International Planetary Defense

An Ethnographic Study

by

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ABSTRACT

Planetary Defense is the scientific field of study dedicated to the detection and mitigation of a potential threat posed to Earth by a Near Earth Object (NEO), whether an asteroid or a comet. It is a fairly recent scientific field of study. The first Planetary Defense offices were created in the United States in 2017 and at the European Space Agency (ESA) in 2019. Should an impact occur, the Planetary Defense community, an international network of Planetary scientists, is set to work in coordination with international and national emergency response services to deal with such a natural celestial disaster. This dissertation will revolve around the hypothesis that over the past twenty-five years Planetary Defense has morphed from a scientific field dedicated to asteroid detection to a broad managerial international technocratic infrastructure. Considering that such a disaster could have consequences of potentially globally catastrophic proportions, including possibilities for large-scale tsunamis, firestorms, and stratospheric darkening, it is critical that any NEO disaster management and coordination efforts be informed by proven theoretical principles and best practices. On a theoretical level, however, connections have yet to be made between the literature of the sociology of natural disaster management and this newly organized field of Planetary Defense management. This dissertation aims to address this knowledge gap by extracting lessons learned and guidelines from the Sociology of Disaster Management and link them to the field of Planetary Defense management.

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ACRONYMS AND GLOSSARY

ASIME: Asteroid Science Intersections with in-space Mine Engineering conference

CNEOS: Center for Near Earth Object Studies

CNES: Centre National d'Etudes Spatiales (French Space Agency)

COSPAR: International Committee on Space Research

EPSC: European Planetary Science Congress

ESA: European Space Agency

ESO: European Southern Observatory

ESPI: European Space Policy Institute

ESRIN: European Space Research Institute

FEMA: Federal Emergency Management Agency

IADC: Inter-Agency Space Debris Coordination Committee

IAA: International Academy of Astronautics

IAC: International Astronautical Congress

IAF: International Astronautical Federation

IAWN: International Asteroid Warning Network

ICSU: International Council of Scientific Unions

ICS: International Council for Science

IDNDR: International Decade for Natural Disaster Reduction

IGY: International Geophysical Year

IPPH: International Planetary Protection Handbook

ISC: International Science Council

LC: Liability Convention (= Convention on International Liability for Damage Caused by Space Objects)

NASA: National Aeronautics and Space Administration

NEO: Near Earth Objects

NED: Nuclear Explosive Device

OST: Outer Space Treaty (= Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies)

PD: Abbreviation of Planetary Defense

PDC: Planetary Defense Conference

PDCO: Planetary Defense Coordination Office

PDO: Planetary Defense Officer

PHA: Potentially Hazardous Asteroid

PHO: Potentially Hazardous Object

PIERWG: Planetary Impact Emergency Response Working Group

PP: Abbreviation of Planetary Protection

PPO: Planetary Protection Officer

PPOSS: Planetary Protection of Outer Solar System

SMPAG: Space Mission Planning Advisory Group. SMPAG is a UN-mandated expert scientific group created in 2014 in order to plan and coordinate near-earth object threat mitigation research internationally.

SMPAG LWG: SMPAG Ad Hoc Working Group on Legal Issues. The purpose of the group is to connect space scientists on Planetary Defense to lawyers who have an expertise in international space law. This legal team was constituted on October 1st, 2016 for the sole purpose of providing legal advice to SMPAG.

SPI: Space Policy Institute

STS: Science and Technology Studies

STSC: Science and Technology Sub-Committee (of the UNCOPUOS)

UNCOPUOS : United Nations Committee on the Peaceful Use of Outer Space

UNGA: United Nations General Assembly

UNHCR: United Nations High Commissioner for Refugees, often known as United Nations Refugee Agency

UNISDR: United Nations Office for Disaster Risk Reduction

UNOOSA: United Nations Office for Outer Space Affairs

CHAPTER 1

INTRODUCTORY CHAPTER

I. Research hypotheses

My research will present three hypotheses:

First, that over the past twenty-five years Planetary Defense has morphed from a scientific field dedicated to asteroid detection to a scientifically-led structure operating at national and international levels. Secondly, that the recent inclusion of social scientists into SMPAG is representative of this change: it illustrates the transition between a strictly scientific network to scientists in charge of managerial decisions wishing to take into account a broader range of expertise than space science and engineering. Thirdly that asteroid threats fall under the category of natural disasters and Planetary Defense Management can thus benefit from cumulated lessons learned cultured within the field of Sociology of Natural Disaster Management.

To face these new managerial responsibilities, I have observed, through ethnographic field work, that the field is opening to new sets of knowledge from the social sciences. The reasoning being to create new collaborations[1], develop a larger and more complete data set in order to better their decision-making process in designing a mitigation mission.

Research goals

The overall goal of this research is twofold: on the one hand, as this domain has been so far strictly developed within the natural sciences, the objective is to understand how it is opening up to other disciplines; on the other hand, in an effort to advance Planetary Defense policy and

[1] As expressed in the SMPAG's 2015 Terms of Reference, cf: https://www.cosmos.esa.int/web/smpag/terms-of-reference-v0, [checked on June 06/26/2019]

management capacities, what is aimed at is to enhance the knowledge of how Sociology of Disaster Management may help design Planetary Defense emergency responses. One point of my argument is to show this can be done by taking into account the socio-anthropological aspects of natural disaster management.

I consequently aim to enable the Planetary Defense community to take into account some additional social considerations beside those they have started to reach out to in the design phase of Planetary Defense Management. My intent is also to help their field in a collaborative and joint effort to meet a challenge that may defy humankind and for which preparedness, even first on a theoretical level, may be essential for all. Considering the scale an asteroid impact may have, social science knowledge relevant to Planetary Defense Management should be made available when rehearsing Planetary Defense scenarios and designing mitigation missions to support the Planetary Defense community's current transdisciplinary efforts[2] and inform them of the preemptive steps that can be taken against the social struggles usually emerging during natural disasters.

Research Objectives

Consequently, I will devote this research to reflecting on the rapid growth of Planetary Defense Management over the past twenty-five years and on how that scientific field has grown into a national and international managerial structure. I will then analyze the UN-mandated SMPAG dedicated to Planetary Defense and through that case study I will analyze the growth of Planetary Defense into a decision-making model to increase preparedness efforts by

[2] I refer here to the term "transdisciplinary" as defined by BAUER, H in "Barriers Against Interdisciplinarity: Implications for Studies of Science, Technology, and Society (STS) ", *Sage journals*, January 1st 1990, https://journals.sagepub.com/doi/10.1177/016224399001500110, [checked on 06/26/2019], according to whom the final result of the collaborative and joint effort between various experts from different disciplines is better than the sum of its parts.

progressively reaching out to other forms of expertise and monitoring such interaction. After establishing from the literature that an asteroid impact could be considered a natural disaster of unprecedented proportions, I will proceed to analyze the field of Planetary Defense through the academic lens of sociology of natural disaster management literature, arguing that there lies an untapped intellectual resource that could be brought to the field of Planetary Defense. This study will show best practices and lessons learned identified by sociologists of Natural Disaster Management applicable to the field of Planetary Defense and establish recommendations.

To this end, this research will answer the following questions: Why is Planetary Defense experiencing rapid growth? How is Planetary Defense transforming into a managerial structure? How is the field answering to these new managerial responsibilities? Why and how can lessons learned from Sociology of Natural Disaster Management be applied to the field of Planetary Defense?

In the process, I will be answering the question of how NEO threats, a non-imminent but potentially catastrophic space hazard, are currently anticipated, conceptualized and managed. This line of inquiry will include exploring Planetary Defense Management as a technocratic system, i.e. the management of a field or institution by technical experts[3]. This part will shed light on the multi- and trans-disciplinary attempts from Planetary Defense decision-makers to better their understanding of social sciences issues related to natural disaster management, as well as the current limitations of such interactions. Although the findings of my research are that Planetary Defense Management is increasingly approached in a transdisciplinary and holistic way, I nevertheless argue that the field would benefit from more dedicated scholarly

[3] cf. Merriam Webster dictionary, https://www.merriam-webster.com/dictionary/technocracy,[checked on 06/26/2019]

efforts aimed at integrating methods and perspectives from the social sciences into its decision-making processes.

In my conclusion, I will provide recommendations to space policy actors in charge of the nascent field of Planetary Defense management on how to best integrate lessons learned from sociology of natural disaster management. By this work, I also hope to interest sociology of natural disaster scholars to come and further explore the new field of natural celestial disaster management which, I argue, is a new subset of their own field of natural disaster management. As a general motivation, this research is an integral part of my long-term desire not only to study the management of decision-making processes within international space institutions, but also to find out in greater depth how to incorporate insights and methodologies from the social sciences into space threat management. Finally, I seek to inform readers of current decision-making processes whose access to the general public is generally limited.

Ethnographic method

I have used direct and participant ethnographic observation in order to understand the Planetary Defense community and the evolution of the field from within. I have analyzed and reported on the new sets of knowledge from the social sciences the Planetary Defense community is acquiring through the SMPAG case study. In order to accurately address my subjectivity, I have also acknowledged my own biases which I will detail in the second chapter dedicated to my research methodology.

I will also present a set of key Planetary Defense institutions illustrating the growth in the managerial responsibilities of this scientific field, among which the US National Aeronautics and Space Administration Planetary Defense Coordination Office (NASA PDCO), the European Space Agency Planetary Defense Office (ESA PDO), the United Nations Committee

on the Peaceful Uses of Outer Space (UNCOPUOS), the UN-mandated Inter-Agency Warning Network, the UN-mandated Space Mission Planning Advisory Group (SMPAG) and the SMPAG's ah-hoc Legal Working Group (SMPAG LWG). These institutions fall into two categories depending on whether they work at a regional and/or national level or whether they operate on an international scale. This research will present an analysis of the way Planetary Defense Management is currently being organized in the United States and on international platforms.

From my observations of the Planetary Defense Management community, and notably through my Case Study of SMPAG, I observed endeavours to: 1) increase preparedness efforts (in order to better meet the responsibilities of preparing for a potentially global threat); 2) Expand Planetary Defense interaction with social sciences which I believe is done in order to 3) Improve Planetary Defense Management using larger and more complete sets of data, theoretical understanding and critical insight.

Scientists leading national Planetary Defense offices or chairs of Planetary Defense international groups are currently in charge of:

1) Coordinating scientific Planetary Defense research

2) Designing a technical emergency response to a potential asteroid threat

3) Warning the heads of Space Agencies (who would then warn the heads of States) and the heads of federal emergency agencies - such as the Federal Emergency Management Agency (FEMA) in the US.

4) Advising on best practices regarding asteroid threat management

5) Progressively reaching out to other domains of expertise such as that of social sciences, to inform their decisions.

II. Literature review

1) Sociology

Sociology of Science Literature

Over the last decades a large number of studies in sociology of science have altered the perception of the scientific world, legitimizing the analysis that the scientific milieu is a truly social environment. Latour's *Laboratory Life* (1979)[4] in sociology of science and anthropology on the observation of the scientific process has inspired me - through his analysis and deconstruction of scientific data production within a neuroendocrinology research laboratory - to observe the space environment I have been part of through the lens of sociology of science and Science and Technology Studies (STS). As space research involves a great variety of scientific and social science disciplines and cultures, I felt the need to deepen my knowledge in Sociology of Science and most specifically in the case of this research in Sociology of Natural Disaster Management. Several reasons led me in that direction:

First, as a researcher trained in socio-anthropology, I detected sociological themes discussed by the Planetary Defense community, notably during their biannual scenario exercise at the Planetary Defense Conference 2017[5]. There they would, for example, question how to connect with local populations, how to be aware of their needs, predict their reactions to an asteroid threat and avoid creating a mass panic. They, however, never referred to this line of questioning as sociology per se. I cannot firmly assert that sociology of natural disaster is something that the Planetary Defense community is not aware of, but I can attest that sociological questionings were discussed without referring to them as part of a larger field of social science research.

[4] LATOUR, B., *La vie de laboratoire*, Ed. La Découverte, Paris, 1979.
[5] Cf. International Academy of Astronautics (IAA) biannual Planetary Defense Conference 2017, held in Tokyo, Japan in May 2017.

Most often, they would talk about "communication". For example, they would ask journalists how they would break the news to the populations, how they expected these populations to react, whether they anticipated mass panics, etc., all of which are questions that pertain to sociology and could have, therefore, been directed to sociologists.

I also observed that when they connected with natural disaster specialists, this was always done empirically: for instance, in their concern to face the possible fall of an asteroid into the ocean, Planetary Defense scientists would invite emergency teams used to dealing with tsunamis to help them design and prepare for emergency responses. It became clear to me that the Planetary Defense community, in order to prepare for an asteroid impact, was seeking lessons learned from other areas of expertise.

What I mean by "lessons learned" is explained in the definition that NASA, ESA and the Japanese Space Agency (JAXA) agreed upon in 1999 which states: "A lesson learned is knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. (…) A lesson must be significant in that it has a real or assumed impact on operations; valid in that it is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or eliminates the potential for failures and mishaps, or reinforces a positive result."[6]

Following this model, I decided to go back to Socio-Anthropology, the discipline that I was trained in and to which all these questions seemed to be repeatedly yet tacitly addressed by the Planetary Defense community. In that discipline, a subfield seemed more specifically central to their concern, that of Sociology of Disaster Management.

<u>Sociology of risk and disaster management literature</u>

[6] SECCHI, P., "Proceedings of Alerts and Lessons Learned: An Effective way to prevent failures and problems", *Technical Report WPP-167*, Noordwijk,1999.

This type of literature was useful in two main ways: not only did it help me clarify definitions and concepts, but it also guided my way of approaching the field of Planetary Defense Management. Indeed, research such as Bourg, Joly and Kaufmann's "*Risk to threat: thinking about catastrophes*"[7] and Peretti-Watel's "*Sociology of Risk*"[8] define in great detail the differences between a risk, a hazard, a catastrophe and a man-made vs. a natural disaster[9]. All these definitions will be presented and analyzed both later in the introduction and in the last chapter (chapter 5) dedicated to lessons learned from sociology of natural disaster management. The understanding of these definitions allowed me to theoretically establish the fact that an asteroid impact can be considered a natural disaster/catastrophe. I consequently decided to focus on such a sub-field of sociology to pursue my research as it appeared to be the best and most fitting form of sociology to understand the impacts an asteroid threat would have on populations.

Secondly, previous readings had taught me that sociology of natural disaster was quite an empirical field of sociology: it was often based on multiple readings of "practitioner literature" where research questions often come from direct observation and tend to answer very practical problems. Reading the works of sociologists and anthropologists of natural disaster management such as Douglas[10] and Revet[11] in addition to reading reports from project manager

[7] BOURG, D., JOLY, P-B., KAUFMANN, A., *Du Risque à la menace : Penser la catastrophe*, PUF, Paris, 2013.

[8] PERETTI-WATEL, P., *Sociologie du risque*, Armand Colin, Paris, 2007.

[9] Readers may notice that I mostly refer to French sociologists of risk when discussing risk analysis in my introduction and final chapter. I hope that this focus will, in addition to helping me better my understanding of theoretical concepts presented in my mother tongue, contribute to highlight the works of some non-English speaking experts in the field.

[10] DOUGLAS, M., Risk and Blame. Essays in cultural theory, Routledge Ed., New York, 2015.

[11] REVET, S., *Anthropologie d'une catastrophe : les coulées de boue de 1999 au Vénézuela*, Presse de la Sorbonne Nouvelle, Paris, 2007.

experts in natural disasters such as Decrop and Charlier's "*From scientific expertise to negotiated risk, the case of mountain risk*"[12] enabled me to extract empirical lessons learned that could be brought and applied to the field of Planetary Defense Management. It was Decrop's[13] work on how to best manage the consequences of avalanches, trying to coordinate efforts among the various emergency stations spread out around the Alps, that inspired me to follow a similar pattern. From then on, I turned my exploration of Sociology of Disaster Management literature into a search for lessons learned applicable to the field of Planetary Defense management.

As mentioned above, lessons learned is a common practice in the field of space research. I made the same observation when I attended the PDC and PD experts' meetings[14] where lessons learned appeared as a trusted empirical way to address an issue. I consequently thought it would be the right method to adopt to introduce concepts and conclusions from sociology of natural disaster management to the Planetary Defense community.

As my case study on SMPAG will demonstrate in my fourth chapter, the number of transdisciplinary projects and connections to social science expertise by the planetary defense community seem to have been steadily increasing over the past five years, to the point where an ad-hoc legal working group dedicated to Planetary Defense was created in 2016. I actually joined the field of Planetary Defense in 2016 for the dedicated purpose of serving as a liaison between the new social scientists brought into the field of Planetary Defense and the scientific group SMPAG. My role has been to coordinate the report of the SMPAG ad-hoc legal working

[12] DECROP, G., CHARLIER, C., *From scientific expertise to negotiated risk, the case of mountain risk*, Cemagref Editions, Cachan, 1997.
[13] DECROP, G., CHARLIER, C., *From scientific expertise to negotiated risk, the case of mountain risk*, Cemagref Editions, Cachan, 1997.
[14] My field works will be listed and detailed in my second chapter "Methodology and field work".

group through group meetings, group calls and editorial work. As such, I am a primary witness to their nascent efforts to turn towards social science expertise. Their goal was to gain complementary knowledge to improve Planetary Defense decision-making processes and preparedness efforts. I saw there an opportunity to extend this transdisciplinary effort to building a bridge between them and sociologists of natural disaster management.

For the Planetary Defense community, my work may serve as an opportunity to connect with a set of knowledge they have already attempted to address without explicitly referring to it in theoretical terms and possibly to start inviting such experts to their transdisciplinary meetings.

For my socio-anthropologist colleagues, I see this bridge as an opportunity to increase their awareness of a form of natural disaster that has rarely been addressed in their field. The absence of Planetary Defense in Sociology of Natural Disaster Management literature may be explained because: 1) the latest large asteroid impact on our planet precedes human civilization and 2) it is my hypothesis that Planetary Defense Management is a very nascent technocratic system, that has just emerged from the scientific field of Planetary Defense over the past 25 years[15].

Indeed, I will argue that there has been a transformation in the field of Planetary Defense during the last quarter century, in as much as what was once specifically a scientific field has now been developing policies and has morphed into a form of scientifically-led structure where Planetary Defense scientific experts have now managerial responsibilities, at national and international levels. These new decision-making powers and responsibilities enticed Planetary Defense leaders to seek transdisciplinary forms of knowledge in order to make their decisions with what they wish to be as complete a set of data as possible. Adding to this set of data, the sociology

[15] I refer here to 1994, date of the impacts of Comet Shoemaker-Levy 9 on Jupiter which led to efforts to discover, track and catalogue NEOs, as well as the 1995 first United Nations international conference dedicated to Near-Earth Objects.

of natural disaster management lessons learned is consequently timely and designed to pursue and extend the Planetary Defense current efforts to reach out to the social science community. In return, in addition to observing a new form of natural disaster, sociologists may be interested in observing, analyzing, informing and interacting with this new managerial scientifically-led structure that is becoming the field of Planetary Defense.

In addition to Sociology of Disaster Management literature, I relied on another nascent field of literature which I refer to as the Social Sciences and Humanities (SS&H) of Space Literature. I explored such literature in order to familiarize myself with both the works of practitioners in the field of space using social science concepts to reflect upon their domain of practice as well as the works of sociologists, historians and anthropologists who have conducted field works and ethnographic studies of the space industry. Both literature have been extremely useful to help me put into perspective what I was observing in my own field work as well as helping me reflect on my ethnographic method and positioning as a scholar/practitioner. My writing aims to fit in such new literary community.

2) Space Literature

The domain of space research itself encompasses a wide range of disciplines and is studied through theories and practices. Consequently, this literature originates not only from scientists and engineers but also from social scientists working on disciplines as diverse as History, Policy, Law, Economics, Sociology, Ethics, Philosophy, Psychology, Science and Technology Studies (STS), etc. All of them have their own standards, and methodologies or intents intrinsic to the field they come from. Given the multidisciplinary nature of the field, I thought it important to grasp the nature of that varied and diversified literature and organize it in distinct categories:

A tentative classification of "Space Literature"

Four main categories of Space literature can be distinguished:

1) Personal journeys

This category encompasses writings from active members of the space sector narrating their own or others' lives and experiences as space professionals. This can range from the biographies of astronauts and famous space entrepreneurs[16], to celebratory publications regarding institutions' senior employees[17] (often following the narrative of lessons learned from career-long expertise), to forms of ethnographic tales. The point of view is that of insiders and they always endeavor to be humanly and technically informative about the inner-structures of the space sector.

2) Scientific articles & reports

This refers to reports and articles put together by academics, government employees, think tanks, associations, experts' groups or professional institutions, released either on a decadal basis (such as the *Decadal Surveys*[18] of the National Academies), or annually (like the *Space Report*[19]), or sporadically made available through the institutions' websites. Other types of professional reports can be the results of investigations following major accidents (like the *Challenger*[20] and *Columbia* accidents). It is to be understood that this form of literature has a widely varying degree of specificity and technicality: from highly specialized to general readings offering practical overviews of the space sector.

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[16] VANCE, A., *Elon Musk, Tesla, PayPal, SpaceX, and the Quest for a Fantastic Future*, Ecco Press, New York, 2016.
[17] WRIGHT, R., Johnson, S., Dick, S.J., *NASA at 50, Interviews with NASA's Senior Leadership*, Washington DC, 2011.
[18] Cf. http://sites.nationalacademies.org/ssb/ssb_052297, [checked on 06/26/2019]
[19] Cf. https://www.thespacereport.org/, [checked on 06/26/2019]
[20] VAUGHAN, D., *The Challenger Launch Decision, Risky Technology, Culture and Deviance at NASA*, The University of Chicago Press, 1996.

3) Space Science Communication / Popularization

This refers to publications from professional Space Societies/Associations/Advocacy Groups and Space Journals whose endeavor is to help Space knowledge become more accessible to the general public. It is to be noted that many of such groups do not solely focus on communication activities and vulgarization campaigns. They can also be involved in larger scientific projects, launch scientific initiatives in partnership with governmental missions, provide professional reports to the space sector experts and lead academic studies. An example of such an advocacy group conducting communication efforts would be the non-profit *The Planetary Society*[21].

4) Social Science & Humanities (SS&H) Studies

SS&H studies are conducted by professional historians, ethicists, anthropologists, psychologists, etc. who will apply their expert disciplinary knowledge to the domain of Space, offering a variety of different lenses through which to observe a sector dominated by scientific and technological expertise. They can range from professional manuals dedicated to space law to policy analysis to ethnographic studies. Their diversity and range invite to a more detailed description through the annotated bibliography below. Although it is the lesser known of the three Space Literature categories listed above, this category of Space Literature was the most useful to my PhD research.

Considering the diversity of such literature, I have classified this bibliography into six headings:

1) Manuals; 2) History of Space & Society; 3) Multidisciplinary Space "themed" literature;

4) Sociology and Ethnography of Space; 5) Space Psychology; 6) Space Ethics & Philosophy.

Each of these categories will be described in a short paragraph and will be illustrated by a minimum of two literary reviews (listed in alphabetical order) of representative readings.

[21] Cf. http://www.planetary.org/, [checked on 06/26/2019]

1) Manuals

A few SS&H of Space manuals exist. Some are bound to one specific discipline, such as the *Handbook of Space Law*[22] by Law Professors Von der Dunk and Tronchetti. Others will tend to blend Space Law, Policy and Society domains such as did Soucek and Brünner with "*Outer Space in Society, Politics and Law*"[23], Pelton and Jakhu with "*Global Space Governance: and international Study*"[24] and Dickens and Ormrod's *Palgrave Handbook of Society, Culture and Outer Space*[25]. These manuals are often quite large (up to 1,100 pages for the *Handbook of Space Law*) and have all a recent date of publication (all but one were published between 2015 to 2017). This illustrates an increase in popularity of and demand for such literature, created in a "manual format". This can be interpreted as an emerging desire to professionalize the field by providing volumes capable of being used in (future) classrooms.

2) History of Space & Society

History of Space readings are what compose the bulk of non-scientific Space Literature. Following a chronological narrative, History of Space & Society literature will often focus on the political history and societal impacts of space programs, underlining the benefits of space research to society as a whole. It is usually authored by professional historians [26]. Here are two examples of such literature:

Dick and Launius *Societal Impact of Spaceflight*[27] presents, in a chronological order of Space Missions, how each spaceflight has impacted the American – even the world -- vision of Space Exploration. The book emphasizes the impact spaceflight had on the public and how, for

[22] VON DER DUNK, F., TRONCHETTI, F., *Handbook of Space Law*, Elgar, Northampton, 2015.
[23] BRÜNNER C., SOUCEK, A., *Outer Space in Society, Politics and Law*, Springer, New York, 2011.
[24] JAKHU, R.S., PELTON, J.N., *Global Space Governance: An International Study*, Springer, Montreal, 2017.
[25] DICKENS, P., ORMROD, J., *The Palgrave Handbook of Society, Culture and Outer Space*, Palgrave Macmillan, London, 2016.
[26] KRIGE, J., *NASA in the World, Fifty Years of International Collaboration in Space*, Ed. Palgrave Macmillan, New York, 2013, is a good example of such literature.
[27] DICK, S.J., LAUNIUS, R.D., *Societal Impact of Spaceflight*, NASA press, Washington DC, 2007.

instance, public support translated into increased funding. It also highlights the public's reactions to mishaps, or accidents such as those of *Challenger* and *Columbia*. One element the authors make crystal clear is the intertwined relation existing between Space Applications (in Space and on the ground) and the Societal effects they may have on the general population.

Krige's *NASA in the World, Fifty Years of International Collaboration in Space*, presents the History of NASA from its creation to its most recent international collaborations (as is the case with the ISS). It presents NASA's role nationally and internationally, as a leader and a partner, comparing the various forms collaborations with Western Europe, Russia, China, Japan, etc. took on. It also details the reactions of the agency's international partners throughout their own political and technological developments. It is a useful read to understand better the positioning of NASA internationally and helps consider the global Public Space Sector as a possible alliance of a multitude of national space systems, mainly led by the US. However, NASA's relations with the Private Sector are rarely brought up, the focus of the book being rather centered on inter-agency collaborations between nations.

3) Multidisciplinary "Space Themed" Literature

Space Economics, Law and Policy literature do not yet lead separate literature fields. They rather compose a single literary group that often combines the three disciplines to provide an analysis on one common "space theme". These readings use a multidisciplinary structure, each chapter being written by the author of a different discipline, e.g. one chapter dealing with the space policy of a certain topic, another focusing on its economic structure, or on its legal impediments etc. They will serve as multifaceted studies of often "trending" space issues. Examples of such literature are:

Lewis's *Mining the Sky*[28] is a classic example of what constitutes most of Space Literature (along with space history books): it is a transdisciplinary book presenting the history, policy, law and ethics of a common space theme (here, Asteroid Mining). It focuses on very practical questions and provides a somewhat precise overview of the topic. In addition to their informative role, such books underline the intertwined yet often tacit relation existing between space law, space policy and space management.

Moltz's *Crowded orbits, Conflict and Cooperation in Space*[29] is another example of the themed overview of a Space topic. In the absence of worldwide applicable (and agreed upon) Space Law to develop and interpret this specific issue, the book focuses and sheds light on the politics, policies and diplomacy surrounding today's mostly unregulated space challenge: space debris mitigation[30].

