or from the funding possibilities and structures concerning aspects of coordination, for example the framework programs by the EU (FP6/FP7/ERA-NETs), EUROCORES programs by the European Science Foundation (ESF), or facilities via ESFRI.

2.3 Landscape of International Research Programs (IRPs)

In the previous paragraph I have described types and levels of collaboration. An international research program is by definition a form of collaboration, and this can be used as a start for developing a framework for this study. Developing tools to study context of international research programs is important.

As noted before, exploring how IRPs come into being and evolve can be described distinguishing between *governance and knowledge dynamics*.(Laredo and Kuhlmann 2007; Kuhlmann and Heimeriks 2009). This conceptualization makes a distinction between aspects of coordination, funding and institutional possibilities and impossibilities on the one hand, and the characteristics of a research area or field on the other. Our understanding of concepts will be deepened in the following paragraphs.

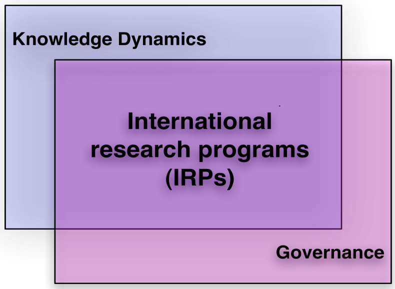

Figure 2.3: scheme of conceptualization Knowledge dynamics and Governance.

2.3.1 Knowledge dynamics

The term knowledge dynamics refers to different elements of knowledge production that are content-wise driven; different research areas have a specific set of characteristics. Conceptualizing knowledge dynamics can be done using Bonaccorsi's search regime. Supplementing, Whitley's study on types of fields can be used to attain insight in knowledge dynamics. Both theories look at the organization of research fields in terms of focus of content production but these theories differ in their approach. In chapters 4, 5, and 6, I will use selected parts of these theories for a case study on how researchers are creating new knowledge in CERN, CoML and IHDP respectively.

Search regime

There are various ways of describing aspects of knowledge dynamics. Bonaccorsi uses the concept *search regime* to describe characteristics and patterns of knowledge production. A search regime is an abstract concept that is not a particular field or discipline but rather a consistent set of dynamic *properties of the search process/practice*. (Bonaccorsi 2008) Bonaccorsi's idea of regime is comparable to Rip and Kemp's concept of *socio-technological regime* that can be defined as "the rule-set of grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills ands procedures, ways of handling relevant artifacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures." (Rip and Kemp 1998) Bonaccorsi uses regime to analyze scientific practice, while Rip and Kemp study broader technological transitions/innovation, which of course also involves scientific practices.

Bonaccorsi describes different empirically grounded properties that characterize search regimes (figure 2.4), which he uses to indicate whether new emerging sciences have other properties than established sciences. One of the aspects that Bonaccorsi addresses as being an important argument to develop a new approach towards science areas is that research is becoming more and more interdisciplinary or multidisciplinary. Bonaccorsi uses mainly quantitative methods (bibliometric research, key word analysis) to analyze these characteristics.

Aspects of Search regime	
Rate of growth	
Rate of divergence	Divergence/Convergence
Complementarity	Technical
	Cognitive
	Institutional

Figure 2.4: Search regime as defined by Bonaccorsi

Rate of growth refers to the capacity of an area, specific regime, to progress within the same institutional setting. It concerns the relative growth of scientific fields. Indicators like publications and patents can be used to show increase in scientific production and emerging new keywords can indicate the entry of new fields.

Diversity of search is the second element, which indicates how search regimes or research fields have converging or diverging characteristics. An example of convergent science is high-energy physics, a conventional field where most scientists agree on a certain research direction. On the other hand, according to Bonaccorsi, there are sciences, especially emergent sciences, which have a divergent pattern. Within such field there exists a shared hypothesis in an accepted paradigm so they belong to the same regime but there is disagreement on the direction of search and there arise various sub-hypotheses. These types of fields have a complex character. (Bonaccorsi 2007)

Thirdly, *complementarity* refers to "the extent to which different human or material resources are needed as input, in addition to the intellectual resources of the scientist himself." These complementarities can arise at different levels: *technical, institutional and cognitive*. Technical complementarity concerns the role of large shared facilities or equipment. Cognitive complementarity refers to the collaboration patterns and epistemic needs; different competences that might be needed to accomplish a research goal. Regimes can have a multi-disciplinary or interdisciplinary character. (Bonaccorsi 2007) Institutional complementarity refers to the degree to which research needs different institutional settings where scientists contribute each other in bringing together different type of data and skills. (Bonaccorsi 2008)

Bonaccorsi is not completely clear about the boundaries of a search regime. Search regimes can be multidisciplinary but when it concerns a divergent fields he does not visibly frame when a regime would for example split into two regimes, and, secondly, if regimes are possible on different levels of aggregation. A question one could ask in context of the international research programs is whether one should define a regime such that it covers the program or that it is possible to have more regimes being part of one big program? These kinds of questions arise when you use vague definitions. In my analysis I will try to develop a solution to this problem based on the empirical data we have found.

The conception of Bonaccorsi's institutional complementarity will not be operationalized in this study, since this concept does not clearly belong to knowledge dynamics. In the conceptualization of co-evolving governance and knowledge dynamics, these institutional arrangements are covered by governance and are in this study not seen as a characteristic of a field/search regime. Nevertheless, it is not that remarkable that we find aspects of knowledge dynamics that can also be ascribed to governance factors since this landscape of IRPs in terms of governance and knowledge dynamics is a co-evolving and intertwined conceptualization. Thus, covering the landscape as complete as possible requires an awareness of the possibilities of different ways to describe the same thing and making choices.

Whitley and types of fields

The aspects that Bonaccorsi uses to indicate knowledge dynamics of the search practice are closely related to Whitley's theory on the intellectual social organization of sciences. Whitley formulates different types of research fields. Concerning the *dimensions of organization and control*, Whitley looks at different *intellectual structures and environmental circumstances* to distinguish different fields. He differentiates analytically between the *degree of mutual dependence* between researchers and the *degree of task uncertainty*. He further splits these two dimensions into aspects of *strategic and functional dependence*, and of *strategic and technical task uncertainty* to make the classifications of different types of sciences. (Whitley 2000)

Whitley acknowledges and explicates that these analytical distinctions are interconnected and that some combinations are more likely to appear than others. Furthermore, analytically there are combinations possible that would describe fields that are very unlikely to exist since they would be very unstable. As I will show, the research areas of the three studied cases can be placed in these categories that are rather stable.

Dimension of mutual dependence

The degree of *functional dependence* refers to what extend researchers have to share their scientific findings with co-researchers before they can make knowledge claims that are accepted and regarded as useful for the field. In a field with high functional dependence, scientific outcomes that are based on commonly shared existing knowledge and that makes use of the same methods, materials and theories are more likely to get published and accepted by the field.

The degree of *strategic dependence* is about the coordination of research goals within a field. To what extent do researchers need to convince and persuade their co-scientists of the significance and importance of their research? It concerns the development of for example research agendas and funding possibilities and allocation of resources and thus a political part of doing research.[5]

Dimension of task uncertainty

The degree of *technical task uncertainty* is about the extent to which scientific experiments; technique and materials used are well understood and produce reliable outcomes. This for example includes whether results can be interpreted in different ways. Or in case of low uncertainty results can be derived more or less straightforward because procedures are standardized and errors can be recognized relatively easy. Success of these kinds of experiments can be determined unproblematic.

The degree of *strategic task uncertainty* refers to the extent in which scientists are willing to tolerate alternative approaches or consider problems that have a different nature than the dominated one in the field. It concerns "the uncertainty about intellectual priorities, the significance of research topics and preferred ways of tackling the, the likely reputation pay-off of different research strategies, and the relevance of task outcomes for collective intellectual goals". (Whitley 2000) This level of adjustment of intellectual goals is an important element of this dimension since when uncertainty about these goals exists this affects the stability and uniformity of the field.

Expectations Whitley and Bonaccorsi and IRPs

Both Bonaccorsi as Whitley provide frames on how to typify research areas or regimes. They do not provide a clear method of *how* to analyze these different aspects. They are heuristic theories and are open for different methodological approaches. This openness leaves space for interpretations of the theories themselves and, following, the possibility to combine aspects of both Whitley and Bonaccorsi, since they do not have exclude each other. Whitley's ideas were originally based on qualitative research whereas Bonnaccorsi's work was quantitative.[6] However, both theories could be used for qualitative as quantitative research. Similarities of theories can be found for example in how the dimension of mutual dependency relates to aspects of convergence/ divergence. High functional and strategic dependency indicates highly convergent areas. Technical complementarity relates both to functional dependence as technical task uncertainty.

It is to be expected that research collaboration in areas with high technical complementarity are likely to occur in a centralized organization. These areas are rather convergent and, because of high dependency, researchers share goals and the organization can be more tight (for example with strong shared decision-making) than in field with low dependency (that are often more divergent). Based on these knowledge dynamics explanations of the organization of research programs might be given. Some IRPs are characterized by aspects of strong centralization, like Cern. In areas with high cognitive complementarity and low cognitive dependency, collaboration is likely to have a different nature, for example by showing a looser network character, which can be expected with the social science program IHDP. Origin of such collaboration is expected to be less knowledge driven and cognitive complementarity in collaboration might be a result of a negotiation in research agenda building and possibilities to get funding (governance aspect). The origin, development and organizational forms of IRPs can thus be understood with the help of knowledge dynamics hat affect their configuration.

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[5] Note that again in defining knowledge dynamics this way, ('disguised') governance issues arise which indicates the difficulty of separating the two.

[6] Considerations regarding Bonaccorsi's quantative work and Whitley's qualitative work can be found in a paragraph in Appendix B.

2.3.2 Governance of science

Governance focuses on a form of coordination that, within the ideas of a co-evolution of science, technology and society has a *socio-technical character*. (Rip 1995; Ende and Kemp 1999) It also includes the roles of relevant *actors* in a *network* and how these actors can enable or restrict certain developments. The concept of governance can be given different meanings but here it refers to *institutional arrangements and policies*. (Kuhlmann and Heimeriks 2009) Kuhlmann defined governance in his inaugural lecture as “the dynamic interrelation of involved (mostly organized) actors, their resources, interests and power, fora for debate and arenas for negotiation between actors, rules of the game, and policy instruments applied.” (Kuhlmann 2001; Kuhlmann 2007; Kuhlmann 2007) This broad definition of governance can be applied to the science system and Kuhlmann and Heimeriks expect different types of dynamics towards post-national institutions and policies in the research system. (Kuhlmann and Heimeriks 2009)

The development of *institutional arrangements*[7] take place both on a meso and macro level and tend to become post-national. Many scholars recognize this Europeanization or internationalization of the research system and science policy. (Rip and Meulen 1996; Meulen van der 2002; Edler 2005; Bonaccorsi 2007; Kuhlmann 2007; Heinze and Kuhlmann 2008) When a multi-level approach is used, the aspect of globalization or internationalization has to be taken into account. Shifts in types of governance have been portrayed by Kersbergen and van Waarden and can be seen in forms and mechanisms of governance, the location of governance, governing capacities and styles of governance. (Kersbergen and Waarden 2004) It is acknowledged that actually steering institutions and spheres are only possible to a limited degree. Concentrating on the research system, Rip and van der Meulen make an effective distinction between *steering* and *aggregation*. (Rip and Meulen 1996) Steering refers to the attempt of the nation (or broader on a European level) to have researchers and their communities to work towards more top-down determined goals. It is about the way the research system responds to these ‘external’ impulses as a competence rather than on specific attempts of steering. Aggregation refers to the “institutionalized processes of agenda building and the infrastructures for such processes” which is rather bottom-up. Rip and van der Meulen argue that aggregation is preferred over steering in a post-modern research system.

Governance of research is thus conceptualized in terms of aggregation of local results into the program, institutionalization, research programming, funding of research. Expected is that funding arrangements on different scales affect the characteristics and organization of the program. New governance patterns may develop within international programs inducing changes in research policy.

2.4 Conceptualization of the landscape

In framing a landscape for international research programs we make an analytical distinction between knowledge dynamics and governance. Realizing that these two aspects are interrelated and co-evolving, approaching IRPs with this framework can provide us insight in how international research programs come into being and what characterizes such co-operations and how the essential congruence is found between different forces. (Laredo and Kuhlmann 2007; Kuhlmann and Heimeriks 2009) We can look for enabling or restraining effects on the characteristics of the research programs. There can exist tension between the governance and knowledge dynamics when it concerns the expectations and appointing goals for research. (Bonaccorsi 2007; Kuhlmann and Heimeriks 2009) For international research programs, the situation is quite complex, also because policies both on national and international levels are effective. The science system can be seen as a complex adaptive system and although governance can be understood as a dynamical force, in this study, a

[7] When studying processes of governance scholars quite often use the term *institutions.* Institutions as I will use it do not have to refer to concrete entities. I will use a conception used by economist Richard R. Nelson Nelson, R. R. (2008). "What enables rapid economic progress:what are the needed institutions?" Research Policy 3: 1-11. who sees institutions as structures and forces that mould and hold in place ‘laws, norms, expectations, governing structures and mechanisms, customary modes of organizing” that structure social interaction in a durable way.

simplification of governance will be used as more static factors that affect the shape of the IRPs. Of course, a reflection is needed whether and to what extent this simplification was legitimate.

The landscape of international research programs including the conceptualizations of governance and knowledge dynamics is drawn in a scheme (figure 2.5).

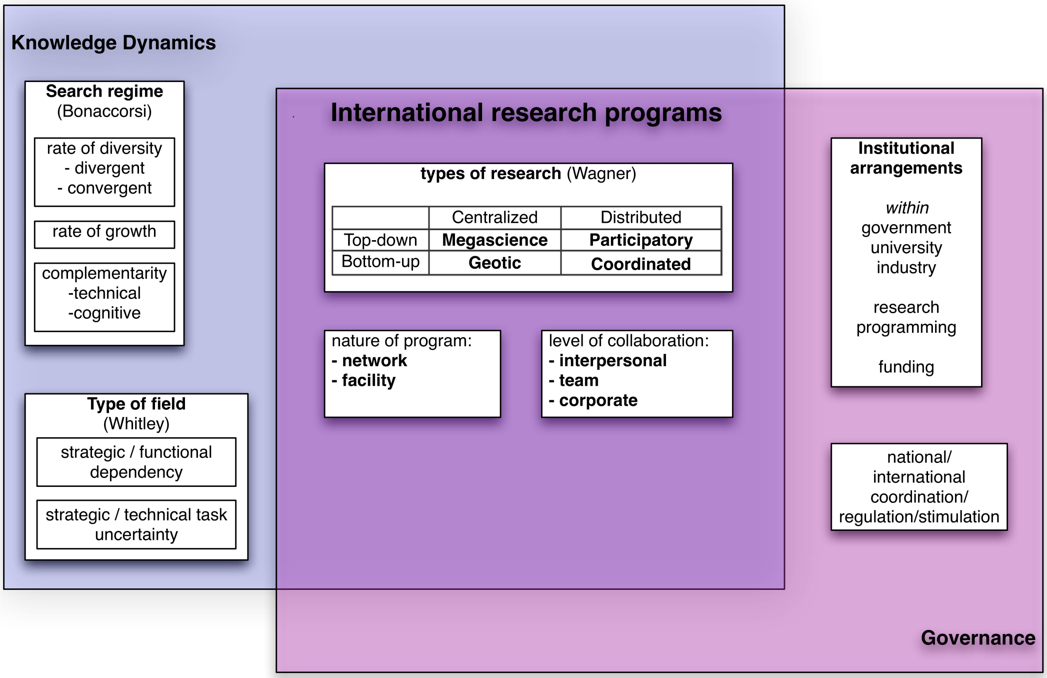

Figure 2.5: Full conceptualization of IRPs: knowledge and governance dynamics

2.5 Research question

In this chapter an analytical framework of the landscape of international research programs was developed. I have elucidated how the natures of collaborations vary and also how a balance between knowledge dynamics and governance is at stake. The aim of this thesis is to get insight in these dynamics with a main focus on knowledge dynamics and international research programs. The leading research question will be:

*"What is the interrelation between the **knowledge dynamics** of a **research field**, **governance,** and the **characteristics of international research programs**?"*

In the next chapter I will operationalize my research question and develop a qualitative methodology.

3 Research method

3.1 Method of investigation

Based on a first scan of the landscape of international research programs, three cases were selected on their characteristics. The scan and first attempts to develop a database are described in Appendix A. The selection procedure of the cases will be described in paragraph 3.2. These three perspectives are used to approach the IRPs:

1. Characteristics of the international research program: origin/development/organization
2. Knowledge dynamics of the research area(s) of the IRP
3. Governance aspects of the IRP

Dividing the analysis into these three domains with guiding subquestions (Appendix B) made the conceptualization of chapter 2 operational. Since this research project is very explorative, general hypotheses have been defined quite broad as well as case specific hypotheses. These hypotheses can also be found in Appendix B. The focus of this study is mainly on meso level aspects.

The empirical part of this study included document analysis (f.e. strategic reports and evaluations), and interviews with relevant actors (including researchers and research managers f.e. members of the scientific steering committee of the programs). Furthermore, secondary sources are used on historical analysis.

3.1.1 Interviews

The major goal of the interviews was *exploring* the IRP research field, organization structure, and dynamics of the program. The background and position of the interviewees were diverse so the conducted interviews had an *open character*. A general interview protocol was used (Appendix C, in Dutch), which was adjusted for each actor depending on already available information. The interview protocol was mainly used as a mnemonic device to cover all different themes. A list of interviewees can be found in Appendix D.

3.2 Selection of cases

The three cases that have been selected after the first IRP scan are:

- CERN - high energy physics
- IHDP - social environmental sciences
- CoML - marine biodiversity/taxonomy

All three programs belong to different types of fields or ‘research areas’. Furthermore, the nature of the programs varies (more network like collaboration and facility). This *variety of research areas* and different characteristics of the *shape of the collabora*tion are important in the exploration of dynamics of the landscape. Moreover, the choice for these three programs was also based on *availability of secondary literature and access to research managers that* could be interviewed.[8]

The time frame to be studied to get the dynamical aspects of knowledge dynamics are depicted in the scheme below and are based on the time frames of strategic reports. They cover the main elements of why the program has today’s shape. However, this time frame is not limiting since important historical events will be part of the analysis when describing origin of the programs. The three studied programs and their fields are depicted in figure 3.1.

[8] When it concerns national aspects, the focus of this study will be the Netherlands.

International research program	**CERN** (European Organization for Nuclear Research)	**IHDP** (International Human Dimensions Program)	**CoML** (Census of Marine Life)
Research field	**High energy physics**	**Social environmental sciences**	**Marine biodiversity/ taxonomy**
Scope: **time frame** (main focus. However, origin and development will also be described)	period 2000-2012	period 2007-2015 (based on most recent strategic plan IHDP)	period 2002-2012
Considerations	CERN presented in literature as typical example of Big Science (Knorr Cetina 2003) Available literature on knowledge dynamics (search regime research Bonaccorsi) Conventional field of search, not emerging Fundamental research Facility, centralized Nikhef as Dutch contribution to experiments	Because climate research is a global practice so international nature of research IHDP decentralized, network like program, multi/interdisciplinary program IHDP is part of ESSP which is a collaboration of several big international programs (Leemans and al 2009)	Network like program, distributed Field that is changing but quite disciplinary (Vermeulen 2009) Use of shared database (OBIS) as important element of collaboration Emerged bottom up

Figure 3.1: scheme with three IRPs

4 Case I: CERN

March 30th 2010, the Large Hadron Collider (LHC) hit a record of accelerating proton beams up to 3.5 TeV.[9] Media attention was given broadly and the whole world could witness how high-energy physicists celebrated this event and declared a *'new era of physics'*. With these collision experiments (with higher energy levels than ever before) the predicted existence of the Higgs particle could be proven, a goal of experiments with CERN's detectors ATLAS and CMS.

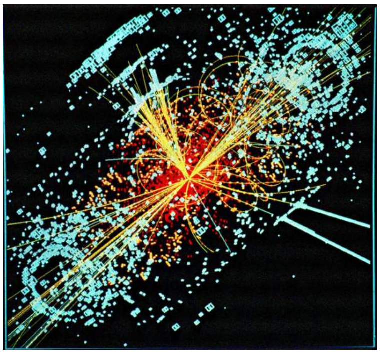

Figure 4.1: simulated particle collision (CERN website)

4.1 Origin, organization and development

In 1954, twelve European countries, including the Netherlands, signed a convention that established CERN, an acronym that stands for Conseil Européen pour la Recherche Nucléaire (European Council for Nuclear Research). (Hermann, Krige et al. 1987) CERN was the first international scientific organization set up after the war. Its establishment can be seen as a scientific and political success that made it possible for European scientists to compete at top level in the field of high-energy physics, the study field on the interactions between particles that CERN soon focused on. (Krige 1993) The research orientation of CERN has not changed that much in the past 50 years and still is fundamental physics (finding out what the Universe is made of and how it works).

> "At CERN, the world's largest and most complex scientific instruments are used to study the basic constituents of matter — the fundamental particles. By studying what happens when these particles collide, physicists learn about the laws of Nature." (CERN 2010)

Since the establishment of the convention, CERN has built several accelerators at the facility near Geneva (Switzerland). The accelerator that is currently running is the LHC (Large Hadron Collider).[10] The high-energy physics experiments at CERN are big scale and are long-term projects. Accelerator and detectors are expensive set-ups and the development of this equipment demands complex engineering to fit the requirements of the sophisticated experimental goals. (Nikhef 2007; Nikhef 2009)

National motives for the convention

Historian John Krige explains that the convention was preceded by a long period of lobbying by officials of different countries; a process where the different involved countries had to weigh their pro and contra arguments before joining the convention. Krige denotes that governments set up and joined CERN mainly because of national interest and for each nation the considerations were slightly different. Key arguments were scientific promises and spreading costs for particle research. The scientific motives were, beside the promises of the field, directed at gaining prestige within the field and competing with USA. The cost aspect was important because no individual European government could even consider building the experimental set-up alone. For small countries, being part of CERN was the only way of having a say in developments at this leading edge of research in high-energy physics. (Krige 1990) An important counterargument according to Krige was that CERN would drain resources from national programs. Krige points out that for some governments it was a younger generation physicists convincing older generation to need and make use of the accelerator and

[9] LHC, the latest accelerator, is located 100meters underground in the 27km long circular tunnel where the old LEP was located. LHC accommodates 6 active experiments that study the particle collisions created by the accelerator using different approaches and techniques.

[10] Other accelerators that are part of CERN are: SPS (super proton synchroton), PS (proton synchotron), ISOLDE (isotope separator) and AD (antiproton decelerator)

detector set-up at CERN. Krige's observations on the establishment of CERN are in line with Wagner's observation that "government officials often negotiate financial contributions and missions for mega science projects, which consequently are likely to serve both political and scientific interests." (Wagner 2008) Since High Energy Physics is a fundamental research field, industrial opportunities were initially not present and were not particularly interesting for governments. (Krige 1993; Nikhef 2007; Merali 2010) Some countries though (f.e. United Kingdom) addressed that participation to CERN could benefit national economy but that was considered to be a side issue. However Krige found that nowadays, governments are becoming more concerned with concentrating resources in research that are not only fundamental but also could bring a potential benefit to national economic growth. So these investments are "aimed at appropriation and local diffusion of scientific and technological know-how, in order to improve national capabilities." (Krige 1993) As we will see in the organization of CERN these dynamics are also present at CERN.

Location of the current[11] facility

The choice to build the laboratory CERN in Geneva was encouraged by the fact that Switzerland had been neutral during Second World War (making collaboration with Germany easier). Furthermore, the city is located quite central in Europe, and that Switzerland has a longer tradition in hosting international programs. (Hermann, Krige et al. 1987)

Network and facility

"CERN is not an isolated laboratory, but rather a focus for an extensive community that now includes about 60 countries (20 members) and about 8000 scientists…. Although these scientists typically spend some time on the CERN site, they usually work at universities and national laboratories in their home countries."(CERN 2010)

The organization of CERN can be seen as a *network* established by the convention[12], *and* as a *facility* (CERN the laboratory near Geneva). Wagner typically depicts CERN as an example of a centralized facility (Wagner 2008). CERN is a facility and in that way centralized. But the scientists contributing to CERN also work in their own universities and laboratories; being distributed research. This distributedness can be found in technical/ engineering practices of CERN as well as theoretical particle physics, and data analysis or simulations of collisions. For example in engineering, Krige illustrates how different national institutions execute fragments of the building of the detectors.[13] (Krige 1990) Various actors develop the different components.

CERN started with only 20 members but nowadays the community exists of scientists (physicists, engineers and specialized scientists) of 60 countries and even scientists from the US began to participate in CERN.[14] These scientists participate in research projects in return for a contribution in terms of manpower, materials or cash or any combination of these.(CERN 2010)

CERN organization

From the beginning, the philosophy of the organization was that CERN should work as a university, meaning that work had to be *published openly*. There are no relations with the military, and, just like universities, permanent posts should be discouraged so that the institute would be *flexible and open* for every member state researcher. (Hermann, Krige et al. 1987) Another part of CERN's philosophy is that the laboratory should *never compete with the institutes and universities from the member states*.

The schematically representation of the organization structure of the facility CERN is quite hierarchical with a director-general on top managing different departments. In the organization, the

[11] Another (future) facility of CERN could be possible on another location. (Interview Linde)

[12] The convention currently contains 20 member states but the network of researchers collaborating includes about 8000 scientists

[13] Not the accelerator but the detectors require and posses the most advances technology.

[14] Since 80s non member state scientists began to participate that has technical, financial and political benefits. [ref krige!]

different member states are represented in the *CERN Council* (CC). Each project has its own *body of scientific steering.(CERNcouncil 2006)* Representatives are selected based on experience and recognition in the field, which does not depend on nationality.

CERN and the Netherlands: Nikhef

When we look at the Dutch participation of CERN we find the Netherlands Institute for High Energy Physics (Nikhef) as a key actor. Nikhef is an institute of FOM (Foundation for Fundamental Research on Matter)[15] that represents all Dutch particle physics research. Nikhef's major task is contributing to CERN but also participates in other particle physics projects/programs like Antares. (Nikhef 2007) There is a difference between Nikhef the *institute* and Nikhef the *collaboration.* The research institute Nikhef is located at the Amsterdam Science Park. The collaboration Nikhef exists of the Nikhef institute and four university particle physics groups: RU Nijmegen (RU), University of Utrecht (UU), University of Amsterdam (UvA), VU Amsterdam (VU).

4.2 Knowledge dynamics

CERN has been often used as the perfect example of Big Science and many scholars have studied its research field. (Krige 1990; Krige 1993; Disco 1998; Bonaccorsi 2008; Wagner 2008) The experiments have a rather disciplinary character and belong to the field of High-Energy Physics (HEP), also referred to as particle physics. HEP is the main research area guiding CERN research. This is also reflected in the Dutch organization of the CERN research contribution since Nikhef, the Dutch Institute of *High Energy Physics*, coordinates all Dutch participation in CERN. High Energy Physics can be seen as a search regime (Bonaccorsi 2008).

CERN and advanced technology

As indicated before, the equipment needed for experiments in HEP are complex and expensive. The big experimental setups, both detectors and accelerators, demand advanced technology. New technologies are developed to make the ambitious scientific goals possible. Krige denotes that HEP is typically technology-enabled science: technologies are defined after highly competitive international selection processes.[16] (Krige 1993)

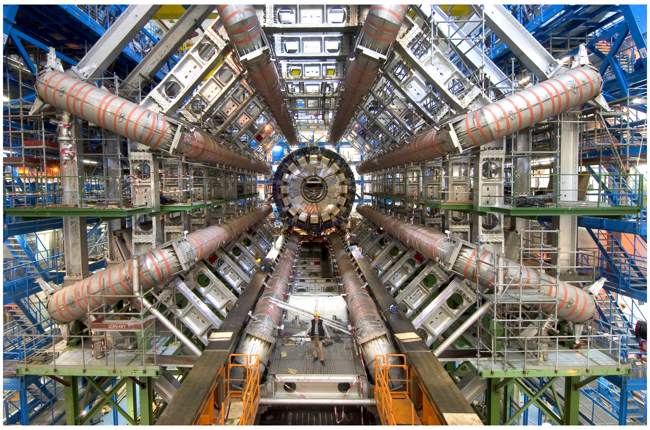

Figure 4.2: ATLAS

The technology at CERN here refers not only to mechanics and electronics but also computing. At CERN the World Wide Web was invented and developed due to the need to share data. And more recent, the development of the grid computing technology got a boost in the anticipation of the large data volumes (20 PB/year) and high CPU requirements needed for the analysis of the measurements of LHC. (Nikhef 2009)We can observe that the development was partially guided by needs of the researchers. Not only has technological development in computer science led to improved possibilities for analyzing detector data but it has also contributed to the development of programs to run complex simulations of collisions that can predict outcomes.

HEP and other disciplines

High-energy physics is the key discipline in CERN research, and can be seen as one cognitive domain, though a divide can already be appointed between theoretical physicists and experimental physicists who however share the same theories and models but differ in their approach. As we have

[15] (In Dutch) FOM stands for Stichting voor Fundamenteel Onderzoek der Materie.

[16] In many cases scientific discoveries follow technological breakthroughs. Krige 1993

seen in the previous paragraph, CERN research is characterized by advanced technology where also other disciplines are at stake like engineering sciences (of detectors and accelerators), computer science and mathematicians. (Interview Linde) The role of these involved areas can be an object to study 'an sich', because physicists often see them as facilitating to the 'real' scientific work at CERN (for example the quest finding the Higgs particle) and thus as merely providing the environment to do experiments or developing structures to analyze data. However research at CERN is built on a fuse of these areas.

Krige appoints correctly that high-energy physics involve different characteristics. "Building detectors, in short, involves a variety of activities and mobilizes a number of very different skills and techniques, all of which are now seen to be an integral part of doing physics, not a distraction from its main purpose, all of which are included in what it means to be a physicist." (Krige 1993) Within high-energy physics, physicists, programmers and engineers work in large teams and tend to treat each other as professional equals: they share the same objective of building a detector (or accelerator). (Krige 1990; Disco 1998; Merali 2010) For example, Prof. Herman ten Kate (Twente University) is involved in research on superconducting magnets that are developed and used in the ATLAS detector.[17] This knowledge of material science and engineering science of superconducting magnets has enabled possibilities in HEP and is considered to be a condition for high energy physics experiments nowadays.

The inter-dependency of different areas at CERN is also reflected in the composition of CERN Staff members. In 2009 we see 71 research physicists, 914 engineers and scientists, 838 technicians, 387 administrators and office staff, 190 craftsmen. (Other: fellows 294, paid associates 290, students 199, and apprentices 24). (Merali 2010)

Search regime and HEP

Following from the previous paragraphs we can state that the level of *technical complementarity is high* for HEP. We can also observe cognitive complementarity because of the involvement of several disciplines. Large experiments like in high-energy physics require diverse disciplinary knowledge as we have seen in the previous paragraph. From the perspective of high-energy physicists, the other involved disciplines are complementary to their epistemic needs. Another way of viewing this is that within the search regime of IRP CERN there is an interdependence of these various disciplines in the collaboration, which brings us to a relative high degree of cognitive complementarity.

In a bibliometric study Bonaccorsi has used the example of the established field high-energy physics to study growth patterns, rate of diversity and complementarities. He used scientific output (publications) of the top 1000 scientists in terms of citations.[18] According to this study, which is based on the use of new words in scientific publications, HEP is a field with a relative low rate of growth. Growth with Bonaccorsi is determined by new word popping up in publications in the past 5 years.

However, when we look at HEP over a longer time period, a recent publication in nature shows that over the past 35 years "experimental teams in high-energy physics have increased in size by two orders of magnitude" (Merali 2010) This quantitative given shows us yet another perspective and shows that hard conclusions cannot be drawn straightforward. It could be that Bonaccorsi has a different conception of the field high-energy physics leading to distinct dynamics and flexibilities. Which brings us to the dynamical aspect of the field or search regime HEP. How did the field change over time? The field high-energy physics did not change a lot over the recent years but changes took

[17] "A magnet system of three superconducting toroids and a solenoid with record overall system dimensions of 25 m in length and 22 m in diameter, generate the magnetic field for particle bending in, respectively, the muon and inner detectors in the ATLAS experiment at the Large Hadron Collider." Kate ten, H. (2008). "The ATLAS superconducting magnet system at the Large Hadron Collider ", from http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TVJ-4SMNXVV-1M&_user=10&_coverDate=09%2F15%2F2008&_rdoc=1&_fmt=high&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=1371993900&_rerunOrigin=google&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=7a84c64035e2ff764f50eb332983e956.

[18] Based on received citations using commonly accepted data sources (Bonaccorsi 2008)

place when it concerns the possibility of doing experiments and sharing and analyzing data. Experiments that take place nowadays were not possible with detectors 35 years ago, which explains the growth of experimental teams. Furthermore, development in computing technologies has made advanced simulations feasible and technologies like the www has made it possible to share data and do distance analysis. It is no longer necessary for groups or scientists to visit CERN to be involved.

Concerning the rate of diversity, Bonaccorsi shows with a keyword analysis that the HEP is a convergent field. (Bonaccorsi 2008) This convergent character of the field can also be observed when looking at how the research area HEP is almost focused on CERN (projects) alone. And even within CERN how within the organizational structure of CERN where within the community agreement is pursued when decisions have to be made about for example design of experiments (Merali 2010) If the field had been divergent, it would not have been possible to work with this structure of consensus and bottom up approach. Of course there exist different ideas of how to approach problems (for example CMS and ATLAS both study the Higgs particle differently).

Frank Linde confirms that all researchers that are working for CERN research feel connected and linked. They belong to one community and everyone is contributing to the big experiment. Of course, there is competition but when you look at publications they are shared. Everyone who has contributed a bit will be author of the publication (technicians included). I will come back to the implications of this shared authorship because of this system; individual scientists have to use different routes to become visible and recognized for their own contributions.

Whitley and HEP

In terms of Whitley and related to the elements of the research area high-energy physics, it is a field that is characterized by low strategic and technical task uncertainty and by high functional and strategic dependency. Experiments in the HEP field produce reliable outcomes and success of experiments can be derived un-problematically because they are not open for various interpretations. The techniques and methods are well understood and agreed upon[19]. Researchers within HEP usually agree on the approaches to consider problems and the field can be seen as quite uniform. Though different approaches are used for example to proof the Higgs particle these approaches can co-exist in the CERN collaboration, which also indicates a low uncertainty[20]. Concerning dependence, strategic dependence is high and reflected by the concentration of HEP in the establishment of CERN (strength of network and the existence of the facility). Coordination of HEP research is largely organized bottom-up as consensus is found between researchers. Because of the dependence on expensive technique, researchers in HEP have to agree on methods (which is a large part of the process), and, for a large part, make use of the same experimental setups (detector, accelerator).

Whitley names this stable type of field: Conceptually integrated bureaucracy. According to Whitley this type of field is directed at “producing specific theoretically oriented knowledge” which is an adequate description of the CERN research. (Whitley 2000)

4.3 Governance

4.3.1 Governance and organization

As I have illuminated in the first paragraphs of this section on CERN, the birth of this big program took a long period with (political) negotiations. The preceding negotiation and the involvement of so many partners (countries) make the alliance very strong. Countries that are part of the alliance are not likely to withdraw.[21]

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[19] Referring to the finding that HEP is a convergent field

[20] When strategies and goals would differ widely and there is no agreement, it is unlikely that a stable program can exist where there is space for both.

[21] As we have seen last year when Austria announced to leave CERN, but in the end stayed in the collaboration. Andrew Zimmerman Jones. (2009). "Austria to Leave CERN." from http://physics.about.com/b/2009/05/11/austria-to-leave-cern.htm, reuters, S. W. (2009). "Austria to stay in particle physics lab after all." from

The CERN Council

Starting by illuminating the more formal organization structure of CERN, the CERN Council (CC) has the responsibility for all decisions concerning CERN as a whole and is the highest authority of the organization. The CC meets twice a year and exists of two delegates of each of the 20 member states; one representing the government's administration and the other representing national scientific interests. For the Netherlands, Frank Linde (director Nikhef), explains that someone from the ministry OCW, who is related to the money, attends the meetings with a scientific member as advisor. (Interview Linde)

For the Netherlands, preceding the CC meeting, a Dutch CCC (CERN Contact Committee) meeting is held. This Dutch CCC exists of all Dutch funding agencies (OCW, NWO, and FOM), the Dutch CERN Council members, two selected Dutch staff members of CERN (the institute) and finally the Dutch program leaders of the CERN experiments, the leaders of the four university groups of Nikhef and Nikhef's director.(Nikhef 2007)

The CC members appoint the Director-General (usually for 5 years) who runs the laboratory that exists of several sectors and departments. At present, Rolf-Dieter Heuer fills the position of Director-General. The CC "controls CERN's activities in scientific, technical and administrative matters. The Council approves programs of activity, adopts the budgets and reviews expenditure." A Scientific Policy Committee and Finance Committee assist the CC. This Scientific Policy Committee (SPC) is appointed by the CC and is composed of scientists elected by their colleagues based on scientific eminence, so independent of nationality or belonging to member states. The task of the SPC is to "evaluate the scientific merit of activities proposed by physicists and makes recommendations on CERN's scientific program." Representatives from national administrations are seated in the Finance Committee (FC). The FC deals with "all issues relating to financial contributions by the Member States and to the Organization's budget and expenditure."

There is little rivalry between the members of the community of CERN. (Krige 1990; Merali 2010) While there seems to be a hierarchy in the organization looking at the CERN Council there is no simple top-down decision making. CERN's collaboration is characterized by "healthy organized competition between subgroups working to build different components for the detector quickly and efficiently" (Krige 1993) The following quote illustrate this shared-decision making:

> *"During the birth stage of ATLAS, LHC management had to choose between various proposals for detector designs offered by rival groups at different universities and institutes. It might seem that the most obvious and efficient strategy would be for a committee of experts to make a decision about which technology to use. However, the ATLAS group did not take that path, says Knorr Cetina"* (Merali 2010)

Instead of a committee of experts deciding what path to choose, what they did was retesting the options until all agreed on single plan. Frank Linde, director of Nikhef, confirms this observation and also Cornelis Disco explains that an industrial model of top-down organization simply does not fit CERN. (Disco 1998)(Interview Linde, Kleuver) As I have illuminated before, decisions are based on consensus within the community in meetings where representatives are jointly deciding.

Another important aspect is that researchers consider each other as professional equals. They all work with a common objective (theoretical physicist, experimental physicist, engineer or technician). (Krige 1993) All people working for CERN feel as they are co-acting, and strongly connected and dependent on each other even when they are working at their home institutions like the Nikhef in Amsterdam (interview Linde en de Kleuver, personal information Erwin Bielert, Jeroen van Leerdam en Martijn Gosselink). As a single researcher you can only fulfill a small task in the big

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http://physics.about.com/b/2009/05/11/austria-to-leave-cern.htm,

http://www.reuters.com/article/idUSTRE54H3T320090518 experiment so you need each other and have to work as a team.[22] Collaboration is essential at CERN and using the big experimental set-ups of high-energy physics and different teamwork with the same detector where accelerator time is a scarce resource and should be used adequate.