Suzuki's *Policy Logistics and Institutions of European Space Collaboration*[31] is a space policy and administration read. The author here focuses on the growth, history and complexity of European Space collaboration, within and out of ESA, on policy, legal and managerial levels. Although extremely informative with regards to European space constitutions, the implementation of various policies and the internal structures of the various national space agencies in Europe, it somewhat fails to provide information on the people working within the described institutions. This seems exemplary of a general trend in Space literature which rarely features or details the different actors at play in policy implementation. This is possibly due to

[28] DICK, S.J., LAUNIUS, R.D., *Societal Impact of Spaceflight,* NASA press, Washington DC, 2007.
[29] MOLTZ, J.C., *Crowded orbits, Conflict and Cooperation in Space*, Columbia University Press, New York, 2014.
[30] Could be added to that list: SOLOMON L.D., 's *The Privatization of Space Exploration, Business, Technology, Law and Policy*, Transaction Publishers, New Brunswick, 2008.
[31] SUZUKI, K., *Policy Logistics and Institutions of European Space Collaboration*, Ashgate Ed., Aldershot, 2003.

the fact that administrative structures have longer lifespans than the actors heading them. An ethnographic study of such institutions could help provide that missing piece of the puzzle.

4) Sociology & Ethnography of Space

Sociology and Ethnography of Space literature is more recent (2000s) but offers interesting multi- and even trans-disciplinary approaches to studying a variety of Space communities from within. They report on human interactions and group dynamics that impact and are impacted by the researchers work throughout the lifetime of a space mission. Good examples of such literature would be Vertesi's "*Seeing Like a Rover*"[32] and Messeri's "*Placing Outer Space*"[33]:

Seeing Like a Rover and Placing Outer Space are two of the very few Space Ethnographic pieces of literature written to this day. Vertesi, on the one hand, followed from the inside the construction of the Mars Rovers cameras and reflected on the "construction" of the imagery of the Red Planet. From her point of view, that construction is not only a direct feed from Mars but mainly a representation of what the scientists were looking for and have consequently built the cameras to picture. Messeri, on the other hand, explained how the work of astronomers and astrobiologists contributes to "place" in outer space, and to map inhabited worlds such as Mars, through observations, cartography and their own imagination. The observation of human behavior and the hindsight of the two authors are rare enough to deserve being regarded as a major contribution to the nascent field of space ethnography. However, Vertesi & Messeri only wrote a couple of pages on Space Politics and the influence of fluctuating budgets due to political instabilities in the overall projects they were observing. They treat their research as

[32] VERTESI, J., *Seeing like a Rover, How Robots, Teams, and Images Craft Knowledge of Mars*, The University of Chicago Press, Chicago, 2015.
[33] MESSERI, L., *Placing Outer Space, An Earthly Ethnography of Other Worlds*, Duke University Press, Durham, 2016.

specific case studies and as a result do not venture into extrapolated interpretations with regards to the larger space community.

5) Space Psychology & Psychiatry

Space psychology & psychiatry[34] is perhaps the most "technical" literature of this list. It focuses on the applied methods and their results. Through the presentation of tests submitted to past and future astronauts, its main goal is didactic and consists in avoiding the possible complications inherent in long-term confinement missions. Space psychology and psychiatry usually appear under the forms of scientific manuals listing protocols, experiments, results and interpretations. Their authors are psychiatry professionals working either with a Space Center or a Medical Center. Two examples of this literature are:

Presented as a manual, Kanas and Mansey's *Space Psychology and Psychiatry*[35] is a detailed methodology-driven research and can be considered a scientific read. Composed of detailed data and charts on the different findings of human performance monitoring in space, this study reveals another category of literature: a social science kind of literature written as a scientific manual based strictly on empirical work. This type of literature seems at the boundary of natural and social sciences.

Vakoch's *Psychology of Space Exploration, Contemporary Research in Historical Perspective*[36], focuses on the human psychological preparation that is required to go and work in space. It, however, does not explore the psychological impact of human-crewed flights on

[34] KANAS, N., MANSEY, D., *Space Psychology and Psychiatry*, 2nd Ed., Microcosm Press, El Segundo, 2008 (1st Ed. 2003) & VAKOCH, Douglas A., *Psychology of Space Exploration, Contemporary Research in Historical Perspective*, NASA Press, Washington DC, 2011.

[35] KANAS, N., MANSEY, D., *Space Psychology and Psychiatry*, 2nd Ed., Microcosm Press, El Segundo, 2008 (1st Ed. 2003).

[36] VAKOCH, D.A., *Psychology of Space Exploration, Contemporary Research in Historical Perspective*, NASA Press, Washington DC, 2011.

society (at large), the way *Social Impact of Space Flight* did. Here is a collection of various abstracts on topics such as: astronauts' selection, preparation (detailing the methods as well as the facilities in which they take place) and recuperation. The last chapter presents, nonetheless, a detailed list of the authors' biographies, in which the reader can discover how they got to work on the psychology of space. These last few pages are particularly useful to help map out how these non-scientists were able to enter a quite scientific and technical space field through social and cognitive sciences.

6) Space Ethics & Philosophy

Space ethics and philosophy is a fairly recent and extremely under-developed field of SS&H space literature. Its authors (less than a dozen worldwide) are either philosophy professors looking at space as an original case study worthy of ethical and philosophical reflection, or deeply engaged space enthusiasts using this platform to share their vision and hopes for the future of the field.

As two examples of professional ethicists looking at the Space World, we can cite Scottish philosopher Milligan with his two main contributions: *"Nobody Owns the Moon"*[37] and *"The Ethics of Space Exploration"*[38] (both recently published, respectively, in 2015 and 2016) and French ethicist, Arnould and his "*Icarus' Second Chance, The Basics and Perspectives of Space Ethics*"[39].

For their part, space enthusiasts such as Franck White[40] became very popular with the publication of the Overview Effect.

[37] MILLIGAN, T., *Nobody Owns the Moon*, McFarland Editions, Jefferson, 2015.
[38] SCHWARTZ J., MILLIGAN, T., *The Ethics of Space Exploration*, Springer, London, 2016.
[39] ARNOULD, J., *Icarus' Second Chance, The Basis and Perspectives of Space Ethics*, Springer, New York, 2011.
[40] WHITE, F., *The Overview Effect, Space Exploration and Human Evolution*, 3rd Edition, AIAA Press, Reston, 2014.

White's *The Overview Effect,* describes the author's belief that it is important for humanity to see the world with a "from above", borderless perspective, the way astronauts got a chance to see it. From his point of view, advocating crewed space flights and bringing more humans into Space would be an effective way of promoting peace. He also advocates the possibility of a more technocratic model in the USA, where past astronauts, who have had the rare opportunity to glimpse an "overview" of our world while in space, would be good political candidates for science and peace advocacy in public office. The book also details a variety of astronauts' portraits and interviews, offering an interesting "insider's look" into the field while keeping a unique philosophical approach.

After categorizing the different forms of space literature and offering an in-depth look into the current content of the social sciences and humanities of space literature, it now seems relevant to have a critical hindsight and assessment of some common practices within this literature.

A critical reading of Social Sciences & Humanities of Space Literature

1) A USA-focused literature

First of all, the space community is by any standards a relatively "small" community when compared to other scientific ones. Needless to say, the authors and experts in such young fields as SS&H of Space[41] represent an even smaller number. It is, however, to be noted that this small number of academics comes from an even smaller number of SS&H of Space programs, such as McGill University for Space Law or GWU Space Policy Institute. This creates a predicament in so far as the SS&H literature that is written is strongly oriented towards an analysis of the North American (mainly the US) Space Sector and is almost completely nonexistent regarding

[41] I am excluding here the domain of History of Space which counts a large amount of academics and obtained official recognition at the very beginning of the Space Race when T. Keith Glennant, the agency's first administrator, created NASA's History office in 1959.

emerging space powers such as India or Malaysia. This can be most obvious when looking at the table of content of SS&H of Space main manuals such as "*Global Space Governance*"[42] and "*Outer Space in Society, Politics and Law*"[43], which have very little content on non "major" Space powers.

2) A "close-knit" network

Furthermore, if we look closely at the bibliographies of the aforementioned manuals, we can see that, in their introductory chapters, they usually promote a study involving experts from around the world. However, upon reading their biographies, we are likely to discover that most of these experts come from similar programs and sometimes the same classes. Though turning to colleagues might be quite an understandable method of recruitment when one wants to take on the colossal task and responsibility of writing an "everything space policy & law" handbook for example, this may raise some biases. Moreover, some disciplines seem to be sometimes over represented within a literature whose aim is to represent a diverse set of disciplines[44].

3) Problems and solutions

The purpose of this criticism is to remind the reader of the presence of "natural" biases in SS&H of Space works, which have been so far rarely if not at all addressed in the literature

However, with the current growth of professionalized literature, academic programs, and international transdisciplinary conferences – all opening up their doors not only to more disciplinary diversity[45] but to new transdisciplinary research programs – the solution to this

[42] JAKHU, R.S., PELTON, J.N., *Global Space Governance: An International Study*, Springer, Montreal, 2017.
[43] BRÜNNER C., SOUCEK, A., *Outer Space in Society, Politics and Law*, Springer, New York, 2011.
[44] More than 2/3 of the 15+ contributors of the newly released "*Global Space Governance: An International Study"* (Springer, Montreal, 2017) have graduated from McGill Law School and 3/4 were legal professionals, even though the manual itself addresses as much Space Law as it does Space Policy, Economics & History.
[45]As an example of that tendency, it can be noted that for the first time, space lawyers, policy makers and economists will be convened to the next bi-annual international Planetary Defense Conference (PDC) held in Washington DC in 2019: http://pdc.iaaweb.org/, [checked on 06/26/2019]

problem may come naturally with an enlarged pool of professionals, sensitized and aware of the variety of fields and experts constitutive of SS&H of Space.

It can also be noted that new hybrid works from scientists working in the space sector and writing "Space Journeys" essays using socio-ethnographic methods, are emerging and could embody the start of a new transdisciplinary current of ethnographic space scientists. Eventually, few challenges remain unsolved and solutions do emerge. Such is also the case of the potential meaningfulness of these new "insiders" for the field of SS&H of Space, a benefit worth exploring now.

The role of "insiders"

Space scientists writing about their own field is no new phenomenon. This dates back to the beginning of the Space Age. Such readings were classified in the "Personal Journeys" category at the beginning of this dissertation. As astrophysicist Alan Stern's explains in "*Our Universe, the Thrill of Extragalactic Exploration as Told by Leading Experts*":

"Within this book you will find both a lot of modern astrophysical science, and an insider's perspective about how turn-of-the-century astrophysics is done […] in reading this collection of essays you will learn a good deal of the inner workings of modern astronomy, and its techniques and its state of knowledge. But you will also learn a good deal about the inner workings of a few of its most noted practitioners."[46]

This "insider's" perspective is not claimed as an ethnographic positioning here but advertises more as a useful "managerial purpose", namely understanding a system from within and sharing personal lessons learned so that the rest of the community may benefit from decades of experience.

[46] STERN, A.A., *Our Universe, The Thrill of Extragalactic Exploration As told by Leading Experts*, Cambridge University Press, Cambridge, 2001.

Such readings are full of descriptions and analyses pertaining not only to the technical challenges that were met but also to the human dimensions of the space missions these scientists were part of. Yet, if ethnography is an understanding of a community from within and is, as is explained by ethnographer Walcott, executed by "being there" and "doing it"[47], what differentiates these professional tales from ethnographic space studies? A tentative yet clear answer is provided in his chapter entitled "Is everybody an ethnographer?":

"In spite of the fact that in their own way and for their individual purposes "everybody's doing it", the formal label "ethnographer" and "ethnography" seems best reserved for those who pursue such endeavors intentionally as a facet of a professional career, those for whom ethnography is not only a way of looking and seeing but a preferred way of looking and seeing"[48].

Following that logic, the difference between, on the one hand these scientific space practitioners observing and reporting on their community's activities from within, and on the other hand "professional" ethnographers, would be that space scientists do not have the "intent" of creating ethnographic knowledge in order to make it an "ethnographic professional career". This does not seem to be enough of an argument to deny ethnographic practices.

Paradoxically enough, some experts in science and technology studies also looked into that question and came up with a quite opposite analysis. In the most recent *Handbook on Science and Technology Studies*, Preda argues that experts of their own fields are in the best position to conduct an analysis of their own system as they have a deeper knowledge of its flaws and unspoken/tacit codes than any outsider analyst:

[47] Harry F. Walcott explains it most clearly and concisely in "*A way of seeing*"[47] when he says, *"there is no substitute for « being there » and « doing it », as ethnography will always be a practice prior to being a theorized field*", WOLCOTT, H.F., *Ethnography, a way of seeing*, Altamira Press, New York, 2008, p.4.

[48] WOLCOTT, H.F., *Ethnography, a way of seeing*, Altamira Press, New York, 2008, p.280.

"The analyst does not know the social environment he studies better than its own actors do and it is a mistake for him to try to use an obvious existing definition of the apparent groups that make up the field"[49].

Bell's "*The Interstellar Age: The story of the NASA men and women who flew the forty-year Voyager mission*"[50], illustrates Preda's point: the various portraits and descriptions of the Voyager team(s) the author painted as an inside member of the team made him aware of various pieces of knowledge an outside "professional" ethnographer would decidedly not have had access to.

Professionals in their own fields have the capabilities of pushing doors that an outside observer may not know even existed, and thus are able to further and deepen a general reflection. I would consequently argue that rather than try to establish or redefine what constitutes (or not) an "ethnographical work", these Space Literature "Personal Journeys" should be considered as ethnographies and put into the hands of Sociology of Science students as they have embraced – possibly unintentionally – the ethnographic methods of "*being there and doing it*" and bring to the field a unique and non-reproducible expert/insider's perspective.

In that respect, I would position myself as a sort of in-between: although I started my field work as a graduate student conducting ethnographic work, the three years I spent fully employed in the sector have led me to adopt more of an insider's "lessons learned-oriented" type of approach to pursue my research.

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[49] HACKETT, Edward J., AMSTERDAMSKA, Olga, LYNCH, Michael, WAJCMAN, Judy, *The Handbook of Science and Technology Studies*, 3rd Ed., The MIT Press, Cambridge, 2008, Chapter 35: PREDA, Alex, "STS and social studies of finance", p.915.

[50] BELL, J., *The Interstellar Age: The story of the NASA men and women who flew the forty-year Voyager mission*, Dutton, New York, 2016.

This hybridization process is also reflected in my dissertation: History, STS, Ethnography, Policy, Law and other disciplines I studied over the years to develop my research have provided me with precious methodological tools. I am hoping that this work, the result of such transdisciplinary hybridization, will be considered a useful contribution to the Social Science and Humanities of Space literature.

III. General background on Planetary Defense

1) The scientific field of Planetary Defense

Since its formation, the Earth has been impacted a large number of times by foreign objects, one of which is believed to have precipitated the extinction of dinosaurs 65 million years ago. Due to the development of space technologies during the second half of the 20th century, the growing capabilities of modern telescopes and the consequent detection of more and more Near Earth Objects (NEOs), the field of Planetary Defense has developed over the past recent decades to detect and mitigate asteroid threats to Earth. One of the main characteristic of the field is that it has to deal with gigantic effects of a very low probability event. A recent example was the effects caused in 2013 by a small 18-meter object that exploded over the scarcely populated area of Chelyabinsk, Russia. It had the force of 30 atomic bombs and caused 1,000 injuries and significant material damage. Perhaps the most famous 20th century example occurred in 1908, when a space-rock twice as large released over Siberia an energy equivalent to 185 Hiroshima bombs and devastated forests over 2,000 square kilometers. Mechanically, with the exponential growth of the world population, this risk must be taken more and more seriously[51].

Planetary Defense scientists conduct asteroid characterization studies and develop detection as well as mitigation methods (using impactor experiments, lasers, etc.). The point is to be able to

[51] MELAMED, N., "Planetary Defense against asteroid strikes: risks, options, and costs", Center for Space Policy and Strategy, January 16, 2018, https://aerospace.org/paper/planetary-defense-risks-options-and-costs/ [checked on 06/20/2019]

identify an asteroid early enough and with enough precision to be able to choose as accurately as possible the most relevant mitigation method to deflect a threatening asteroid away from the Earth's trajectory. Within this research, I will often use the terms "NEO threat management" and "asteroid threat management" as synonyms even though Near Earth Objects encompass not only asteroids but also comets. This choice comes from the fact that all the field work and Planetary Defense scenarios I have been part of during my 3-year research have used asteroids rather than comets for their exercises. I should also underline that NEO/Asteroid threat management is only a subset of Planetary Defense management, given that part of Planetary Defense consists in the monitoring of Near Earth Objects and that only an extremely low percentage of them could become threatening to Earth.

2) Distinguishing Planetary Defense from Planetary Protection

Planetary Protection and Planetary Defense are often confused[52]. So much so that the distinction between the two is routinely explained in the first five minutes of most presentations given by Planetary Protection experts[53]. Contrary to Planetary Defense, which focuses on Near-Earth Objects potential threats to Earth, the purpose of Planetary Protection is to prevent contamination between Earth and other bodies in the context of space exploration missions and to ensure that scientific investment in space exploration is not compromised by cross-contamination[54]. This domain was developed along the space conquest started in the 1960s. Theoretical concerns were raised as early as 1956 at the International Astronautical Federation

[52] I repeatedly witnessed the European Space Agency and NASA Space Agency Planetary Protection Officers (PPOs) teach the difference existing between Planetary Protection and Planetary Defense so that PP trainees may not make that common mistake. Such instances happened at the NASA Cape Canaveral Planetary Protection Training 2016, at the European Space Agency Planetary Protection training in Stuttgart, Germany in October 2016 as well as at all of the four Committee on Space Research (COSPAR) Planetary Protection of Outer Solar System (PPOSS) international tutorials I organized in Japan (2017), USA (2018), Germany (2018) and China (2018).

[53] Cf. first slide of the presentation by ESA PPO Gerhard Kminek on "*What planetary protection is not*": http://pposs.org/wp-content/uploads/2017/03/2.-PPOSS-Planetary-Protection-Basics-G.-Kminek.pdf, [checked on 06/20/2019].

[54] Cf. http://pposs.org/pp-101/, [checked on 06/20/2019]

7th Congress in Rome before the Committee On Space Research (COSPAR[55])'s first recommendations in 1958. As Planetary Protection takes into consideration the environment in which the experiment is conducted (on the Moon, Mars, Icy Moons of Jupiter and Saturn, or Asteroids), its guidelines will vary. The goal is to avoid as little contamination as possible in places where human-brought particles/spores could grow and spread (such as in the under-ice oceans of Enceladus[56]). Planetary Protection also applies to sample-return missions[57].

After having established what Planetary Defense is (and is not), I will now provide definitions of the theoretical notions I will be referring to in this research.

IV. Concepts, definitions and theoretical background

1) Definitions

I will be focusing on the notion of asteroid hazard, threat and catastrophe management. I will first define the terms "risk", "threat", "hazard", "disaster" and "catastrophe", then underline their differences and explain why I decided to dedicate my research to some of these concepts over others.

Risk

As defined by Dupont in "*Dictionary of risks*" (2004)[58], a risk is defined as a probability a hazard will be happening. The notion of "risk" is often defined as an equation: for instance that of 1) the probability of a negative event happening multiplied by the damage such an event would cause, 2) an unforeseen turn of events multiplied by what is at stake[59] or 3) the product

[55] Disclaimer: I have worked for the Committee on Space Research (COSPAR) as the Planetary Protection of Outer Solar System (PPOSS) project officer from September 2015 to January 2019.
[56] Enceladus is one of Saturn's natural satellites and is believed to have a liquid ocean under its iced surface.
[57] Missions bringing samples back to Earth from asteroids, moons or planets such as Mars.
[58] DUPONT, Y., *Dictionnaire des risques*, Armand Colin, Paris, 2004.
[59] *Ibid.*

of the convolution of hazard and vulnerability[60]. The determination of risks can be brought back to the determination of an "uncertainty". As Le Breton explains, both risk and uncertainty are "terms that overlap semantically and are often used as synonyms. [61]" A risk may also be defined as something that is potentially harmful. It is, he says, "a quantified uncertainty, a potential danger likely to be created by a coincidence." [62] The definition given to the word risk also determines its usage and will depend on whether it is used as a synonym of "choice", "danger", "challenge" or a synonym of "anticipation of the future"[63]. In the world of Planetary Defense, the term "risk" is used by astrophysicists when discussing the potentiality of an asteroid impact. There will be "a risk" of an asteroid impacting the Earth.

Existential risks, hazards and threats

An asteroid impact could be considered an "existential risk"[64], a risk that could either annihilate intelligent life or permanently and drastically curtail its potential. In that sense, the risk of an asteroid larger than 10km in diameter impacting the Earth may be classified as an existential risk. On the other hand, when discussing the potential for Earth to be impacted by an asteroid, the NASA Planetary Defense Coordination Office (PDCO) official webpage recommends using the word "hazard" [65]. For instance, one can read there that "*NEOs present a hazard to Earth of being impacted*.[66]" As for the word "threat", the same Planetary Defense Office advises to use

[60] Cf. BIRKMANN, J., *Measuring Vulnerability to Natural Hazards, Towards Disaster Resilient Societies*, United Nations University Press, New Delhi, 2006.
[61] Le Breton, *Sociologie du Risque*, p.3 : *« Risque et incertitude ont un domaine sémantique qui se recouvre et ils sont souvent utilisés comme des synonymes (…) Le risque est une incertitude quantifiée, il témoigne d'un danger potentiel susceptible de naître d'un événement ou d'un concours de circonstances »* Translation:*« Risk and uncertainty partly overlap semantically and are often used as synonyms (…) Risk Is a quantified uncertainty ; it indicates a potential danger likely to be created by an event or a coincidence ».*
[62] *Ibid.*
[63] Translated from the French : « La définition du terme risque détermine son impact, selon si l'on l'entend comme synonyme de « choix », de « danger », de « défi » ou « d'anticipation de l'avenir » p.128.
[64] DUPONT, Y., *Dictionnaire des risques*, Armand Colin, Paris, 2004.
[65] https://www.nasa.gov/planetarydefense/overview, [checked on 06/20/2019].
[66] Ibid., [checked on 06/20/2019].

it only when a specific object has been identified on a potential impact course towards Earth. It says, for instance, "*The Center for Near Earth Objects calculations shows this object is an impact threat to Earth"*[67]. This distinction, following the instruction of the Planetary Defense scientific community's statement, between hazard and threat consequently helps us distinguish the following two types of statements:

- When talking hypothetically about an impact, the term hazard is to be employed.
- Conversely, when it has been determined there is potential for an actual impact, the term threat is to be employed.

In other words, in Planetary Defense, Near Earth Objects can be considered hazardous. They however become "threats" if and when a potentiality to impact Earth has been determined. Then, Earth would be at "risk" of an "asteroid threat". Moreover, the term "threat" also carries the significance that one wants to be protected from it. As Dupont explains in "*Dictionary of Risks*", the concept of threat is thus underpinned by the idea that one has become aware of the danger posed by a hazard and wants to be protected from it [68].

As a result, when talking about the Planetary Defense scenarios used at the Planetary Defense Conferences (PDCs) I attended, I will talk about asteroid "threats". In these scenarios, an asteroid was detected and it was determined it was going to impact the Earth. It was also decided by the scientists in the room and the two lead scientists and authors of the scenario, that something should be done to mitigate such a threat.

Making the distinction between the term "threat" and the term "disaster" is also important. A natural disaster, unlike a threat, refers to an event that populations have experienced in the past,

[67] Ibid., [checked on 06/20/2019].
[68] Cf. DUPONT, Y., *Dictionnaire des risques*, Armand Colin, Paris, 2004.

by being directly or indirectly affected by it. Furthermore, Pigeon[69] explains that the term "disaster" suggests that the event exceeds the capacities of local management. For example, if/when an asteroid is on its route to impact Earth, the term asteroid "threat" will be used. Once it has impacted the earth, the term "disaster" will be used. A major asteroid impact is something unprecedented in human experience. Consequently, when talking about NEO research and detection, the terms "threat" and "disaster" are incorrect and should not be used, the proper word to use being "hazard".

Risk perception

The question of whether or not to communicate to the general public information regarding a detected space threat, as well as the questions arising from this are central elements in risk literature. Is it the responsibility of space researchers to share such risks with the general population? Can they run the risk of creating mass panics? Or is it their responsibility to arouse fear to some degree as a pedagogical tool to make the public understand the risks at hand and potentially raise their support to fund preventive research projects? Another question raised is to know what can be considered an "acceptable risk" in space? In this regard, Douglas's 1992 *Risk and Blame. Essays in cultural theory*[70]can be enlightening. As Douglas argues:

"There is a value judgment [in defining what is harmful and what is not] (…) That judgment introduces a first social dimension in the way "risk" is defined." [71]

Douglas shows that risk perception is determined by culture and varies according to social contexts. She thus rules out a "universal" understanding of risk. This interpretation of "individual" risk perceptions clashes with the idea of a universal risk terminology which could

[69] PIGEON, P., REBOTIER, J., *Les politiques de prévention des désastres, Penser et agir dans l'imperfection*, ISTE Ed., London, 2017.
[70] DOUGLAS, M., "Risk and Blame. Essays in cultural theory"[70], London & New York, Routledge, p. 38.
[71] *Ibid.* p.12.

be wished for by international humanitarian governance bodies such as The United Nations. For example, more than a year of SMPAG's ad-hoc legal working group was spent defining legal terms relevant to an asteroid threat, most based upon the vocabulary defined with United-Nations international law treaties, in order to avoid what they would refer to as "misunderstandings". The idea of individual risk perception, and with it the difficulty of anticipating how various populations will respond to a global threat, only compounds the work of those whose responsibility it is to assess whether or not information about a potential risk should be communicated to the public (or more accurately, "publics" here). Not only is there no single perception of risk but there also seems to be as many ways of perceiving risk, threat and disaster as there are cultures. For instance, McCabe[72] underline that several civilizations have developed different ways of thinking and acting regarding risk as they perceived it. Indeed, in the research McCabe conducted on Africa's arid and semi-arid areas, especially among Turkana shepherds in the North East of Kenya, he showed that drought is not perceived by these communities as a disaster but as a normal element of the environment they live in, and act accordingly[73]. As Joly explains, "The problem does not lie so much in the potential existence of a danger as in the fact that that danger is - or is not- accepted by a given population."[74]

This last point brings us therefore to the idea that multiple rationales and analytical models need to be developed in order to address global risks such as those posed by a Near Earth Object impact. As Le Breton develops:

[72] MCCABE, T., "Impact of and response to drought among Turkana pastoralists: Implications for Anthropological theory and hazards Research", in HOFFMAN S. M. and OLIVER-SMITH A, (Ed.), *Catastrophe and culture, The anthropology of disa*ster. Santa Fe: School of American Research Press., Oxford, 2002.
[73] *Ibid.*
[74] Translated from JOLY. J-B., *Du risque à la menace*, pp.61-62, "*Le problème n'est pas tant l'existence potentielle d'un danger que son acceptation ou pas par une population*".

*"*This shows the need for developing analytical risk reduction models that, far from being unique and rigid, should be malleable and should have the capacity to integrate the notion of 'multiple rationality'. In that way, if people's participation is to be obtained (…) understanding that multiplicity of approaches cannot be neglected simply because of the assumed irrationality of the parties directly involved."[75] As Douglas and Le Breton say in "*Risk Acceptability according to social sciences*", individuals define their own risks, in the sense that they will discriminate between the risks they acknowledge and react violently to, from those they will ignore[76]. Given that a risk will be perceived differently on account of individual mental representations and social practices, it could be imagined that space risk acceptability will greatly vary in range, depending on the population possibly impacted. To summarize the definitions offered by these sociologists, the meaning of the very word "risk" will depend on who defines it, on the set of social circumstances and judgments considered, as well as in the way such a risk will be communicated to a set population. This population is itself diverse, so that risk will be perceived, imagined, taken into consideration, or ignored in as many different ways.