Publications

HEP is a field where publications are an important element of scientific output.[23] CERN uses an authorship policy for publications where all researchers who have contributed appear on a scientific paper (alphabetical order); technicians and engineers included. PhD students address that it is difficult in high-energy physics to become visible and show what your added value has been in a project because of this publication policy. From a publication you cannot see what an individual contribution was of a researchers so you need also other strategies to become visible in the community (among the people of your specialty).[24]

Protection member states and convention

The initial convention stated that the CERN laboratory must place its orders for goods, equipment and supplies with industries in the member states. (Krige 1990) This measure was taken to protect the member states and to generate some economic profit in the member states. Goods could only be gathered from other nations if it was proven that the member states could not provide it. The nations closer to the facility however could profit more because of shorter travel and transport distance. Decisions for which nation could provide what is also organized around a consensus.
Nowadays these restrictions are more flexible and "physicists, engineers and specialized scientists from non-member states participate in research projects (experimental and theoretical, accelerator and detector engineering, informatics etc.) in return for a contribution in terms of either manpower, materials or cash or any combination of these." (Krige 1990)

Dutch contribution CERN and focus

When you are at CERN (or outside of the Netherlands) people will talk about Nikhef when it concerns Dutch high-energy physics research explains Frank Linde who is the director of the Nikhef institute as well as director of the collaboration Nikhef. He addresses that outside the Netherlands, the individual universities that are part of the collaboration are not to be emphasized as such. In short, Frank Linde points out: *Dutch participation of CERN is (==) Nikhef* (the collaboration).

Frank Linde elaborates that Nikhef coordinates the Dutch contribution to LHC, which involves contributions to the three experiments (detectors) ATLAS, ALICE and LHCb. Dutch participation excludes CMS (the experiment 'competing' with ATLAS). Within the collaboration Nikhef each of the universities is contributing to one experimental program of CERN to avoid fragmentation within the Netherlands. For example University of Utrecht (and Nikhef the institute) focus on the ALICE experiment and the UvA (University of Amsterdam) has a focus on the ATLAS experiment. Though Nikhef's particle physics is not solely concentrated on CERN, accelerator-based research at CERN is considered the backbone of particle physics in the Netherlands. (Nikhef 2007)

Indicating some of the contributions of Nikhef to CERN, Nikhef is one of the founding members of the ATLAS experiment (161 institutes and 35 countries are involved with ATLAS). Nikhef's contribution to ATLAS comprised research and development for the muon detection system and the construction of all 96 precise muon chambers of the largest type in the central part (barrel). These chambers were designed outside CERN and were later transported, tested and installed at CERN. (Nikhef 2007)

[22] These elements have come across in the section of knowledge dynamics: the low level of functional and strategic dependence.

[23] Nikhef publications between 2000-2006: 1200 Nikhef (2007). Self-evaluation report 2000-2006 FOM institute for subatomic physics Nikhef. Amsterdam, FOM Nikhef.

[24] I will not further elaborate on these strategies of becoming visible in this community but they involve for example the attendance and active involvement at group sessions/ brainstorms.

Not only particle physics groups in the Netherlands are working for CERN. Especially when it concerns computing technologies and detector engineering different disciplines are needed and university groups are involved of which I will now illuminate two.

Superconducting magnets
Recognized expertise in a field is very important to get the responsibility to contribute to an element of a detector or accelerator. For example, the Dutch group of Herman ten Kate (Twente University) gained the privilege to design and deliver the superconducting magnets for ATLAS and LHC based on recognition within his field.[25] Additionally, Prof ten Kate is also involved in developing magnets for ITER (International Thermonuclear Experimental Reactor, nuclear fusion research).

Researchers from this Twente group working on superconducting magnets are working in Twente as well as at CERN in Geneva. These researchers can have double contracts and be employed by both explains PhD student Erwin Bielert, who is involved in designing superconducting magnets for the possible next version of LHC.[26]

Grid computing
"Thousands of scientists around the world want to access and analyze this data, so CERN is collaborating with institutions in 34 different countries to operate a distributed computing and data storage infrastructure." (web_communications_cern 2008)

As illuminated before, grid computing is a very important technology that has been developed for CERN to process the gigantic amount of data that is generated with the experiments. Nikhef plays an important role in this development. The Nikhef group was one of the five partners in the European DataGrid (EDG), a 5th framework program[27] project that served as incubator for the grid technique, policies, software and collaboration for the LHC Computing Grid (LCG).

In Amsterdam, one of ten LHC "Tier-1" large computer centers is located that is the biggest in Europe for the ATLAS experiment. (Nikhef 2007) [28] The data analysis centre is located at the SARA computing centre.

Network and facility
In the previous paragraphs we have seen that not all research is executed at the facility CERN. Since the technological possibilities of the WorldWideWeb and Grid computing it has become easier to do high energy physics research from a distance. Experimental data can be transported and analyzed elsewhere. The role of the facility CERN is still of major importance but it is no longer a must for researcher to go to Switzerland to do research. This development has changed the nature of research executed at the home stations of the institutes like Nikhef.

In line with CERN as a network, there are possibilities in the future to establish new facilities on different locations. The current negotiation about a possible linear collider is not restricted to be built at the current CERN facility.

4.3.2 Governance and funding

The money that circulates in CERN research can be approached from several angles. This complicates the options to give a clear overview. The money that directly flows from the member states will be discussed first.

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[25] Twente University is emphatically not part of the Nikhef collaboration since its research goals focus on 'side issues' (engineering) aspects of CERN's experiments. There are close connections with the Nikhef institute and the collaboration partners. This is a strategic decision (Linde)

[26] These magnets are to be positioned near the collision point (ATLAS). The energy level will increase so these new magnets need to have improved heat removal capacities and be tolerant for higher radiation.

[27] Framework Program by the European Union

[28] Furthermore, Nikhef recently proposed a new investment for instalment EGEE FP project (Enabling Grids for E-sciencE)

CERN general funding

CERN annual budget is more than 600 million euros.[29] This budget is based on normalized contributions of the member states based on Gross National Product. The largest investments are from Germany (19.88%), UK (14.70%), France (15.34%), and Italy (11.51%). The Dutch contribution is 4.79%, which is about 34.7million euros. This money flows directly from the ministry of OCW to the CERN institute and does not work with a just return policy, meaning that no matching is needed and there is space for a competition on lowest price and best quality. CERNs general budget is used for the facility CERN and the network/collaboration.

However, this is not the only money that goes around within high-energy physics at CERN. Projects need to be financed and therefore other resources are invoked. To get more insight in these aspects of project funding I will focus my attention again to the Dutch organization of particle physics research.

Dutch funding HEP research

Nikhef's joint research program receives funding from five different sources(Nikhef 2007):

- Base funding for the FOM institute (thee sum of program budgets and mission budget)
- FOM program funding for the three uni groups (RU, UU, VU) UvA included in Nikhef institute budget
- project funding acquired by institute FOM or third parties EU NWO ministry of EZ
- lease of former accelerator buildings and housing Amsterdam internet exchange
- the personnel and material budget provided by the four university partners.

Nikhef's annual budget sums about 10 million euros. Note that the universities of the Nikhef collaboration also get their own first money stream funding. Here, we already see a mixing of budgets, which makes a calculation of a total budget very difficult.

An example of NWO funding of Nikhef are the NWO 'groot' and 'middelgroot' grants that have been allocated for the ATLAS project for the upgrade of the detector program and for further developing the technical infrastructure.(Nikhef 2009) Part of the detectors is funded via ESFRI. Additionally, FP grants are allocated to both Dutch CERN researchers, research projects as the facility CERN.(ESFRI 2008; Nikhef 2009) ATLAS data analysis that is performed by physicists is financed from the program exploitation budget as well as from further project-oriented budget FOM 'projectruimte', NWO grants and EU program FP and 'Marie Curie'. Projects are also strengthened by allocation of NWO 'Vernieuwings Impuls' (also known as 'VI', for example Veni and Vidi for LHCb experiment). For CERN, ESF is not part of the scala of funding arrangements. When we look at the funding of the superconducting magnets, groups that are involved find money at CERN but also apply for grants at the EC or NWO. Often, difficult constructions are taken to divide costs for research employees between CERN and research institutes.

There have been changes in the strategic focus of FOM financing that follow a tendency of research that needs to be valorized. This trend is noticeable looking at the resources of fundamental research. (Nikhef 2007) Linde further stresses a threat that the preparation time and lifetime of experiment in HEP is much longer than in other fields and thus also longer than the funding cycle that is applied for (physics) projects. (Nikhef 2007) The future of a follow up of LHC[30] is still questionable and currently under negotiation. Note that the main costs of HEP experiments are to develop the accelerator and detector, build in 6 years, weighs a lot and costs millions.

[29] 887.385 million CHF in 2009

[30] Internation Linear Collider (ILC) future linear collider. Ambition: ILC fundamental as complementary LHC (approved by CERN council) "European Strategy for particle physics"

Europe increasing important role in setting agenda for the contract rewarding of large scale research facilities such as those needed in particle research. This has led to the formation of networks between funding agencies. (interview Linde, Kleuver)

4.4 Sub conclusion CERN

Research at CERN is mainly characterized by the knowledge dynamics of the research area High Energy Physics (HEP). HEP can also be seen as one search regime. Unfortunately, HEP carries the word physics but as a search regime it does not solely concern (theoretical and experimental) physics. Areas like mathematics, computing science and super conducting material science co-shape the knowledge dynamics that we find at CERN. Most important for the search regime is the high technical complementarity that HEP typifies: referring for instance to the technologically advanced detectors and accelerators and grid computing needed to execute and shaping the research. Cognitive complementarity is also present on a medium scale. Research fields like computing science and engineering sciences (f.e. material science on superconducting magnets) play a large role when it concerns the development of detectors and accelerators and data analysis. In general, CERN can be seen as the primary organization determining the global HEP research agenda.

Regarding the organization of CERN, building detectors and accelerators is just too expensive for one nation and requires advanced technology, which explains the necessity to establish a multinational collaboration and the centralized aspect. We have to acknowledge however that research is not only executed at CERN but also at the partner institutes and universities. The network of CERN has exceeded the 20 member states to 80 participating countries that participate both in their own institutes as well as at the facility CERN.

The institute CERN is funded by national contributions based on national gross product based on a convention providing strong roots for a structural program. Furthermore, a wide range of funding arrangements like Framework Programs and national grants fund actual research. This variety in funding arrangements makes it difficult to sketch the exact money flows, which affects strategic decisions.

CERN is characterized by a strong organization structure. This structure can be denoted as hierarchical but the bottom-up shared decision-making is of great significance in its success. This shared decision-making would not have been possible if the research area would have had less functional and technical dependence. This high dependence together with low technical and strategic task uncertainty makes the field HEP a stable field according to Whitley: ‘conceptually integrated bureaucracy’.

Case	**CERN**
Distributed/centralized	Centralized and distributed aspects
Top-down/bottom-up	Both
Wagner category	Mega science
Knowledge dynamics	
Search regime IRP in general	
Growth	Low
Diversity	Convergent
Technical complementarity	High
Cognitive complementarity	Relatively high
Whitley	
degree of mutual dependence	
strategic	High
functional	High
degree of task uncertainty	
strategic	Low
technical	Low
Category field Whitley	Conceptually integrated bureaucracy
Funding	From ministries based on g.n.p. Projects and grants EU FP, national research councils like NWO
Organization structure	Seeming hierarchical organization facility CERN, project level experienced scientists in network, nations irrelevant

Figure 4.3: overview CERN characteristics

5 Case II: Census of Marine Life (CoML)

*"The Census of Marine Life (CoML) is **a growing global network of researchers** in more than **50 nations** engaged in a ten-year initiative to assess and **explain the diversity, distribution, and abundance of marine life in the oceans - past, present and future**. Through 2010, scientists worldwide will work to quantify what is known, unknown and what may never be known about the world's oceans." (CoML 2010)*

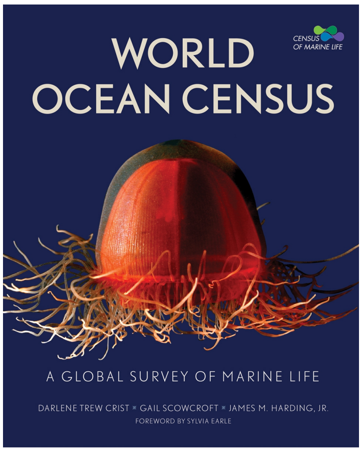

Figure 5.1: Cover of the world ocean census book.(CoML)

5.1 Origin, organization and development

The origin of Census of Marine Life can be found in the remarkable story of two scientists who discussed biodiversity issues over a beer and decided to do something about it: count all fish in the ocean. (Vermeulen 2009) These two individuals are Jesse Ausubel and Fred Grassle. Ausubel is a program officer at the Alfred P. Sloan Foundation and professor in human ecology at the Rockefeller University (New York). Grassle is professor benthic ecology at Rutgers University. The combination of Ausubel, who is mainly concerned with science policy related issues, technology development and communication, and Grassle, who is an academic (marine biologist) was essential for this origin. Through Ausubel's position they managed to get basic funding at the Sloan Foundation, a foundation that supports research in science, technology and economy (established in 1934 by Alfred Sloan, a former president of General Motors).

The idea of counting all fish that live in the oceans was soon extended to *marine life*. In 1998, the Sloan foundation board decided to make the program happen. Subsequently (in 1999), an international Scientific Steering Committee (SSC), the governing body of CoML was formed to determine scientific goals and provide guidance. The program was granted money for a period of 10 years and several project themes were selected. Experienced and recognized scientists from all over the world were selected by the SSC and brought together to shape the projects. At first the involved scientists were mainly Americans but soon also European scientists got involved with CoML.

The SSC of CoML is supported by a central secretariat and also regional nodes were formed like the European Committee CoML (EuroCoML) in 2003. An important actor in Europe is Carlo Heip, one of the founders of the EuroCoML and also member of the SSC of CoML. Furthermore, Heip is the director of the NWO research institute NIOZ (Nationaal Instituut Oceaan en Zeeonderzoek[31]).

In 2001 the program was up and running with planned pilot phases (2002-2004), main field project (2005-2007), and analysis and integration (2008-2010) for the different projects. These are

[31] Royal Netherlands Institute for Sea Research

held together by a central governance structure (the SSC and projects with SCs, the regional CoML nodes, which will be illuminated later in this section). The different projects that are executed by the census are thematic selections of the big scope of Census. Every project has its own scientific (steering) committee that set up a strategic research plan.

The most important goal of CoML is to make a comprehensive database. This database should be available to everyone and should include information on all forms of live in the sea. When the program started, about 215,000 species had been described and since then over 7000 new species have been added to the list. To gather data, CoML established the Ocean Biogeographic Information System (OBIS). OBIS is an open access alliance of people and organizations aiming at sharing marine biogeographic data on the world wide web wider than the set of data that CoML offers.

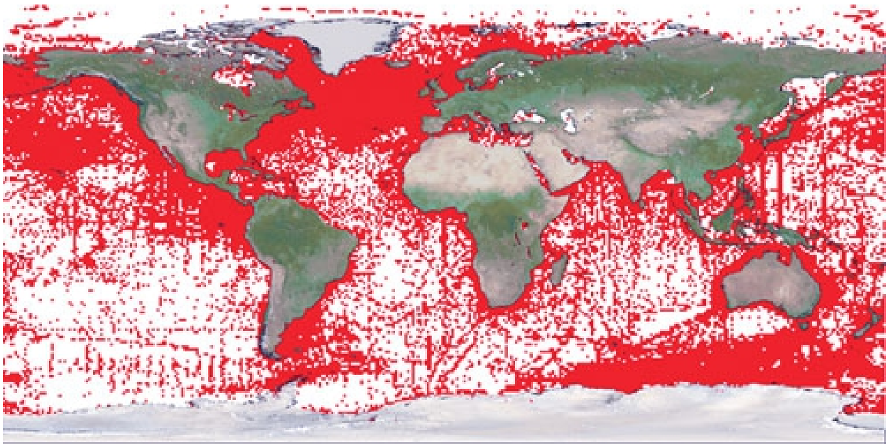

Figure 5.2: Since 2000, the Ocean Biogeographic Information System, OBIS, has grown to 14 million records from 232 databases. The red dots on the map show the global distribution of the OBIS records. Image: OBIS (http://www.coml.org/media-resources/maps.)

While CoML had intentions to continue when the Sloan Foundation funding finishes in 2010, so far, no new sources are found that guarantee a basic funding for a lasting program. It is yet not sure how the program will continue but people involved are working hard on synthesis of outcomes and looking for future options.

5.2 Knowledge dynamics

One specific discipline cannot cover the different research projects within the Census of Marine Life. The goals of the Census are extensive and therefore within the area of *Marine Biology* different fields are involved. Using the broad covering name Marine Biology, the essential elements of the research area that covers research within Census will be illuminated. But since knowledge dynamics on project scale involve research areas with more specific characteristics, I will also describe two projects as examples. These more specific research fields on project scale vary from marine taxonomy, ecology, zoology, biochemistry, and biodiversity research. I will use these two angles of analyzing knowledge dynamics to find their overlap and distinctions that can help tracing Census multidisciplinary (or even interdisciplinary) success. So, first, I will elaborate on these general knowledge dynamics of Marine Biology characteristic for the program. Secondly, I will show the different nature of research on project scale using the projects International Census of Marine Microbes (ICoMM), and Census of Marine Life Zoo plankton (CMarZ).

5.2.1 Marine biology

Using a more historical approach to approach the research area Marine Biology, a link can be made between the type of research of the Census of Marine Life and the traditional scientific research in *natural history*. Niki Vermeulen (Vermeulen 2009) shows that *measuring, mapping, and modeling the* *world* is still the main characterization of a contemporary natural history project like the CoML. For CoML, this measuring, mapping, and modeling focuses on the ocean and sea.

The type of work however has changed substantively in interaction with recent scientific, technological and societal developments. (Vermeulen 2009) For example, transformations took place because of the development of technologies like genomics (bar-coding). Carlo Heip, director of NIOZ, points out that also the use of satellites has had a great impact on the research practice and organization. (Interview Heip 2010). Synoptic imaging and also instrumentation used to detect the seabed has changed the field as well. Carlo Heip explains that the knowledge of what lives in the oceans had increased enormously in the past 30 years due to these technologies and also because of the Census. Particularly marine biodiversity research is a field that has grown in the past years because of climate change studies. With the research executed in CoML theories and models can be developed of how the circumstances in the oceans have changed over the past years.

Expeditions in marine research

Marine research is generally characterized by expeditions or so-called 'cruises'. Expeditions are set up broadly and different groups are on board or alternate to take samples and do measurements at several places in the ocean. Research groups from different disciplines can be on board at the same time. For example, one doing meteorological research and another taking samples for a study on Plankton. (Interview Annelies Pierrot-Bults) Part of the analysis of samples is often already executed on board. Each research team can bring equipment to do analysis on board in a container. When a research team leaves and a new research team arrives they will then change the containers with equipment. (Interview Stefan Schouten). As a researcher, you can join an expedition by 'purchasing' research time on a ship. For instance, the Dutch NIOZ (Nederlands Instituut voor Onderzoek der Zee) owns a ship that can be 'rent' for about 10,000 euros a day (including crew). Illustrating what a working day includes: in the deep ocean, to gather samples of a vertical colon you need 4 hours to go down and 4 hours to get up again. Building a ship like the one NIOZ owns costs about 40.5 million euros. Not only the boat but also the equipment to take samples is often expensive and complex.

International character of Marine research and sharing data

Marine biology, and sea research, is par definition international since research is based on a collection of samples gathered at different locations all around the world during expeditions on international waters. For instance a practical exemplar, research samples are taken from several places at the boundaries of tectonic plates where life can be found on the seabed. Sea research also has a typical aspect of locality because samples cannot be gathered from everywhere and the research results are based on these samples of research stations. Thus, the area of where samples come from limits the scope of the research. Within a research project decisions have to be made about the location of the research, which is also dependent on the type of funding (which I will explain in the next section).

Due to the introduction of the database OBIS, researchers can use each other's data and it becomes easier to compare and link data. This can be of great advantage for the type of statements that can be made (from local to global). The creation of the OBIS database transforms the research practices because it offers availability of information. The database is shaping the scientific disciplines and not only structuring and storing data. These changes for example in biodiversity research are affected by databases not only change the work practice but also a certain outlook on life. (Vermeulen 2009)

With the introduction OBIS some dissimilarities in research cultures were accentuated. Carlo Heip illuminates that within biology it is less common to share data than in field like physics or chemistry. Biologists, as he experienced, are somewhat anxious to put data in OBIS. Heip illuminates that within the Census, and also in general, molecular biologists are more familiar and willing when it comes to sharing and making use of each other's databases. According to Heip, the strength of research can be found in combining data, also between different disciplines. Census of Marine Life managed to break the ice for sharing data but some obstacles have to be taken still. This is also a governance aspect that I will come back to.

5.2.2 Project scale

Illustrating differences in research practice within the Census I will briefly illustrate two projects of CoML.

Marine Biochemistry: Microbes

The Census project International Census of Marine Microbes (ICoMM) is a project that studies microbes the world's smallest organisms, which account for 90 percent of biomass in oceans. Prof. Dr. Jan de Leeuw from NIOZ is an important Dutch actor in this project as a member of the CoML Secretariat. His research at NIOZ focuses on marine sediments "to reconstruct past microbial communities, biosynthetic pathways, biogeochemical cycles, environments and climates". (icomm 2010) It belongs to a field of *organic biogeochemistry,* a field that makes use of by isotopic analysis of organic compounds in micro-organisms, marine waters and sediments. Drilling samples come from all over the world (see figure 5.3). A drilling sample consists of a column of soil and analyzing composition of different slices tells us more about the (changing) circumstances in the ocean. These drilling samples are globally shared. Microbes are a perfect indicator to analyze circumstances in the ocean (water temperature, presence of nutrients) and thus to study climate change in the oceans during, because these small organisms (have to) respond easily to changes. (interview Schouten)

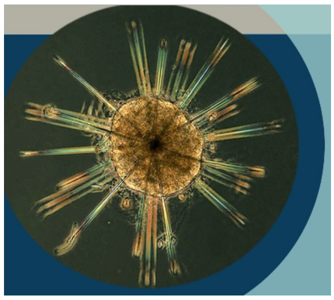

Figure 5.3: micro-organism

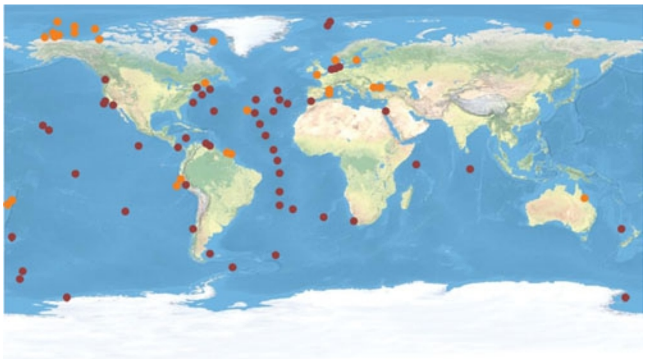

Figure 5.4:The map shows the locations of samples collected by 40 field projects employing the 454 tag-pyrosequencing technology. Image: ICoMM, http://www.coml.org/media-resources/maps.

Analysis of the soil samples is done with techniques like mass spectronomy that have an origin in chemistry. Microbiologists also study these microbes. At NIOZ these microbiologists work closely together with the biochemists but have clearly divided tasks and are situated at different locations of the institute. Here we see some cognitive complementarity.

Though goals of the project are aimed at explaining climate change, Stefan Schouten (ICoMM researcher at NIOZ) addresses that it is still difficult to link the ICoMM research to elements of global change. To predict climate change, research over a long term is needed, at least 60 years to extrapolate and the research of Census is can be used as a start with this focus but cannot result in precise answers concerning climate change. (Interview Schouten) With the societal global change concern this field of research has grown the past years.

Marine taxonomy: Chaetognaths

Another project of CoML is the Census of Marine Zooplankton (Cmarz) which works towards a taxonomically assessment of biodiversity of animal plankton. (CMarZ) “Plankton are drifting organisms in aquatic environments, including marine and fresh water. They are the base of the food web in these environments.” (Encyclopedia of Earth) [32] In this study accurate information is gathered on zooplankton species diversity, biomass, biogeographical location, genetic diversity and community structure.[33] The plankton population indicates if the ocean is healthy, because of its position in the food chain, which is why plankton research and counting population is relevant and important. Without plankton in the oceans, the bigger animals cannot exist. The CMarZ project has carried out more than 80 cruises to collect samples.

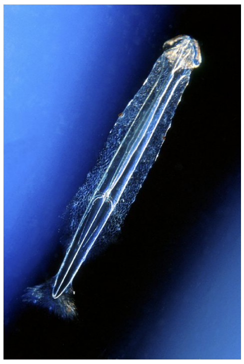

Figure:5.5: plankton image

Annelies Pierrot-Bults, senior researcher at the Zoological Museum of the University of Amsterdam, is member of the steering group of CMarZ.[34] Her research is concerned with taxonomy of Chaetognatha, a phylum of predatory marine worms that is also known as arrow worms (figure 5.5). She got involved with the Census because of her research connections in Norway and her research of determination and counting Chaetognaths fit exactly within the CoML.

In practice, her research involves determining these worms under a microscope (figure 5.6) and counting how many are present at which depth in a water column. Pierrot-Bults illuminates that taxonomy has become an unpopular field and that it does not attract many (PhD) students. Within the Netherlands she is one of the few studying plankton. Taxonomy does not have a fashionable character because of the use of “old-school” technologies and this lack of money for people. Pierrot-Bults addresses that through Census there is money for expeditions in her field but she is alarmed by the scarce availability of funds for researchers. (Interview Pierrot-Bults)

Annelies Pierrot Bults explains how her research field, taxonomy, has changed due to genetic technology. It is now possible to identify new species and relationships differently. It used to be a problem that some species that live in deep sea cannot be kept in shape when you bring them to the surface (since the pressure change that will damage to organism). But genetic analysis of those deep-sea species is still possible. However, here is a difference in approach between taxonomists like Pierrot-Bults and molecular biologists. Namely, for instance naming of species happens in a different way, using different categories. Taxonomists and molecular biologists sometimes have difficulties in understanding each other and that can sometimes collide. The distinct standardization of description and followed by a coordination of the work can be seen as a main cause for that. Both taxonomy as genetics are characterized by the ability to produce standardized descriptions of objects. (Stemerding and Hilgartner 1998) Molecular biology and genomics are transforming taxonomy (not only morphology). It has broadened the scope to deep-sea and micro-organisms.

[32] “Zooplankton are small protists or metazoans (e.g. crustaceans and other animals) that feed on the phytoplankton [that live from photosynthesis]. Larval stages of larger animals, such as fish, crustaceans, and annelids are included here. Zooplankton are in turn consumed by small fishes.” (Encyclopedia of Earth)

[33] “This assemblage currently includes ~6,800 described species in fifteen phyla; our expectation is that at least that many new species will be discovered as a result of our efforts. The census will encompass unique marine environments and those likely to be inhabited by endemic and undescribed zooplankton species.” (CMarZ website)

[34] Besides being member of CMarZ, Annelies Pierrot-Bults is also member of Mar-Eco and the bar-coding working group of CoML

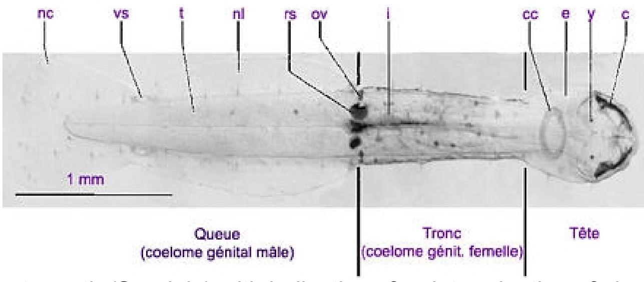

Figure 5.6: image of a cheatognath (Spadela) with indications for determination of characteristics. Image: CMarZ

Comparability scientific data and knowledge
The research of these two projects shares a focus on the ocean and collecting of data to be put in OBIS. However, they are further barely connected or even comparable. The technical aspects of how to get samples are comparable. For a taxonomist it can be essential to be on board during an expedition while the marine geochemist execute his research anywhere in a lab (for instance at the NIOZ institute on Texel, Netherlands).

5.2.3 Search regime and type of field

Next, I will describe the knowledge dynamics in terms of Bonaccorsi's search regime and Whitley's type of research field.

Search regime
Providing statements about the characteristics of search regime(s) based on this data has limitations. It is an extensive task to unravel the various knowledge dynamics of different disciplines that play a role. The illustration of the two fields of the projects described above has however given us some insight in the marine biology area that is characterized by a semi-high technical complementarity, a long tradition of working individualistically that is now changing because of the demand to share information and connect research output in a quest for answering biodiversity questions. Niki Vermeulen addresses that the style of collaboration has changed in marine biology (the scale and scope of research are larger). (Vermeulen 2009) The field of biodiversity (including marine biodiversity) is growing because of its relation with global change issues. Different disciplines are connected within the Census but still perform their own research in their own way. This sometimes leads to conflicts of research practice like the discussion between molecular biologists and taxonomists about the way to categorize and standardize in the databases (because of distinct research traditions and methods).

Considering the rate of growth no decisive answer can be given. Publications of the program or these research areas have not been studied for this thesis.[35] The intention of CoML was to create a space to migrate these fields. In terms of search regime it is a search for cognitive complementarities. I define CoML's search regime as one of high cognitive complementarity.[36]

One could say that the traditional research areas are affected and changes by the attempts of collaboration that sometimes lead to convergence and other times divergence. It clearly points out that research areas are dynamic which complicates the labeling an area with one specific name.

[35] A bibliometric study like Bonaccorsi's study on HEP could give us insight in these aspects of growth and convergence/divergence.

[36] Though involved fields within CoML used to be different search regimes (narrow, convergent, with low cognitive complementarity) but now these fields might be growing towards each other through the program and becoming one search regime with high cognitive complementarity (and possible possess more and more converging characteristics).

Whitley and Census
Applying Whitley, I will typify the research area marine biology as a whole instead of labeling all disciplines involved on project scale. Describing characteristics this way, it becomes clear where difficulties between the areas are present and where commonalities are found. Since we are trying to detect how knowledge dynamics affect the system this approach will illuminate the elements of program success the best.

Typifying the research field using Whitley's categories, CoML research area as a whole can be seen as a rather low (to medium) technical and low (to medium) strategic task uncertainty and a high functional dependence and a medium (to low) strategic dependence.[37] The same as for CERN's research the success of results of experiments can be derived quite unproblematic. These techniques and materials used within the various projects as has been described before are well understood which indicates the low strategic task uncertainty. Although Whitley typifies the field biology by its varied, unstable and not so clearly ordered goals (Whitley), we see that the construction and defined goals of marine biology in a program overcomes this field's characteristic when we look at CoML.

Regarding the collection of different research projects and disciplines within the CoML the strategic task uncertainty as a whole can be seen as low to medium. For example looking at the distinct preferred ways of tackling taxonomy between taxonomists and microbiologists. These can exist parallel but due to the program researchers are challenged to find strategies of working together which might lead to converge of research areas (an effect that also has roots in scientific planning and thus governance). Same counts for intellectual priorities that, still considering the research area of Census as a whole, are determined by the scientific planning which steers the research. Within marine biology, researchers share data with colleagues and build upon each other using same methods materials and theories. Regarding dependencies, we can derivate a relatively high functional dependence. The research network of Marine Biology is strong in the various separate research areas. Researchers within each involved field know how to find each other and use same methods and thus build on each other's knowledge. But note that since more research disciplines are involved within CoML that use different models and approaches, the functional dependence is one of the elements were a balance has to be found within the program. There is no intrinsic functional or strategic dependence between microbiologists and taxonomists but within CoML these field become more dependent on each other.

According to Whitley this characterization of a field fits in a category of: *technically integrated bureaucracy*, producing empirical specific knowledge. This empirical specific knowledge relates to marine biodiversity collected in OBIS.[38]

5.3 Governance

5.3.1 Governance and organization

The Census of Marine Life has generated an umbrella for marine research that included everyone for the first time. Census started as an American initiative but soon spread out over Europe and other parts of the world. There are platforms like the Scientific Committee Ocean Research (SCOR) from ICSU and the Partnership for Observation of the Global Oceans (POGO, http://www.ocean-partners.org/) but they require membership fee that is to high for developing countries. Within the Census it was possible for developing countries to join because there was no such fee. Researchers were brought together based on expertise instead of on their financial capacities. Just like with CERN, the structure presented seems hierarchal but also with Census the bottom-up dynamics are more significant as I have already elucidated with the peculiar origin of the program and how researchers became connected to the program (Interview Heip, Interview Pierrott-Bults)

[37] Here we see the same difficulties as applying Bonaccorsi since the boundaries of research fields have to be drawn before focusing on its characteristics.

[38] When the program CoML would not be there, strategic uncertainty would be high and thus the field would be a " professional adhocracy".

As already drawn, the organization of the CoML is quite clear-cut with a secretariat based at the “consortium for Ocean Leadership” in Washington. This secretariat is governed by a SSC that coordinates the various research projects that were determined in the early phase of the Census which are reflected in twelve national and regional implementation committees. The ambitions of CoML were high but not all research goals could be covered with the projects. Furthermore there is a synthesis group that has a task to organize, integrate and synthesize the data to guarantee an overarching message after the 10year program has finished. Note that the communication and outreach department has a key role in the CoML program.

Each project has its own organization structure with a body functioning as a steering group or committee. These organization structures are more or less comparable for each of the research projects. For instance, ICoMM has its own small secretariat, a Scientific Advisory Council (SAC) and several working groups. Each project group defined its own research strategy. Census has brought a large group of marine biologists together but in these early decisions they had to exclude some fields. Heip appoints that when these projects were formulated, some research groups at NIOZ could have been part of the Census if they would have been more active in this first lobby.

Important to notice in the origin of the projects of CoML is how scientists were consulted when determining research goals. This bottom-up development guarantees success and continuity (Niki, Annelies). Furthermore, research connections are important when developing a community sharing the same language and world is necessary. Vermeulen points out that these connections at the CoML are geographical and epistemological: researchers from different countries are brought together as well as researchers with different disciplinary background and generating multi-disciplinary efforts for example leading to combination of various research methods or data analysis. (Vermeulen 2009)

OBIS: organization

A governing board manages the Ocean Biogeographic Information System (OBIS) with advice from the CoML SSC. OBIS is also an active participant in the Global Biodiversity Information Facility (GBIF). The philosophy is that by publishing about Ocean life through OBIS, duplication is avoided.

The International Ocean Committee (IOC) by UNESCO has adopted the OBIS database in June 2009 into the Oceanographic Data and Information Management (IODE) program, which strengthens OBIS’ position. (IOC/INF1250 2008).

OBIS governing board will continue its tasks in consultation with the IODE officers until the synthesis of CoML completed. To maintain the identity and visibility of OBIS within IOC, the IOC states to take “into account the interest and commitment built up within the ocean biodiversity research community over the last decade, including the ability to interact with other relevant intergovernmental and international bodies.”(IOC/INF1250 2008)

Output CoML

CoML has invested in showing what research has been realized and what data has been gathered also outside the scientific domain. For instance, a beautiful documentary “Oceans” was released in 2009. Furthermore, the communication department has invested in popular science books and an extensive program website including nice images of findings and maps of research footprints(CoML 2011).

Future Census

The year 2010 is the final year of the project and Sloan Foundation will not extend its funding. In the first section of this chapter I have addressed the different planned phases of Cenus: pilot phases (2002-2004), main field project (2005-2007), and analysis and integration (2008-2010). CoML is now in its final phase, which is difficult and everyone tries to manage to realize the deadline goals. Even when the program ends, the connections between researchers will still exist and within the CoML people are working on synthesis coordinated by the Synthesis committee to develop format of integration. Continuity is also on this agenda but this concerns mainly the continuity of the research connections of the network form. There is no assurance for future big science programs in marine biology, but census has brought people together. (interview Heip, Pierrot-Bults) As I have indicated before, the Census has formulated their research goals in projects that could not cover all fields or domains of marine biology, which have had an inclusion/exclusion effect on the marine researchers that could participate. A next development of a marine biology network would be extending the scope and include a wider set of researchers and research fields. The European Census node can still be of importance, together with the ESF Marine board. Furthermore, ESF programs euroDEEP and euroDIVERSITY that link with CoML have been fulfilling a role of indirect steering national research policy which affects future funding possibilities for marine biology research.

5.3.2 Funding

The Sloan Foundation offers so called “seed money”. This basic funding of the 10-year program covers starting costs, administration costs, organization of meetings and outreach. It is quite unique for a program in marine biology that research is funded this way. Resources to fund the projects have to be found elsewhere. Annelies Pierrot and Carlo Heip both explain how they use the wide variety of funding possibilities to keep their projects running varying form FP to ESF and national funding. It works more or less the same that money for research projects is collected through all possible (mainly national) channels. This makes it, just like with CERN, practically impossible to make an overview of the budget. With CoML this is even more problematic because of the distributedness and looseness of the projects. Worries about the international versus national orientation of funding is uttered: “Next to problems with reaching the ambitious goals within ten years, the tension between the international orientation of the scientific project and the national orientation of research funding complicates global collaboration.” (Vermeulen 2009)

NWO

Dutch money that flows into CoML can be found along several ways. First, the NIOZ is an institute of NWO and gets general funding for facilities and staff of which some contribute to the Census. Secondly, the NIOZ groups and other groups in the Netherlands that are participating in CoML projects submit proposals at NWO for (open) competition via the department ALW (Earth and Life Sciences), VI (vernieuwingsimpuls) or the theme ‘Duurzame Aarde’.

CoML projects also receive funding via ESF’s (European Science Foundation) eurocores project EuroDEEP. EuroDEEP stands for Ecosystem Functioning and Biodiversity in the Deep Sea and is a eurocores program that is a collaboration of 9 funding agencies: België, Frankrijk, Ierland, Italië, Noorwegen, Polen, Portugal, Spanje en Nederland.

Heip explains that in the Netherlands a focus is on the program ZKO (Nationaal programma zee- en kustonderzoek), which is not related to census research. There is a limited budget for marine or sea research and ZKO can be seen as a competitor in the funding field. Heip addresses how ZKO is partly funded by Dutch ‘aardgasbaten’. These resources are not allocated by NWO. The NIOZ has profited from this Dutch money as well improving its infrastructure.

EC

Within the European Commission, sea research has always had an advantage because of its tradition and its necessity for European collaboration. This necessity especially counts for smaller countries.[39] The somewhat privileged position of Marine Research at the EC is a great benefit for the allocation of research funding through FPs, explains Heip. However the time frame of FPs is relatively short for the expeditions with the scale of CoML so proposals for FP grants are based on subprojects.

Census scientists experience a shift in research policy from fundamental to applied research. The need to have clear search objective is a general tendency. That CoML is covering the projects that apply for FP money provides an answer to this problem because CoML has broadly outlined these

[39]Actually, only bigger countries like France, the United Kingdom and Germany can really afford to do research alone

aspects of application. CoML for example has found support in environmental problems.[40] However, fundamental fields suffer from this shift in policy.

5.4 Sub conclusion CoML

The Census of Marine Life is a program with the ambition to explore and map ocean life. The overarching goal has been to develop a database (OBIS) to gather data and to create one corpus. OBIS integrates the various marine biology related disciplines of CoML. The existence of CoML creates cognitive complementarity since various disciplines are becoming related and challenged to work together.

Marine biology is characterized by expeditions where samples to be studied are gathered to map and model the world of ocean and sea. It is not a hierarchical research area, but structured by classification methods. The way of doing research is still closely related to doing ‘natural history’. Expeditions, and the used equipment to get samples, are expensive. Costs are shared between different research disciplines that all execute their own part of their research during cruises. CoML has provided access to Census expeditions but researchers had to find additional funding for their specific research. Marine researchers apply for funding in their own country or region (f.e. EU FPs).