To dig deeper into the ways one's culture will influence one's consideration of risks, I will analyze in my fifth chapter the various lessons learned from sociologists of natural disaster

[75]*Ibid.*, pp. 147-148 *"Cela montre la nécessité de développer des modèles analytiques pour la réduction des risques qui ne soient pas uniques et inflexibles, mais au contraire élastiques et capables de prendre en compte la notion de " rationalité multiple (…) En ce sens, si l'on cherche à obtenir une participation populaire (...) la compréhension de cette multiplicité d'approches ne peut être négligée sous prétexte d'une irrationalité présumée de ceux qui sont directement impliqués."*

[76] DOUGLAS, M., LE BRETON, D., "*Risk acceptability according to social sciences*", New York, Basic book, 1986, p.56, "*Les individus faisant partie d'un système définissent leurs risques et réagissent violemment à certains, en ignorant d'autres, d'une manière compatible avec le maintien de ce système*." translated to "*Individuals integrated in a system define their own risks and react violently to some while ignoring others, in a way that preserves the sustainability of that system*."

management and how they could be applied to the nascent field of Planetary Defense Management.

2) Looking for transdisciplinarity

Risk is in itself a multi- and trans-disciplinary notion: it encompasses notions of sociology, political sciences, economics, law, and ethics[77]. As Musset further explains,

*"*An interdisciplinary dialogue is required to work on the theoretical and methodological study of risks and disasters.[78]" It shows the necessity of mixing several schools of thought in order to better predict the variety of reactions a risk management process could and would entail. Furthermore, as Garcia-Acosta and Musset pursues, *"*the line between disciplines is progressively blurring (…) and the process is all the more noticeable in disaster study. The topic is so complex that the various fields of expertise have to transcend the boundaries of their own disciplines to produce the collective data needed to analyze in the same time sequence the various facets of the phenomena under study. This is the only way to understand both their dynamics and the results achieved.[79]"

Considering how low the probability a space threat such as a NEO impact is from happening, one efficient way of dealing with it is to train and practice such cases based on natural disaster risk management. Such exercises are gaining momentum in places like the Planetary Defense Conference but there are still very few risk experts involved in such a scenario, which serves as an example of Planetary Defense underutilizing social science experts. For example, I will show

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[77] LE BRETON, D., *Sociologie du risque*, Que sais-je, Paris, 2017.

[78] GARCIA-ACOSTA, V., MUSSET, A., *Les Catastrophes et l'Interdisciplinarité*, L'Harmattan, Paris, 2017, p.5 : "*Un dialogue interdisciplinaire est nécessaire pour travailler sur l'étude théorique et méthodologique des risques et des catastrophes.* "

[79] *Ibid.*, p.10 : " *Un effacement progressif des frontières entre les disciplines …processus d'autant plus sensible quand on s'intéresse à l'étude des désastres. C'est un sujet tellement complexe qu'il oblige les spécialités à transcender les limites de leurs disciplines afin de produire des connaissances collectives destinées à analyser de manière simultanée les différentes facettes des phénomènes étudiés. C'est la seule manière d'en comprendre à la fois la dynamique et les résultats*. "

in my fourth chapter devoted to SMPAG how careful these space experts were in inviting in their group legal experts and analyze the ways they had of keeping control over this interaction. The space community would therefore benefit from expanding their circles to sociologists and disaster risk experts so that their simulations might take into account the diversity and complexity with which a planetary threat would need being handled.

I will now examine the various space institutions which allowed me to conduct my field work.

V. Institutions

In order to present my observations, I will first provide some background information on the various groups that make up what I consider to be the international space risk policy community and that I was able to operate in.

The International Committee on Space Research (COSPAR)

COSPAR was founded in 1958 as an outgrowth of the International Geophysical Year (IGY) by the then-called International Council for Science (ICSU) which first became the International Council for Science (ICS) and is now the International Science Council (ISC) since its merging with the International Social Sciences Council in July 2018. COSPAR members are national scientific institutions, primarily Academies of Science. The first and foremost objective of COSPAR is to promote international scientific space research by emphasizing the free exchange of results, information and opinions between top scientists from around the world. It achieves this goal through the organization of biyearly scientific assemblies and symposia where issues concerning international space research are discussed. It also publishes two journals: “Advances in Space Research” and “Life Sciences in Space Research” and a bulletin “Space Research Today”. COSPAR also aims to spread knowledge and data internationally in order to give the world scientific community free access to "sharable” results

and technologies. However positive a role COSPAR fulfills in space science diplomacy, it can be noted that COSPAR's decision-making powers are circumscribed due to the fact that its members are international scientists and researchers who do not carry political state representation. Nonetheless, COSPAR plays an important role in international space risk management, especially with regards to Planetary Protection by providing a venue for all space scientists experts to meet regularly at COSPAR's assemblies, symposia and workshops. It is through my work at COSPAR as coordinator of the International Planetary Protection Handbook (IPPH) that I was integrated into the Planetary Protection community in 2015 and met the following year with the Planetary Defense community.

The United Nations Committee on the Peaceful Use of Outer Space (UN COPUOS)

UN COPUOS was established in 1959 by the UN General Assembly to "govern the exploration and use of space for the benefit of all humanity (…) review international cooperation (…) and study legal problems arising from the exploration of outer space"[80]. To date (June 2019), UNCOPUOS has grown to 92 member states and constitutes one of the largest committees of the United Nations. UNCOPUOS is currently constituted of is composed of 2 annual Sub-Committee meetings:

- A Scientific and Technical Sub-Committee meeting brings together national delegations of space experts to discuss advances in space science research.
- A Legal Sub-Committee meeting (usually scheduled around mid-April) brings together legal experts (also through national delegations) to discuss international law and space law issues.

[80] Cf. http://www.unoosa.org/oosa/en/ourwork/copuos/index.html, [checked on 06/26/2019]

- A third meeting, the COPUOS General Assembly, is organized every June and brings together members of both Sub-Committees as well as diplomats, space agency representatives and space policy experts. Only the members of national delegations are entitled to join and observe the General Assembly. Observers sit at the back of the Assembly room and cannot use a delegation seat. These delegation seats are limited to two per country. Side rooms reserved for private meetings, such as the one used for the SMPAG meetings, are closed to the public.

Regarding the attendees of these meetings, it is usually considered that the COPUOS Scientific and Technical Sub-Committee is composed of scientists and diplomats with some scientific background whereas the Legal Sub-Committee is composed of lawyers. As for the June General Assembly, it is composed of diplomats and of a few scientists and lawyers who are members of the sub-committees. Each sub-committee is independent and carries its own procedures.
The two COPUOS Sub-Committees are held 2 months apart from each other, which does not allow for many interactions between space lawyers and space scientists.

The International Asteroid Warning Network (IAWN)

IAWN was established in 2013 as a result of a United Nations-endorsed recommendation[81] for an international response to a potential Near Earth Object (NEO) impact threat. The recommendation dealt with the creation of an international group of organizations involved in detecting, tracking, and characterizing NEOs.[82] The IAWN is tasked with developing a strategy to assist governments in the discovery, monitoring, and physical characterization of potentially hazardous NEO population. It does so by using optical and radar facilities and other assets based

[81] Cf. http://www.unoosa.org/oosa/en/ourwork/topics/neos/index.html, [visited on 06/20/2019].
[82] Cf. IAWN official webpage: http://iawn.net/, [checked on 06/20/2019].

in both the northern and southern hemispheres and in space. It also serves as the coordinator of observation campaigns for the detection of potentially hazardous objects and recommends policies regarding criteria and thresholds for the notification of an emerging impact threat. IAWN is also the entity responsible for warning all entities identified by UN COPUOS Member States as being responsible for the receipt of notification of an impact threat if such a threat were to be detected. It currently includes eighteen members[83] from Europe, Asia, South and North America.[84]

The Space Mission Planning Advisory Group (SMPAG)

The creation of SMPAG is the result of a recommendation provided by the Working Group on Near-Earth Objects (NEOs) of the Scientific and Technical Subcommittee of the United Nations COPUOS in June 2013, during COPUOS's fiftieth session. SMPAG was then formally endorsed by the Committee and by the sixty-eighth session of the General Assembly in December 2013. As its terms of reference state: "The primary purpose of the SMPAG is to prepare for an international response to an NEO threat through the exchange of information, development of options for collaborative research and mission opportunities, and to conduct NEO threat mitigation planning activities."[85] SMPAG is composed of international scientific experts in Planetary Defense. It works closely with IAWN. If an object was detected through IAWN and was determined to possibly be a threat to Earth, SMPAG members would be in charge of planning a mitigation mission. In 2016, SMPAG requested the assistance of a group of fifteen international lawyers and asked them to provide answers to international law questions that could rise from the planning of such a mitigation mission.

[83] *Ibid.*
[84] *Ibid.*
[85] Cf. SMPAG official webpage: https://www.cosmos.esa.int/web/smpag, [checked on 06/20/2019].

VI. Dissertation outline

This research investigates the ways in which Planetary Defense management is currently being developed, the ways in which this natural science-led field is integrating social sciences expertise and the ways in which it could be informed by sociology of natural disaster management literature.

Main Hypothesis

This dissertation will revolve around the main hypothesis that over the past twenty-five years Planetary Defense has morphed from a scientific field dedicated to asteroid detection to a broad managerial international scientifically-led structure.

Outline

Following the introductory chapter, my second chapter will present the methodology I have followed as well as the fieldwork I have conducted over the past three years; this has been conducted both within the field of Planetary Defense in the United States and internationally, and within the various academic institutions I have attended. I will then dedicate my third chapter to analyzing the scientific field of Planetary Defense; I will also examine the birth of its national and international policies as well as the processes through which Planetary Defense Management emerged within the past five years (2014-2019) as an asteroid impact prevention system. In my third chapter, I will then deepen my analysis through a case study dedicated to one of the main Planetary Defense Management international groups, the United-Nations mandated Space Mission Planning Advisory Group (SMPAG) in order to analyze the ways in which this scientifically-led system is currently reaching out to other disciplines, mainly international law, in order to improve its decision-making processes. In my final and concluding chapter, I will then propose ways forward to enhance current Planetary Defense management policies based on the social science lessons learned from the domain of sociology of natural disaster management.

CHAPTER 2

METHODOLOGY AND FIELD WORK

Introduction

I have investigated the field of Planetary Defense through ethnographic field and desk research over the course of a 32-month period (from October 2016 to May 2019). I conducted this research as an insider using my status as a practitioner in the field to better understand its structure and decision-making processes from within. To that end, I have found it necessary to use an ethnographic method which I will detail in this chapter.

Research objectives

In my field work I have researched how Planetary Defense management is currently being developed, how it could be informed by sociology of natural disaster management literature and in which ways this natural science-led field is integrating social sciences. This ethnographic approach to the field of Planetary Defense allowed me, jointly with literature in ethnographic field research, space literature and Sociology of Disaster Management theories, to address two major goals: First, to analyze current national and international Planetary Defense management policies, reflecting on the current efforts undertaken to reach out to social science expertise as a means of improving policy readiness and effectiveness. Secondly, to analyze and extract lessons learned and guidelines from Sociology of Disaster Management and link them in an innovative and informative way to Planetary Defense management.

I- Research and Field Work

1) Desk research

As detailed in my literature review, my desk research started with readings in Ethnographic methodologies, Social Sciences and Humanities of Space literature, and other literature. I then pursued my readings analyzing expert reports from natural disaster managers in order to extract

possible lessons learned applicable to Planetary Defense management. I also conducted some technical research on the field of Planetary Defense, turning most often to the NASA, ESA, IAWN and SMPAG dedicated Planetary Defense public documents including webpages, understanding the difference between the various sorts of NEOs, of detection technologies and of available mitigation method. After familiarizing myself with the vocabulary and the main notions of Planetary Defense, I pursued my desk research by conducting an analysis of all twenty-four IAWN and SMPAG minutes from their first meetings in February 2014 until the last ones held to date in February 2019, as well as four Planetary Defense policies developed in the US and at the United Nations from the late '90s to 2019 which established SMPAG, IAWN and NASA PDCO. The analysis of these policy and management resources will be detailed in my following chapter dedicated to Planetary Defense science, policy and management.

I then linked the lessons learned that I had extracted from my Sociology of Disaster Management and Planetary Defense readings to my empirical Planetary Defense field work, results which will be presented in my final chapter and conclusion.

2) Field Work

Field Work Calendar

The collection of observations I made throughout this three-year period comprised seven key international space meetings and conferences:

- **February 1st, 2017**: The United Nations Committee on the Peaceful Use of Outer Space (UNCOPUOS) Technical Sub-Committee Meeting's Space Mission Planning Advisory Group (SMPAG) annual meeting in Vienna, Austria.
- **March 28th, 2017**: The UN COPUOS SMPAG Legal working group 1st meeting, in Vienna, Austria.

- **May 15-17th, 2017**: The International Academy of Aeronautics (IAA) 5th Biennial Planetary Defense Conference (PDC)[86], held in Tokyo, Japan.
- **October 9-12th, 2017**: The SMPAG secondary meeting in Toulouse, France.
- **June 22nd-28th, 2018**: the UNCOPUOS UNISPACE +50 in Vienna, Austria.
- **Sept. 29-Oct 6th, 2018**: The 69th International Astronautical Congress in Bremen, Germany.
- **April 28-May 3rd, 2019**: The IAA 6th Planetary Defense Conference (PDC) in Washington DC, USA.

Meanwhile, I was also able to participate in professional meetings at ESA, at the French and German Space Agencies (CNES & DLR), at COSPAR, at NASA Headquarters (Washington DC), at the European Space Policy Institute (ESPI, Vienna, Austria), and at the United Nations by attending several COPUOS meetings and workshops as well as the United Nations-mandated IAWN annual meetings.

Entering the field

My entry into the field of Planetary Defense happened in the fall of 2016. I had been working for the Committee on Space Research for a year and attended the ASIME[87] conference in Luxembourg where I met Dr. Line Drube, an expert in asteroid-rotation modeling and a member of SMPAG, a United Nations-mandated working group of international scientific experts dedicated to asteroid threat detection, characterization and mitigation (cf. chapter 4). This group, created in 2014,[88] had decided to create an ad-hoc group of legal experts in

[86] It was the International Academy of Astronautics (IAA)' 5th Planetary Defense Conference (PDC), held in Tokyo, Japan on May 15-17th 2017, http://pdc.iaaweb.org/ [January 10th, 2019].
[87] The Asteroid Science Intersections with in-space Mine Engineering (ASIME) Conference, http://fmispace.fmi.fi/index.php?id=asime16, [checked on 06/20/2019].
[88] Cf. Introduction and chapter 3 and 4 for more information.

international space law to answer some of the legal questions SMPAG members had about asteroid threat mitigation planning. Dr. Drube had volunteered to coordinate the group by collecting all inquiries from SMPAG members and build an expert report answering these questions with the help of the legal experts. I volunteered to coordinate the lawyers and was voted in by SMPAG members as the co-coordinator of the working group.

It was not the first time I was coordinating a group of experts. In 2015-2016, I had been the coordinator of six teams of five experts each from a variety of disciplines - ranging from space science to space history, STS, law and economics – as part of an ASU/NASA project directed by Ed Finn at the Arizona State University Center for Science and the Imagination[89]. Since 2016, I had also been working for COSPAR as the coordinator of the COSPAR-led International Planetary Protection Handbook (IPPH) for the European Commission-funded "Planetary Protection of Outer Solar System" (PPOSS) project[90].

This dual responsibility as co-coordinator of the space lawyers and liaison with the SMPAG scientists allowed me to be invited to the SMPAG bi-annual meetings (held in September and February each year in different locations) as well as to the 2017 and 2019 Planetary Defense Conferences (PDCs). That professional opportunity made it possible for me to discover the world of Planetary Defense from within. My dual background in Earth Science and in Law and Policy enabled me to act as liaison. In addition, whenever needed, I translated technical lexicon to the lawyers and legal expressions to the scientists, serving in some modest way as a disciplinary translator between the two experts' groups.

[89] This research resulted in the publication of "*Vision, Ventures, Escape Velocities: A Collection of Space Futures"*, available on the ASU CSI webpage: https://csi.asu.edu/books/vvev/, [Checked on 06/26/2019].
[90] Cf. www.pposs.org, [Checked on 06/20/2019].

Through my work as co-coordinator of the SMPAG ad-hoc legal working group, I was put in an opportune situation, where I could observe from up-close the construction of Planetary Defense management's steadily increasing reach into the social sciences.

A year and a half later, in June 2018, Dr. Drube left the German Space Agency for the Danish Space Agency and stopped working on Planetary Defense to dedicate her time to project management. Before leaving her role as SMPAG's ad-hoc legal working group founder and lead, she nominated me as main coordinator, which was confirmed by SMPAG in the fall of 2018. My work consists in coordinating the advancement of the legal report, and in continuing to serve as the liaison between SMPAG members and the lawyers. This job meant that I had to acquire thorough and comprehensive knowledge of Planetary Defense and of the main legal issues rising from a potential asteroid threat. One main issue stemmed from the fact that, in order to mitigate an asteroid threat, SMPAG experts wished to know if sending a nuclear device in space could be envisioned without breaking international law. Technically speaking, this nuclear method was described to me as well as to the lawyers' group attending SMPAG meetings as an efficient means to vaporize enough of an asteroid's surface to deflect it. Some SMPAG members were also concerned that it could break the asteroid into pieces which would then fall onto different locations around the Earth. Consequently, two of the main questions the legal report to be released in the fall of 2019 on the SMPAG website will aim to answer are: 1) Is the launch and use of a nuclear device in space possible under international law? and 2) Would a country (or group of countries) be liable for damage if the mitigation mission they conducted changed the ultimate zone of impact of an asteroid?

Biases

I have explained above in some detail what my Planetary Defense work currently consists of because I have to acknowledge my own biases as one of the few social scientists working in the

field and conducting simultaneous research on the increased presence and use of social sciences in that field.

On the one hand, I am well positioned to experience such changes from within. On the other hand, it is necessary for me to acknowledge that the only reason I am able to observe these trends comes from the fact that the ad-hoc legal working group had just been founded and allowed me to gain access to this field in the first place. My positioning and this work are consequently a result of a movement from SMPAG to include legal inquiries into their way of planning for an asteroid threat mitigation plan. I was made an insider by SMPAG members like Dr. Line Drube[91], Dr. Gerhard Drolshagen[92] and Dr. Detlef Koschny[93] who invited me in and who created sessions dedicated to legal, communication and economics issues in Planetary Defense Management within the main Planetary Defense Conference (PDC 2017 and PDC 2019) that the community organizes every two years. Regarding my background, my MS in Earth Science from Bordeaux 1 University and my LLM in Air and Space Law from Leiden Law School[94] armed me with enough knowledge in both disciplines to embrace the role of LWG coordinator. However, as I am neither a NEO nor an International Law expert, I had to trust my colleagues from both disciplines about the information they provided me with during the development of the LWG report to SMPAG. I also acknowledge that conducting a field work focused on IAWN, SMPAG and PDC annual/biennial meetings provided me with a diverse yet limited view of the Planetary Defense community as a whole.

[91] Line Drube is a Danish physicist, asteroid expert and founder and first lead of the SMPAG Ad-hoc Legal Working Group on Planetary Defense.
[92] Gerhard Drolshagen is a German physicist, asteroid expert and Chairman of SMPAG since its creation in 2014.
[93] Detlef Koschny is a senior asteroid expert at the European Space Agency and SMPAG member (from the German delegation).
[94] Program I am currently enrolled in, in parallel to the American and French PhDs.

Additionally, and as Katz explained in his ethnography of workers[95], some ethnographers can see their ethnographic work as "crossing sides". They feel it necessary to develop a local view-point anchored in a specific time and place. The risk is that with an embedded point of view, the researcher might lose his/her critical and analytical eye and be "swallowed up" within his/her field work. As a professional whose function it is to facilitate the interaction between scientific experts and legal experts, I am aware and acknowledge that even though this positioning probably allowed me to dig deeper than an outsider into the field of Planetary Defense management, I have had the temptation to adopt the intrinsic bias of seeing in a positive light this transdisciplinary collaboration. In order to counter such a tendency, it became necessary for me to exercise critical thinking and reflect on the weaknesses and limits of the SMPAG scientists-lawyers' interactions. Such limits will be addressed in my fourth chapter dedicated to a SMPAG case study.

I will now present the ethnographic method that I have used to conduct my research. In this sub-section, three axes will be addressed: 1) The ethnographic method 2) its relevance to field research 3) its limits in my research.

II- The ethnographic method

To better understand the field of ethnography, it is first necessary to review its origins: Ethnography, from the Greek "ἔθνος" (= *ethnos*, "people, nation") and "γράφω" (= *graphy*, "writing") is often conceived as a practice[96] rather than a discipline and can be defined as the practice of observing a group from within. Ethnographic practice offers a concrete

[95] KATZ, J., "On the Rhetoric and Politics of Ethnographic Methodology", *Annals of the American Academy of Political and Social Sciences* # 595 (2004), pp. 280-308.

[96] Harry F. Wolcott explains it most clearly and concisely in "*A way of seeing*" when he says, *"There is no substitute for* "*being there*" *and* "*doing it*", *as ethnography will always be a practice prior to being a theorized field*", WOLCOTT, H.F., *Ethnography, a way of seeing,* Altamira Press, New York, 2008, p.4.

approach to field research, a method of seeing through interaction and/or direct observation. The researcher will join the members of a community and offer an insider's description of their specific world, of their interactions as well as of their social codes and values. It evolved from the School of Chicago's methodology, namely that which emerged from the Sociology Department of the University of Chicago[97]. It puts interaction analysis at the center of sociological understandings and requires guidelines that will be detailed below.

1) Background

Ethnography is a research practice which gets its disciplinary origin from Sociology and Anthropology. It is based on the work of Simmel (Berlin, 1859 - Strasbourg 1918), who first developed the idea that someone looking at individuals, at their psychology and personal beliefs, could then map and explain foreign social phenomena. In opposition to Levi-Strauss' structuralist view, where individuals only undergo social rules, the School of Chicago put the individuals at the heart of social constructions. They were among the first to generalize field work and develop the idea that researchers should "step into the shoes" of those they were observing. Since 1892, The School of Chicago has been one of the leading academic groups using and developing ethnographic methods with a view to developing a comprehensive form of sociology. Last but not least, ethnography can be used for qualitative as well as quantitative research-analysis as direct observations can turn into a channel to produce social science data.

2) Ethnographic literature

To understand Ethnography as a concept of historical value, researchers dedicated manuals on the field and wrote ethnographic tales, which I will now introduce.

<u>Manuals</u>

[97]The research was fueled by Chicago's extremely fast expansion over a particularly short span. As the population grew from 5,000 inhabitants in 1850 to more than one million in 1890 and to 1.4 million in 1930, the city became a living laboratory.

Several genres compose this sub-category of ethnographic literature. There are a few ethnographic manuals defining the foundations of Ethnography as a practice such as: Atkinson, Coffey, Delamont and Lofland's "*Handbook of Ethnography"*[98], Wolcott's "*Ethnography, a way of seeing*" [99], Beaud and Weber's "*Guide de l'enquête de terrain*"[100], and Handwerker's "*Quick ethnography*"[101]. There is also classic literature such as Garfinkel's "*Research in ethnomethodology*"[102] whose aim is to go deeper into the interactionist movement and the rites of interaction. It makes sense of the difference between "self" and "social" identities and studies the actors' motivations while keeping the actors' interactions at the very heart of the field analysis. Others, such as Feldman, Bell and Gerger's "*Gaining Access: A practical and theoretical guide for qualitative research"*[103], and Georges and Jones's, "*People studying people: The Human Element in Fieldwork"*[104] offer practical advice for ethnographic field research.

Ethnographic tales

Ethnographic tales were also greatly useful to my research, as they describe ethnographers in a variety of field works. Many of them present chapters on their methodology. They share helpful detailed bibliographies, experiences and questionings. Reading ethnographic tales also sheds light on the researchers' doubts and struggles and offers the reader/researcher guidance on how to overcome them.

[98] ATKINSON P., COFFEY A., DELAMONT S., LOFLAND, J., AND LOFLAND, L., *Handbook of Ethnography*, Sage Publications, London, 2001.
[99] WOLCOTT, H.F., *Ethnography, a way of seeing*, Altamira Press, New York, 2008.
[100] BEAUD, S., WEBER, F., *Guide de l'Enquête de Terrain*, La Découverte, Paris, 2010.
[101] HANDWERKER, W.P., *Quick Ethnography*, Altamira Press, Boston, 2001.
[102] GARFINKEL, H., *Recherches en Ethnométhodologie*, PUF, Paris, 2007.
[103] FELDMAN, M.S, BELL, J., & GERGER, M.T., *Gaining Access: A practical and theoretical guide for qualitative research*, Altamira Press, Walnut Creek, 2003.
[104] GEORGES, R., JONES, M.O., *People studying people: The Human Element in Fieldwork*, University of California Press, Berkeley, 1980.

The ethnographic tale usually starts with the author explaining the field he/she decided to study, followed by the steps, circumstances and context which allowed him/her to enter such a field. Such were the cases of Wacquant's "*Corps et Âme*"[105] and Read's "*The High Valley*"[106] which are written as first person accounts. The reader is invited to follow the journey of the researcher as he/she discovers the community he/she is integrating. This method is called narrative ethnography.

This journey is usually detailed in the researcher's field diary. The ethnographer then works on putting into perspective the various patterns of interactions he/she observed after often transcribing full-length discussions with some of his/her key observees.

As is explained by French sociologist Peretz in the preface to "*Street Corner Society"* all ethnographic tales usually follow a similar structure:

"1) choosing a field; 2) entering the milieu; 3) defining your role and the role that other play; 4) establishing conditions of observation and team work; 5) note-taking; and 6) discovering the main scheme/ pattern."[107]

III- Using the ethnographic method for field research

It could be said that doing field work for an ethnographer is as important as going to the Archives for a historian. Ethnographic methods can be seen as a tool box that may be useful to all the social scientists and humanists (sociologists, anthropologists, political scientists, philosophers, historians…) who try to understand a field from within. The role played by the investigation and the investigator is, as Whyte says, "*a means to reveal the indigenous*

[105] WACQUANT, L., *Corps et âme, Carnets ethnographiques d'un apprenti boxeur*, Agone, Marseille, 2000.
[106] REID, K., *The High Valley*, Columbia University Press, New York, 1994.
[107] WHYTE, W.F., *Street Corner Society, La structure sociale d'un quartier italo-américain*, La Découverte, Paris, 2002, p.20, translated from the French : "*1) Le choix du terrain. 2) l'entrée dans le milieu, 3) les rôles occupés, 4) les conditions d'observation et le travail d'équipe, 5) la prise de note, 6) la découverte du schème principal.*"**.**

society".[108] Field work can, however, take many forms and be approached in a large variety of ways. I will underline the ethnographic practices that were available to me when I entered my field work, then the ones I ultimately chose and the reasons why I did so.