CoML is a network with bottom-up structures. Scientific planning took place at the beginning defining goals of different projects that could be further developed when researchers were attracted that defined additional research directions. One secretariat in Washington and regional nodes characterize the infrastructure of CoML. An important role of the Secretariat is to coordinate output (not only scientific).

CoML has come to an end in 2010 but has given impulse to convergence within the field marine biology: on the one hand gathering data and store it in OBIS, and on the other trying to bring together standardizations and methodologies (f.e. of taxonomists and microbiologists). The formed regional nodes and connections between researchers are lasting even now CoML’s Sloan Foundation funding ended. The connections (EuroCoML, ESF Marine Board and programs) have generated a future infrastructure. One thing is sure, research on ocean life as a specific research focus has been put on the map by the Census.

[40] The focus on environmental problems has the same character as when in 70ies there was a focus on pollution and effect of heavy metals in sea organisms and ecosystems which boosted marine research.

Case	**CoML**
Distributed/centralized	Distributed
Top-down/bottom-up	Bottom-up
Wagner category	Coordinated
Knowledge dynamics	
Search regime IRP in general	
Growth	High
Diversity	Rather convergent
Technical complementarity	Relatively high
Cognitive complementarity	Low
Whitley	
degree of mutual dependence	
strategic	Low
functional	High
degree of task uncertainty	
strategic	Low
technical	Low
Category field Whitley	Technically integrated bureaucracy
Funding	Sloan Foundation ESF, national research councils, FPs
Organization structure	Distributed network with steering committee. Loose organization. Project themes are determined but content has to be provided and decided by appointed researchers.

Figure 5.7: overview CoML characteristics

6 Case III: International Human Dimensions Program (IHDP)

6.1 Origin, organization and development

The International Human Dimensions Programme on Global Environmental Change (IHDP) was established in 1997, institutionally sponsored by the International Social Science Council (ISSC) and the International Council for Science (ICSU). In 2007, UNU (United Nations University) became a third sponsor and the Secretariat of IHDP (UNU-IHDP) was housed in Bonn (Germany).

"(IHDP) works toward understanding and addressing the effects of individuals and societies on global environmental change, and how such global changes, in turn, affect humans. By integrating humans into the debate on global environmental change, IHDP addresses some of the most poignant, and widespread challenges of our day. As such, it is a producer of new knowledge that can flow into the work of scientific assessments from other organizations and enhance their ability to answer critical questions of interest to the policy world."(IHDP_annual_report 2010)

The establishment of this social science program on global change was unique because, for a long time, climate research was merely associated with the natural sciences.[41] (interview Leemans) The ICSU and ISSC program IHDP provided a shift in focus to the human dimensions of global change as *complementing* to the natural sciences. Examples of issues that IHDP explores are sustainability, coastal zones, environmental governance, green economy, health, human behavior, and extreme risks. (IHDP 2007)

What characterizes IHDP is that it is a network of networks. Its organization structure is looser than CERN or even CoML. The organization of a network like IHDP might seem unconfined, but the backbone structure is essential for the program concerning research agenda building. On a high level of aggregation we find the IHDP Scientific Committee (IHDP-SC) and the executive director (ED). The current ED is dr. Anantha Duraiappah, an experience environmental development economist, who is appointed by the UN. The 10 members of the IHDP-SC are representative scientists from the field. The members are approved by the ICSU, ISSC and UNU. The IHDP-SC develops a strategic plan to cover the different disciplines and themes. IHDP has several core projects. Two of IHDPs projects are coordinated in the Netherlands. These projects are Earth System Governance (IHDP-ESG) and Industrial Transformation (IHDP-IT).[42]

On a project level, each project has its own Scientific Steering Committee (SSC). These SSCs are appointed by the Steering Committee. Scientific planning takes place on these levels of the organization. Later in this chapter I will draw how these committees are composed and how there exists a balance between top-down and bottom-up elements.

Besides these official committees that set goals for the different projects, it is difficult to appoint who is actually involved in IHDP's research. Scientists can become a member of the IHDP community. You can become part of IHDP when your academic work fits in the goals of one of the projects, recognized

[41] Climate change had to be seen as a problem first, scientifically and politically. The World Climate Research Programme (WCRP), a joint sponsorship of ICSU and the World Meteorological Organization (WMO), was already positioned in 1980, and the International Geosphere-Biosphere Programme (IGBP) was established in 1987 (also by ICSU).

[42] Both programs have important SSC members at the Institute for Environmental Studies (IVM) that is located at the VU University

by the steering committee. However, these members are not listed precisely, so determining how many researchers are involved is difficult.[43]
One might expect that it becomes clear from scientific publications whether a specific research was done for IHDP. However, from papers within the field of social environmental science, you can neither derive whether a specific researcher is a member of the IHDP network nor that research was executed for one of the IHDP projects. (interview Leemans, interview Biermann) As will become clear later in this chapter, this can be associated with how research in this program is funded.

Secretariat
The secretariat in Bonn (UNU-IHDP) that is part of the UNU has an important role in the network. Especially because IHDP is a loose network that includes various different disciplinary activities. On the IHDP website we can read:

> *"There is strength in numbers, but it must be harvested. The IHDP Secretariat serves the programme as a whole, acting as the central hub between all nodes of the network. It plays a central role in development, implementation and evaluation of the programme's goals. Our strength lies in being able to "hold" the programme together through opening up channels of communication, collecting information, and disseminating results that are essential to the smooth operation of the programme. We lobby for the programme, organize activities and events, and develop research and policy capacity in order to meet the programme's goals. Additionally, the Secretariat acts as a knowledge broker between the programme, practitioners and the press, bringing research findings to users who can best utilize them. Our group approach, facilitated by the Secretariat, simplifies efforts, and intensifies effectiveness."* (IHDP 2010)

This role of the secretariat that is described above indicates the importance of its existence as it facilitates the necessary negotiations and translations. In the next sections it will become clear how IHDP needs this loose structure because of its knowledge dynamics and the governance patterns that we appoint. We will see that the organization of a network must be able to respond to changes. So, the steering body of a network (SC, SSC, secretariat) needs to cover the domain to feel what is happening in the network and be able to negotiate between the various actors. Before continuing, it must be stated that this program, of all three cases, is the program where governance and knowledge dynamics are the most intertwined and difficult to pull apart.

The central secretariat in Bonn is not the only fixed institutional body. Also on a project level, an institution can be appointed for each project that fulfills similar tasks on a project level. For example, the Institute for environmental studies (IVM) at the VU University hosts the Earth System Governance project (ESG), one of the core projects of IHDP. Several VU researchers are actively involved in this project, including professor Frank Biermann (VU university) who currently chairs the Scientific Steering Committee of ESG.

ESSP
Since 2001, four international research programmes on global changes (IGBP, WCRP, IHDP and Diversitas) are brought together under the flagship of ESSP: the Earth System Science Partnership. The umbrella network ESSP tries to integrate studies of the earth system as an interdisciplinary activity through development of joint projects and tuning research agendas.

[43] On a project level, involved scientists are better visible and often documented and published on a project website.

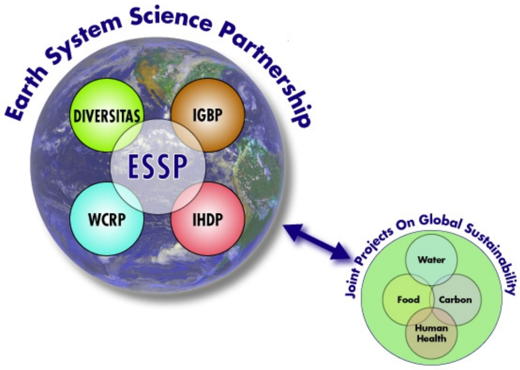

Figure 6.1: overview of the umbrella ESSP and its joint projects

Currently, professor Rik Leemans is the chair of the ESSP SC. Leemans involvement in climate change research is comprehensive since he also chairs the KNAW Global Change Committee, owns a research chair at Wageningen University (WUR), is member of the NWO group "thema duurzame aarde", and, as the chair of ESSP, attends IHDP-SC board meetings. Leemans can be seen as a key-actor in global change research since he participates on different levels as a research representative coordinating scientific focus but also translates this research perspective to science policy and vice versa.

6.2 Knowledge dynamics

Knowledge dynamics of IHDP are not easily characterized, since they depend on the various research areas that are involved within IHDP. These various areas have characteristics in common but also differ on aspects. Hence to generate a full image of IHDP's knowledge dynamics, ideally, these separate disciplines should have to be unraveled. However, for the purpose of this study I will focus on knowledge dynamics of the overarching research area and to appoint differences and similarities.

Social Environmental Sciences
IHDP is a program that is organized to bring various social sciences together with a specific focus on global environmental change. The general research area of IHDP is *social environmental sciences*. This is a broad research area consisting of various disciplines with different characteristics. Within IHDP's projects, a variety of researchers from different fields participate. These researchers belong to fields like political science, anthropology, environmental science, geography, and sociology. (interview Biermann, interview Leemans).

> *"IHDP provides insights into critical topics [of global environmental change], researching how humans affect the environment, how they are affected by it, and how to respond to these changes. Alongside the natural, life, and environmental sciences, IHDP's perspective - that which view global problems as social and societal challenges - is imperative to the successful adaptation to and mitigation of these risks." (IHDP 2010)*

As we read in the previous passage, IHDP uses a wide formulation of its research. The construct IHDP is focused on bringing together the social sciences in the context of global environmental change. In that sense it searches for a high rate of cognitive complementarity that I will illustrate in the next paragraph on Earth System Governance (ESG). The next paragraph will contain several organizational aspects that illustrate how cognitive complementarity is aimed for and realized.

Earth System Governance project (ESG)
The Earth System Governance project is one of IHDP's core projects. It is a follow up project of the Institutional Dimensions of Global Environmental Change (IDGEC) project that was chaired by

professor Oran Young. Young has also been chair of the SC of IHDP until 2010. ESG aim is *“exploring political solutions and novel, more effective governance systems to cope with the current transitions in the biogeochemical systems of our planet. The normative context of our research is sustainable development: We see earth system governance not only as a question of governance effectiveness, but also as a challenge for political legitimacy and social justice.”* (ESG 2010)

Frank Biermann, professor of environmental governance at the VU University is the leader of the ESG project that will be running until 2018. Biermann explains that this project is a global network itself, what sometime makes that people see it as an empty shell. (interview Biermann) However, associated faculties, 100 internationally recognized scientists, form the base of the ESG project. The involvement of ESG furthermore includes research groups from all over the world, but also individual researchers can become research fellow. An important research group for ESG is from Lund University. This university will be hosting the ESG project and soon an international project office is inaugurated. The VU University group IVM is another important group in ESG. There is not a one-to-one fit between being involved in ESG and working at IVM. (Interview Biermann) Other groups are from Colorado State University, Stockholm Resilience Centre, and Australian National University that with several others serve as research centers for ESG. ESG’s website presents the project fellows and research groups and serves as a communication channel to researchers and political actors.

Biermann points out that during the composition of the Scientific Steering Committee of ESG (ESG-SSC) an important aim was to involve researchers of a wide area. For the ESG SSC, disciplinary and geographical diversity are a requirement, otherwise the SSC will not be approved by the IHDP-SC. Geographical diversity involves residence and not origin of a researchers.
This composition comes with difficult negotiations. This process takes time. The social sciences, according to Biermann, are based on diverse theoretical frameworks. It is therefore challenging to involve different researchers with distinct scientific roots (for example realism, Marxism, and institutionalism). With specific decisions in scientific strategy and goals you have to be aware of inclusion and exclusion principles. ESG’s approach was to develop a scientific plan leaving space for different approaches. ESG struggles for example with the tension between positivism and constructivism but has tried to capture both views in its scientific planning. The focus of the scientific plan is analytical. (Interview Biermann)

The ESG-SSC developed a scientific plan that has been approved by the IHDP-SC. When the scientific plan is approved, the SSC gives substance to this project plan by involving other researchers. The ESG scientific plan also focuses on the joint projects of the ESSP program (food, carbon, water, human health). In that sense, ESG tries to connect to the broad environmental approach that integrates natural and social sciences.

Search regime and social environmental sciences

What brings the various disciplines together and how are they linked in climate research? The aim of this section is to investigate to what extent the knowledge dynamics hold the program together. Using one search regime ‘social environmental sciences’, describing research on the program level, will help defining complementarities. Though the diverse disciplines involved in IHDP could be seen as different search regimes, a one-regime approach will be used because the establishment of the program already shows an aspiration for a social environmental science regime.

The presence of many different disciplines in IHDP shows that cognitive complementarity is high, or at least that its organization is aimed at high cognitive complementarity. Within the social sciences there exist different research schools and methodologies that co-exist. Bringing together dissimilar schools within one field is a tough job. That tensions exist between the various involved fields can be deduced from the difficulties of composing a balanced scientific (steering) committee where all fields are represented. (interview Biermann, interview Leemans)

If you want to include several schools in a project requires flexibility and this is also why IHDP’s network is loose. Fields with dissimilar characteristics can be linked through IHDP because a large social science community supports its content. Seemingly divergent fields can co-exist in the program and could possibly converge due to the program. However, to what extent this cognitive complementarity takes place is based on the organization of the projects but it also determined by the researchers involved. As illustrated, inclusion and exclusion takes place both when a scientific steering committee is composed as well as when the scientific steering committees decide on the scientific plan.

These individual social science fields are characterized by low technical complementarity, which also holds for the regime social environmental sciences. Because of the attention to human dimensions of global environmental change as complementing to the natural sciences this area has grown in the past decenia. The growth of the area can partly be attributed to the establishment of IHDP as a programme. Of course, development of technologies in the past 20 years has increased the ability to have fruitful long distance collaboration in these disciplines since data sharing and connecting became possible through the Internet. (Interview Leemans)

Since we approach social environmental sciences as one search regime we can state that this regime is divergent. In many cases there has to be found an agreement because research methodologies can be opposed.

Whitley and social environmental sciences

In the social sciences, research data is often multi-interpretable (Whitley 2000), which is also something we see in the social environmental sciences. There is no consensus on what frameworks to use and methodologies differ because of different research schools and traditions. As I pointed out earlier, for instance one of the challenges of IHDP is to bring together positivists and constructivists. (Biermann) Researchers with distinct ideas co-exist and do not need to find consensus. So, researchers within the same discipline can be opposed and still co-exist in one program, but because of this character, there is also flexibility of different fields with distinct methodologies. However, for a successful program, one strives for consensus to guarantee agreement on results. (interview Biermann)

What we see for the social environmental sciences is that problems and goals are intrinsic varied and unstable (high degree of strategic task uncertainty). Nevertheless, the scientific (steering) committees of the program try to overcome these issues by formulating scientific goals that are clearly ordered through negotiations. One could say that through IHDP's planning, they try to reduce strategic uncertainty and increase strategic dependence. Overall, the current regime can be seen as a *fragmented adhocracy*. This category is only to a certain extent suitable for a program since this category is characterized by “relatively diffuse contributions to broad and fluid goals which are highly contingent upon local exigencies and environmental pressures” (Whitley). Through scientific agenda setting, the social environmental sciences might be evolving to a more partitioned bureaucracy area where theoretical coherence and closure is pursued by standardization and planning. The fairly broad problems and issues that are studied in the social environmental sciences are relatively diffuse, but because of the program set-up IHDP researchers have to demonstrate how their contributions fit in with those of other members of the research area.

6.3 Governance

6.3.1 Governance and organization IHDP

In this section the governance patterns within IHDP will be illuminated. Focused will be on the role of the institutional partners, the composition scientific (steering) committees, scientific planning, decision-making, and research funding.

ISSC, ICSU and UNU

In the first paragraph of this chapter I have indicated the position of the ISSC, ICSU and UNU as institutional sponsors. These three bodies serve as important access points to the world of international politics and scientific planning for IHDP but financially their contribution is not of eminent importance. The International Social Science Council (ISSC) is an international non-profit-making scientific organization with headquarters at UNESCO House in Paris. It is the primary international body representing the social and behavioral sciences at a global level. The International Counsel for Science (ICSU) is a non-governmental organization that represents a global membership that includes both national scientific bodies (113 members) and international scientific unions (29 members). Through this extensive international network, ICSU provides a forum for discussion of issues relevant to policy for international science and the importance of international science for policy issues.(ICSU 2010) United Nations University is for IHDP probably the most important player and IHDP's secretariat is part of the UN agency in Bonn. The three institutional sponsors guide the overall development of IHDP and they select for example the chair of the IHDP-SC, the Executive Director (IHDP Bonn) and carries out reviews. (IHDP_annual_report 2010)

IHDP aims at contributing to reports of the Intergovernmental Panel on Climate Change (IPCC) and states that it is important that scientists and policymakers find common ground and shared forms of communication. (IHDP 2010)

Composition of SSC and SC

Composing balanced scientific committees and scientific steering committees demands many negotiations as was discussed in the paragraph on ESG. As was explained before, the SC has to be approved by the institutional sponsors ICSU, ISSC, and UNU. The project SSC's are approved by the SC. Scientific managers Leemans and Biermann both explicitly addressed the importance of *geographical (residence) diversity and disciplinary diversity* within these committees. Only when the SSC's reflect a wide scope of research areas and locations, a scientific plan will be developed where a varied group of researchers are represented and thus can contribute (because their research fits in the program goals). Negotiations for scientific planning take place in the SSC's, whose members carry out the research specific varied goals bottom-up. The success of the projects is dependent on internationally recognized researchers that become fellows of the projects.

Network

The network character of global environmental research and IHDP has been addressed as an important characteristic. IHDP's projects are also characterized as networks and hold individual researchers and research groups. Nodes in the network are the Secretariat and project hosting bodies. Furthermore, there are several national HDP committees. In the Netherlands this HDP committee is not a separate committee but part of the KNAW Global Change Committee. This Global Change Committee (GCC) is composed of both social scientists as well as natural scientists that discuss and prepare research objectives of environmental research. The main objective of the GCC is to stimulate Dutch scientists to "participate in national and international global change research and to facilitate contacts between these researchers and potential funding agencies". (Institute_for_technology_assessment_and_systems_analysis_ISIS 2010)

The overall umbrella network ESSP that includes all big climate change programs also affects the research agenda's of the individual programs, explain Leemans.

The value of umbrella networks is sometimes underestimated, according to Leemans. That is why in 2010, a scientific journal was launched to create a wider visibility of the strengths of ESSP and the possible synthesis of the global change programs. Publications that discuss results of research that took place within the themes one of the projects are not presented as such. Project websites serve as a channel for research output communication. Important output is furthermore presented in the annual program report. An overview of publications that are rooted in the program is not available, in the same way as it is difficult to generate an overview of participating researchers (members).

The role of the secretariat was already denoted in the organization section at the beginning of this chapter. This body is also responsible for output like the annual report, evaluations and scientific program plan (current scientific plan runs from 2007-2015).

Leemans addresses that the many layers of a programs affect each other. For example, the board of the umbrella ESSP indicates important elements for each of the programs that can subsequently be discussed in the programs SCs. Leemans explains that these themes often not only have an effect on the research but these themes can be retrieved in science policy as well because they translate research themes into policy advise. Scientific committees indicate focus points (themes) that science policy makers also decide and act on. Leemans points out that each research and research program has its own mandate. These programs and projects respond to each other and are inevitably connected (through scientific planning). IHDP underlines its science policy interaction in its annual report.

> *"Efforts to enhance two-way communication between scientists and members of the policy community and the attentive public constitute the third pillar of IHDP's Strategic Plan. One goal is to ensure that policy perspectives are taken into account starting with the framing of research agendas and running through to the dissemination of scientific results. A second goal is to ensure that practitioners are aware of policy-relevant science and motivated to take the results of rigorous research into account in framing issues for consideration, selecting policies, and implementing them in various settings." (IHDP_annual_report 2010)*

To stimulate integration of research between the various climate programs, ESSP has brought forward the joint projects on sustainability focusing on four areas: food, water, human health, and carbon. We have seen that projects like ESG answer to this theme request in their scientific plan. (Biermann, Betsill et al. 2009)

6.3.2 Funding

IHDP's funding can be divided in program funding and IHDP research funding. The program IHDP, which encompasses the coordination body of the program, is funded donor based. Figure 6.2 shows that Germany (BMBF) and the USA (National Science Foundation) are the most substantial sponsors of IHDP. The budget is about 1 billion USD and is used to finance for example the coordination and agenda setting of the program. For example, with this budget, board meetings, conferences, seminars and summer schools are funded.