1) A personal journey

An ethnographic work can be a very personal endeavor. As Anteby explained[109], a part of him believed that the reason why he decided to study the Harvard Business School landscape only a few months after being hired there, was to help him subdue that new environment, to learn everything there was to learn from the inside so as to know where to position himself in the institution he had recently joined. For others, such as Dubé, it was a question of legacy: of sharing her years of knowledge of the field and of passing them onto the next generations of educators[110]. For Masson, it was about identifying the lessons to be learned from high school management in France in the '90s, as a professor who dedicated his career to the sociology of education[111]. Most of these ethnographers dedicated their lives to education and teaching sociology and/or anthropology. But all of them picked their field work for personal reasons; they chose a community to discover and to grow in, put themselves out of their comfort zone, and spent a year or more in an unknown environment. A researcher's journey can also be highly determined by the people they meet and by timing. Some decisive elements in my personal research include the following:

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[108] *Ibid.*

[109] ANTEBY, Michel, *Manufacturing Morals: The Values of Silence in Business School Education*, The University of Chicago Press, Chicago, 2013, p. 180.

[110] DUBE, G., *Parcours d'une formatrice d'enseignants au Québec, Autoethnographie d'une quête transpersonnelle*, L'Harmattan, Paris, 2015.

[111] MASSON, P., *Les coulisses d'un lycée ordinaire : Enquête sur les établissements secondaires des années 1990*, PUF, Paris, 1999.

Having a reliable entry link was of paramount importance as it was a key part in my anchoring in the space community: that was the case of "Doc" for Whyte[112], of "Bucky" for Wacquant[113], and for my part, of Jean-Louis Fellous, who introduced me to the world of international space research and COSPAR. In the footsteps of Anteby[114] I chose to study the expert field I was entering and used the resources it offered to understand from within the key considerations at work by its actors. I was drawn to acquire an in-depth understanding as it offered a cross-section of several challenges and problematics of the disciplines I had already studied from history to anthropology, to science and political science, to law.

Nothing can be achieved without luck. As Reimer explained in "*Varieties of Opportunistic Research*"[115], field works often "open up" and "close" thanks to a random meeting, or unexpected invitations to key events. The main drawback is that the method used is therefore not stable in the sense that it becomes a gamble. Moreover, as interesting questions only reveal themselves from the field, it is hardly possible to plan them ahead of time. Consequently, an ethnographer needs to seize the opportunities at hand. This is what I did when I was hired in 2015 as COSPAR's Planetary Protection of Outer Solar System (PPOSS) project officer and the following year, as the co-coordinator of the UN-mandated Space Mission Advisory Group (SMPAG) Ad-hoc Legal Working Group on Planetary Defense. I knew these were unique opportunities to observe a space field of research from within, very much in the vein of Whyte's work and I seized the opportunity. However, never could I have ever predicted that I would

[112] WHYTE., W.F., *Street Corner Society, la structure sociale d'un quartier italo-américain*, La Découverte, Paris, 2002

[113] WACQUANT, L. *Corps et âme, Carnets ethnographiques d'un apprenti boxeur,* Agone, Marseille, 2000.

[114] ANTEBY, M., *l'Ecole des Patrons,* éditions rue d'ULM, Paris, 2015.

[115] REIMER, J., "Varieties of Opportunistic Research", *Journal of Contemporary Ethnography*, no. 4, 1977, pp. 467-477.

meet Dr. Line Drube at the ASIME conference in October 2016 and be given the opportunity to join the field of Planetary Defense soon afterwards.

2) The ethnographer's role

Most of the ethnographic literature supports the idea that an ethnographer's role is twofold. It is to:

A) Provide the outside world at large with a look into a community that would otherwise remain mostly unknown to it. But most importantly:

B) Create new knowledge from and for the community he/she has joined:

As a practitioner, my work has been to coordinate the ad-hoc legal working group report for the United Nations-mandated Space Mission Planning Advisory Group (SMPAG). It may be useful to keep in mind that, as Anteby underlines in "*Manufacturing Morals*" [116], the members of the community I have observed, i.e. Planetary Defense scientists, will most certainly already know some if not all of the technical data and definitions I will be sharing in this research. However, in the footsteps of Masson, I wish my academic research-- and most specifically the lessons learned from Sociology of Disaster Management that I will be providing in my fifth chapter -- will serve the Planetary Defense community. I also hope the overarching reflection I am conducting on the way Planetary Defense is transforming from a scientific field to a technocratic structure may be as much of interest to my social science as to my PD colleagues.

3) Positioning

The ethnographer may or may not be identified as a full participant of the community he/she is observing. Several types of positioning can thus be listed:

[116] ANTEBY, Michel, *Manufacturing Morals: The Values of Silence in Business School Education*, The University of Chicago Press, Chicago, 2013, p. 188 "*The ethnographic approach enhances what most of them (the actual members) already know. This (book) aims primarily to depict what the actual members see as self-evident*".

A) The researcher may be identified as an outsider participating in the group's activities. In some studies, he/she will clearly be identified as an anthropologist or a sociologist participating in some activities while keeping an "outsider's" identity. Being identified as an anthropologist or a sociologist allows the community to perceive and acknowledge the observer as an expert who can question the community by resorting to different sets of tools such as questionnaires, surveys, or interviews, whether they be directed or semi-directive.

B) The researcher may choose to develop a temporary new identity: his/her intent is to be considered a legitimate member of the community he/she enters by embracing a specific function in order to stay as close as possible to his/her observees.

C) The researcher may adopt a third positioning altogether: being already part of a community he/she may then endeavor to observe from within. He/She will use ethnographic methodologies to theorize what he/she got used to living within the group and to offer a unique insider's look at and analysis of his/her own community. My research falls under this last category as I have been, over a three-year period, a practitioner in the field of Planetary Defense using my "insider's" positioning to identify the evolutions and stressors of my field of practice.

4) Methods

Using direct observation

No matter what the positioning adopted may be, the ethnographer has to come in his field with a suitable method to observe and understand the community he/she is entering. Some start their field work with specific theoretical questions in mind. Others use the method of direct observation[117]: they come into a field without a specific set of theories and find in what they observe some questions worth pursuing further. The observer will then compare these new

[117] ARBORIO, A-M., FOURNIER, P., *L'Observation Directe*, Armand Colin, Paris, 2015.

questions to existing theories. This direct observation approach has been a common practice of the School of Chicago, especially used for workplace sociology. Direct observation does not, however, entail that the observer will participate in the group's activities and largely depends on the field work opportunities available to the observer.

Using participative observation

It can first be noted that many field works may not allow for participative observation as the ethnographer would, to that purpose, need to gain a function or obtain a position within his/her observed community, which can be challenging. Moreover, many field works can be conducted without proper funding, which often does not allow the unpaid researcher to participate in the group's activities for long periods of times. This is all the more regrettable as, whenever available, participative observation for extended periods of times can be greatly useful in order to build an in-depth and more personal understanding of the researcher's community.

For this research, I had the opportunity of conducting some direct observation while attending national and international expert meetings[118] as well as practicing participative observation when I took part in the biennial Planetary Defense Conferences 2017 and 2019 and their respective Planetary Defense simulation scenarios.

4) Short and long-term field works

A temporary role

Most ethnographers come to join their field for a limited period of time. They are often academics like, for instance, Wacquant and Anteby who selected what they considered an interesting field to explore namely and respectively, a boxing club in Chicago and the Harvard Business School (HBS). They both were participant-observers. However, they were soon to leave their recently studied community once their research was over: Wacquant got back to

[118] Cf. Field work list introduced earlier in this chapter.

teaching sociology at Harvard while Anteby ended up leaving HBS to go and pursue his teaching career at Boston University (B.U). Rarer are the Ethnographers staying (or allowed to stay) in the world they studied. Wacquant, for example, insisted several times during his research on the fact that he had envisaged quitting his academic life to become a professional boxer, but finally decided to stick to his "original plan" and get back to academia. Anteby, on the other hand, reflected for a while on the importance of continuing his research, while getting the feeling that his writing on his own colleagues and the institution he was part of could jeopardize his professional career development. He was particularly concerned that it might derail his tenure track and left for B.U prior to the publication of his research on HBS.

Day-to-day observations

Some ethnographies can be made on a day-to-day basis, the way Jounin described his journey with construction workers in "*Chantier interdit au public, enquête parmi les travailleurs du bâtiment*"[119]. For his part, Peneff, observed day-to-day activities in the emergency room of the Parisian hospital he worked in, a study described in "*L'Hôpital en urgence*"[120].Whyte did likewise in "*Street Corner Society*"[121].

Being "on site": The benefits of immersive long-term stays

In order to become fully immersed in their field work, Wacquant spent more than three years at the Chicago Woodlawn boxing gym and Peneff worked for one year as a part-time hospital porter. Likewise, Jounin[122] spent a full year working as a construction worker in Paris. As Peneff explains in *l'Hôpital en urgence*:

[119] JOUNIN, N., *Chantier interdit au public, Enquête parmi les travailleurs du bâtiment*, La Découverte, Paris, 2009.
[120] PENEFF, J., *L'Hôpital en Urgence*, Editions Métailié, Paris, 1992.
[121] WHYTE, W.F., *Street Corner Society, La structure sociale d'un quartier italo-américain*, La Découverte, Paris, 2002.
[122] JOUNIN, N., *Chantier interdit au public, Enquête parmi les travailleurs du bâtiment*, La Découverte, Paris, 2009.

"The sociologist's query to be involved in the work for a long period of time gave him an immediate advantage over the attempts of other outsiders (journalists, researchers, managers)."[123]

Ethnographers are consequently used to settling in a community to better explore it from within. For example, Whyte moved into an apartment above a pizzeria in the Italian corner of NYC for the entirety of his research.

Other ethnographers, such as Helmreich in "*Alien Ocean, anthropological voyages in microbial seas*"[124] focused instead on key-moments, such as international conferences and governmental decisions as axes to their stories. Studies like Vertesi's[125] and Messeri's[126], who are both close to specific teams in space research laboratories, can be seen as a mix of both practices: experiencing, on the one-hand, a day-to-day immersion into their observed communities but also reporting on long-term stay observations within their space research teams.

My positioning is somewhat in keeping with that: when I was sent to key Planetary Defense conferences such as the biennial 5-day long PDCs 2017 and 2019, I would actively conduct day-to-day observations for my research, take notes and interact through participative observation. However, regarding my part as a practitioner in the field, I believe it would be more accurate to define my field work as permanent rather than as a "long stay".

5) Cyber evolutions

In this digital age, some communities do not need a physical location, nor do they have one. The ethnographers of internet communities, of support groups created on the internet or even

[123] PENEFF, J., *L'Hôpital en Urgence*, Editions Métailié, Paris, 1992, p9, translated from the French : « *La demande de participation au travail sur une longue période permit d'emblée de distinguer favorablement la tentative du sociologue par rapport à celle d'autres étrangers (journalistes, chercheurs, cadres* ».

[124] HELMREICH, S., *Alien Ocean, anthropological voyages in microbial* seas, University of California Press, 2009.

[125] VERTESI, J., *Seeing like a Rover, How Robots, Teams, and Images Craft Knowledge of Mars*, The University of Chicago Press, Chicago, 2015.

[126] MESSERI, L., *Placing Outer Space, An Earthly Ethnography of Other Worlds*, Duke University Press, Durham, 2016.

of international communities, such as the one of Planetary Defense, do not have headquarters that ethnographers could settle in per se. The space community, like many others, has grown to become a multi/transnational sector and requires a multi-site form of ethnography. As a result, an online presence through intensive email exchanges, skypes and web-conferences became part of my day-to-day field work.

6) A way of looking back: autoethnographies

Most often, autoethnographies are conducted by experts in their own domain who decided to turn a critical eye on their profession in order to extract the lessons learned from their career environment. Illustrating such an approach is the autoethnography of Dubé entitled "*Parcours d'une formatrice d'enseignants au Québec*"[127]. Once retired, Dubé wrote the autoethnography of her professional experience, as a form of legacy to the generations to come. Similarly, sociologist of education Masson worked on the organization of French high schools in the 1990s and applied his professional academic knowledge in his book "*Les coulisses d'un lycée ordinaire: Enquête sur les établissements secondaires des années 1990"*[128]. One might say they were as carried by the field they were exploring as they were guided by the training and theoretical knowledge that allowed them to decode their surroundings. Most often, however, autoethnographies seem to be written by retired professionals wanting to provide feedback on a domain they spent their careers in.

In that sense, I would not consider this research as an autoethnography, but rather as an ethnographic work based on direct and participative observations, done by a practitioner who used her positioning as a young professional discovering the field of Planetary Defense to conduct a scholarly research.

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[127] DUBE, G., *Parcours d'une formatrice d'enseignants au Québec*, L'Harmattan, Paris, 2015.
[128] MASSON, P., *Les coulisses d'un lycée ordinaire : Enquête sur les établissements secondaires des années 1990*, PUF, Paris, 1999.

7) Ethnographic tool: The importance of a field journal

Ethnographers follow a methodological routine composed of ethnographic notes usually written down in a journal by the researcher during his/her field work. This field journal helps the research keep track of his/her experience all along his/her journey into the discovery of the community he/she is investigating. Journals can take the form of a physical paper diary, in which the researcher will confide in regularly about the different experiences, emotions and questions which arose each day. Journal entries can then be used as data for the researcher's writing of his/her ethnographic research. It can serve as a reminder of useful quotes from key actors as they are written in the heat of the moment but can also allow the researcher, when looking back at his/her notes, to re-discover his/her own journey and deepen his/her understanding of the field he/she was investigating. Some authors will write in their journals either at the end of each day like Anteby, or on the fly while in the field. Note-taking on the fly gives the researcher the opportunity to write down more details that would otherwise be easily forgotten. However, such notes need to be revisited later on, so as to order and make sense of them. Because of its practicality, I decided to use a digital journal, writing my entries on my computer in a dedicated file. This also allowed me to write some of my observations on the spot, while participating in meetings.

IV- The limits of the ethnographic method

1) The struggles intrinsic to looking from within

As Bourdieu explained in *Homo Academicus*, it can become difficult for an embedded ethnographer to distance him/herself from the world he/she observes and from the identity he/she developed within such world:

"By choosing for object the social world we are caught in, we are bound to encounter […] a certain number of basic epistemological issues*."* [129]

Having trouble detaching oneself from the indigenous experience is therefore to be expected.

2) A non-reproducible experience and a partial view

As most field works are based on one-time opportunities and luck, it is understood that they may not be reproducible. As Jounin explained in "*Chantier interdit au public*":

"Reproducing the method is very unlikely, bound as it is with the opportunities offered by the field and the very personality of the researcher".[130]

Furthermore, it is to be noted that the researcher will only see what he /she is allowed to see by the community. For each ethnographic research, it is important that the researcher be clear on what he/she had and did not have access to, and on what will remain inaccessible to him/her. As Schwartz explained in "*Le monde privé des ouvriers*":

"I knew, when I started this research, that the most intimate layers of the private sphere would stay largely, if not entirely, inaccessible to me." [131]

Being able to witness the birth of the ad-hoc legal working group and the growing interest of SMPAG in social science fields seems to have been a unique and non-reproducible opportunity to research the field of Planetary Defense from within. On the one hand, as a "space debutante", I often found myself able to ask questions meant to learn my own profession while doing this ethnographic work. But I do acknowledge the fact that as a junior in such a field, I missed some

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[129] BOURDIEU, P., *Homo Academicus*, Stanford University Press, Paris, 1990, p.11, Translated from the French : *« En prenant pour objet un monde social dans lequel on est pris, on s'oblige à rencontrer […] un certain nombre de problèmes épistémologiques fondamentaux ».*

[130] JOUNIN, N., *Chantier interdit au public, Enquête parmi les travailleurs du bâtiment*, La Découverte, Paris, 2009, p.243, translated from the French : " *La reproductibilité de la méthode est faible, tant elle est liée aux opportunités que laisse le terrain et à la personnalité même de l'enquêteur.* "

[131] SCHWARTZ, Olivier, *Le Monde Privé des Ouvriers*, p.35, translated from the French : "*Je savais, certes, en entamant cette recherche, que les couches les plus intimes de la sphère privée me resteraient largement, si ce n'est totalement, inaccessibles* ".

information about Planetary Defense such as that shared during high level meetings like the NASA-FEMA simulation/coordination exercises[132]. As I did not have access to that information, I therefore endeavored to study and analyze it through their public minutes.

3) Debates on ethnographic neutrality and guilt

The notion of "neutrality" is up for debate in most if not all ethnographic studies. It may be summed up by the following questions: Does the ethnographer come in with pre-conceived notions? If so, how is he/she to understand them and distance him/herself from them? Can neutrality really be reached? Furthermore, as Van Maanen and Kolb explained in "*Professional Apprentice*" [133], it is difficult for any ethnographer entering an unknown field not to feel like a sort of "traitor", reporting on what he/she is observing:

"*We live with the persistent idea that, deep, down, field work could be considered a betrayal".*

Such personal limits and struggles are unavoidable and I did take them into consideration throughout my field work research. For example, I kept being aware that I was both an insider as well as an observer within SMPAG. This dual positioning encouraged me to seek advice from ethnographic tales to maintain neutrality. I am however aware that, like any researcher, I have intrinsic biases. To detect those, I turned to my committee for guidance.

Conclusion

Using ethnography to explore and analyze the field of Planetary Defense appears to be a useful but nonetheless delicate endeavor. Nevertheless, much like Peneff whose work at the hospital resulted in practical managerial lessons learned that were directly applicable to the field he was

[132] Cf. NASA-FEMA exercise 2016 summary: https://www.nasa.gov/sites/default/files/atoms/files/ttx3_final_report_1may2017_final_3.pdf, [checked on 06/26/2019]

[133] VAN MAANEEN, J., KOLB, D., "The Professional Apprentice: Observations on Fieldwork Roles in Two Organizational Settings", In *Research in the Sociology of Organizat*ions, Greenwich CT: JAI Press, 1989.

working in and being part of, I hope that my findings will be helpful to my Planetary Defense community and will devote the fifth and final chapter of this dissertation to that end.

CHAPTER 3

AN ANALYSIS OF PLANETARY DEFENSE POLICY AND DECISION-MAKING PROCESSES

*"*It is not about Hollywood, it is not about movies, this is ultimately about protecting the only planet we know right now to host life*"*. - James Bridenstine, NASA Administrator (2018-present), April 29th 2019, opening ceremony of the Planetary Defense Conference 2019, Washington DC, USA.

Introduction

Based on the direct and participant ethnographic observations I made of the field of Planetary Defense, I will address in this third chapter my main research hypothesis that throughout the past twenty-five years Planetary Defense has morphed from a scientific field dedicated to asteroid detection to a broad managerial international and scientifically-led structure.

The questions raised in this chapter are: How did Planetary Defense scientists organize themselves? What were the reasons behind the developments of their own Planetary Defense national and international policies? Which elements enabled this scientific community to become a structured international entity led by Planetary Defense experts?

To answer these questions, I will examine how the main national and international policies shaped the field of Planetary Defense from 1994 to 2019. My investigation will follow a chronological order that will stress the temporal, technological and managerial characteristics of the evolution.

First of all, it is important to note that the rapid growth of Planetary Defense science and NEO detection occurring over that time span was correlated by new national and international institutions that were established by dedicated policies. National budgets were created by the United States and European Space Agencies (NASA and ESA); and official offices and structures were set up nationally and internationally to host these institutions. All of the above mentioned institutions were established with a view to fulfilling specific managerial roles. For example, as will be developed in my SMPAG case study, SMPAG's Terms of Reference clearly state that SMPAG would serve as first responder to design a mitigation mission if an object larger than 50m was detected to have a probability of impacting the Earth higher than 1%. This specific role paved the way for the economic, political and structural growth of the Planetary Defense field whose historical background I will examine after defining the terms most often used in Planetary Defense to understand the specificities of the field and its stakes.

I- Definitions

Planetary Defense

According to the NASA Planetary Defense Coordination Office (PDCO)[134], Planetary Defense is the term used to encompass all the capabilities needed to detect an asteroid or a comet which might impact the Earth, to give warnings, and to either prevent these impacts or mitigate their

[134] Cf. https://www.nasa.gov/planetaryDefense/overview, [checked on 06/26/2019]

possible effects. Planetary Defense is considered applied planetary science to address a Near Earth Objects impact hazard.[135] Planetary Defense involves:

- Finding and tracking near-Earth objects that pose a hazard of impacting Earth;
- Characterizing those objects to determine their orbit trajectory, size, shape, mass, composition, rotational dynamics and other parameters, so that experts can determine the severity of the potential impact event, warn of its timing and potential effects, and determine the means to mitigate the impact; and
- Planning and implementing measures to deflect or disrupt an object on an impact course with Earth, or to mitigate the effects of an impact that cannot be prevented. Mitigation measures that can be taken on Earth to protect lives and property include evacuation of the impact area and movement of critical infrastructure[136].

Fig. 1. The five pillars of Planetary Defense Management (source of graphic: NASA[137])

Asteroids

[135] *Ibid.*
[136] Cf. https://www.nasa.gov/planetaryDefense/faq, [checked on 06/26/2019]
[137] Cf. https://www.nasa.gov/planetarydefense/overview/, [checked on 06/26/2019]

Asteroids, also called minor planets, are rocky, metallic, and/or icy pieces of planetary debris that never formed into a planet or that were created by catastrophic disruptions of earlier-formed protoplanets. They date from the early formation of our solar system about 4.6 billion years ago. Most of the nearly 800,000 currently-known asteroids[138] orbit within the asteroid belt between Mars and Jupiter or are Trojans, meaning that they share an orbit with a larger planet (most with Jupiter), but do not collide with it[139]. Asteroids that cross Earth's orbital path are known as Earth-crossers[140]. The population is estimated to contain between 1.1 and 1.9 million asteroids larger than 1 kilometer (0.6 mile) in diameter, and millions of smaller ones[141]. The three main classes of asteroids are based on their composition: C-type (chondrite), S-type (stony), and M-types (metallic). Occasional close encounters with planets or other asteroids can change the asteroids' orbits, occasionally redirecting them onto paths that cross the orbits of the planets. More than 350 asteroids are known to have companion moons (some have more than two)[142]. While numerous, these objects are small: the total mass of all the asteroids combined in our solar system is less than 10% that of Earth's Moon.

Near-Earth Objects (NEOs)

The term 'Near-Earth Object' (NEO) refers to any asteroid, comet whose orbit brings it close to Earth (within 50 million kilometers, or approximately 7800 Earth radii). Comets are generally icy bodies that have very eccentric orbits and a wide range of orbital periods[143]. Because comets comprise less than one per cent of the NEO population[144], I will focus on the

[138] Cf. https://minorplanetcenter.net/iau/lists/ArchiveStatistics.html, [checked on 06/26/2019]
[139] Trojan asteroids can be ahead or Cf. https://solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/in-depth/, [checked on 06/26/2019]
[140] Cf. https://solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/in-depth/, [checked on 06/26/2019]
[141] Cf. https://minorplanetcenter.net/iau/lists/ArchiveStatistics.html, [checked on 06/26/2019]
[142] Cf. http://www.johnstonsarchive.net/astro/asteroidmoons.html, [checked on 06/26/2019]
[143] *Near Earth Objects and Planetary Defense*, United Nations Office of Outer Space Affairs, p.8, http://www.unoosa.org/documents/pdf/smpag/st_space_073E.pdf, [checked on 06/26/2019]
[144] Cf. http://www.unoosa.org/documents/pdf/smpag/st_space_073E.pdf, [checked on 06/26/2019]

other 99% and will generally refer to asteroids when addressing the question of NEO threats. They range in size from a few meters to several hundred kilometers wide (like Vesta)[145], with smaller objects being far more numerous than larger objects. These asteroids sometimes reach the ground, but even those that disintegrate in Earth's atmosphere – like the one that caused the Chelyabinsk event in 2013[146] – can create explosive airbursts, with resulting shockwaves that may shatter glass, damage buildings and injure anyone who happens to be nearby.

NEO: A natural hazard

In disaster management, a distinction is made between human-made related hazards, such as those of Space Debris (which are, by definition, human-made objects[147]) and natural hazards such as potential volcanic eruptions, tsunamis and asteroid impacts. In this regard, a Near-Earth Object impact threat could be considered a natural unpredictable hazard. A lookback at the historic background of asteroid-related catastrophes sheds light on why this type of space hazard arouses a growing interest and response in recent years.

Potentially Hazardous Objects/Asteroids (PHO/PHAs)

NEOs which come much closer to Earth (within 8 million kilometers: about 1250 Earth radii, or about 21 times the distance between the Earth and Moon) and of a size large enough (more than 140m[148]) to cause significant damage on Earth on at least a regional scale are called Potentially Hazardous Objects. Of the more than 20,000 NEOs known today[149], there are nearly

[145] Cf. https://solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/in-depth/, [checked on 06/26/2019]
[146] Cf. ROFFEY, R., *Russia's EMERCOM: Managing emergencies and political credibility*, FOI Ed., 2016: https://www.foi.se/rest-api/report/FOI-R--4269--SE, [checked on 06/26/2019]
[147] Cf. IADC definition of Debris: https://www.iadc-online.org, [checked on 06/26/2019]
[148] Cf. https://cneos.jpl.nasa.gov/about/neo_groups.html, [checked on 06/26/2019]
[149] Cf. https://minorplanetcenter.net/iau/lists/Unusual.html, [checked on 06/26/2019]

2,000 objects classified as potentially hazardous objects (PHOs). Many have a non-zero chance of hitting our planet[150]; indeed, of these 2,000 PHOs, 865 have been determined by the American and European Space Agencies as requiring close follow-up observation[151].

Setting standards

Based on these distinctions, The NASA Planetary Defense Coordination Office has also set standards regarding possible damage caused by an asteroid impact, depending on its size[152]: An impact from an object measuring 140 meters or larger is predicted to produce damaging local-scale effects, those larger than 300 meters might have large regional effects, and objects 1 kilometer or larger could have a global effect on the Earth[153]. Statistically, about two thirds of Near Earth Objects larger than 140 m still remain to be discovered[154]. Even an NEO as small as 10 meters diameter, under certain conditions and assumptions, could be hazardous and its impact could lead to significant local damage and injuries[155].

However, Planetary Defense is not limited to the scientific field it started out to be. It has expanded into two other branches: that of Planetary Defense Management and that of Planetary Defense Policies. These three aspects will be presently examined and analyzed.

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[150] Cf. http://www.esa.int/Our_Activities/Space_Safety/Risky_asteroids, [checked on 06/26/2019]

[151] All are listed on the European Space Agency "risk list". Cf full list at: http://neo.ssa.esa.int/risk-page;jsessionid=38c0fcf9b6c490c91fda2ceb8928, [checked on 06/26/2019]

[152] Cf. https://www.nasa.gov/planetaryDefense/, [checked on 06/26/2019]

[153] Cf. Planetary Scientist Cathy Plesko's interview with WIRED during the Planetary Defense Conference, May 2019, https://www.youtube.com/watch?v=IURHSh4ISeo&t=46s, [Checked on 06/26/2019]: "*A city-killer would be a football-field-sized so 100-150meters by 250 meters. It also depends if it is denser. With a metallic composition, a 100m asteroid could be a city-killer. If it is less dense, it would create an airburst which, over a populated area, would be dangerous. Objects up to a kilometer would create a global disaster because it is going to kick up a lot of gunk into the atmosphere and it is going to change the climate in pretty bad ways. If you look back into the early 1800s, (around the 1820s), there was a super volcanic eruption that put a bunch of ash up into the upper atmosphere and blocked out enough sun that they didn't have summer in the northern atmosphere that year. Crops in the US failed, there was famine, it snowed in New England that summer in July and that's the kind of things we would see; so we need to do our homework to be ready if/when a n asteroid were to be detected with an orbit crossing the Earth*."

[154] Cf. https://www.nasa.gov/planetaryDefense/faq,[checked on 06/26/2019]

[155] *Near Earth Objects and Planetary Defense*, United Nations Office of Outer Space Affairs, p.11, http://www.unoosa.org/documents/pdf/smpag/st_space_073E.pdf, [checked on 06/26/2019]

II- Historical background of NEO research and detection (1990-2000s)

To understand how Planetary Defense management came to be, I will first present a quick history of Planetary Defense management and policy, through the examination of asteroid exploration and coordination efforts since the early 1990s. Even though a clear timeline is difficult to establish as events presented below can be of quite different natures (natural phenomena, national endeavors and international efforts) a chronological order will still be preferred, in order to highlight the parallel development of certain entities and projects, enablers of the emergence of the coordination and management of the scientific research field of Planetary Defense:

65-66 million years ago: The Chicxulub asteroid impacted the Earth and is believed to have caused a mass extinction of most non-flying dinosaurs and many other species.

1883: In the early 2000s, NASA research scholar Foy analyzed anew historical astronomical observations from Mexico and suggested that in 1883 the Earth narrowly avoided a "near-extinction event"[156]. He determined that a billion-ton comet missed the Earth by only a few hundred kilometers. Each fragment was bigger than the asteroid or comet thought to have exploded above Tunguska, Russia, in 1908. He estimated that if that comet had hit the Earth, it would have had 3,2775 times the impact of the Tunguska event and would have been devastating enough to wipe out to extinction many animal species, including humans.

1908: It is estimated that a 100-million-kilogram asteroid entered Earth's atmosphere traveling at a speed of about 54,000 kilometers per hour and heated the air surrounding it to 25,000

[156] Foy, H. "Reanalysis of 1883 Observations Suggests a Billion-Ton Comet Buzzed Earth", Space Safety Magazine, Jan 2nd 2013, http://www.spacesafetymagazine.com/2013/01/02/reanalysis-observations-recorded-1883-zacatecas-mexico-suggest-fragments-billion-ton-comet-close-earth/, [checked on 06/17/2019].

degrees Celsius. At a height of about 8.5 kilometers, the combination of pressure and heat caused the asteroid to fragment and annihilate itself, producing a fireball and releasing energy equivalent to about 185 Hiroshima bombs above Siberia. [157]

1991-1993: NASA's *Galileo* mission was the first spacecraft to encounter an asteroid up close: it flew past asteroids *Gaspra* in 1991 and *Ida* in 1993 and discovered the first moon of an asteroid Dactyl, orbiting Ida[158].

1994: The impacts of Comet Shoemaker-Levy 9 on Jupiter in 1994 led to efforts to discover, track and catalogue NEOs, especially those that may pose a hazard to the Earth[159].

1995: A United Nations International Conference dedicated Near-Earth Objects was held at United Nations Headquarters in New York. Organized by the UN Office of Outer Space Affairs (UNOOSA), the Conference raised the awareness of Member States to the potential threat from NEOs and proposed an expansion of existing observation campaigns to detect and track NEOs. It was one of the first gatherings of this magnitude to discuss the phenomenon at an international level. Policy perspectives emerged from the Conference to increase awareness of the threat from NEOs and to provide guidelines for cooperative observation, research and mitigation programs.

1998: NASA launched its first dedicated Near-Earth observation program[160].

[157] Cf. https://science.nasa.gov/science-news/science-at-nasa/2008/30jun_tunguska, [checked on 06/26/2019].
[158] Cf. https://solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/exploration,[checked on 06/26/2019].
[159] Cf. https://solarsystem.nasa.gov/asteroids-comets-and-meteors/comets/p-shoemaker-levy-9/in-depth/ and *Near Earth Objects and Planetary Defense*, United Nations Office of Outer Space Affairs, http://www.unoosa.org/documents/pdf/smpag/st_space_073E.pdf, [checked on 06/26/2019]
[160] Cf. https://cneos.jpl.nasa.gov/about/search_program.html, [checked on 06/26/2019]

1999: NEO hazards received further attention at the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), which resulted in the Vienna Declaration on Space and Human Development. The Vienna Declaration contained 33 specific recommendations, endorsed by the United Nations General Assembly, one of which was to address the need to improve international coordination of activities related to near-Earth objects. In order to implement that recommendation, in 2001 the Committee on the Peaceful Uses of Outer Space established the Action Team on near-Earth Objects (Action Team 14). The work of this Action Team resulted in recommendations for an international response to the threat of near-Earth object impacts. The recommendations[161] provided for an international response to the NEO-impact threat, agreed under the auspices of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS).

2003: The Japanese Space Agency (JAXA), launched on May 9th, 2003 *Hayabusa*, a robotic spacecraft developed to return a sample of material from a small near-Earth asteroid named 25143 Itokawa to Earth for further analysis. *Hayabusa* was the first spacecraft designed to deliberately land on an asteroid and then take off again.[162]

2004: A close pass to the Earth of 360-meter diameter PHO *Apophis* in December 2004 brought Asteroid impact threat to the headlines. It was then calculated that the asteroid would flyby very close to the Earth again in 2029 but would not impact it.[163]

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[161] As contained in document A/AC.105/L.330, cf. http://www.unoosa.org/oosa/oosadoc/data/documents/2013/aac.105c.1l/aac.105c.1l.330_0.html, [checked on 06/26/2019]

[162] RAYL, A.J.S, "Japan's Hayabusa [MUSES-C] Swings By Earth on Way to Asteroid Itokawa", *The Planetary Society*,2004,https://web.archive.org/web/20101128123442/http:/planetary.org/news/2004/0520_Japans_Hayabusa_MUSESC_Swings_By.html, [checked on 06/26/2019]

[163] Cf. https://cneos.jpl.nasa.gov/doc/apophis/, [checked on 06/26/2019]

2005: *Hayabusa* rendezvoused with Itokawa in September 2005 to study the asteroid's shape, spin, topography, color, composition, density, and history. In November 2005, it landed on the asteroid and collected samples in the form of asteroid dust. A few months earlier, the Torino Scale – a method for categorizing the impact hazard associated with near-Earth objects (NEOs) - was published and has since become a world standard. That same year, the United States Congress passed the *NASA Authorization Act of 2005* to detect, track, catalogue, and characterize the physical characteristics of 90 percent of the NEO population down to 140 meters in size.

2010: On June 3rd, *Hayabusa* successfully returned to Earth with a small amount of asteroid dust to be studied by scientists.

2013: On February 15, 2013 a 14 m-wide asteroid detonated over the Russian city of Chelyabinsk. According to reports from the Russian Emergency Command[164], 1613 individuals were treated at local hospitals for injuries suffered from its effects.

The early 2000s seemed quite rich in asteroid research and detection. All these elements may be taken into consideration to understand the "why" of the recent development of Planetary Defense policies and the construction of a managerial structure at NASA, ESA, and through a United Nations mandate that I will now analyze.

III- The growth of Planetary Defense coordination efforts (2010s)

1) National and regional efforts

American leadership

[164] Cf. Roffey, R., *Russia's EMERCOM: Managing emergencies and political credibility*, FOI Ed., 2016: https://www.foi.se/rest-api/report/FOI-R--4269--SE, [checked on 06/26/2019]

NASA has functioned as the lead entity to coordinate the detection and threat information of Near-Earth Asteroids within the observational community[165]. More than 95% of all NEOs have been discovered by NASA-funded surveys, mainly through detection using ground base telescopes[166].

The recommendations contained in the *National Aeronautics and Space Administration Authorization Act of 2005* (Public Law 109-155) were welcomed by the General Assembly in its resolution 68/75 of December 2013[167]. They proposed to ensure international information in sharing, discovering, monitoring and physically characterizing potentially hazardous NEOs with a view to making all countries aware of potential impact threats, particularly developing countries with limited capacity in predicting and mitigating a NEO impact. In these recommendations endorsed by the United Nations the emphasis was placed on the need for effective emergency response and disaster management in the event of the discovery of a NEO-impact threat.

These recommendations entailed the creation of two entities established in 2014, namely The International Asteroid Warning Network (IAWN) and the Space Mission Planning Advisory Group (SMPAG) which represent important mechanisms at the global level for strengthening the coordination of Planetary Defense.

Moreover, as a result of a set of hearings by the NASA Advisory Committee following the Chelyabinsk explosion in 2013, in conjunction with a White House request to double its budget,

[165] Cf. NASA-FEMA 2014 Planetary Defense exercise: https://cneos.jpl.nasa.gov/pd/cs/ttx14/NASA.FEMA.Exercise.Report.2014.pdf, [checked on 06/26/2019]

[166] https://www.nasa.gov/planetarydefense/, [checked on 06/26/2019]

[167] Cf. The General assembly (…) Welcomes with satisfaction the NASA recommendations for an international response to the near-Earth object impact threat, endorsed by the Scientific and Technical Subcommittee at its fiftieth session and by the Committee at its fifty-sixth session; Resolution adopted by the General Assembly on 11 December 2013 [on the report of the Special Political and Decolonization Committee (Fourth Committee) (A/68/423)] 68/75.

NASA's Near Earth Object Program funding was increased to $40.5 M/year in its FY2014 (Fiscal Year 2014) budget and to $60 M/year in its FY2018. It had previously been increased to $20.5 M/year in FY2012 (about 0.1% of NASA's annual budget at the time)[168], from an average of about $4 M/year between 2002 and 2010[169]. NASA's Planetary Defense budget has consequently increased from $4M/year in 2002 to $60M/year in 2018 and this tendency does not seem to be slowing down, with the Trump administration expressing in 2018 its intension to triple NASA's Planetary Defense budget in the coming years from $60M to $150M/year[170]. Yet, the US National Academy of Sciences review of hazards and mitigation strategies for NEOs estimated in 2010 that the deflection or destruction of a NEO would cost between $1.7 billion to $3.5 billion[171]. This means that the entirety of the expected tripled NASA budget would cover less than 9% of the cost of the lowest estimate for an asteroid deflection mission. Additionally, these estimates were made "without including risks of accidents, mistakes or unforeseen damages in space or on Earth from these activities.[172]"

Nonetheless, with supportive policies, with 95% of NEOs discoveries to its name, with six times ESA's Planetary Defense budget[173], the largest Planetary Defense research budget in the world and the launch in 2016 of the first national Planetary Defense Coordination Office (PDCO),

[168] POWELL, C.S. "Developing Early Warning Systems for Killer Asteroids", *Discover*, August 14, 2013, pp. 60-61.

[169] JOHNSON, L., NEO Observations Program in "United States Government Policy and Approach Regarding Planetary Defense", Agency Grand Challenge Seminar Series, Near Earth Object Programs Executive, NASA HQ, February 28, 2014, pp. 7, 15.

[170] Cf. BENDER, B., "NASA's asteroid defense program aiming for more impact", Politico, September 21st 2018, https://www.politico.com/story/2018/09/21/nasa-asteroid-defense-program-834651, [Checked on 06/26/2019]

[171] Cf. *Defending planet Earth: near-earth object surveys and hazard mitigation strategies*, National Academy Press, Washington, DC, 2010.

[172] *Ibid.*

[173]ESA's Planetary Defense budget was of $10M/year for the fiscal year 2018. Cf. ESA's Planetary Defense Officer, Rüdiger Jehn, http://www.esa.int/Our_Activities/Space_Safety/Hera/Planetary_defence, [checked on 06/26/2019]

NASA leads the way in the worldwide coordination of Planetary Defense science, policy and management.

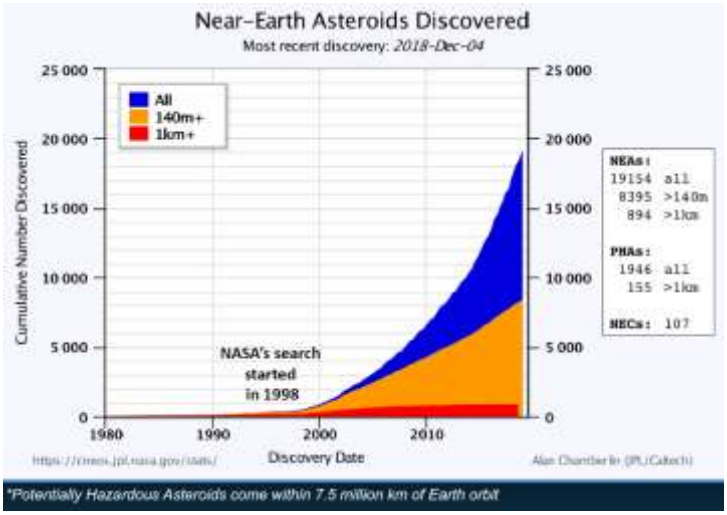

Fig. 2. Progress in the discoveries of NEOs. The red curve shows the inventory of those larger than 1km. (source of graphic: NASA[174])

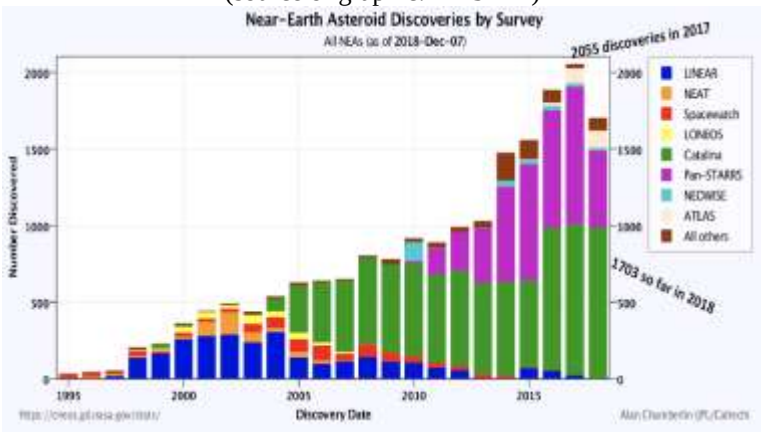

Fig. 3. Detection of asteroids by land observatories and NASA NEOWISE Program (source of graphic: CNEOS JPL NASA[175])

The Planetary Defense Coordination Office (PDCO)

Established by NASA in January 2016[176], the PDCO provides early detection, tracking and characterization of potentially hazardous objects (PHOs). Structurally, the PDCO is the office

[174] Cf. https://cneos.jpl.nasa.gov/stats/totals.html, [checked on 06/26/2019]
[175] Cf. https://cneos.jpl.nasa.gov/, [checked on 06/26/2019]
[176] NASA established the Planetary Defense Coordination Office in January 2016 in response to the NASA Office of Inspector General's 2014 report, "NASA's Efforts to Identify Near-Earth Objects and Mitigate Hazards."

in charge of coordinating all US government efforts in responding to an impact threat[177]. It will issue warnings of the potential impact and its effects; it also conducts studies on technologies for mitigating potential asteroid threats. PDCO is also in charge of providing information to the media and the public on close approaches by PHOs.

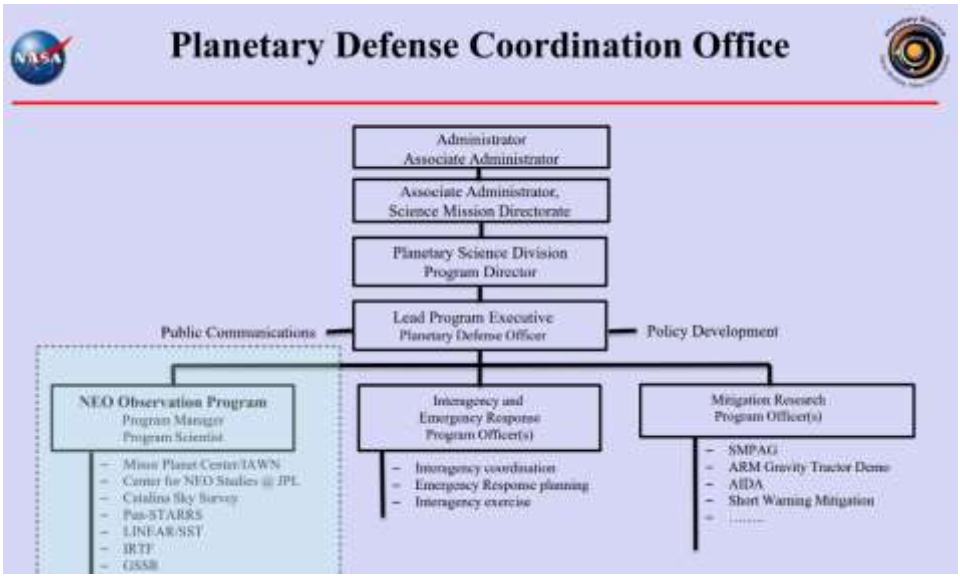

Fig. 4. The NASA Planetary Defense Coordination Office (PDCO) flow diagram (source of graphic: NASA PDCO[178])

The PDCO works with other government agencies to develop and update a National NEO Preparedness Strategy and Action Plan[179]. The PDCO also provides expert input on the nature and effects of asteroid impacts to the Federal Emergency Management Agency (FEMA), so that adequate emergency response can be prepared in the event of a PHO impact that is not

[177] Cf. NASA Policy Directive NPD8740.1, *Notification and Communications Regarding Potential Near-Earth Object Threats*, Jan 27th 2017, https://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPD&c=8740&s=1, [checked on 06/26/2019]

[178] Cf. https://www.nasa.gov/planetarydefense/organization, [checked on 06/26/2019]

[179] Cf. National Near-Earth Object Preparedness Strategy and Action Plan, US National Council For Science, https://www.whitehouse.gov/wp-content/uploads/2018/06/National-Near-Earth-Object-Preparedness-Strategy-and-Action-Plan-23-pages-1MB.pdf, [checked on 06/26/2019]

possible to avoid. As discussed in the joint NASA-FEMA letter of February 2014[180], plans are moving ahead to form a Planetary Impact Emergency Response Working Group (PIERWG). The PDCO will contact the Executive Office of the President and the US Congress and other government agencies if a hazard had greater than a 1% chance of impacting Earth over the next 50 years[181].

The PDCO also coordinates efforts with the space agencies of other nations as a member of the multinational International Asteroid Warning Network (IAWN) and the Space Missions Planning Advisory Group (SMPAG), under the endorsement of the United Nations Committee on the Peaceful Uses of Outer Space[182].

One can notice that one of the key words emerging from the PDCO's website[183] is that of preparedness, a word that is also central to disaster management and to the concerns of NASA's National Near-Earth Object Preparedness Strategy and Action Plan presented below. The PDCO essentially acts as the first governmental asteroid impact prevention structure[184].

2018 The new US National NEO Preparedness Strategy and Action Plan

The US National Near-Earth Object Preparedness Strategy and Action Plan[185] prepared by the interagency working group for detecting and mitigating the impact of Earth-Bound Near-Earth Objects of the National Science and Technology Council, was released in June 2018 by the

[180] Cf. NASA-FEMA 2014 Planetary Defense exercise: https://cneos.jpl.nasa.gov/pd/cs/ttx14/NASA.FEMA.Exercise.Report.2014.pdf, [checked on 06/26/2019]
[181] Cf. https://www.nasa.gov/planetaryDefense/overview, [checked on 06/26/2019]
[182] Cf. National space policy of the United States of America, June 28th 2010, p.16: " The United States Pursue capabilities, in cooperation with other departments, agencies, and commercial partners, to detect, track, catalog, and characterize near-Earth objects to reduce the risk of harm to humans from an unexpected impact on our planet and to identify potentially resource-rich planetary objects.", https://history.nasa.gov/national_space_policy_6-28-10.pdf, [checked on 06/26/2019]
[183] Cf. *Ibid.*
[184] Cf. https://www.nasa.gov/planetaryDefense/overview, [checked on 06/26/2019]
[185] Cf. National Near-Earth Object Preparedness Strategy and Action Plan, June 2018 https://www.whitehouse.gov/wp-content/uploads/2018/06/National-Near-Earth-Object-Preparedness-Strategy-and-Action-Plan-23-pages-1MB.pdf, [checked on 06/26/2019]

White House and is aimed at improving national preparedness to address the hazard of NEO impacts. The Action Plan covers the next 10 years and leverages on existing capabilities, national and international, public and private, to effectively manage the risks associated with NEOs. The progress in implementation is to be reported annually to the US National Science and Technology Council, its Subcommittee on Space Hazards and Security. The strategy contains five goals, supported by associated actions in the areas of: 1) Enhancing NEO detection, tracking, and characterization capabilities; 2) Improving NEO modeling, prediction, and information integration; 3) Developing technologies for NEO deflection and disruption missions; 4) Increasing international cooperation on NEO preparation; and 5) Strengthening and routinely exercising NEO impact emergency procedures and action protocols[186]. The FEMA administrator is to implement response and recovery actions necessary to save lives, mitigate suffering, and limit property damage[187].

NEO impacts pose a significant and complex risk to both human life and critical infrastructures, and have the potential to cause substantial and possibly even unparalleled economic and environmental harm. In the United States, this Strategy and Action Plan provides a road map for a collaborative and federally coordinated approach to developing effective technologies, policies, practices, and procedures for decreasing U.S. and global vulnerability to NEO impacts.

[186] Cf. National Near-Earth Object Preparedness Strategy and Action Plan, June 2018, p.22, https://www.whitehouse.gov/wp-content/uploads/2018/06/National-Near-Earth-Object-Preparedness-Strategy-and-Action-Plan-23-pages-1MB.pdf, [checked on 06/26/2019]

[187] Current authorities granted by the Robert T. Stafford Disaster Relief and Emergency Assistance Act, https://www.fema.gov/media-library-data/1519395888776af5f95a1a9237302af7e3fd5b0d07d71/StaffordAct.pdf and the Post Katrina Emergency Management Reform Act https://emilms.fema.gov/IS230c/FEM0101200.htm, [checked on 06/26/2019]

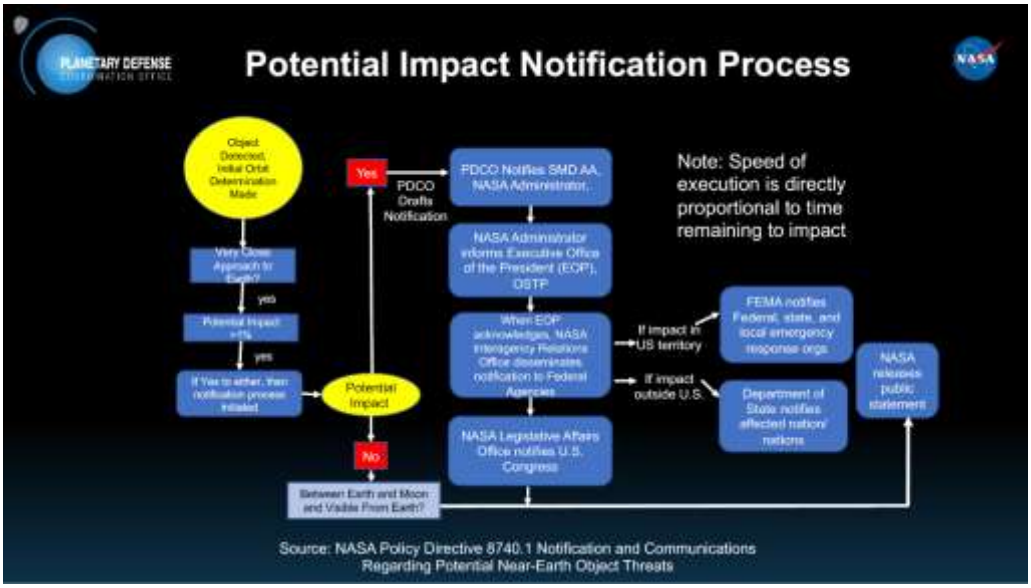

Fig. 5. The USA Planetary Defense inter-agency NEO threat notification process (source of graphic: NASA[188])

But given the proportions such an event could take, international collaboration seems inevitable. For the moment the European Space Agency is the only other space agency with similar structures and programs.

The European Space Agency's Planetary Defense Office (PDO)

ESA's PDO is one of four key elements in the Agency's space safety and security activities. The goals of the Office are to:

- Become aware of the current and future position of near-Earth objects relative to our planet
- Estimate the likelihood of Earth impacts
- Assess the consequences of any possible impact
- Inform relevant parties, e.g. national emergency response agencies[189]

[188] Cf. https://www.nasa.gov/planetarydefense/organization, [checked on 06/26/2019]
[189] Cf. http://www.esa.int/Our_Activities/Space_Safety/Risky_asteroids, [checked on 06/26/2019]

- Develop methods to deflect any “risky asteroids”

The ESA Planetary Defense Office is situated within the Space Security and Safety Office, which is itself a continuation of the ESA Space Situational Awareness program.

In 2019, the ESA Space Situational Awareness has been evolving from a focus on awareness to a wider emphasis on space safety and security activities, including mitigating and preventing threats from space, protecting the Earth, society and economically vital infrastructures on Earth and in orbit[190].

ESA’s upcoming Space Safety Program

ESA’s Space Safety Program is an initiative that intends to elevate ESA’s current Space Situational Awareness to a more strategic level and will be put before the next ESA Ministerial Council by the ESA Director-General in November 2019. The mission statement of the program is: “Protection of our Planet, of Humanity, and assets in space and on Earth from dangers originating in Space. It contains three main areas for space safety, namely Space Weather, Planetary Defense, and Space Debris - Clean Space (prevention and remediation). A Space Safety Office, including a Planetary Defense Office, has already been established.”[191]

Given the scale of the problems both NASA and ESA Safety Space Programs endeavor to tackle, it makes sense to regroup in alliances. I will now consequently present what has been developed in Planetary Defense under the auspices of the United Nations.

[190] Cf. http://www.esa.int/, [checked on 06/26/2019]
[191] Cf. http://www.esa.int/Our_Activities/Space_Safety/Risky_asteroids, [checked on 06/26/2019]

2) International Efforts

With 865 Potentially Hazardous Objects (PHOs) currently requiring close follow-up[192], approximately 500 new NEOs discovered each year, some larger than 140 meters in diameter (the standard for an asteroid which would create a regional/trans-border impact on Earth), the development of a transnational or international structure could support the national and regional efforts to handle NEO trans-border hazards.

For sociologists of natural disaster management, these multilateral organizations are not merely tools at the disposal of States. Quite the contrary: they emerge as pivotal places where standards, rhetoric, knowledge, tools and practices are produced.[193] Pre-existing natural disaster management models already exist at the United Nations, for example. One of them is the *Disaster Charter* or *Charter On Cooperation to Achieve the Coordinated Use of Space Facilities in The Event of Natural or Technological Disasters*. It serves as an example where nations have formed an agreement to share and exchange remote sensing information without charges after a major natural or other disaster, which then may serve in helping to organize and mobilize a recovery mission.[194]

The International Space Station Intergovernmental Agreement (IGA) is another example of international space collaboration. Signed in 1998, it bonds 15 countries into a team that has built and managed the International Space Station, arguably one of the most complex multinational technical achievements ever conducted.[195]

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[192] All are listed on the European Space Agency "risk list". Cf full list at: http://neo.ssa.esa.int/risk-page;jsessionid=38c0fcf9b6c490c91fda2ceb8928, [checked on 06/26/2019]

[193] Cf. REVET, S., *Anthropologie d'une catastrophe : les coulées de boue de 1999 au Vénézuela*, Presse de la Sorbonne Nouvelle, Paris, 2007. p.12.

[194] Source: UNISDR, "From shared risk to shared value – the business case for disaster risk reduction. Global assessment report on disaster risk reduction. United Nations Office for Disaster Risk Reduction (UNISDR), Geneva, 2013.