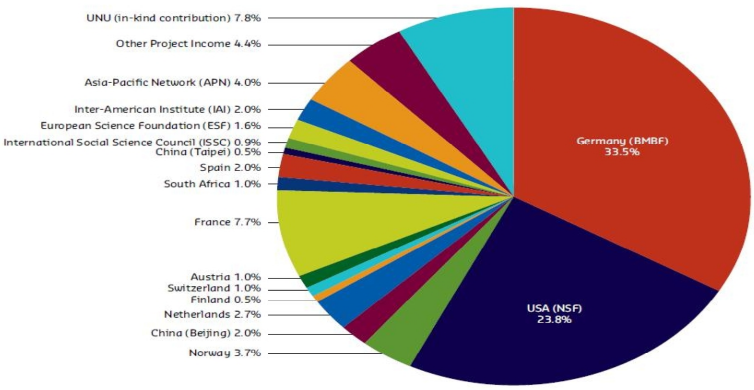

Figure 6.2: IHDP's Donor Countries (IHDP_annual_report 2010)

Hence, the program funding is, just like with CERN and CoML, mostly to fund infrastructural purposes and to facilitate meetings and program planning. IHDP's projects will at first receive seed money from the program but have to find independent funding and become self-supporting. (Interview Biermann)

Since actual research is not funded by the project, each group has to provide its own funding. Researchers individually or jointly submit proposals to get funding for research that fist within the projects of IHDP. In their proposal they can have profit by explicitly stating that the proposal is endorsed by ESG or IHDP. (interview Biermann, interview Leemans) Members of research projects often collaborate when it concerns grant applications. Biermann explains that for example US partners are submitting a proposal to the NSF that is comparable to a large European application. Both refer to each other and address that the proposal is endorsed by the project.

In the Netherlands, funding of IHDP related research is likely to be applied for through NWO's interdisciplinary section "Duurzame aarde" and the department MaGW (Maatschappij en GedragsWetenschappen/ social and behavioral sciences).

Researchers are mostly nationally oriented when it comes to research funding. (interview Leemans) Dutch researchers in global environmental science receive their funding mostly from NWO (MaGW, ALW and theme Duurzame Aarde) and the Marie Curie Framework Programmes of the EC. Within ESG, about 40% of the research is funded by European grants (FP). ESF is also funding IHDP related networks/project but its role is not to fund research but to bring together networks and agendas.

The IHDP Secretariat or the ESG hosting institutions have no significant role in finding funding. The International Group of Funding Agencies (IGFA) can be appointed as an important node in the funding network of global change research. IGFA serves as a forum for debate for national funding agencies to create effective funding policy in the global sciences.

> *"IGFA has provided a unique discussion forum for senior officials involved in global change research funding from different countries, linking them with representatives of International Research Programs and leading scientists in the field. Topics of interest to all of the funding agencies, such as priority setting in research funding, information exchange on new initiatives or infrastructural questions, are high on IGFA's agenda."*
>
> *(IGFA 2010)* http://www.igfagcr.org/index.php/about-igfa

IGFA is thus not a funding agency but contributes to prioritizing Global Change Research on national research agendas.

According to Leemans, each research has its own mandate. You cannot build you own agenda but have to respond to each other. An international program can help in setting this agenda, which can be adopted by funding agencies. The role of the program coordinator is to facilitate this arena of negotiation and translation.

6.4 Sub conclusion IHDP

The social sciences have been neglected for quite some time in global environmental change research as its focus was on the natural sciences for a long time. The establishment of IHDP has been a counterweight to the natural sciences.

The network program International Human Dimension Programme of Global Environmental Change (IHDP) finds it strength in its potential to develop a research agenda for the social environmental sciences. Through its ties with ICSU, ISSC and UNU as institutional sponsors, IHDP has access to the international world of politics and contributes for example to the IPCC reports.

The social environmental sciences as one research area (or search regime) consist of various disciplines varying from (anthropology, environmental sciences, political sciences, economy) that are in general characterized by high technical and strategic uncertainty and low functional and strategic dependence. However, the aim and desire of multidisciplinary (and inter-disciplinarity) of the program is integration of these fields: cognitive complementarity. Bringing together these areas is a challenge in the organization of IHDP.

IHDP's network is rather loose, organized in projects that also have a network character. The coordination comes from the secretariat and together with steering committees research goals are defined (scientific planning). The institutional sponsors have to approve the IHDP-SC and the projects SSCs are appointed by the SC. The composition of these committees is essential. Choices directly affect the possible contribution of researchers (inclusion/exclusion). The network is stronger when it includes a wide scope of recognized researchers. Therefore, one strives for geographical diversity and disciplinary diversity to avoid unnecessary exclusion. Members of the SSCs are internationally recognized scientists and because they are representing the research community they have mandate. The umbrella ESSP is established to connect the natural and social sciences and stimulates synthesis and visibility.

The IHDP Secretariat is nationally funded (major sponsors Germany and the US). Actual research money has to be gathered by individual researchers. Just like CoML and CERN, we have found that in the social environmental sciences the wide scope of funding arrangements is used. Advantages are to be found again on the national orientation of researchers when it comes to applying for grants. The IGFA is playing an increasing role on a level of negotiation, since national agencies can discuss the issues that receive attention and jointly develop focus for funding research on global environmental change.

IHDP's added value lies in the prospective of convergence of general research goals of global environmental change, complementarity of disciplines, and the affiliation with international science policy.

Case	**IHDP**
Distributed/centralized	Distributed
Top-down/bottom-up	Bottom-up
Wagner category	Participatory
Knowledge dynamics	
Search regime IRP in general	
Growth	Relatively high
Diversity	Divergent
Technical complementarity	Low
Cognitive complementarity	High
Whitley	
degree of mutual dependence	
strategic	Low
functional	Low
degree of task uncertainty	
strategic	High
technical	High
Category field Whitley	Fragmented adhocracy
Funding	National contributions Projects: FPs, national research councils, ESF (funding agenda setting IGFA)
Organization structure	Loose organization: network of networks. Project planning: scientific plan/goals are set by SSC/SCs whose members are appointed by institutional sponsors (ISSC, ICSU, UNU).

Figure 6.3: overview IHDP characteristics

7 Synthesis IRPs, knowledge dynamics and governance

In this study, three international research programs have been investigated to learn more about the nature of IRPs, their landscape and dynamics. In this consideration I will illuminate resemblances and differences between the IRPs and explicate a first interpretation of these findings. As I have addressed in the introduction of this thesis, this work has been very much pioneering, initiated when it appeared to be difficult defining and characterizing large-scale research programs developing a database. Further research is desirable to better understand implications of these findings.

Paragraph 7.1 focuses on assembling and learning from the three cases CERN, CoML, and IHDP, and noteworthy aspects concerning differences and similarities of characteristics of the IRP, knowledge dynamics, and governance. This paragraph addresses the heterogeneous character of IRPs. In paragraph 7.2, the concept integrator will be introduced to understand what brings and hold a program together. Concluding, in paragraph 7.3, the intertwinement of knowledge dynamics and governance aspects in the roles and positions of research managers will be indicated in terms of interconnected arenas.

7.1 Three case studies

Following from the conceptualization, the chosen approach of this study was to unravel the interwoven governance and knowledge dynamics and relate this to the organization of the IRPs. The first step of this synthesis is assembling the three cases and discuss issues along the three perspectives: characteristics of the IRP, knowledge dynamics and governance.

7.1.1 Characteristics and nature of the IRP

Application of Wagner's characteristics, have provided an image of distinct categories of the selected programs (figure 7.1) that have been discussed before in the case study chapters.

Case	**CERN**	**CoML**	**IHDP**
Wagner category	**Mega science**	**Coordinated**	**Participatory**
Distributed/centralized	Centralized	Distributed	Distributed
Top-down/bottom-up	Top-down	Bottom-up	Bottom-up

Figure 7.1: Wagner's categories and the three cases

Wagner's categories illuminate the dissimilarities between the programs. They are useful for understanding differences between the programs but the following considerations should be taken into account based on the empirical data found in this study.

Top-down organizations with bottom-up characteristics

Within the three cases *both* top-down and bottom-up structures are present. In Wagner's conception of top-down organization, top-down requires a type of formal coordination of negotiation; officials leave little space for individual researchers to contribute to the organizational structure and to the bigger scientific goals that are set. Wagner uses the example of CERN where these negotiations about financial contributions and missions had to take place between officials of different nations. It is correct to argue for an existing top-down structure because formal negotiations have to take place to establish programs of this scale, but I would like to make two remarks. Firstly, this kind of top-down dynamics are present for all three cases in the phase where the program is established. Large-scale programs are preceded by negotiation on a high level of aggregation. Secondly, while research agenda building happens on this high level of aggregation (hierarchical referred to as top-down), it does not exclude bottom-up dynamics that are of major importance and affect the content of the research agenda and organization as well. Moreover, a focus on CERN's top-down dynamics underexposes the bottom-up structures that are existent in the big science projects.

In the case study CERN, I have shown the importance of shared decision-making. Within IHDP, agenda setting on a thematic line happens more top-down whereas for content of the program is built on a negotiation in the SC bottom-up. The same counts for CoML. I believe, these bottom-up dynamics are not to be underestimated. They can be of major importance for the setting of goals and generating support. For all three programs, research questions and research goals are mainly determined bottom-up. A Scientific Steering Committee consists of researchers representing different disciplines and/or geographical location of research. A Scientific Committee appoints these researchers based on their expertise and recognition. Within the program one aims to create a steering committee that represents all researchers participating and thus research to be driven bottom-up. An IRP can only function within a structure where the ideas and wishes of researchers resound in the other levels of the organization by research managers that represent and translate the research practices. I have found these dynamics within all three cases. I will further illuminate the role of IRP research managers as translators and negotiators in paragraph 7.4.

Especially the existing bottom-up structures are of great value for the success of a program, but both top-down as bottom-up structures can be appointed to International Research Programs. With Wagner's interpretation, these top-down are more present which can be related to the way she approaches the collaboration of CERN to be a centralized facility, which will be discussed subsequently.

International research programs as networks

Applying Wagner on CERN (like in table 7.1) accentuates CERN's facility aspect. CERN is often given as the standard example of Big Science, which provides an image of IRPs mainly as facilities. This common image of Big Science as a *facility* is somehow obscure.

In this study I have shown that CERN on the one hand is a big facility, but, even more important, possesses aspects of decentralization (distributedness). CERN is foremost a convention and is thus strengthened by the presence of an underlying network of scientists (that is distributed). Researchers, of 580 universities and institutes, execute their work for a significant part at their home institutions (and not only at the facility near Geneva). This distributed aspect is intensified since the development of technologies that made it possible for researchers to work on data at their home institutions while they are physically separated from the experiment.

As I have shown, CoML and IHDP are distributed. This is mainly related to the knowledge dynamics of the research areas involved in these programs, which will be illuminated in paragraph 7.1.3). The distributed research for CoML and IHDP is somehow different from CERN since their data cannot be gathered from one experiment location, like CERN, but is based on data from different geographical locations. In that sense distributedness for CoML and IHDP is a requirement whereas CERN's research could theoretically be performed at one single location. Within CoML, data gathering and analysis can be geographically separated. OBIS is used to gather and share data online so that everyone can build analyses from a broad shared dataset.

When we look at CoML and IHDP we see mainly distributed aspects but there is a necessity of some centralization. The shape this centralization takes in distributed programs that are mainly characterized by its network, can be described in terms of a homeport (that will be described in the Governance section of this chapter, paragraph 7.1.3)

Wagner's categories proved to be insightful understanding different characteristics of the organization of the three research programs. The interpretation and use of the variables (the distinction in bottom-up versus top-down and distributed versus centralized) can however be somewhat confusing and not reflecting the nature of the programs completely.

Underlying networks, that are distributed and have bottom-up qualities, are essential for the success and organization of IRPs. This does not mean that all research program networks are comparable. However it addresses that facilities can and should also be approached as networks. Yet, these networks do not shape a homogeneous landscape but are rather heterogeneous. This can be understood by distinguishing aspects of governance and knowledge dynamics. For example, we become to understand that the (possible) level of centralization of the network is largely dependent on knowledge dynamics; especially on the level of technical complementarity, and on cognitive complementarity, which I will address in one of the following paragraphs.

7.1.2 Governance

Organization structure
As indicated in paragraph 7.1.1, all three IRPs are characterized by a typical network structure. The organization structure of all three programs is quite similar, characterized by bodies as scientific committees (SC) and scientific steering committees (SSC) connecting, researchers and determining research agendas. The intensity of control of a SC over the research agenda varies and is affected by the extent of control over resources by the research managers (members of SC and SSC).

In the program CoML the organization is loose and the involved scientists can interpret the research agenda that has been agreed on by the SC at the beginning of the program. This also has to do with the fact that CoML is a 10 year program. Within CERN, the organization is tighter (and more dynamic) because consensus has to be found on the directions of research since choices in detector design affect many researchers. For CERN one might argue that the CERN research agenda is determining the research goals of the field high-energy physics. IHDP's structure is looser but its goals are explicitly to connect different disciplines within the social environmental sciences. To warrant multi-disciplinary research, projects are defined stricter and members of SSCs (project leaders in specific) have a key role to carry out this task. This connecting of areas within IHDP is not so much knowledge driven but rather affected by the access to the arena of politics.

When money is allocated on a high level of aggregation, researchers are more dependent on the program. For CERN, researchers depend highly on the decisions of equipment where for IHDP we barely find financial dependency of researchers because they have to collect their own research funding. CERN's researchers depend to a larger scale on money that is distributed top-down.

Composition of scientific committees and scientific planning
In a research network in general, research colleagues share a motivation to work together on a research goal. Following from the three cases it can be concluded that Scientific Steering Committees (SSCs) and Scientific Committees (SCs) are the bedrock of a research program. For the composition of these various scientific (steering) committees, the recognition of expertise is central in the selection process to become a member. Since IRPs are often concerned with multi-disciplinary research, the composition these committees can be a difficult task. It is essential to have representatives of the different fields and geographical areas in the Scientific Board or Committees for a vital program. Actors with different background have access to different funding arrangements and can carry out negotiations at various levels, which was stressed in various interviews with research managers. (interview Leemans, interview Biermann, interview Heip, interview Linde/ Kleuver)

Different phases precede actual research including strategic plan, developing a research agenda, and gathering and connecting experienced researchers. The scientific committees fulfill an important role in scientific agenda setting. SCs are responsible for developing a strategic plan and SSCs formulate research goals on a project level. So, focusing on this level of the organization provides insight in the negotiations and dynamics of research agenda building where both governance and knowledge dynamics play a role. In paragraph 7.3, a framework to understand the dynamics of the roles of these key actors in the network will be introduced using a concept of interconnected arenas.

Homeport
International conferences, websites, seminars, and workshops (on program or project scale) are essential to keep the network viable. These activities are usually executed from one location, a 'secretariat', which is more than purely administrative. I would suggest to use the name *homeport*. The homeport generally organizes and coordinates the program's activities, including coordination of strategic planning, hosts the program website and also monitors financial issues. Homeports are an essential element in the organization of an IRP both for researchers as well as visibility for policy

makers (and coordination of communication). There needs to be a body to carry out and fulfill these various preconditions.

For CERN, the function of the facility, next to housing the experiments, is also a homeport function. IHDP and COML have secretariats functioning as homeport. IHDP's secretariat is housed in Bonn (at the UNU campus). CoML has a Secretary in the US. The word secretariat undermines its position within the program. It is not only concerned with administration tasks but really functions as a homeport, a space where one can return. In the interviews it has often been addressed as a basic need for a vital program. (interview Heip, interview Leemans)

Even on a project level it is of importance to have homeports as institutional bodies. For high-energy physics in the Netherlands Nikhef can be seen as one. An example for IHDP is the secretariat for the Earth System Governance project at the Institute for Environmental Studies (IVM) at VU University. CoML also has regional nodes. The EuroCoML for example works towards regional implementation in de EU.

Funding

The organization of the IRPs are closely related to the way the program is funded, which is determined historically and is often preceded by a period of negotiations before the actual establishment of the program.

Structural funding and research project funding

CERN and IHDP have structural funding but CoML's funding is ending in 2010. I have seen that the national research councils do not facilitate the basic funding of IRPs but that mostly other institutions generate this essential structural funding. These agreements are realized on higher levels of aggregation. For example they are agreements between national ministries or structural funding comes from one independent actor. CERN's structural funding was determined in the CERN convention and is based on gross national product of the member states. For IHDP, negotiations by and between the ISSC, ICSU and UNU preceded the funding agreement between the different states. In case of CoML, one big funding actor, the Sloan Foundation, guaranteed 10 years funding.

National research councils do not provide structural funding because they are restricted by national science policy. National science policy is dependent on national government terms and thus has a temporal character. Standard funding arrangements usually have fixed terms, most of them for a period of 4 to 5 years. The European Commission (its Framework Programmes) and NWO (and ESF) mainly use this kind of impulse funding. Impulse project funding is a basic principle of national research councils, even on international scale. NWO's task is to support and stimulate research. (MinOCW 2009)

Four years is a proper time frame for most *research projects* but when it concerns sustainable networks or programs with an international character, more certainties are needed for a longer term. Goals of research programs exceed the scale of projects. The large investment of negotiations on a high level of aggregation that precede the existence of an official program makes that program goals are defined on a broad scale. It is a major task for the research managers to be involved in negotiations to get structural funding.

International collaboration is stimulated. For instance in Europe, the European Commission (EC) facilitates ERA networks. These ERA networks get funding on a project term (4 yrs). Once this impulse period is over, they are supposed to have generated their own structural funding and to have become sustainable. ESF grants also focus on building a network rather than funding actual research.

In the previous paragraphs, I have illustrated that some structural funding is a necessity to meet preconditions of research. However, funding actual research (projects) involves all different funding arrangements. In the three cases we observed that researchers make use of all kind of available resources (FP, NWO, VI, ERC, ESF). For example, in all three cases there are researchers have been granted a financial impulse from the national VI (Vernieuwings Impuls) and there have been projects funded under the Framework Programme.

The strength of the international character of an IRP, with researchers participating from all over the world, is that these researchers have access to different funding arrangements on regional or local levels. For example, Dutch researchers can apply for Dutch NWO funding while a German colleague researcher can go to DFG. So, in that case, they can avoid competition and research funding becomes complementary. We see that researchers in these programs still have a national focus for financing their research also because the focus of their research is often restricted to their own region. Funding agencies will rather allocate resources to research in their own region.[44]

On a European level funding possibilities are also used by these programs. The EC's framework programme is an important resource. Also ESF offers possibilities. Often, these European grants require agreements between nations, an advantage for already international research programmes. For example, for an ESF EUROCORES program national research councils have to approve the participation and agree on financial issues.

Utilizing different research funding sources requires projectization and strategic planning. For example, a program's strategy can be taking effort in addressing certain research topics on the European agenda to separate budget for research projects.

Monitoring funding of IRPs

A difficult aspect concerning funding of IRPs is that it is not transparent how much money circulates in an IRP. For all three cases it has been difficult to attain insight in the annual budget when you include research projects. The budget of an IRP is often the sum of several grants and often these grants do not flow into the program itself but to participating organizations. Especially for IHDP and CoML the project's communication is based on output and not so much on providing information about awarded grants. Even when you search for money streams from the funding organizations like FP or NWO it is complex to get the image complete. For example, national funding agencies like NWO do not have a clear overview of how their money flows into the programs, of the organization of these bigger international programs, or how other funding agencies contribute. Their bodies mainly focus on and monitor NWO's own contribution. (interview Kessel) Completing this image is already complex since NWO funding includes a sum of their funding instruments that can have different nature: funding projects or individuals, and different 'disciplinary' departments can contribute to the same program, which is not transparent.