[195] Cf. PELTON, J. N., ALLAHDADI, (Ed.) F., *Handbook of Cosmic Hazards and Planetary Defense*, Springer, New York, 2015, Volume 2, p. 1060.

Planetary Defense Conferences have also been held since 2001, bringing world experts of the field together every two years. Their chairs, Lindley Johnson (from NASA) and Gerhard Drolshagen (from ESA), became the first chairs of the newly formed United Nations-mandated International Planetary Defense networks IAWN and SMPAG in 2014, underlining the fact that Planetary Defense experts had started developing their network for the past decade and a half and enabled the birth of these two international entities. With a continually rising NEO discovery rate (Figure 2), the need for these two international forums has come to the fore: IAWN and SMPAG are two organizations that meet that demand. Their functions are therefore bound to increase substantially in the future.

IAWN

The International Asteroid Warning Network (IAWN) is made up of partner space agencies, scientific institutions, observatories and other interested parties performing observations, orbit computation, modelling and other scientific research related to the impact potential and effects of asteroid impacts on the Earth. Its mission is to foster a shared understanding of the NEO hazard and optimize the scientific experiments done on these small celestial bodies. IAWN signatories include members from Europe, Asia, and South and North America[196]. IAWN's primary functions are to:

• Conduct and coordinate the search for NEOs that may pose a hazard to the Earth

• Make follow-up observations and characterization of NEOs

• Communicate the risks and benefits of NEOs to the public

• Maintain a clearing house for NEO data

• Maintain a database of impact consequences, and ultimately,

[196] Cf. List of IAWN member institutions: http://iawn.net/about/members.shtml, [checked on 06/26/2019]

• Serve as the principal trusted source of information on NEOs[197]

Fig. 6. List of members of the International Asteroid Warning Network (IAWN) as of June 2019 (source of graphic: IAWN[198])

If IAWN is a network dedicated to the detection and characterization of NEOs, SMPAG is the group that will plan for a mitigation mission if IAWN were to detect an asteroid threat.

SMPAG

The Space Mission Planning Advisory Group (SMPAG) is a forum that links the space agencies of Member States with other relevant entities and lays out the framework, timeline and options for initiating and executing space mission response activities, as well as promoting opportunities for international collaboration on research on technology and techniques for NEO deflection. Its responsibilities and primary purpose include preparing for an international response to a NEO threat through international collaboration based on the exchange of information and to conduct NEO threat mitigation planning activities[199]. The establishment of SMPAG was recommended by the Working Group on Near-Earth Objects (NEOs) of the

[197] Further information on IAWN can be found at www.iawn.net, [checked on 06/26/2019]
[198] Cf. www.iawn.net, [checked on 06/26/2019]
[199] Cf. SMPAG Terms of Reference: https://www.cosmos.esa.int/web/smpag/terms-of-reference-v0, [checked on 06/26/2019]

Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space during its fiftieth session, held in February 2013, and formally endorsed by the Committee at its fifty-sixth session in June 2013 and by the sixty-eighth session of the General Assembly in December 2013**.**

SMPAG addresses the following main areas:

• Reference missions, technology road maps and collaborative research

• Communication and exchange of information

• International treaty and policy aspects - identifying issues for possible detailed reviews within appropriate forums

• Mitigation campaign planning activities

In 2015, SMPAG started developing its work plan, comprising initially 11 work plan items, each of which is the responsibility of one or more members of SMPAG. The work plan is a road map for Planetary Defense at the global level, including agreements on initial criteria and thresholds for response actions to the threat of impacts, considerations of mitigation mission types and technologies, and the mapping of threat scenarios to mission types, as well as developing a plan of action in the event of the discovery of a credible threat[200].

In 2016, SMPAG also agreed to establish the SMPAG Ad Hoc Working Group on legal issues to address possible legal questions related to the work plan items of SMPAG.

Relation between UNOOSA and IAWN & SMPAG

Since their respective creation in 2014, a balance of power has been created between NASA and ESA, with NASA chairing IAWN while ESA chairs SMPAG. Both IAWN and SMPAG submit an annual report to COPUOS and its Scientific and Technical Subcommittee under the

[200] Activity reports and special presentations are available on its website at www.smpag.net, [checked on 06/26/2019]

agenda item on NEOs. Finally, and in compliance with General Assembly resolution 71/90 of December 6th 2016, UNOOSA acts as secretariat to SMPAG.

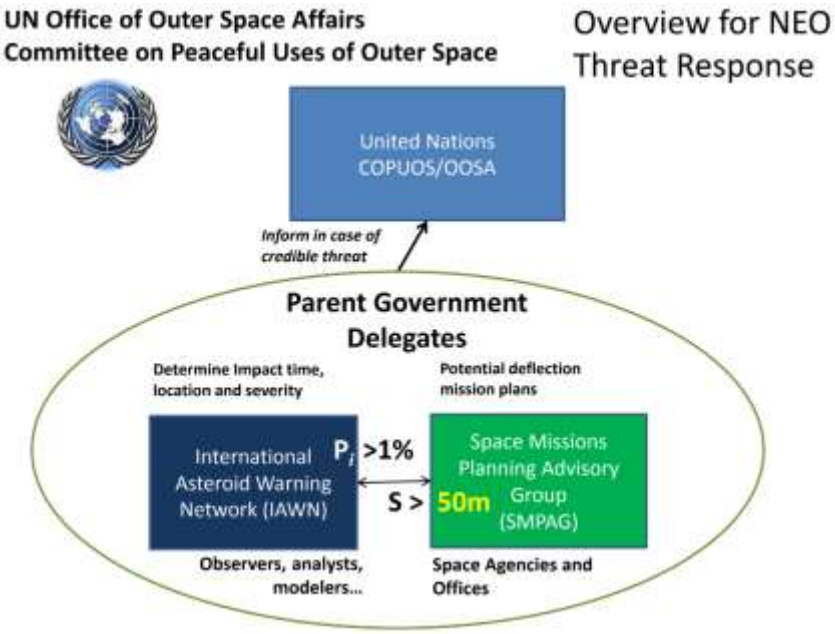

Fig. 7. Relationship of IAWN and SMPAG to the United Nations (source of graphic: UNOOSA[201])

Decision-making processes

In December 2016, NASA published the "National Near-Earth Object Preparedness Strategy", the first iteration of what would become the National Action Plan published in June 2018, which was the product of the Interagency Working Group for Detecting and Mitigating the Impact of Earth-Bound Near-Earth Objects (DAMIEN) of the National Science and Technology Council (NSTC)[202]. This report states the recommended criteria and thresholds for an impact response action.

In order to explain the key differences between IAWN and SMPAG, I will now present an assessment of the decision-making process for both entities:

[201] Cf. *Near Earth Objects and Planetary Defense*, United Nations Office of Outer Space Affairs, http://www.unoosa.org/documents/pdf/smpag/st_space_073E.pdf, [checked on 06/26/2019]
[202] Cf. https://www.nasa.gov/sites/default/files/atoms/files/national_nearearth_object_preparedness_strategy_tagged.pdf, [checked on 06/26/2019]

First, IAWN will warn of a possible impact for all NEOs exceeding a 1% probability of impact for all objects greater than 10 meters in size. Preparedness actions on the ground should be started if the probability of impact is assessed to be greater than 10%, predicted within 20 years and if the object is characterized to be more than 20 meters in size.

SMPAG, is tasked to start mission option(s) planning when it is warned of the three following elements:

1) of a possible impact predicted to be within 50 years,
2) of an object characterized to be greater than 50 meter in size and
3) with a probability of impact predicted greater than 1%.

In the event of a credible impact threat prediction, warnings will be issued by IAWN. If the object is larger than about 50 m and the impact probability is larger than one per cent within the next 50 years, SMPAG will start to assess mitigation options and implementation plans for consideration by the United Nations Member States. The objective is the global protection of the ecosystem, of human beings at large and their property on Earth, and of human civilization from the effects of a devastating asteroid impact.[203].

To meet these objectives, scenarios have to be carefully imagined, developed and put into practice. Following the creation of IAWN and SMPAG in 2014, the Planetary Defense Conference 2015 introduced a new element to its bi-annual week-long scientific event: a mock Planetary Defense Scenario, meant for Planetary Scientists to rehearse their decision-making skills through a fictional asteroid threat.

The Planetary Defense Conference (PDC) Scenario

[203] Cf. *Near Earth Objects and Planetary Defense*, United Nations Office of Outer Space Affairs, p.12, http://www.unoosa.org/documents/pdf/smpag/st_space_073E.pdf, [checked on 06/26/2019]

I have been able to attend two of the three Planetary Defense scenarios organized in parallel to the biennial PDCS since 2015. I attended the PDCs 2017 and 2019 in Tokyo, Japan and Washington DC USA respectively, each lasting five days. There I was able to observe as well as participate in this mock simulation of an asteroid impact threat. Attendees were planetary scientists, astrophysicists and space engineers working in the field of Planetary Defense. At the end of each conference day, two hours were dedicated to constructing a multi-step process to mitigate the threat. Every day, new information would be communicated and the scientists, paired into teams depending on their expertise, would come up with ways to deflect the asteroid. Some were in charge of conducting and modeling research in order to assess the NEO's physical parameters (density, volume, etc.) and characterize it (shape, velocity, orbit, rotation, etc.). Others had to assess its corridor path (the zone within which the asteroid is to possibly impact the Earth), at which velocity it would be impacting Earth and the damage it may cause. That hazard was then projected onto a given territory revealing its weaknesses. The next step was for experts in disaster management and emergency response to delineate an area at risk and deliver the ensuing results to the concerned communities[204]. The knowledge designed upstream was then delivered downstream to a group of "stakeholders" consisting of other scientists whose responsibility was then to make decisions on which mitigation to attempt.

When interviewed at the Planetary Defense Conference 2019 on why scientists have been rehearsing PD mitigation scenarios for each of the past three PDCs over the past 6 years, here is what Cathy Plesko, Planetary Scientist at Los Alamos National, Laboratory had to say:

"We are doing this now because it is the first time we have been capable of doing it. You can't deflect a tornado or a hurricane right now, you can't glue a fault shut so the San Andreas doesn't

[204] Based on the PDC 2017 and 2019 scenarios.

have earthquakes anymore. But with an asteroid or a comet it looks like we are pretty much there"[205].

Attending both Planetary Defense conferences and role-playing the scenario myself allowed me to experience from within the ways in which planetary scientists train themselves in the decision-making process. It is on these occasions that I noticed that both conference chairs were also SMPAG and IAWN chairs as well as the respective heads of the NASA and ESA Planetary Defense Offices. In order to learn more about what appeared to be a scientifically-led system where the highest levels of each Planetary Defense decision-making structure were held by the same or similar individuals, namely high-level Planetary Defense scientific experts, I decided to conduct a dedicated research into SMPAG, the international Planetary Defense Management group on which the following chapter of this research will focus. It allowed me to analyze how the field of PD is responding to the new challenges and responsibilities of becoming a managerial structure.

[205] Cf. Cathy Plesko Planetary Scientist at Los Alamos National, Laboratory, https://www.youtube.com/watch?v=IURHSh4ISeo, [checked on 06/26/2019]

CHAPTER 4

A SMPAG CASE STUDY, AN ETHNOGRAPHIC DIVE INTO A PLANETARY DEFENSE COORDINATION GROUP

Introduction

In this chapter, I will share my observations and analysis of the ways in which the Planetary Defense SMPAG group has been reaching out to some social scientists in order to inform their decision-making process in the planning of a mitigation response to an asteroid impact threat. In this occurrence, I will use the term "social science" in accordance to the definition of the European Science Foundation[206], which states: "The social sciences are those subjects which examine and explain human beings. This includes a variety of ways – from understanding how minds work, to how societies as a whole function. The major social sciences are Anthropology, Archaeology, Economics, Geography, History, Law, Linguistics, Politics, Psychology and Sociology."

From the observations I conducted, I came to the conclusion that the ways the group is, on the one hand reaching out to social science experts and on the other hand supervising the interaction, illustrative of the managerial powers newly held by SMPAG. This reveals a tension between a form of openness and the will to ensure that the authority to make decisions remains in their hands. I will illustrate this point by explaining in this chapter the way SMPAG reached out to international lawyers, created an ad-hoc legal working group and developed guidelines for such a group to operate, namely that it requested that its physical meetings be scheduled in parallel of scientific events and/or the UNOOSA STSCs and requested the sole control over the publication of the group's results.

[206] Cf. www.esf.org, [checked on 06/29/2019]

Sources

During the third meeting of SMPAG that convened in February 2015, all participants agreed that a summary of each meeting should be made publicly available. As a result, each of SMPAG's meeting minutes since its creation have been made available online on the SMPAG website[207]. I will use these minutes and the time I spent at the SMPAG meetings as coordinator of their ad-hoc legal working group to report on my findings which are two-fold. First, that SMPAG is a self-organized scientific system. Second, that SMPAG's evolution over the past three years, reaching out to social scientists, is representative of the way the scientifically-led field of Planetary Defense has been morphing since the early 2000s into a managerial structure. I will now first detail the list of instances I observed first hand during my field work, where the Planetary Defense community progressively reached out in varied ways to social scientists:

I- Planetary defense and Social Sciences

Since 2013, NASA has conducted annual simulation exercises with the US Federal Emergency Management Agency (FEMA) management, communication and emergency alert experts so as to learn from one another. Immediately after its creation in the fall of 2014, SMPAG reached out to legal experts in 2015 to build an ad-hoc legal working group in order to know from legal experts themselves the leverage they had in resorting to various mitigation methods. In 2016, ESA organized a 3-day workshop dedicated to Planetary Defense and communication (inviting international Planetary Defense experts and journalists) so as to know how they perceived Planetary Defense and how they transmitted their own perception to the general public. Since the Fall of 2016 (6 times in total) the SMPAG Chair has invited the Ad-hoc LWG lawyers at all SMPAG bi-annual meetings and the SMPAG minutes show time after time that longer time

[207] Cf. https://www.cosmos.esa.int/web/smpag, [checked on 06/29/2019]

is spent on discussing legal aspects of Planetary Defense. All these elements show the growing importance granted to the interaction between the Planetary Defense community and social scientists as well as the growing complexity and precision of the topics addressed.

In June 2018, the SMPAG UNSTSC representative acknowledged the lawyers' work in his annual activity report presented at the UNCOPUOS General Assembly, officially stressing their contribution, the importance of the questions they are attempting to answer and the importance of the light they shed on the subject;

For the first time since the first PDC in 2008, the PDC 2017 chairs dedicated half a day of the PDC 2019 5-day program to education and communication. Finally, legal issues became central to the PDC impact scenario 2017 – Indeed, the main question of the table topic exercise scenario focused around the lawful or unlawful use of nuclear devices as a viable mitigation method[208];

At the PDC 2019 they dedicated two half days to law, education and communication, hence double the time previously allocated, organized a lunch panel to exchange with scientific journalists, created two specific categories for "the press" and "legal advisers" into their PDC impact scenario;

They dedicated the one travel award given by the Planetary Defense Conference organizers to a young space lawyer so that she could attend the conference and present parts of the work of the ad-hoc legal working group.

All these examples clearly show the growing importance the Planetary Defense community has empirically granted social scientists. But none was clearer to understand SMPAG's approach to social sciences than its creation of its own ad-hoc legal working group, which I will now analyse in more detail.

[208] Cf. IAA Planetary Defense Conference table topic exercise 2017, http://pdc.iaaweb.org/?q=content/2017-tokyo, [checked on 06/26/2019]

II- THE SMPAG ad-hoc Legal Working Group (LWG)

1) Ethnographic positioning

I conducted research for this chapter while pursuing my professional work as the coordinator of SMPAG's ad-hoc legal working group on Planetary Defense, a role that I started playing in October 2017. Through this work, I had the opportunity to participate in several international meetings that brought together the Planetary Defense scientific community from October 2016 to May 2019. During that time period, I attended two biennial International Academy of Astronautics Planetary Defense Conferences which took place in Tokyo in May 2017 and in Washington DC in May 2019, respectively. As the coordinator of the ad-hoc working group, I coordinated a report dedicated to the legal issues of Planetary Defense, which will be presented for review to SMPAG in October 2019. The work necessitated monthly group calls with a team of fifteen international space lawyers and six Planetary Defense scientific experts, including Lindley Johnson, NASA's Planetary Defense Officer. This enabled me to observe first-hand dynamics between the planetary defense scientific group and the group of the first social scientists invited to join the planetary defense scene.

Launched in 2014, SMPAG brought together a group of fifteen international lawyers the following year (2016) and asked them to provide answers to international law questions which may rise from the planning of a mitigation mission. This ad-hoc working group, which I continue at the time of writing to coordinate, has been tasked by the SMPAG scientific coordination group to answer questions such as: Would a country be liable for damage if the mitigation mission they organized failed? Do countries have an obligation to try to deflect an asteroid once it has been detected? Would it be possible to launch a nuclear device in space in order to deflect the asteroid?

The newness of SMPAG and of the field of Planetary Defense in general made it possible for me to observe the growing place social scientists are starting to occupy within a core scientifically-led structure. In this chapter,

As stated in the SMPAG Terms of Reference, "*The objectives of SMPAG are to (…) build consensus on recommendations for Planetary Defense measures*". To that end, SMPAG members decided in 2015 to start reaching out to legal experts in order to improve their decision-making abilities. I will analyze this progressive openness through new questions (towards communication/ journalism/economics/policy and especially law) but also tension arising from a desire to monitor the interaction; I will also review the process which brought fifteen international legal experts into the scientific structure that is SMPAG; and finally will address the key remaining managerial challenges the group has to face.

2) SMPAG's election system, or how to keep a balance of power between ESA and NASA

After a number of preparatory meetings that go back to 2010, the first formal meeting of the group took place in February 2014 at ESOC in Darmstadt. It was hosted by ESA. ESA Planetary Defense expert scientist Gerhard Drolshagen was elected by consensus as interim chair. Since then SMPAG and IAWN meetings have been organized twice a year: once in late January-early February, linked to the UNCOPUOS Technical Subcommittee meetings organized annually in Vienna; and another time in connection with a Near-Earth Object research main conference/meeting held somewhere else around the world. Such a coordination designed to link SMPAG and IAWN meetings to an already existing conference seems to be common practice in the space world. During the time I spent in the field of Planetary Protection and during the research I dedicated to the Space Debris community, I noted similar practices. When asked why, the organizers explained to me that budget was usually quite limited and that it

made it easier on everyone involved, especially international groups, to pair their responsibilities and group their meetings. Finding a common meeting day for twenty experts coming from around the world, renting a conference room somewhere with an often non-existent budget, and getting these twenty experts to have the authorization from their own organizations to be sent on a mission, leave their work and their team for a few days can be quite daunting given the number of contingencies that need to be overcome. Rather than risking being unable to convene, experts do their best to meet on the margins of the main conferences they have already planned to attend, to exchange ideas with their peers and present their latest results to their colleagues. Organizing SMPAG and IAWN meetings in parallel to the UN Technical Sub Committee meetings means benefiting from the fact that the SMPAG and IAWN members are already all in the same location. Moreover, as the organizer of the Technical Subcommittee meetings but also as the official secretariat of SMPAG and supporter of IAWN, the United Nations Office of Outer Space Affairs, host of the UNCOPUOS Technical Subcommittee every year, provides the room, technical support, food and beverages for the entirety of these two meetings. During the several meetings I attended, I can attest that the IAWN and SMPAG meeting rooms were situated just a couple of floors above the Technical Subcommittee General Assembly room and were scheduled either a day prior to or a day after the end of the Technical Sub-committee meeting. These meetings were consequently, by design, held in conjunction with, and because of, already scheduled Planetary Defense / NEO-related expert scientific events.

The second SMPAG meeting was held in June 2014 in Vienna, in parallel to the UN COPUOS general meeting. The following years, one meeting was held in parallel to the UNCOPUOS

subcommittee meeting in February[209], the other, in conjunction with an NEO-related main conference[210]. At this second SMPAG meeting in 2014, ESA was formally and unanimously elected as chair for the following two years. Since then, no other SMPAG member has proposed another chair as candidate, re-electing instead Drolshagen for three successive two-year mandates in 2014, 2016 and 2018. The same situation happened at IAWN, which re-elected the same NASA Chair 3 times in a row. At the last 2019 SMPAG meeting, however, it was underlined that new candidates should be put forward. To pursue the current balance of power between ESA and NASA, both of which are the respective chairs of SMPAG and IAWN since their creations, one could imagine that roles would be reversed, with the next chairman of IAWN coming from ESA and the one from SMPAG coming from NASA.

3) Opening the door to "outside expertise"

During this second meeting, the decision was made to accept observers to the full meetings from appropriate organizations i.e. "with expertise in fields relevant to the topic of Planetary Defense", say the minutes, and not "with expertise in Planetary Defense". This difference is to

[209] Cf. 3rd (Feb 6th 2015) 6th (Feb 16th 2016) 8th (Feb 1st 2017), 10th (Jan 31st 2018), 12th (Feb 13 2019), SMPAG meeting took place on Feb 6th 2015, once again in Vienna, in the margins of UN COPUOS technical subcommittee meeting. See below for the remaining meetings.

[210] The minutes' report that it was agreed at the 7th SMPAG meeting held in October 14th 2016, that, generally, a yearly full SMPAG meeting should take place on the margins of the STSC session in Vienna. The 2nd meeting was held as a SMPAG Steering Committee meeting at a rotating location, in conjunction with a space-related conference. IAWN and SMPAG were to be regularly invited to the sessions of STSC as observers and were to report annually on the progress of their work. UNOOSA was to serve as the permanent secretariat to SMPAG; SMPAG's 4th meeting (April 9th and 10th 2015) was held at ESA European Space Research Institute (ESRIN) in Frascati, Italy prior to the Planetary Defense Conference 2015 held in ESRIN the following week; its 5th meeting was held on November 10th 2015 at the Residence Inn, National Harbor, MD, USA, on the margins of the meeting of the American Astronomical Society (AAS)'s Division of Planetary Sciences in National Harbor, Maryland, USA; the 7th (October 14th, 2016:) right before the Division for Planetary Sciences (DPD)'s European Planetary Science Congress (EPSC) meetings in Pasadena, USA; the 9th (October 11th 2017) was held in Toulouse, France; The 11th (October 18th 2018) was organized in Knoxville, Tennessee, United States, in conjunction with the meetings of the International Asteroid Warning Network (IAWN); The 13th will be held on September 13th 2019 at the European Southern Observatory (ESO) in Garching, near Munich, preceded by a meeting of the International Asteroid Warning Network on 12 September 2019

be noted. It can be interpreted as an open door to experts from other disciplines. Only a few months later, SMPAG created its own ad-hoc legal working group and allowed fifteen space law experts to attend its meetings. It thus recognized space lawyers as having an expertise "in a field relevant to the topic of planetary defense", which I would interpret as disciplinary inclusive.

In the SMPAG's third meeting the following year[211] , the need for a social science expertise was this time explicitly stated, as shown by the minutes' statement: "The meeting participants recognized that in addition to issues addressed by SMPAG for a real planetary defense campaign, other issues like legal responsibility, decision-making process and financing will have to be addressed which are outside the scope of SMPAG." It can be understood in that statement that SMPAG wishes to remain a strictly scientific group as legal, policy and economics expertise are considered "*outside the scope of SMPAG*". These non SMPAG members are nonetheless invited as observers, SMPAG members - all of whom are scientists - wishing to reach out to the lawyers as a supportive resource.

4) Progressively integrating legal expertise

Legal issues were for the first time considered by SMPAG during their sixth meeting held on February 17th 2016. Two presentations were given to introduce the subject: one on legal issues in Planetary Defense, the other giving an overview of existing space laws relevant for SMPAG[212]. The new step taken was that SMPAG unanimously agreed to establish an Ad-Hoc Working Group on legal issues. Delegations were asked to nominate representatives for the Ad-Hoc Working Group and, in addition, to suggest international space lawyers for the Ad-Hoc

[211] SMPAG's 3rd meeting was held in Vienna on February 6th 2015 in the margins of the UN COPUOS technical subcommittee meeting.
[212] Cf. Presentations by L. Drube and P. Stubbe, DLR, to be found on smpag.net, [checked on 06/26/2019]

WG by May 31st 2016. The first meeting of this Ad-Hoc WG on legal issues was held on the margins of the 54th session of STSC in Vienna in 2017.

As stated earlier, UNCOPUOS has two subcommittees: a technical one and a legal one. Before I was nominated coordinator of the ad-hoc legal working group, I asked the SMPAG chair why they had not asked the legal subcommittee to create its own Planetary Defense working group to tackle the legal aspects of Planetary Defense. I then discovered that both committees worked in parallel rather than jointly. The UNCOPUOS technical subcommittee is attended by scientists and engineers and the UNCOPUOS legal subcommittee is attended by lawyers who are experts in international space law. The objective of SMPAG in creating its own legal working group was consequently to keep the task coordinated by themselves, namely scientists, and not by lawyers. The goal of the ad-hoc legal working group report was to inform scientists and to answer their legal questions. These scientists could thus decide on the ways to design a potential asteroid mitigation mission with a complete set of information, which includes legal questions. Consequently, instead of proposing that a legal report be written on Planetary Defense questions by lawyers within the UNCOPUOS legal subcommittee, with the risk they might end up with a legal report written in a scholarly way that could fail to answer all of their own questions, the SMPAG experts had decided to create their own ad-hoc legal working group. Links with the UNCOPUOS legal subcommittee were, however, not severed as most if not all of the legal experts assembled in this ad-hoc group are also members of the legal subcommittee. Once the SMPAG ad-hoc legal working group report is concluded (it is scheduled to be delivered in the Fall of 2019), the report might eventually be presented by the team of lawyers to the legal sub-committee although this was stated by SMPAG as “not a priority”.

SMPAG's main goal was to have their legal questions answered as efficiently as possible. Creating their own group of lawyers to answer their legal questions is a method that shows how international space law is valued, namely as a form of knowledge that is required by SMPAG in order to make their decisions. However, it can hardly be understood as an open invitation to all social science experts.

The 7th SMPAG meeting, held on October 14th 2016 in Pasadena, USA, strongly focused on determining the ad-hoc legal working group guidelines. Some deserve to be underlined here to better understand the dynamics between both groups. First, it was made clear that the ad-hoc legal working group was to only answer to the SMPAG scientists[213]:

1) It was agreed that the nomination process would be as follow: lawyers would have to be nominated by a SMPAG member and such a nomination would then have to be unanimously approved by all SMPAG members.

2) It was said that the number of members of this Ad hoc WG should be limited to fifteen legal experts and that the group should include four SMPAG members and Planetary Defense technical experts to help provide insight into SMPAG's questions and answer the technical questions the lawyers may have. Consequently, scientists Gerhard Drolshagen from the European Space Agency (ESA) and the Chair of SMPAG, Alan Harris from the German Space Agency (DLR), Bill Ailor from the International Academy of Astronautics and Lindley Johnson from NASA were appointed. DLR planetary scientist Line Drube was to coordinate the group from October 2016 to June 2018 and I, co-chair during that period, became main coordinator in June 2018 after Dr. Drube left her position to pursue new professional opportunities at the Danish Space Agency.

[213] Cf. minutes of the 7th SMPAG meeting on October 14th, 2016.

Altogether, four to five space scientists were to join every phone call and meeting of the ad-hoc legal working group, bringing the composition of this legal group to two thirds made up of lawyers and one third made up of scientists.

In a discussion during the 7th SMPAG meeting, it was stressed that the working group membership should be geographically balanced. Consequently, countries from the Russian Federation and from Asia were invited to nominate their candidates, although none did. It is nevertheless important to note that the lawyers in question, even if nominated by a SMPAG member from their national space agency, were brought in as international law experts and not as national representatives[214].

3) The Ad-Hoc Legal working group was to follow a similar meeting pattern as that of SMPAG and was therefore to meet, as SMPAG does, on the margins of the UNCOPUOS Technical Subcommittee meetings (rather than the legal subcommittee meetings)[215].Through the creation of this working group, SMPAG scientists showed how interested they were and how much they valued exploring the legal aspects of Planetary Defense with experts of those fields. The same could be said about IAWN which states in its terms of reference the importance for both communities to turn to external experts: "Participants in the IAWN recognize the need to consult with experts in science communication, risk communication, public policy analysis and emergency management in developing messages and other content for communication with various audiences"[216]. It is to be noted that the fields of expertise of these external experts are

[214] The subsequent legal report states such disclaimers in its opening remarks: *"The views expressed in this Report are the views of the members of the Ad-Hoc Working Group on Legal Issues and do not express the views of national governments, ministries or agencies."*

[215] Consequently, The Ad Hoc Legal Working Group on planetary Defense's first physical meeting was held on the margins of the 54th Scientific and Technical Subcommittee session in Vienna, which took place January 30th to February 10th 2017.

[216] Cf. IAWN Statement of intent, http://iawn.net/documents/iawn_statement_of_intent.pdf, [checked on 06/26/2019]

different from those chosen by SMPAG, though still pertaining to the social sciences as previously defined in the report on SMPAG's third meeting. But, as these above listed examples show, this scientifically-led system also made sure that they established the necessary conditions ensuring a clear and direct scientific leadership to this transdisciplinary endeavor.

During its most recent and twelfth meeting on February 13th 2019, SMPAG detailed the key lessons learned from the SMPAG Ad-Hoc Legal Working Group Executive Summary: Considering that during an NEO impact threat emergency situation there could potentially be limited time to make decisions and take action, it was advocated that a number of documents related to potentially future planetary defense missions be developed before an actual threat was detected. These documents could address important points that were to be considered before action was taken to mitigate an NEO impact threat. It was envisaged that the points considered include:

- Elements of a mandate for States carrying out a planetary defense mission;
- A draft agreement by the potentially affected State(s) and the State(s) capable and willing to conduct the mission;
- Modalities for the cooperation among States participating in the mission;
- Common procedures to undertake the mission;
- Liability considerations, such as a limitation or a waiver of liability for States conducting the mission and modalities for the compensation of victims;
- Generally agreed criteria for the selection of planetary defense methods; parameters for the need for authorization for certain planetary defense technologies, most importantly Nuclear Explosive Devices (NEDs);

- Safety standards for the conduct of planetary defense missions.

The precision and minutiae of these recommendations contrast with the first report written in 2014 which was less than a page long. This change is evocative of the growing work and dedication to Planetary Defense Management and its international coordination through IAWN and SMPAG.

III. SMPAG remaining challenges

The line between science and politics is blurred in a scientifically-led system where scientists are in charge of making political decisions. In Planetary Defense management, the Planetary Defense scientists are their own policy makers. They are the ones who coordinate efforts with all the other government agencies (FEMA, State Department, White House, etc.) They even train themselves to make decisions on various scenarios they make up every two years internationally at PDC and every year nationally in the United States through planned exercises between the Planetary Defense Coordination Office (PDCO) and the Federal Emergency Management Agency (FEMA). They do so in order to be prepared for an event which in essence remains to date difficult to predict (cf. Figure 8, which illustrates the number of NEOs believed to be as-yet undetected).

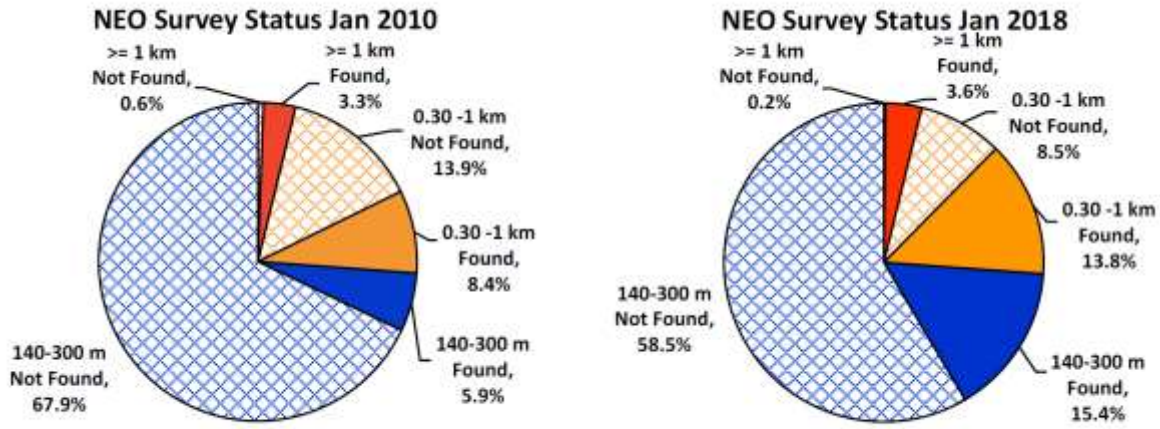

Fig. 8. Evolution of Near Earth Asteroid detection between 2010 and 2018
(source of graphic: NASA [217])

Decision-making responsibilities

In addition to facing the challenge of trying to control an incontrollable threat, these planetary defense scientists have to work with uncertainties and have to consider them all (*e.g.*, that an orbit may be changing, that deflecting maneuvers may change the orbit of the asteroid, thus possibly changing the impact corridor, etc.). They also bear the responsibility of the management of an impact prevention campaign as large numbers of people might be displaced in vain due to a "would-be" impact, or could fail to be moved in time after a partially successful mitigation mission resulted in another zone being impacted. Finally, they have to be careful not to have recurring or too frequent warnings so as to not saturate the news, create unnecessary panics, or desensitize people to an asteroid impact threat. In the PDC scenario, they expressed their desire to "keep people's trust".

[217] Cf. https://www.nasa.gov/planetarydefense, [checked on 06/26/2019]

Conclusion

It can be observed that the transformation of the field of Planetary Defense is giving rise to several forms of tensions, including a tension between interaction and monitoring: on the one hand, SMPAG members are opening up to interactions with other stakeholders as is exemplified by the coordination efforts made with communication, legal and FEMA emergency experts; on the other hand, they are striving to contain the interactions and to maintain control over decision making processes.

In practice, the Planetary Defense community adopted national (FEMA-NASA) and international (IAA PDCs) scenario exercises in 2014-2015, and ever since it has expanded participation in conferences to non-scientists, has opened up award competitions, and one of its branches, SMPAG, has created an integrated working group of legal experts within their ranks. It is also to be noted that the participation of SMPAG members to the SMPAG LWG group calls and meetings has led to open conversations, and regular clarifications about what SMPAG was seeking from the LWG. Their objectives were also quite clear: it was agreed upon in a matter of a few months that the working group would focus on providing lessons and summaries of existing legal knowledge on the topic of Planetary Defense. This method seemed to fit what SMPAG was looking for, namely not getting involved in remarks on the Planetary Defense-related legal issues that remained to be solved, but rather getting an understanding of articles and treaties in international law which could be directly connected to Planetary Defense issues and notably to the questions surrounding the use of nuclear devices in space.

Given SMPAG's current decision-making structure, my observations lead me to think that scientists are gradually recognizing the need for an expertise in the social sciences without desiring to lose their decision-making power. This is why the system remains entirely led by scientists. This being said, it cannot be denied that there is an openness on the part of these

scientists towards transdisciplinary and the complexity it brings with it. But in order for social scientists to be present or represented in Planetary Defense spheres, there is a need for funding that has yet to be addressed. So far social scientists, as any other experts, cannot take part in a conference that is not directly pertaining to their field but in which they would be a very useful addition. This year, the prize for young research awarded to attend Planetary Defense Conference 2019 was given to a young legal scholar. That choice was dictated by the desire to increase the number of legal, policy and economics experts, a desire expressed in the oral conclusion remarks of the previous PDC in Tokyo in 2017. There is, therefore, quite a delicate balance between the status quo in the decision-making process structure and an openness to transdisciplinarity. It would be however hasty to speak of a holistic tendency.

As the LWG group coordinator, it is by experiencing this interaction and by following the empirical method of these scientists that I became convinced it was possible to look likewise at a form of social science dedicated to understanding the functioning of human society during natural emergency crises: sociology of natural disaster. Considering the scope of the population possibly impacted, this field may have much to offer to the world of Planetary Defense Management. In my following chapter, I will consequently detail my logic, analyze and underline the various lessons learned from Sociology of Disaster Management applicable to the growing field of Planetary Defense Management.

CHAPTER 5

LESSONS LEARNED FROM SOCIOLOGY OF DISASTER MANAGEMENT

Introduction

After seeing SMPAG reach out to legal and communication experts and valuing their input to improve their decision-making process; and after understanding that their approach to social sciences was empirical and based on a "lessons learned" approach, I realized I had an opportunity to, on the one hand, explore the field of sociology of natural disaster management and extract lessons learned; and on the other hand, bring such lessons to the field of Planetary Defense. These lessons learned will be helpful to experts for both theoretical and practical reasons:

I- Relevance of Sociology of Disaster Management

I researched sociology of natural disaster literature in order to find lessons learned from previous natural disasters which could be applied to the young field of asteroid threat

management. Douglas's theoretical model seemed to me the most appropriate to follow, as she dedicates her research to explaining how disaster management is informative on the ways actors will perceive in different ways a threat and how this will shape decision-making processes. Examining and analyzing threat perception is key to understanding their decision making process. This study faces a particular challenge in so far as Planetary Defense has to deal with a threat that the human race, in its history, has not yet faced. Consequently, no one has ever experienced how the decision-makers, the PD experts and the general population as a whole, will rise to the challenge. It is thus imperative to develop more rigorous and in-depth understanding of the critical sociological issues that policy makers and others would most likely have to contend with during the management of any future space hazard events.

The relevance of natural disaster management is also apparent in the few following examples regarding geographic and temporal scales, the scotomization effect, and socio-cultural and economic fallout: Indeed, existing natural disasters happening on Earth could be compared to ones that may result from an asteroid impact and help support the current preparedness efforts developed by the Planetary Defense community.

Geographic Scale

As addressed in Chapter 3, depending on the asteroid's characteristics (size, composition, velocity, angle on entry), an impact on Earth could either be local (such as what happened in Chelyabinsk), or regional, national or global. Similarly, the predicted San Andreas fault earthquake commonly known as "the Big One" is foreseen to impact all of the United States in a plurality of ways. The great seismic activity and possible detachment of California from the

rest of the main land would create important economic repercussions: according to the *U.S. Geological Survey Open File Report 2008-1150*, the damage impacts of the earthquake, which was estimated through 13 special studies and 6 expert panels, would cause about 1,800 to 2,000 deaths, 50,000 injuries and $213 billion (FY 2008) in damage and economic losses and severe long-lasting disruption in the fields of agriculture and transportation[218]. This amount represents about the annual budget ($215 bn) of the world's fifth largest economy[219], which would not fail to have national and international repercussions.

Temporal Scale

As also explored in chapter 3, NEO detection has greatly improved over the past twenty five years: it is now possible for an asteroid predicted to impact the Earth to be detected several decades in advance (such as *Apophis* which was detected in 2004 to come back close to the Earth in 2029). Similarly, certain natural disasters are cyclical such as those related to biennial natural phenomenon like El Niño, or prone to happen regularly such as the eruptions of Columbian Nevado del Ruiz volcano. The latter is an example of a large-scale recurring disaster[220] spanning such long periods of time that they outdo human memory. Because Nevado del Ruiz last two eruptions had occurred in 1595 and in 1845, it was difficult for many to accept the danger presented by the volcano; locals called it "the Sleeping Lion"[221]. Yet worse than the actual eruption was what turned out to be the worst volcanic mudflow disaster in historic time and the second worst volcanic disaster of the 20th and 21st centuries[222].

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[218] Cf. https://pubs.usgs.gov/of/2008/1150/of2008-1150.pdf, [checked on 06/26/2019]
[219] California's 2019 budget amounts to $ 215billion out of a total GDP of $ 2.7 trillion in 2018. California ranks fifth after the US, China, japan and Germany, Cf. www.calmatters.org, [checked on 06/26/2019]
[220] The volcano erupted in 1595,1623,1805,1826,1829,1831,1845,1916, Dec 1984-March 1985, 1987-1991 according to the United Nations Disaster Risk Reduction (UNDRR), cf. https://www.unisdr.org
[221] Cf. News coverage of November 13th 1985, www.news.bbc.co.uk [checked on 06/26/2019]
[222] Cf. VOIGHT, Barry, *The 1985 Nevado del Ruiz volcano catastrophe: anatomy and retrospection*, Penn State University Press, Philadelphia, 1989. The flows of lava coalesced and entrained debris, vegetation and ponded water to form lahars, the Javanese word used internationally to mean a mud or debris flow of volcanic origin.

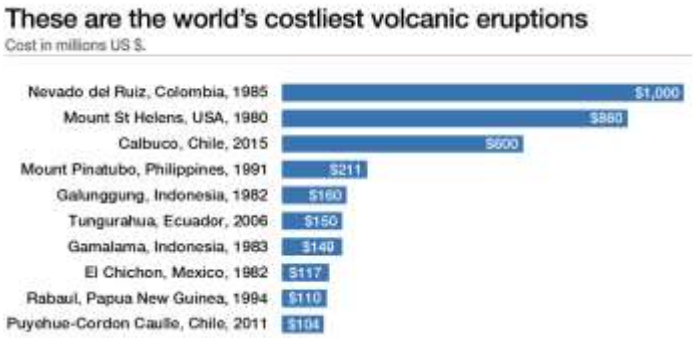

Fig. 9. World's costliest volcanic eruptions (Source: The EM-DAT International Disaster Database[223])

Its death toll ranks fourth in history, behind only to Tambora in 1815 (92,000) and Krakatoa in 1883 (36,000) both in Indonesia, and Mount Pelée, Martinique, in 1902 (28,000)[224]. Nevado del Ruiz may consequently also serve as an example of a recurring disaster whose secondary effects are worse than the irruption itself. Studying such natural disasters may help the Planetary Defense community prepare for major secondary effects resulting from an asteroid impact. Finally, lessons may be extracted from the local knowledge and resilience developed from Columbians in this region, having had to face throughout multiple generations the same recurring natural disaster. Such knowledge may be useful when designing Planetary Defense policies meant to be resilient and adaptable to an impact detected several decades in advance.

Scotomization effect

Some natural disasters are also compounded by the problems of scotomization - a psychological and cultural defense mechanism consisting of automatic or unwilling denial meant as a "blind

These lahars successive lahar waves obliterated Armero (population 29,000), the prime regional agricultural center. About five vertical kilometers below the summit of Ruiz, Armero became a crypt sealed in lahar mud. Over 20,000 were entombed and 5,000 more were injured. In the vicinity of the volcano, all roads, bridges, telephone lines, power grids and aqueducts were damaged or destroyed. Sixty percent of the region's livestock, thirty percent of its grain sorghum and rice crops, and half a million bags of coffee were lost. Lahars buried 3,400 hectares of the agricultural land, damaged or eradicated fifty schools and two hospitals, destroyed 5,092 homes, 58 industrial plants and 343 commercial establishments, and damaged the National Coffee Research Center. About 7,700 were rendered homeless. Total damage exceeded a billion dollars.

[223] Cf. https://www.emdat.be/, [checked on 06/26/2019]

[224] Cf. https://www.unisdr.org, [checked on 06/26/2019]

spot" to avoid any possible anxiety[225] - as well as and the challenge of gaining public trust - which would be vital in a situation where Planetary Defense experts were to advise some populations to evacuate a zone that may be impacted. These "Black Swan" phenomena can be too foreign and unbelievable to be understood and believed by some population. Such is the case with Climate Change, which remains for some "*too big to believe*"[226] considering how catastrophic its consequences have been described within a timeline beyond a human being's average lifetime.

Population displacements

Finally, an asteroid impact may also have indirect social effects which would be hard to predict and be spread out over long periods of time. The Planetary Defense community may learn from socio-anthropologists who have worked on cases of costly and long-lasting natural disasters such as the ones which impacted the Japanese city of Fukushima on March 11th 2011. The earthquake and tsunami which impacted Fukushima are considered the costliest natural disaster in human history, with a cost estimated at $235 billion and which Japan has not yet fully recovered from. Together, they resulted in almost 16,000 deaths, as well as 6,000 people injured and 2,500 still missing. More than 470,000 people were ordered to leave their homes and about 174,000 were still displaced in march 2016[227]. Such a problem of population displacement is one that would need to be taken into consideration by the Planetary Defense community. As illustrated in figure 10 below, The United Nations Refugee Agency estimated that out of the 70.8 million people forcibly displaced worldwide, 80% live in countries neighboring their

[225] The notion of scotomization will be explored in greater details later on in this chapter (p.114).
[226] Cf. GORMAN S., Gorman. J., "Climate Change Denial, Facing a reality too big to believe", *Psychology Today*, Jan 12, 2019, https://www.psychologytoday.com/us/blog/denying-the-grave/201901/climate-change-denial, [checked on 06/26/2019]
[227] Cf. According to the Reconstruction Agency, set up by the Japanese government to oversee the reconstruction of the country's infrastructure, industry and livelihood.

countries of origin. When rehearsing an asteroid impact scenario, such data should be taken into account to inform countries sharing borders with the impacted country, considering the high probability of refugees they may have to accommodate.

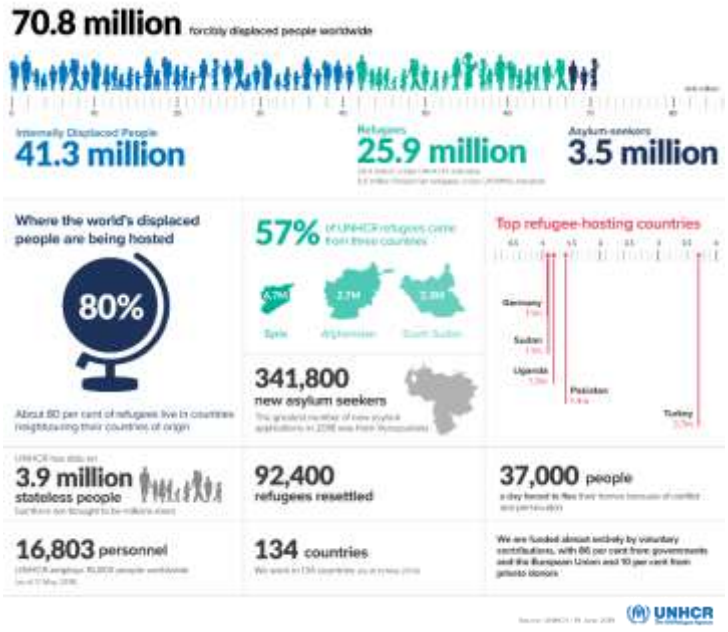

Fig. 10. Displaced populations worldwide (Source: UNHCR[228])

Economic damage

It may also be useful for the Planetary Defense community to increase its awareness of available research by the World Economic Forum which studied and classified the Natural Disasters that inflict the most economic damage, as showed in the figures below:

[228] Cf. https://www.unhcr.org/, [checked on 06/26/2019]

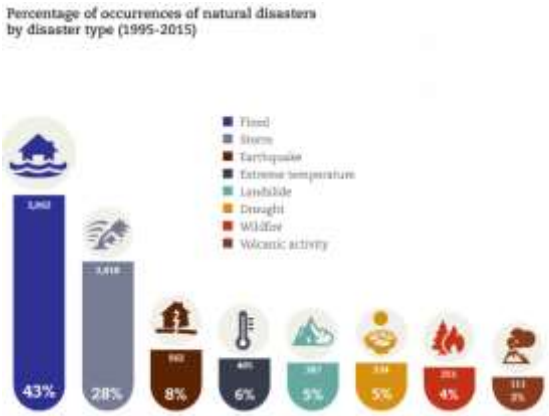

Fig. 11. Percentage of occurrences of natural disasters by disaster type (Source: WEF[229])

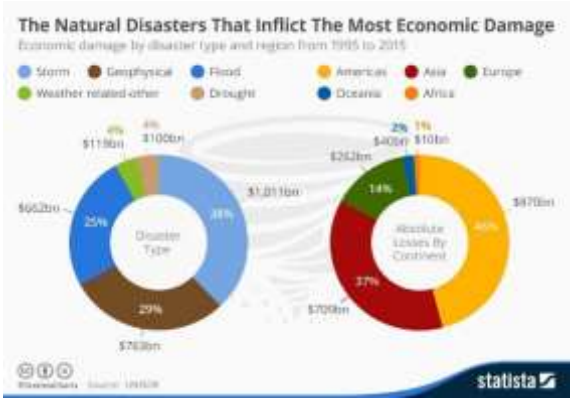

Fig. 12. Natural disasters that inflict the most economic damage type (Source: WEF)

As Fig. 11 and 12 show, floods and tsunamis - which may occur if an asteroid was to fall into an ocean – have been the most common natural disasters over the last twenty years. They account for 43% of all recorded natural disasters and have been evaluated as the third costliest ones, especially if they were to impact the Americas or Asia. Such data may be considered when training for an asteroid impact in an Earth's ocean.

Loss of world heritage

Finally, an asteroid impact may result in great cultural loss which previous disasters may inform the Planetary defense community on. For example, such was the case when Latin America's oldest and most important historical and scientific museum was consumed by fire in Brazil on September 3rd 2018[230]. Much of its archive of 20 million items covering two centuries of work research and knowledge is believed to have been destroyed. The loss to Brazilian science, history and culture was incalculable, The collection included Egyptian and Greco-Roman

[229] Cf. www.weforum.org/agenda/2016/05, [checked on 06/26/2019]
[230] Cf. *"Brazil museum fire: 'incalculable' loss 200-year-old Rio institution gutted*, https://www.theguardian.com/world/2018/sep/03,[checked on 06/26/2019]

artefacts, “Luzia”, a 12,000 year-old skeleton and the oldest in the Americas, fossils, dinosaurs, and a meteorite found in 1784. The fire of Alexandria’s library is also considered a common example of cultural loss. Built in 334BC, the library burnt in 48 BC and with it the largest collection of classical antiquity and Egyptian literature estimated to more than 100,000 pieces of literature.

II-Research process

1) Rational

I consequently decided to focus on Sociology of Natural Disaster Management as it seemed fitting to the preparedness strategy adopted by SMPAG and the “lessons learned” method, both fields I have embraced. I consequently believed that a transfer of knowledge from one to the other might be facilitated from this shared methodology. I also decided to focus on socio-anthropology rather than, say, on behavioral science because socio-anthropology focuses its studies on large groups of people unlike behavioral science. Considering the scale that an asteroid impact may have, I thought best to seek knowledge from a discipline structured around the understanding of group interactions and reactions rather than on individual ones as is the case in behavioral psychology. Finally, an impact would raise local cultural and political challenges that socio-anthropology commonly addresses as the previous examples illustrated.

Asteroid threat management may be understood by deconstructing and analyzing its series of practices and rationales. Through the study of sociology, lessons learned from natural disaster management are made applicable to the field of asteroid threat management. This chapter aims to show in which ways lessons learned from Sociology of Disaster Management could be

applied to the field of asteroid threat management which may be considered a new form of natural disaster.

2) Primary observations

The methodology I have used is a back and forth movement between field work and sociology of disaster literature: I used my position as coordinator and liaison officer between Planetary Defense scientists and international lawyers in order to understand the domain of Planetary Defense management from within. I then turned back to sociology of disaster literature in order to inform the domain I had joined with the most applicable lessons learned I could find. This chapter aims to derive practical insights from an application of existing theoretical and empirical studies to the emerging field of Planetary Defense. Having noticed the lack of major social science input within the field of Planetary Defense, my endeavor is to make this chapter informative for my scientific peers as well as for my social science colleagues interested in the field of disaster management, and to hopefully inspire more social scientists to investigate the diverse and colorful field of international space hazard management.

My observations are based on the information I collected through my role as SMPAG Ad-hoc legal working group coordinator and participant of the last two biennial Planetary Defense Conference (2017 and 2019). The originality of my work comes from the very fact that I entered the terrain as one of the only social scientists present in such nascent meetings. To my knowledge, this is the first study dedicated to the evolutions within the field of Planetary Defense. It is, therefore, the first to use Sociology of Disaster Management to identify and analyze urgent and timely questions facing Planetary Defense decision makers and scientific practitioners. I used my knowledge in space law and space science to coordinate this interdisciplinary group while using my background in socio-anthropology to develop parallels between the young scientific field of Planetary Defense and ways in which other kinds of natural

disasters have been managed and reflected upon by sociologists of disaster in the past thirty years.

The Planetary Defense Conferences (PDC) I attended serve as a platform for planetary scientists coming from all over the world to meet and share their research every two years during a week-long meeting involving technical presentations and a mock-up scenario organized at the end of each day. These mock scenarios are used to help them train and practice the kind of response they would have to give in case of a large-scale asteroid impact. Experts are asked to help plan a mitigation mission of a hypothetical asteroid coming towards Earth. This effort started at the PDC 2015. At each conference, the scenario starts with an announcement on day one that an asteroid has been detected a few years away from Earth and might cross paths with Earth's orbit in the future. Throughout the week, these NEO expert astronomers and space engineers are asked to get organized among teams: some are focused on designing a mission to learn more about the asteroid, characterize the object (its size, shape etc.); some are focused on determining the exact trajectory and corridor path of the asteroid in order to better predict which zone on Earth might be impacted, some others are focused on planning a mitigation mission to avoid such impact by pushing the asteroid away from Earth, while a last group is focused on determining the potential damage such impact would cause (number of deaths, impacted infrastructures etc.). At the end of each day, a jump in time is announced by one of the conference organizers; decisions made by each sub-team are shared with the entire group and the scenario keeps adapting and evolving throughout the week. At the end of the five-day conference, these scientists have either found a way to avoid an impact or worked on ways to minimize the damage caused by the impact.

My first observation -- as I was attending the 2017 PDC in Tokyo -- was that, out of the 200+ attendees, there was only one other social scientist present beside me, a lawyer from the Czech Republic who was there to present a paper on space law. In 2019, an effort was made to create a session of the conference dedicated to non-scientific aspects of Planetary Defense, namely its legal aspects. Two members of the ad-hoc legal working group came to present our latest report. Additionally, I met there one retired NASA employee expert in communication as well as three space lawyers from the Czech Republic (the same one from the 2017 PDC and two colleagues of his). This brought to six (myself included) the number of social scientists present at the 2019 PDC. It can be noted that "social scientists" currently participating in PDCs are lawyers or communication experts. For now, no economist, anthropologist, historian or ethicist has participated in Planetary Defense's main conference. PDC 2019 organizers have, however, informally asked me if I could invite more social science colleagues of mine in the course of conversations, as they wished a broader range of social scientists to be present at the next PDC, scheduled for May 2021 in Vienna, Austria. The lack of social science experts in general and the complete absence of sociologists to reflect upon ways such asteroid threats could be perceived by a variety of actors, was the triggering factor that motivated me to try to create a bridge between the two fields.

III- How Natural Disaster Management can inform Planetary Defense Management

I will presently explore the different ways in which natural disaster management can inform Planetary Defense management. To do so, I will first establish the differences existing between a natural risk, a disaster and a catastrophe. I will then explicit how and when the domain of social sciences started getting interested in analyzing disasters. After that, I will explore the

notion of disaster as an interface as well as the various levels of perception of a natural threat depending on the set of actors which define it. Finally, I will conclude on the various lessons learned from disaster management that may help build the nascent field of asteroid threat management.