Another element concerning funding is the difficulty of the way of monitoring because funding arrangements can work with different structures: just-retour or common pot. When the first type of funding is agreed upon, a calculation can only be made at the end of the period. Various project calculations can be made and there are different ways of calculating these contributions, which again can vary per country or the goal for which the calculation is made. When you look at IRP funding you can find different answers to the budget, which is caused by these different calculations.

	CERN	**CoML**	**IHDP**
Organization structure	Seeming hierarchical organization facility CERN, project level experienced scientists in network, nations irrelevant	Distributed network with steering committee. Loose organization. Project themes are determined but content has to be provided and decided by appointed researchers.	Loose organization: network of networks. Projects are determined; in a general sense research goals are set by SSC/SCs.
Funding	From ministries based on g.n.p. Projects FPs, national research councils	Sloan Foundation ESF, national research councils, FPs	IRP: Contributions nations UNU Projects: FPs, national research councils

Figure 7.2: organization and funding of IRPs

44 For example: NWO will rather fund research focusing on the North sea that research focusing on the Indian ocean.

Transparency and visibility
An element that is noteworthy for the three cases is that the IRPs sometimes struggle with their transparency and visibility. This is an aspect that specifically researchers from CoML and IHDP addressed in the interviews (Interview Biermann, Leemans, Heip). I have also encountered this aspect when developing a database with IRPs (Appendix A). Easily found are the ‘big facilities’ in Europe, for instance through ESFRI. When IRPs have a strong network character, with a small secretariat housed within one of the participating institutions, its size difficult to estimate. The IRP can also be a network of networks; like ESSP is the bigger umbrella network of IHDP, IGBP, WCRP and Diversitas. Within the smaller networks people know how to find each other. Within the bigger network research is divers and only on a higher level of aggregation these linkages are recognized and used for example for political goals or to enhance chances for funding.

Furthermore, scientific output can hardly be traced when we search on the name of the IRP in most cases. Researchers do not name the IRP in their papers, which relates to aspects of in what way researchers feel that they belong to a program. Concerning the nature of the IRP, it also relates to the notion that when a research program is constituted on a formal level, deriving how on other levels collaboration takes place (interpersonal and team) is difficult to deduce empirically. For network programs like IHDP and CoML it is difficult to find out to what extent individual researchers feel connected to the program. I have found that research managers know the position of their research within the IRP, but PhDs and Postdocs might only be confronted with the program at conferences and seminars (and consequently will not name the program in their publications).

7.1.3 Knowledge dynamics

Knowledge dynamics of the three programs have been described using Bonaccorsi’s theory of search regime and Whitley’s theory on social organization of the sciences in terms of technical and strategic task uncertainty and functional and strategic mutual dependency. The emphasis of this analysis is based on qualitative data. Both ways of characterizing a research area can contribute to understanding the organization and dynamics of IRPs. During this study it became clear that appointing names and boundaries to a certain research area is complicated. However, empirical arguments have led to defining research areas for the three case studies. Bonaccorsi provides insight in changing search regimes, which can also be based on external factors like available funding.

Bonaccorsi and IRPs
For each of the three cases, one broad search regime has been designated. As was already indicated in the theoretical chapter, the application of Bonaccorsi’s search regime is flexible. Bonaccorsi’s search regime leaves space to explain multi-disciplinary activity and changing fields (converging sciences) based on empirical data. Since in all three cases multiple research fields affect the IRP, one search regime was empirically defined to understand the knowledge dynamics of the program as a whole. In the case study chapters I have elaborated on the characteristics of these overarching search regimes; these are summarized in figure 7.3.

For CERN this regime is high-energy physics, but with the broad approach of the research area that is consisting of several fields (including particle physics as well as computer science, material science on semi-conductors etc). This search regime is convergent and is characterized by high complementarity. CoML’s search regime has been defined as marine biology, which is an assembly of fields including ecology, taxonomy, biodiversity, and marine geochemistry. This search regime is seemingly a result of available funding and several disciplines work along in the same program, while still performing their own research in their own way. There is no specific need for convergence and in principle there would be space for adjacent fields to join. The search regime of IHDP, Social Environmental Sciences, focuses on how human beings affect, and are affected by, global environmental change. This regime is constituted of various fields like political sciences, sociology, anthropology, and psychology.

In the three case studies I have elaborated on the dynamics of these regimes, referring to dynamics of sub-fields. For IHDP it showed most difficult to argue that the research area can be seen as one regime. A decisive argument for appointing this one search regime is IHDP's aim for cognitive complementarity to bring together disciplines and through the program develop a social environmental science regime.[45] Moreover, applying Bonaccorsi to the three case study has provided insight in the dynamics how research areas fluidly may change and how convergence might be more externally driven convergence by governance aspects (like funding) or internally driven (by changing technical and/or cognitive complementarity).

Whitley and IRPs

Application of Whitley has given an empirical argument that the three program's fields fit in different categories (figure 7.3) since they have different characteristics: High-energy physics (CERN) is an example of Conceptually integrated bureaucracy, Marine biology (CoML) a technically integrated bureaucracy, and the social environmental sciences (IHDP) a fragmented adhocracy.

For CoML and CERN, this type of research area strengthens the cooperation, whereas for IHDP the fragmentation, because of low strategic dependence and high uncertainties, frustrates cooperation and has to be overcome by coordination. One could say that fields that are typified by conceptually integrated bureaucracies and technically integrated bureaucracies are more intrinsically driven to collaborate, which underlines the expectations of chapter 2.

Search regime IRP in general			
	CERN	**CoML**	**IHDP**
Search regime	**High-energy physics**	**Marine Biology**	**Social Environmental Sciences**
Growth	Relatively Low	Medium	Relatively High
Diversity	Convergent	Medium convergent	Divergent
Technical complementarity	High	Medium	Low
Cognitive complementarity	Relatively high	Low	High
Whitley			
degree of mutual dependence			
strategic	High	Low	Low
functional	High	High	Low
degree of task uncertainty			
strategic	Low	Low	High
technical	Low	Low	High
Category field Whitley	Conceptually integrated bureaucracy	Technically integrated bureaucracy	Fragmented adhocracy

Figure 7.3: search regimes/type of field of the three cases

Note that these broadly defined research areas address an overall probability of the kind of international collaboration. Looking at sub fields of the general research area, one might discover tensions between disciplines, like in CoML with taxonomy and molecular biology.

Whitley has also helped understanding how the introduction and development of new technologies has changed research areas. For example, the possibilities to analyze data have been extended and research has become less dependent on location. In all cases it has been pointed out that researchers can be connected locally and globally, in a decentralized way, and cognitive complementarity can be reached even when researchers are physically separated. Though researchers can work together on the same topic over distance, in search regimes with high technical complementarity more centralization is required. Research areas can also change due to collaboration. When researchers from different fields are stimulated to work together (cognitive

[45] The various fields that are involved within an IRP also have their own dynamics. Sometimes the various fields share characteristics, other times they are opposed to each other.

complementarity) they are introduced to other research methods that they might appropriate. We have seen in this study that through the programs research can become integrated for instance data from various fields in the OBIS database. It is possible that an IRP transforms the involved research areas and/or search regimes so that an IRP might become related to one search regime. We always have to acknowledge that research areas or search regimes can change over time. In terms of changing research areas, Whitley provides rather clear characteristics to interpret changes. These changes can have an internal driver (within research area) or external (governance patterns like funding opportunities), or both.

7.2 Integrator

In the previous paragraphs I have illuminated the various differences and similarities of characteristics and dynamics of the three case studies. Wondering why the studied IRPs have been evolving the way they did, I will now focus on the elements that bring and hold the IRP together: an *integrator*. Identification of an integrator helps understanding the characteristics of the program and the interrelation between governance and knowledge dynamics.

An integrator can be found inside or outside the research domain. For CERN, the integrator is the equipment (technical complementarity) that induced internationalization. No individual country could realize a facility like CERN on its own, and its mostly research-based motivation has led to intergovernmental negotiation that established the convention and the collaboration at its current state.

The database OBIS can be seen as the integrator for CoML. The origin for the establishment of CoML was the motivation to collect and assemble marine biology data into one database. This motivation relates to the aim for cognitive complementarity in the research area that can be induced by scientific planning. Applying Whitley has contributed in providing insight in how the research area of marine biology is characterized as an adhocracy but through the program is compelled to shift to a research area that is more bureaucratic, which also leads to tensions. The integrator anchors in the research area but also to governance like scientific planning (external).

IHDP's integrator is mostly related to governance issues, namely the access to international politics through its institutional sponsors UNU, ICSU and ISSC. IHDP is furthermore increasing the visibility of social environmental sciences (complementary to the natural sciences) and through the program it tries to induce more unity in this area (internal). The aim is to increase cognitive complementarity through scientific planning of research within the network that strengthens the position of this research area. More broadly, this aim for cognitive complementarity is also present in the umbrella network ESSP.

These integrators also help identifying tensions within the programs. A vivid example of tension within a program is the tension because of different methodology between traditional taxonomy and microbiologists within the CoML. Also within IHDP, these research fields are in friction since there are cultural difference in the social sciences and also because economists and anthropologists for example use distinct approaches. Tensions can also relate to research policy that affects available resources. Fore instance, IHDP takes effort in addressing social sciences in climate change research which was not on the international research agenda as such, complementing research in natural sciences which has received more attention over the past decades. Emphasizing the tensions within the program, key-actors fulfill an essential role. These key-actors, like members of scientific steering committees, are ambassadors of a program and are important in overcoming tensions for example in strategic planning.

7.3 Interconnected arenas

This study has been pioneering work on international research programs. Analyzing knowledge dynamics and governance aspects of the three cases provided insight in what brings and holds the program together. The integrator is a way to grab this, which can be either more 'internal' related to the research area or 'external' related to governance aspects. Furthermore, I have pointed out how the organization structure of a program is related to the knowledge dynamics of a field. Also, the organization structure affects the research practice. The landscape of international research programs is dynamic, involving different organizational spheres, each with own practices and goals. Wagner also focused on the organization of programs, emphasizing levels of decentralization and centralization, and bottom-up and top-down characteristics. Wagner strongly focused on the organization on a high level of aggregation, the origin of a formal program while recognizing collaboration in research networks and requiring certain equipment.

In the case studies I have indicated that within the IRP networks most research managers serve different roles in different committees, or in other words in different institutional settings. They can be seen as nodes in the network and they fulfill many roles as they can translate and negotiate within and between these different settings that can be found on different levels of aggregation in the organization. These actors are representing the research area and are representatives in policy making.

An example of a researcher with many roles is Professor Rik Leemans who is chair of the ESSP SSC, owns a research chair at Wageningen University (WUR), and is a member of the KNAW global change committee, the IHDP SC, and member of the group “thema duurzame aarde” of NWO. At the research chair in Wageningen, Leemans is a group leader with corresponding tasks but, for instance, he also absorbs the atmosphere of the group. He can understand issues the group struggles with. For example, problems that are faced in the attempt of collaboration with natural scientists who use distinct methodologies. Leemans can relate these issues to other spheres where is active. He can translate and create attention to these issues in these other arenas like the Global Change Committee or ESSP. The other way around he can translate policy related issues to research practice and guide negotiations. It seems likely that specifically these actors that fulfill different roles in different committees that both serve scientific expertise and management/policy are the essential nodes that hold an international research network together. These actors are well aware of the integrator of the program.

In the beginning of this chapter I have illustrated that the strength of the IRP is the network character. When you combine this notion with the conception that research managers are important actors that fulfill various roles in different levels of the organization, a new framework can be developed that illustrates dynamics that are underexposed by the current framework. This framework is a recommendation for further research. Central in this framework is the emphasis on interconnected arenas, maintaining the general notion that governance and knowledge dynamics are co-developing and interrelated in the landscape in international research programs.

This framework underlines the notion of intertwinement of governance and knowledge dynamics but adds a perspective on the role of key-researchers/managers. Recently, scholars have tried to think in terms of network governance or *interconnected institutions* to grasp the co-development and intertwinement of different institutional settings. (Young, Chambers et al. 2008) Arthur Benz’s notion of *interacting arenas* can be used to develop a complementary *framework of the dynamic landscape of knowledge and governance dynamics*.(Benz 2007) Using the visualization in figure 7.4, I will illuminate this suggestion for this approach.

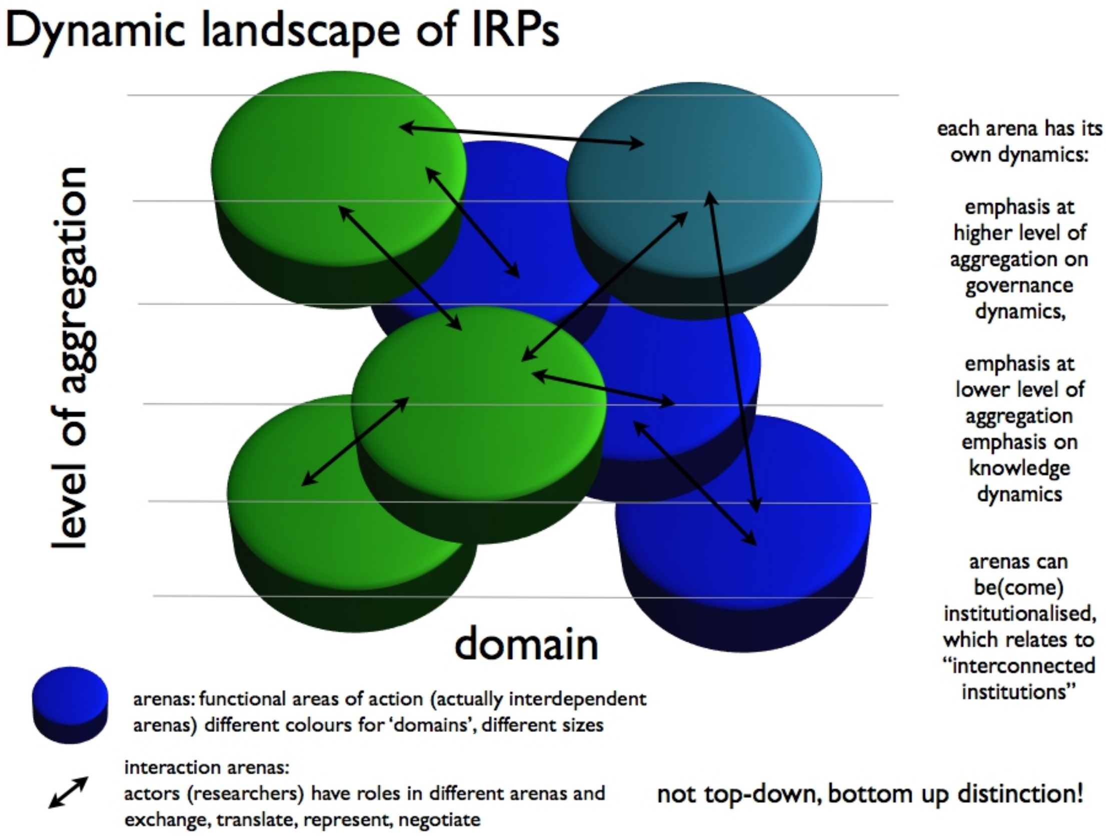

Figure 7.4: Dynamic landscape of IRPs in terms of interconnected arenas

The different arenas represent the functional areas of action that can be seen as interdependent. Arenas are the spaces where negotiation takes place and decisions are prepared and made. Actors can fulfill roles in different arenas at the same time and in this way provide linkages between arenas. This interaction is one of learning, negotiation, exchange, translation and representation. The landscape of arenas has to be seen as dynamic and is mapped by two dimensions: research domain (research area and its knowledge dynamics) and the level of aggregation. Figure 7.4 represents this framework. In the visualization the framework is seemingly statical but one should be aware of the dynamical aspects of these spheres and that this notion goes beyond a distinction between top-down or bottom-up.

The arenas can be institutionalized but do not necessarily need to have an organizational form (institutionalized setting). The landscape of institutional arrangements can overlap the landscape of arenas because some arenas are institutionalized. But analytically these are two distinct notions. For example, new arenas arise and can shift towards different domains or in level of aggregation and later these arenas become institutionalized. On the organizational landscape we might again see developments in the institutionalization of these arenas.

For example, institutionalized arenas in the IHDP program are the project SSCs, the IHDP-SC, the ESSP board but also the Global Change Committee and NWO's members of the theme Duurzame Aarde. More at a distance the other global change programs interact with IHDP. All these different arenas somehow overlap and interact, aspects that can be ascribed to knowledge dynamics, governance dynamics or both.

Actors can be active in more arenas and fulfill a role where they learn in each arena, translate, negotiate and exchange. This is how the intertwinement becomes complex. It is not just a hierarchy of arenas and the distinction between top-down and bottom-up cannot be applied. This framework fits in ideas of science and research as a complex adaptive system. Arenas again have their own dynamics but can also be clustered to indicate research domains with shared dynamics. And one should recognize that it is not only actors who affect the system but also the technological developments that create space for new forms of knowledge production and organization. This proposed framework should be seen as a suggestion to be investigated further.

8 Reflections and outlook

In this study, a framework has been developed to analyze international research programs (IRPs) in terms knowledge dynamics and governance that are interrelated. Three case studies, CERN, CoML and IHDP have provided an empirical body supporting this framework.

Characteristics of the three programs have been illuminated, which provided insight in how the organization is affected by, and changing by, knowledge dynamics and governance. This interrelation of knowledge dynamics of a research field, governance and the characteristics of international research programs is complex. In the previous chapter, several aspects have been highlighted that illustrate how governance and knowledge dynamics affect the organization of international research programs.

Firstly, it can be concluded that an IRP mainly behaves like a network. Though the importance of a homeport facility should not be underestimated, it is the network that is the backbone of the program. We have seen that the network of IHDP is looser than the networks of CoML and CERN. For IHDP, the network is particularly important for research agenda building, whereas the CERN network has a strong epistemic nature. IHDP's body of the organization is the network, strengthened by homeports that have a geographical position and function. CERN and CoML have physical bodies, facilities, that fulfill a more practical research role in the network. It is often the facility that is mentioned when discussing big science. This observation of the institutionalization of internationalization of research is complementary to Wagner's notion of various categories of research collaboration.

Subsequently, following on the analysis of knowledge dynamics of IRPs, it seems likely that the level of complementarity (technical, cognitive) is decisive for the shape of the organization. CERN as typical example of big science is characterized by high technical complementarity. It is likely that IRPs with high technical complementarity have a facility where research is jointly conducted. This facility then also functions as a homeport. Facilities are presumably to occur in regimes that have a convergent character.

As we have seen, CERN is highly dependent on equipment with high costs. Intergovernmental agreements have to be realized to share these costs, requiring good planning and coordination; a hierarchical structure is probable. This does not exclude shared decision-making on a research level when program goals have to be realized. Some research areas contain aspects of decentralization and technical complementarity because of different geographical foci of research as we have seen in the CoML case. For marine research the location where a study is conducted is essential, which can lead to adapted institutional arrangements that can still include facilities. Areas with high cognitive complementarity and low technical complementarity are likely to be organized and coordinated differently, and a big science approach (like CERN) does not suit. IHDP for example encompasses a multi-disciplinary network, which asks for a more flexible and loose organization. Homeports are still important but have a less central role in actual research practices. Yet, institutional sponsors like ISCU, ISSC and UNU have an intrinsic role in the in the coordination of IHDP. It has been observed that the research agenda building in the social environmental sciences are partly coordinated through IHDP's strategic planning. To create space for the wide diversity in methodologies, theories, research problems, and geographical circumstances, the Steering Committees have to be composed carefully. Appointing internationally recognized researchers that represent this geographical and disciplinary diversity is essential and prevents exclusion.

Moreover, the Scientific (Steering) Committees fulfill an essential role in the process of scientific planning (research agenda building and influence on science policy). Members of SCs and SSCs can understand both the research practice as well as (research) politics. These researchers function as key-figures in a network because they are often active in various spheres and committees where they can translate, negotiate and learn between different levels.

The question what brings and holds a program together can be answered by finding an integrator. This integrator, as I have shown, can be driven by a combination of knowledge dynamics (internal by research area) and governance (funding, which could also be a result of joint programming).

Bonaccorsi's conception of technical and cognitive complementarity and Whitley's categorizations have proven to ben helpful in discerning these integrators.

Furthermore, I have shown that specifically key actors within a program are aware of what holds the program together as they learn, negotiate and translate in different spheres. The interrelation between governance and knowledge dynamics is most present at this level of aggregation. It is recommended to further study the governance patterns in these committees to further explore what is needed for success. The proposed framework based on interconnected arenas could be used to indicate these processes and dynamics that affect governance and research aspects. Rigid conclusions are hard to draw after this pioneering work. The developed framework has proved to be useful to study international research programs and could be further developed to study how research areas and the nature of IRPs mutually affect each other. Understanding dynamics of an IRP, it is desirable to study what brings and holds a program together. We have defined the term integrator to indicate this driving force that binds the program. Concluding, this study has illuminated the heterogeneous character of international collaboration and various drivers for internationalization, using empirical data in a newly developed framework. It empirically supports the one size does not fit all strategy in research policy and tends to demonstrate how institutional and funding arrangements have to be flexible to meet the needs of various areas.

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10 Appendices

A. *Database: mapping the field of international research programs*

An analysis of different IRPs was made to explore the field of international research programs. Mapping these programs in a database can help understanding the nature of these IRPs. A database like this did not exist yet in this form so had to be developed. This new database could relate to other databases like the CORDIS database, which is a EU FP database that contains only certain kind of programs. However, the existing databases like Cordis focus on a project level (the fractions of the IRP that are funded separately and therefore relatively easy to distinguish).

Creating a database involves making choices about the *shape and content* of the database and you need knowledge on aspects like the characteristics to be depicted. The development of a database is a process of searching information and making choices. These choices include decisions about what information you need in the database, relevant relationships between types to be depicted etc. These kinds of questions have to be answered in order to develop a database conform the needs and dynamics of the field to be depicted. These requirements of a database and the problems that were encountered can be found in the next paragraphs.

What a database should include
Starting with a first collection of information on different IRPs, a test version of a flexible database was made so during the process mutations could be made later.

After a brainstorm session we decided on some elements that the database should contain:

1. General elements of programs (name, abbreviation/acronym and link to website)
2. Size/dimension of the program (size personnel, budget, number of different partners)
3. Involved organizations (funding/ other regulation)
4. Money stream (Europe/ national so relation between amount of money from which organization to which program)

In a latter phase these additions would be desired:

5. Publications and output (f.e. publications within research field or program and/or from people in the field of social/political sciences)
6. Characteristics of the program in labels (f.e. network / facility, Distributed / centralized, different names of research areas. Might even contain: complementarity cognitive/technical/institutional, rate of growth, rate of diversity, Top-down/ bottom-up organization, Disciplinary or multi- inter- or trans-disciplinary? search regime? type of field/research area keywords?)

Difficulties
Developing this database became a problematic task because the information was difficult to find and the information was d*ifficult to place in categories*. In this paragraph I will address some of the problematic aspects of mapping these programs in a database.

As described above, in the already existing databases, *IRPs cannot be retrieved directly*. Often a link can be made from a project scale to a larger collaboration or program. Via these links you can find the bigger programs but this requires some puzzling. Generally, IRPs have program websites or they can be found on the web via funding organizations like ESF, ministries, NWO, research institutes or other IRPs. Still, covering the set of IRPs is difficult because you cannot see if a program is structural or more project oriented. There is no strict definition of the concept research program. When to call it an

IRP? Is every big project a program? Projects like ATLAS (a CERN project) can also be seen as programs under CERN (a program itself). When is a network big enough that it counts as IRP? When it has a more structural character than a timeframe of one ERA-NET funding?

Furthermore, the IRP websites do not provide you with clear-cut information for example about *budget and size*. The budget of an IRP is often the sum of several grants and sometimes these grants do not go to the program itself but to participating organizations. This varies for example when programs have a network character rather than a centralized facility. Even when you search for money streams from the founding organizations like FP or NWO it is complex to get the image complete. EUROSTAT is currently investigating these money streams and they are meeting these difficulties as. Even NWO does not have a clear overview of how their money flows to the programs. For them it includes a sum of their own funding instruments that have different nature for example funding projects or individuals and different 'disciplinary' departments can contribute to the same program but in the NWO organization this is not transparent. Another element concerning funding is the difficulty the way of monitoring because funding arrangements can work with different structures: just retour or common pot. When the first type of funding is agreed upon, a calculation can only be made at the end of the period. Thus, various project calculations can be made and there are different ways of calculating these contributions, which again can vary per country or the goal for which the calculation is made. When you look at IRP funding you can find different answers to the budget, which is caused by these different calculations.

To make a database you *need to have a clear idea about what relations you want to capture* and thus use *strict characteristics*. These characteristics need to be reflecting the program and the labels used should mean the same for each program. This is has proven to be complicated because even label as centralized/distributed/network/facility need context. Furthermore, the programs apply different naming strategies and are not consequent in their naming. For instance, a program can also be an organization. This is technically difficult in database when adding relations and considering how you will approach a filled database. How can the structure be depicted without making it too complicated? In adapting this design we have to reconsider the goal of the database.

Conclusion: test database and necessity study characteristics IRP

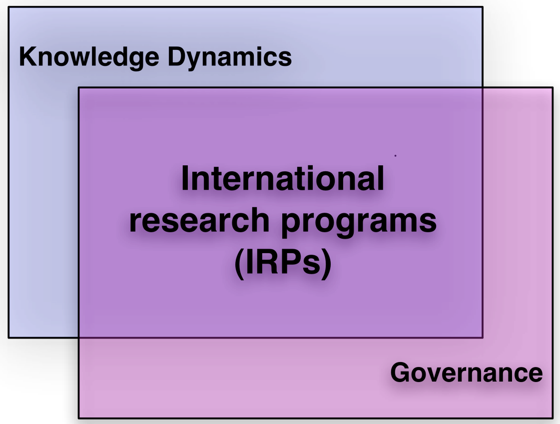
The database project resulted in *a test database (flexible database)* that has been filled with basic information of a set of IRPs including: website information, acronym, links to (funding) organizations. Because of the difficulties as described above, decided was that first a more extensive study on the characteristics of IRPs should precede the continuation of the database project.

Nevertheless, the data in the existing databases can be used as an indicator for IRPs because they can be representing f.e. one of the research projects of a program or are the initiating network from which a bigger program is organized.

B: Sub-questions and hypotheses

*RQ: "What is the interrelation between the **knowledge dynamics** of a **research field**, **governance,** and the **characteristics of international research programs**?"*

Following from the conceptualization, to answer a question on the effect of knowledge dynamics of a research field on the IRP we have to take into account the intertwinement of the knowledge and governance aspects in the landscape. The IRPs are approached from three perspectives.



Generic sub questions for three perspectives (for each program) are:

1. Explore **characteristics of IRP**
   a. How did the program come into being? (Historical, describing)
   b. What is the organisational structure of SC and SSC (secretary?)?
   c. Mapping the IRP in Wagner's dimensions of top-down/bottom-up and distributed/centralized
   d. Exploring levels of collaboration (interpersonal/team/corporate)
   e. What is the affiliation of the researcher (a PhD or staff member) with the international program itself?
2. Explore **knowledge dynamics** of research field
   a. What is an accurate name of the field(s)/area(s)?
   b. What characteristics can be found?
      i. Using theories and concepts of search regime (Bonaccorsi): convergence/divergence/complementarity/rate of growth
      ii. type of field (Whitley): strategic/ technical task uncertainty, functional/strategic dependence
   c. Can the international program be covered with only one 'search regime' or field or are there more involved within the IRP?
3. Explore **governance**
   a. What are institutional arrangements determining/affecting the shape of the collaboration?
   b. How is the research funded?
   c. How are goods allocated?
   d. Roles of different actors (EU FPs, NWO, ESF, KNAW, ERC etc.) [46]

[46] In this thesis I will not gain in-depth knowledge about the actual research policy on national and international level, but exploring the dynamics of different IRPs might hint strengths and weaknesses of the current system.

I have formulated some general hypotheses and hypotheses for the characteristics for each of the cases.

General hypotheses

I. An IRP does not have to be characterized by one search regime (but can exist of more): multiple search regimes or research fields can affect knowledge dynamics of an IRP.

II. In search regimes with relatively high convergence and a likely high technical complementarity, centralized IRPs are likely to be organized/established (f.e. one big experiment needing expensive and technological complex equipment like the facility CERN)

III. The existence of a facility (centralized aspect) does not exclude a strong distributed network.

IV. Distributedness of an IRP can be due to divergence of a field or because of a focus of research on different geographical sites.

V. Research areas affect the nature of an IRP and the organization/nature of an IRP affects the research area.

VI. New technologies that make it possible to share data globally make the centralization of an IRP less urgent or necessary. For example the World Wide Web, database possibilities with access everywhere, and grid computing.

VII. It is difficult to pin point a search regime of an IRP. Boundaries of the definition of search regime are rather vague. Has the IRP developed its own search regime over time?

VIII. Both bottom-up as top-down structures can be observed within IRP. Both can be present and dropping this distinction can be advisable.

IX. Output of IRPs is hardly detectable in ISI web of knowledge when looking at scientific publication and the name of the IRP.

X. When a formal collaboration like an IRP exist, collaboration on interpersonal and team level vary. High divergent fields will have less team of interpersonal collaboration.

XI. Research managers are well aware of their participation to an IRP while this varies for PhD and postdoc researchers who have no role in the organizational aspects. This counts especially for distributed IRPs that are mainly characterized by a network structure.

XII. The origin of an IRP is preceded by negotiations on different levels. Establishing a network of recognized scientists and a guaranteed start budget (seed money) are essential in this early phase.

XIII. An IRP can be organized around a theme in the sense that there is a general guiding question or problem that requires an organization where possibly different fields have to be gathered to search for answers.

The policy aspects will not be explored as such but from the IRPs elements will be brought up when for example referring to funding strategies or structures that illuminate the institutional possibilities and impossibilities. That may show a direction of stylished matches of types of governance patterns and knowledge dynamics that scholars are looking for.

Considerations Whitley and Bonaccorsi

The strength of quantitative research (Bonaccorsi) in the sphere of knowledge dynamics is the *relative ease of visualizing patterns* and changes of structures of the science system or a field. But deciding on the variables (keywords) and start values is a complex phase of this type of research. Bibliometric research makes use of measuring research output that has a factor of *delay* and does not reflect the *internal struggles of research practice,* which might be relevant when it concerns convergence or divergence or collaboration.

In Bonaccorsi's application, judgments are based on keyword analysis. The decision of which keyword to use in a search is disputable. And keywords are not only shaped by individual scientists but are value-laden in the sense that the words used are political/scientific constructs already defined in a process that precedes the moment of 'measurement'. When doing this kind of research it is important to be careful to keep in mind the limiting factors and be aware of the restrictions of the associations you can proof. Furthermore, defining what words to look for requires some kind of qualitative search. It is questionable if quantitative research like Bonaccorsi proposes gives enough nuances to depict the fine distinctions between different fields. It might be the case that especially small details in changing methodologies make a difference when it concerns the characteristics of a field that cannot be caught with quantitative research, especially not doing bibliometric research on output (publications and patents) solely.

Qualitative research on the other hand can give subtle distinctions but generalization based on qualitative data is difficult. This is one of Whitley's weaknesses: his explanation of categories is partly based on a gut feeling but difficult to proof. Bonaccorsi's search regime can also be operationalized in qualitative research. Applying both theories will give us a more complete image of characteristics of different research fields, but the focus will be on the interpretation of qualitative data.

C. Interview protocol (open interview)

(Open interview protocol that was used as a basis for the interviews, in Dutch)

Introductie en achtergrond
Thesis opleiding Philosophy of Science, Technology and Society (van de Universiteit Twente) + Rathenau Instituut
Onderwerp internationalisering van wetenschap en wetenschapsbeleid. Specifieker: naar het effect van *kennisdynamieken van een onderzoeksveld op het karakter van grote internationale programma's*.

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- Dr. ir. F.J. Dijksterhuis (University of Twente)
- Dr. B.J.R. van der Meulen (Rathenau Instituut)
- (John Marks, oud directeur van de European Science Foundation en meerdere functies bij NWO, OCW, is ook betrokken bij dit onderzoek.)

Het achterliggende idee is dat *internationale programma's tot stand komen in een wisselwerking tussen kennisdynamieken (die horen bij het onderzoeksgebied) aan de ene kant en beleidsdynamieken en deze probeer ik deze in kaart te brengen voor een aantal programma's*. Het onderzoek is verkennend van aard.

De drie grote internationale onderzoeksprogramma's, verschillende onderzoeksgebieden die ik bestudeer zijn:

- CERN (European organisation for nuclear research)- high energy physics, particle physics
- IHDP (international human dimensions program)- social (environmental) sciences
- CoML (Census of Marine Life)- marine biodiversity, taxonomy, ecology

(evt. Deze benader ik vanuit 3 hoeken:

- internationale onderzoeksprogramma zelf (de structuur en ontstaan, geldstromen, in hoeverre onderzoekers zich betrokken voelen bij het grootschalige project),
- kennisdynamieken (vanuit theorieën/ conceptualiseringen over type van een onderzoeksveld)
- beleidsdynamieken (wetenschapsbeleid, geldstromen en voorwaarden).)

Onderwerpen waar ik vragen over heb zijn: onderzoeksgebied/domein, structuur van de organisatie internationale programma, financiering, wetenschapsbeleid.

- *vragen om maken opname van gesprek!*
- *Afstemmen hoe lang gesprek duurt*
- *Gebruik data voor scriptie vragen*
- *Check: vragen naar onduidelijkheden*

(alle vragen zijn afhankelijk van hoeveel ik al weet uit de literatuur/document analysis. Vragen die voortborduren op de literatuur, en dus per geïnterviewde verschillend waren, zijn niet in dit protocol verwerkt. De vragen zoals hieronder worden ingeleid en geherformuleerd nav de info die ik tot mijn beschikking heb)

Functie
Wat is uw functie? Welke posities bekleedt u, zowel binnen uw eigen organisatie als IRP?
Hoe bent u hierbij betrokken geraakt? (toelichting loopbaan, ook vakgebied idee krijgen)

Ontstaan programma
Hoe is het IRP ontstaan? (voor zover ik dat nog niet weet)
Welke personen/ partijen waren hier bij betrokken?
Hoe is de Nederlandse betrokkenheid tot stand gekomen?

Organisatie programma:
Hoe steekt de organisatie van het programma in elkaar? (verschillende schillen, secretariaat, SC, SSC ed)
Netwerk/faciliteit? Hoe ziet dit er uit?
Wetenschappelijke advies commissie? Welke verantwoordelijkheden?
Wat zijn de taken en verantwoordelijkheden van de steeringcommittees op project niveau? En SC?
Hoe heeft de organisatie zich in de loop van de tijd veranderd? Kunt u daar meer over vertellen?
Hoe worden doelstellingen geformuleerd?

Als relevant..Vanuit NWO/ OCW (andere ministeries)/ ESF/ EU/ ISSC/ ESSP/ ICSU/ KNAW/ global change committee...wat is hun positie/rol?

Onderzoeksveld
Welke disciplinaire achtergrond heeft u?
Hoe zou u het onderzoeksveld van de IRP omschrijven/ benoemen? (doorvragen..)
Kunt u een korte beschrijving geven?
Hoe is dit onderzoeksveld vertegenwoordigd in Nederland? Instituten of vakgroepen? Zijn deze binnen Nederland aan elkaar gelinkt?
Waarom denkt u is er samenwerking binnen dit onderzoeksgebied? (te maken met onderzoeksagenda land? Thematisch? Linken van gebieden?)
In hoeverre is onderzoek afhankelijk van groot materieel?
Verschillen verschillende instellingen erg in de manier van onderzoek doen?
Conflicten in gebruik van methodes? Waar zijn conflicten aan te wijzen? Wanneer er onenigheid bestaat over onderzoeksdoelen, wat is daar dan de reden voor?
IHDP bv heeft onderzoeksgebieden met verschillende onderzoeksculturen, op welke manier verschillen deze van elkaar?

Ligt dit vakgebied dicht bij ”...”?
Experimenteel/fundamenteel/toegepast...?

Onderzoekers & het programma
Hoe verandert door het programma uw onderzoek? Of de samenwerking met collega’s?
Onderzoekslocaties van onderzoeker (bc CERN zowel Geneve als NL, of CoML expedities naast soms lab werk)?
Op welke manier werken onderzoekers samen? (check hoeverre interpersoneel/ team samenwerking) onderzoekers zien elkaar bij conferenties? gemeenschappelijk publiceren en/of projecten aanvragen?

Output
Hoe vind ik publicaties die uit het onderzoek van het programma vloeien?
Publicaties op naam van het programma?

Eigen wetenschappelijke tijdschriften?
Verzorgd het 'secretariaat' een deel van de communicatie naar buiten toe? Hoe?

Financiering
Hoe zit de financieringsstructuur in elkaar?
programma en losse projecten? EU FPs? (evt links met de industrie?)
Hoe bepalen waar geld heen? SC?
Onderzoekers zelf subsidies vragen? Waar? (FP/ESF/NWO..) En waarom daar?
Heeft u een idee van het totaalbedrag wat er aan onderzoeksgeld omgaat binnen de IRP?
Hoe verhoudt zich dat met onderzoeksgeld voor ....vul maar in: Nederlandse bijdrage/ bepaald project van IRP.

Als onderzoeker, waar loopt u tegen aan als het gaat om financiering van projecten/programma's?
Bij aanvraag aangeven dat onderdeel van programma?
Conflict moeilijkheden die voorkomen inhoud/financiering/beleid?
IGFA bij IHDP, wat haar rol?

Is het programma structureel? Hoe wordt hier voor gezorgd?

Internationalisering en toekomst
Wat zijn volgens u essentiële elementen dat dit programma succesvol maakt? (bepaalde personen, financieringsmogelijkheden, technieken/experimenten)

Zou het onderzoek ook op deze manier haalbaar zijn of gebeuren zonder het overkoepelende programma?

Wat zou er verbeterd kunnen/moeten worden?
Wat voor veranderingen in de organisatie zouden volgens u nog nodig zijn?
Is er momenteel een verandering gaande? Hoe ziet die er uit en wat voor consequenties heeft deze?

D. List of contacts/interviewees

	Name	**Position**	**contact**
CERN			
	Frank Linde	Director of NIKHEF institute high energy physics	Interview*
	Job de Kleuver	Deputy head of science policy department FOM	Interview*
	Jeroen van Leerdam	PhD at Nikhef, LHCb experiment	Different contact moments
	Martijn Gosselink	PhD at Nikhef, ATLAS experiment	Different contact moments
	Erwin Bielert	PhF at CERN/University of Twente, new generation magnets LHC	Phone call
CoML	Niki Vermeulen	PhD, wrote thesis on Big Biology with CoML as case study	Phone call
	Carlo Heip	SSC CoML, director NIOZ	Interview
	Annelies Pierrot-Bults	Researcher Plankton UvA (CoML projects ecoMAR and CMarZ)	Interview
	Stefan Schouten	Researcher microbes CoML project at NIOZ	Interview+ tour at NIOZ
IHDP	Renee van Kessel	Director MaGW NWO	Contact
	Rik Leemans	SSC ESSP/IHDP global change committee, Profe	Interview
	Frank Biermann	IHDP coordinator earth system governance project	Interview (phone call)
general	John Marks	Independent International Science Policy Professional and Research Manager, former different positions at NWO, OCW, ESF	General contact, 3 meetings

* Frank Linde and Job the Kleuver were interviewed together in one interview.