Definitions of risk, threat, hazard and catastrophe

These words need all the more to be precisely defined and differentiated as their common usage differs from the meaning they have in the specific context of disaster management. I will be focusing on the notion of asteroid hazard, threat and catastrophe management. I will first define the terms "risk", "threat", "hazard", "disaster" and "catastrophe", then underline their differences and explain why I decided to dedicate my research to some of these concepts over others.

A risk is defined as a probability a hazard will be happening. The Global Economic Forum Report calls an "*existential risk*" a risk that could either annihilate intelligent life or permanently and drastically curtail its potential[231]. In that sense, the risk of an asteroid impact larger than 10 km in diameter[232] may be classified as an existential risk. On the other hand, when discussing the potential for Earth to be impacted by an asteroid, the US Planetary Defense Office recommends using the word "hazard"[233]. For instance, it says "NEOs present a hazard to Earth of being impacted." As for the word "threat", the same Planetary Defense Office advises to use it only when a specific object has been identified on a potential impact course towards Earth. It says, for instance, "The Center for Near Earth objects calculations shows this object is an impact

[231] Cf. *World Economic Forum Global Risks 2014*, 9th Ed. World Economic Forum, Geneva, 2014.
[232] Based on the 10km Chicxulub Asteroid which impacted the Earth 65,000 years ago and is commonly referred to as the "dinosaur killer" (cf. https://www.space.com/19681-dinosaur-killing-asteroid-chicxulub-crater.html, [checked on 06/17/2019].
[233] https://www.nasa.gov/planetarydefense/overview, [checked on 06/17/2019].

threat to Earth". This distinction between hazard and threat helps us, therefore, distinguish when we are talking hypothetically about an impact, as opposed to when we have determined there is potential for an actual impact[234]. In other words, a threat is a hazard that has become certain. Moreover, the term "threat" also carries the significance that one wants to be protected from it. The concept of threat is thus underpinned by the idea that one has become aware of the danger posed by a hazard and wants to be protected from it [235].

As a result, when talking about the planetary defense scenarios used at the PDC I attended, I will talk about asteroid "threats". In these scenarios, an asteroid was detected and it was determined it was going to impact the Earth. It was also decided by the scientists in the room and the two lead scientists and authors of the scenario[236], that something should be done to mitigate such a threat. On the other hand, when talking about Planetary Defense policy, I will talk about space hazard management in a more general sense.

Making the distinction between the term "threat" from that of "disaster" is also important. A natural disaster, unlike a threat, refers to an event the populations have experienced in the past, by being directly or indirectly affected by it[237]. Furthermore, the term "disaster" suggests that the event exceeds the capacities of local management [238]. For example, if/when an asteroid is on its route to impact earth, the term asteroid "threat" will be used. After the impact, the term

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[234] https://campaignforaccuracyinpublichealthresearch.com/risk-vs-hazard/, [checked on 06/17/2019]

[235] Cf. DUPONT, Y., *Dictionnaire des risques*, Armand Colin, Paris, 2003.

[236] The two lead scientist authors of the IAA PDC Planetary Defense scenarios since their creation in 2015 are two NASA researchers, Dr. Paul Chodas of the Center for Near Earth Objects Studies (CNEO) and Dr. Brent Barbee from Goddard Space Flight center. I was able to discuss the past two scenarios with them while I was at the PDC 2015 and 2017 as the acting Planetary Defense Legal Working Group coordinator.

[237] Cf. DUPONT, Y., *Dictionnaire des risques*, Armand Colin, Paris, 2003, p.61, "*Le concept de risque naturel suppose la prise de conscience du danger représenté par un aléa et la volonté de s'en protéger. (…) La catastrophe naturelle désigne un type d'évènement tel qu'il a été vécu par les populations, qu'elles aient été ou non affectées directement.*"

[238] Cf. PIGEON, P., REBOTIER, J., *Les politiques de prévention des désastres, Penser et agir dans l'imperfection*, ISTE Ed., London, 2017.

"disaster" will be used. Notwithstanding references to the 1883 comet that nearly missed Earth, a major asteroid impact is something unprecedented in human experience. Consequently, when talking about NEO research and detection, the terms "threat" and "disaster" are incorrect and should not be used instead of "hazard". It would also be incorrect to talk about Planetary Defense as a form of natural disaster management, considering that the human race has yet to face a major asteroid impact. All these elements explain why my research is dedicated to understanding the policy and managerial of the specific space hazard that are near earth asteroids[239] in order to notice and analyze the transformation the field of Planetary Defense has faced over the past twenty five years. I will also look at the structures in place if and when such a hazard was detected and represented a threat to our planet, and will go through the lessons learned of natural disasters and catastrophes – so of those already experienced on Earth - to see which lessons learned could be applied to a potential future asteroid impact disaster/catastrophe.

Not a first in human history

When I say that such an event would be "unprecedented", I mean on that scale and in our memories. An asteroid impact would not be the first time the world would face a mass extinction. Such information can be found in pandemics literature. For instance, during the four years of the 1347-1351 pandemic, 20% to 60% of the western world population –depending of sources in a context with few statistics --was killed by the Black Plague. In other circumstances, entire cities were erased due to a natural disaster. Such was the case of the eruption of Vesuvius that destroyed Pompeii in 79 AD. However, these events are so rare that the means to fight them

[239] I am here referring to near earth asteroids and not the more commonly used « Near Earth Objects » (NEO) as those include comets. All the field work I have done and participated in was dedicated to asteroids only. Even though the impacts of an asteroid and a comet may have numerous similarities, I decided to focus my research on the field work I was able to experience and consequently only address asteroid hazard management.

and adapt to them tend to fade over the centuries[240]. That timescale defies generational memory and is one of the challenges facing Planetary Defense. The scope and magnitude of these events is another challenge:

More than a disaster: a "catastrophe", an unthinkable event

Taking upon Dupont's definition of "*catastroph*e", the term refers to a *"*large-scale event entailing major damage, whose social and symbolic consequences are of historical order"; it etymologically means, in the context of Greek tragedy, "the writing of the last stanza (*cata-strophein*)". The word also implies a difficulty in thinking the unthinkable, the unimaginable, and preparing for it or even protecting oneself from it[241]. Accordingly, an asteroid impact would rightfully be a "catastrophe", an unthinkable turn of events. The fact that it is "unthinkable" is one of the specific characteristics of a space risk. This is unthinkable in a unique way because of its magnitude, the scope of its consequences, the rapidity and brutality of the event. A nuclear holocaust may not compare in size, and climate change may span much longer time periods. The science fiction genre, through literature and movies, has visited these risks but they remain nonetheless difficult to comprehend due to the fact that they are not part of human historical consciousness. There is no record of an asteroid impact devastating a large part of the human population nor is there any record of a foreign pathogen brought from outer space. Such is not the case when thinking about other "earthly" natural disasters. Erupting volcanoes or tsunamis are nowadays better known as they are both experienced and studied. The surreal nature of a NEO threat finds a more tangible reference in Pompeiian civilians, taken by surprise and unable

[240] Cf. FAVIER, R., GRANET-ABISSET, A-M., (Dir.), *History and memory of natural risks,* Grenoble, MSH-Alpes, Grenoble, 2000.

[241] Cf. DUPONT, Y., *Dictionnaire des risques*, Armand Colin, Paris, 2003, "*Catastrophe : Evènement causant un sinistre d'ampleur majeure, dont les conséquences sociales et symboliques sont d'ordre historique. (..) Elle désigne étymologiquement l'idée d'un renversement et l'écriture de la dernière strophe de la tragédie grecque (cata-strophein). Elle Implique une difficulté de penser et de se préparer à l'impensable, l'inimaginable (voire de s'en protéger).*"

to protect themselves from a natural but devastating event. Thinking the unthinkable and trying to prepare for it, with very little data available, is one of the biggest challenges when considering such low probability risks. In that context, learning from natural disaster management agencies is essential as they are the most knowledgeable structures on how to deal with potentially devastating and previously unknown phenomena.

Bearing all these elements in mind, asteroid hazards should therefore be categorized as "natural disastrous/catastrophic hazards" (depending on their size and amount of damage they may cause) as they have not been experienced by humans but have been somewhat partially recognized as a possible danger requiring further investigation so as to know better how to protect populations from it.

What distinguishes a "catastrophe" from a "disaster" is thus the exceptional nature of the event as well as the scale of its consequences regarding political involvement, the socio-cultural environment, space and time, and last but not least the way it is perceived: whereas disasters are politically dealt with locally, Quarantelli explains that catastrophes mobilize governments at both a national and an international level as that kind of event impacts a plurality of countries and requires international assistance [242]. Quarantelli also suggests it is harder to recover from a catastrophe than a disaster: as the destruction level is much bigger, populations as well as emergency organizations have no resources, no facilities to turn to: "The distinction we draw between catastrophes and disasters is not just an academic exercise (although the distinction is also important for research purposes not discussed here). What is crucial is that catastrophes

[242] Cf. Quarantelli E, "Catastrophes are different from disasters: some implications for crisis planning and managing drawn from Katrina", *The Social Science Research Council*, 2006, http://understandingkatrina.ssrc.org/Quarantelli/, [checked on 06/17/2019].

require some different kinds of planning and managing than do even major disasters. This is true whether the focus is on the planning for mitigation, preparedness, response or recovery."[243] Moreover, a catastrophe, by its very magnitude, represents a higher scale threat not only to material structures but also to the social and cultural order of the zone impacted [244]. An asteroid with the capacity to destroy an entire region (shared by one or more countries) and creating a large-scale impact on the planet would be considered a catastrophe rather than a disaster. Differences in the time scale of impact also separates a disaster from a catastrophe. The consequences of an asteroid impact could last several hundreds or even thousands of years and may even have irreversible effects. They could entail global imbalances since some species might completely vanish from our global ecosystem. Finally, the distinction between disaster and catastrophe will not only depend on the scale of the event but also on the way it is perceived. On the scale of the event Quarantelli says "In a disaster there is usually only one major target for the convergence after a disaster. In a catastrophe many nearby communities not only cannot contribute to the inflow, but they themselves can become competing sources for an eventual unequal inflow of goods, personnel, supplies and communication".

The distinction between disaster and catastrophe brings us to the notion of perception. The way something is defined will depend on who defines it and how far or closely impacted by the event this person or party is. This theory is put forward by philosopher and essayist Taleb.

"Black Swan" catastrophe and its psychological consequences

[243] Cf. *Ibid*.

[244] Cf. BERLIOZ, J., QUENET, G., "Catastrophes : definitions and documentation" in FAVIER, R., GRANET-ABISSET, A-M., (Dir.), *History and Memory of Natural Hazards*, MSH-Alpes Publishing Company, Grenoble, 2000, p.61 : *"Au sens fort, la catastrophe est une menace radicale contre l'ordre culturel et social, à la fois dans son existence et dans sa signification. (…) La distinction se situe dans le caractère exceptionnel d'une catastrophe. (…) Une catastrophe se caractérise par une forte implication politique. Lors d'un désastre, l'implication politique se limite au niveau local. Une catastrophe mobilise le gouvernement et toutes les instances politiques supérieures.*"

The black swan theory or the theory of black swan events developed by Taleb, in particular in his *Black Swan* essay[245], defines a *black swan* as a low probability, unpredictable event (a so-called "rare event" in probability theory) which, should it occur, would have exceptionally far-reaching consequences. Such catastrophes can create a mental blocking of unwanted perceptions called scotomization. Hoffman and Oliver-Smith explain that rather than reveal real ignorance of the phenomena or a lack of adequate education, this can be interpreted as "*comprehension denial*". That characteristic was identified by Oliver-Smith according to whom *"*many natural hazards are not common enough or do not entail frequent enough disasters, so that they are often unidentified as threats."[246]

Scotomization of the Space Threat

A scotomization is a psychological and cultural defense mechanism consisting of automatic or unwilling denial meant as a "blind spot" to avoid any possible anxiety[247]. Some space events such as the scientifically-established eventual death of our Sun 4 to 5 billion years from now can go unrecognized simply because their reference scales do not make much sense to the general population. Nobody worries about the fate of humans after that because, as human life expectancy does not typically exceed a hundred years, this ultra-generational dimension totally excludes human beings from the phenomenon. They cannot feel either touched or affected by it, nor can they comprehend the stakes concerning such a distant future. Similarly, the risk of

[245] Cf. TALEB, N.N., "The Black Swan: The Impact of the Highly Improbable", *The New York Times*, April 22nd, 2007, https://www.nytimes.com/2007/04/22/books/chapters/0422-1st-tale.html, [checked on 06/26/2019]

[246] OLIVER-SMITH, A., "Theorizing Disasters", in HOFFMAN S. M. and OLIVER-SMITH A, (Ed.), *Catastrophes & Culture : The Anthropology of Disaster*, School of American Research Press, Santa Fe, 2002, p. 142 : "*De nombreux risques naturels ne sont pas suffisamment fréquents ou ne produisent pas de catastrophes assez fréquentes, de sorte qu'ils peuvent souvent ne pas être perçus comme des menaces.*"

[247] Cf. OLIVER-SMITH, A., "Theorizing Disasters", in HOFFMAN S. M. and OLIVER-SMITH A, (Ed.), *Catastrophes & Culture : The Anthropology of Disaster*, School of American Research Press, Santa Fe, 2002, p. 136 : "*Scotomisation (…) c'est-à-dire un dispositif psychologique et culturel de défense qui, à travers une occultation, automatique ou involontaire, vise à ne pas voir un possible élément d'anxiété.*"

an asteroid eradicating the human race can hardly be acknowledged, first due to its low probability rate but also because nothing in human history, except the knowledge accumulated on the extinction of dinosaurs, can prepare humanity to grasp such a broad, unfamiliar and somewhat unnatural idea that the entire human race or even the whole planet could be wiped-out in an instant.

This psychological inability to grasp the "unthinkable" also arouses among decision-makers the fear of grand scale panics among the population. In order to face that particular risk, it is necessary for scientists and politicians to further research and develop adequate answers. The analysis of disaster as an interface may serve that purpose.

Disaster as an interface

A natural disaster is an interface phenomenon, a place of exchange between man and nature, a dialogue between a social system and its natural environment[248]. Anthropologist Douglas identified three main attitudes towards a disaster: optimism, pessimism and fatalism. In the case of an asteroid impact, all the parties involved (scientists, decision-makers as well as the populations) could adopt any of the following attitudes:

- an optimistic attitude: in this case the reaction will be to consider that the asteroid is actually going to miss the Earth or that a mitigation mission will be successful,
- a pessimistic attitude which may result in mass panic and attempts to evacuate the zone of potential impact and,

[248] Cf. DUPONT, Y., *Dictionnaire des risques*, Armand Colin, Paris, 2003, p.63 : "*La catastrophe naturelle est un phénomène d'interface, car elle implique la dialectique entre l'homme et la nature, le dialogue entre un système social et un écosystème*. "

- a fatalistic approach, with people believing that it is their fate to die from the asteroid impact. The latter could be explained by religious and/or spiritual beliefs that this impact is an "act" of God and/or of the Universe and consequently not meant to be prevented.

This fatalistic positioning -- which I had not considered before entering the field of Planetary Defense -- turned out to be expressed on several occasions during my field work when role playing with scientific experts on an asteroid impact scenario at the Planetary Defense Conference (PDC) in Tokyo as well as during an in-classroom exercise I conducted at Harvard University in November 2018 with a group of undergraduate students. On these two occasions, the groups (one of astrophysicists and space engineers, the other one of twenty Harvard undergraduate students (8 freshmen, 4 sophomores, 4 juniors, and 4 seniors majoring in social science, humanities and natural sciences) were tasked to represent countries and role-play the decision-making process they thought would be taking place at the United Nations, if the Security Council had to deal with an actual asteroid threat to Earth. On both occasions some representatives expressed that their population (which they deemed "religious") did not want any actions to be taken, considering that dying under the impact was their fate decided by God and against which they should not intervene. To that argument, a scientist from the PDC expressed his discontent and explained to the group of scientists that if participants thought that God had sent this asteroid their way, why not think that (s)he is the one who also gave them the technological capabilities to mitigate the threat[249]. This is but an example to show that so far no one knows what kind of reasoning might prevail as research is currently lacking. Yet the stakes are high as public perception could influence policy responses.

Social Science and Threat Management: A Recent Pairing

[249] Opinion expressed by a NASA scientist during the role-play exercise taken place at the PDC in May 2019, in Washington DC.

In order to have an idea on which way the balance of perceptions and behavior might tilt, research on disaster management must be encouraged and conducted. Authors such as Guiffra[250] have striven to underline the ways in which crisis management should be regarded as a true object of research from all the social sciences. It is important to tackle natural disaster literature through the social science lens to better apprehend, reflect and make forecasts on the human impact space disasters might have. Historically, Revet explains that it was not until the '60s that sociology and psychology in the United States started to address natural disasters by tackling matters relating to the behavior of populations in disaster situations (Revet, 2007)[251]. Natural disasters have long ranked low in social science research [252]. He argues that the field of natural disaster management has only recently awakened the interest of researchers in anthropology, sociology and geography. These disciplines address the problem by trying to show that "natural" phenomena are not natural per se but are rather the result of an interaction between a natural hazard and the conditions of physical and social vulnerability prevailing among given social categories[253]. Anthropologist Revet argues that only in the 1990s did prevention arouse the interest of "international humanitarian governance" after the publication

[250] Cf. GALVIS, S. J., GIUFFRA J.R, and Ahlers, W.F., Werner, *The Guide to Corporate Crisis Management*, Latin Lawyer Ed. New York, 2019.

[251] Cf. REVET, S., *Anthropologie d'une catastrophe : les coulées de boue de 1999 au Vénézuela*, Presse de la Sorbonne Nouvelle, Paris, 2007 : "*C'est à partir des années 1960 aux Etats-Unis que la sociologie et la psychologie ont abordé les catastrophes* "*naturelles*" *à partir des questions portant sur les comportements des populations dans les cas de catastrophes.*".

[252] Cf. DANHOUNDO, G., *La gestion des catastrophes* "*naturelles*" *: Vers une analyse des fondements de la prise en charge internationale du "risque"*, Editions Universitaires Européennes, Paris, 2011, p.75 : " *Les catastrophes "naturelles" ont constitué pendant longtemps les parents pauvres des recherches en sciences sociales. Depuis peu cependant, elles suscitent l'intérêt des chercheurs en anthropologie, en sociologie et en géographie. L'approche adoptée par ces disciplines consiste à montrer que les phénomènes « naturels*" *ne sont pas naturels en soi mais qu'ils sont le résultat de la rencontre entre un aléa naturel et les conditions de vulnérabilité physique et sociale qui prévalent au sein des catégories sociales*. "

[253] Cf. DANHOUNDO, G., *La gestion des catastrophes* "*naturelles*" *: Vers une analyse des fondements de la prise en charge internationale du "risque"*, Editions Universitaires Européennes, Paris, 2011.

of reports supporting the fact that investing in prevention operations would come cheaper than financing aid and reconstruction operations[254].

It is now my intent to show the contributions of a newcomer in the field of disaster management: socio-anthropology.

Making sense of disasters, catastrophes and perceptions through socio-anthropology

Past records have shown that cosmic events with no material consequences on humans, such as comets or eclipses, may sometimes be perceived as catastrophes. Such was the case of the 1654 solar eclipse which caused widespread panic in Europe[255]. A great gap may sometimes exist between scientists and the general public. Astronomy, like any other discipline, should not be regarded as an equally spread and accessible form of knowledge. Not everyone in the world is versed in the basics of astronomy and the general understanding of astronomical events. Disaster, as previously explored, is an interface between humankind and its environment[256]. The way an astronomical event can be perceived as a disaster or a catastrophe depends on the sets of beliefs and on the cultural background through which such an event is being perceived, and not only on the definitions provided by experts in the field. This also corresponds to the social interface definition of anthropologist Long who saw a social interface as "a critical point of intersection between different life worlds, social fields or levels of social organization, where

[254] Cf. REVET, S., *Anthropologie d'une catastrophe : les coulées de boue de 1999 au Vénézuela*, Presse de la Sorbonne Nouvelle, Paris, 2007 : "*Ce n'est qu'à partir des années 1990 que la prévention a suscité l'intérêt du "gouvernement international humanitaire" suite à l'apparition de certains rapports qui soutenaient qu'il coûterait moins d'investir dans des opérations visant à prévenir que de financer les opérations de secours et de reconstruction.* "

[255] Cf. DUPONT, Y., *Dictionnaire des risques*, Armand Colin, Paris, 2003, p.62 : "*Des phénomènes cosmiques sans conséquences matérielles sur les hommes, des comètes ou des éclipses, peuvent être perçus comme des catastrophes, à l'image de l'éclipse de 1654 qui a suscité une panique générale en Europe*. "

[256] Cf. *Ibid.*, p.63 : "*La catastrophe naturelle est un phénomène d'interface, car elle implique la dialectique entre l'homme et la nature, le dialogue entre un système social et un écosystème*."

social discontinuities based upon discrepancies in values, interests, knowledge and power, are most likely to be located."[257]

The domain of socio-anthropology explores the rich diversity of perceptions possible within one community, the possible interactions with others and the relationships between individuals and the institutions and structures in place to deal with a disaster. Socio-anthropology also enables the analysis of necessary local cultural knowledge, especially useful in emergency relief situations. A disaster will disrupt a pre-established social order that one must get acquainted with in order to better assist that social order. During emergency relief situations for example, if the culture of the impacted populations is not taken into account, the survivors will have an even harder time recovering from the event[258]. Socio-anthropology has raised the importance of socio-cultural elements in disaster management. The latter will now be explored through an analysis of sociology of disaster literature.

Socio-economic vulnerability and inequalities in coping with natural disaster

Inequalities in coping with the consequences of a natural event have been shown by several authors[259]. The vulnerability of the populations needs to be taken into account through the acknowledgment of not only physical vulnerability (which pertains to the nature of buildings and land use – namely resistance of materials and structures in various places) but also social vulnerability and inequalities. Social factors induce the probability that some social categories will suffer more significant damage than others, which will affect their capacity to recover after a disaster. Also, all populations have to face various socio-economic struggles and on most

[257] Cf. LONG, N., "*The multiple optic of interface analysis",* Wageningen University ed., Amsterdam, 1999.
[258] Cf. CLAVANDIER, G., *La mort collective : pour une sociologie des catastrophes*, CNRS Éditions, Paris, 2004 : " *La catastrophe naturelle vient rompre un ordre social préétabli qu'il se faut de connaître afin de l'assister au mieux. Lors de ces situations d'aide d'urgence, une ignorance de la culture des populations impactées « contribue à renforcer les difficultés que les rescapés de la catastrophe auront à se remettre de l'évènement* ".
[259] Cf. REVET, S., *Anthropologie d'une catastrophe : les coulées de boue de 1999 au Vénézuela*, Presse de la Sorbonne Nouvelle, Paris, 2007.

occasions, these socio-economic problems will be perceived as more important than space risks as more urgent and immediately life-threatening. Anthropologists Revet explored in 2007 the idea that, in order to help prepare populations for a disaster situation, the notion of natural hazard needs to be contextualized, put in perspective and compared to everyday risks related to socio-economic hardship. An asteroid impact may take on global proportions and would involve coordinating scientists and decision makers from all over the world. But managing such a threat also necessitates taking into consideration the diversity of public actors that will be involved and the variety of risk perception, which is directly correlated to the immediate struggles some of them are facing as they will take priority over the potentiality of an extremely rare asteroid threat.

In asteroid threat management, this means that the behavior of some populations may be anticipated by taking into consideration the more proximate risks they face on a day-to-day basis. The risk of an asteroid colliding with Earth may seem quite abstract and not of great importance to populations facing immediate life-threatening struggles such as famines, war, economic hardship or lack of health care coverage. The socio-economic limitations these populations face will prevail in their perception of importance over any space risk. Economic inequalities will impact the way disasters are dealt with as well as their amplitude. Danhoundo defines therefore disaster as "the interaction between a hazard and preexisting conditions of vulnerability in disaster-stricken areas"[260] and recommends taking into account the local realities of might-be space risk impacted populations. As he explains: *"*Vulnerability to natural events is closely related to socio-economic conditions. Even though a natural

[260] Cf. DANHOUNDO, G., *La gestion des catastrophes* "*naturelles*" *: Vers une analyse des fondements de la prise en charge internationale du "risque"*, Editions Universitaires Européennes, Paris, 2011, p.56 : "*Un désastre est la combinaison entre un aléa et les conditions de vulnérabilité préexistantes dans les zones sinistrées*. "

phenomenon does not, upon occurring, distinguish "the rich" from "the poor", inequalities between these two groups are noticeable from the very moment of the impact through the aftermath and its consequences. Disasters are the result of an interaction between a particularly vulnerable human population and a potentially destructive agent, among which are found natural events."[261]

Anthropological knowledge

However, these populations cannot be reduced to the mere status of "victims"; nor do they represent a homogeneous category as they come from various and diverse social backgrounds. It should also be remembered that the affected communities have their own resources, competences and skills to manage some emergencies as well as sets of beliefs and must not be merely perceived as powerless victims to be rescued by international institutions that may not always be in touch with the populations they are trying to help. For example, some people might refuse to be moved when learning about a threat of impact. As anthropologists like Boscoboinik have explained, despite seismic shocks or tsunami warnings, human communities have consistently over the ages avoided being displaced, and have refused to leave certain sites or return to them.[262] This can be explained by a variety of reasons among which cultural attachment to their land, or a fatalistic belief that it is "their fate" to be killed by the disaster in question. Obviously, economic reasons can also play an important part in their refusal to be displaced. Indeed, they may not have anywhere else to go and/or may not have the economic

[261] Cf. TEXIER, P. et al., "Risk management stakes in informal urban districts, two case studies: Jakarta (Indonesia) and Angeles City (the Philippines)" in BECERRA, S., and PELTIER, A. (Dir.), *Risks and environment: interdisciplinary research on the vulnerability of societies*, 1st Edition, L'Harmattan, Paris, 2009, p.46.

[262] Cf. BOSCOBOINIK, A., *Le processus catastrophe : vulnérabilités, discours, réponses*, PhD dissertation, Université de Fribourg, 2007, p. 204 : "Malgré les secousses sismiques, les groupes humains ont de tout temps évité les déplacements, ont refusé d'abandonner certains sites ou les ont réintégrés".

resources necessary to leave. Decision makers dealing with asteroid threat management will therefore have to consider that some populations will decide to remain in the zone of impact. Consequently, when thinking about an asteroid impact, resorting to anthropologic knowledge and methods serves to better know and see the population that stands to be impacted, and better understand that each place on Earth has a local identity. It is also to be noted that it might be counterproductive to use a rhetoric that would tend to impose a sovereign power over an overly generalized and uniformly perceived category of "victims" for that would fail to pay enough attention to contextual and cultural differences.

Consequences of psychological impact on the various parties

Another aspect that needs to be taken into consideration when thinking about the ways an asteroid threat may be perceived is the psychological impact such news may have on the populations in question. By that I mean not only the population supposed to be impacted but also the ones which are not on the impact corridor. Such a distinction has been specifically set up during the latest PDC scenario in May 2019, which was a novelty - as it was not addressed in previous PDCs. This is a relevant novelty as it relates to the evolution of Planetary Defense – one of my research objectives. The organizers decided to ask some volunteer participants of the conference to play the role of "non-impacted populations". They also asked their thoughts and recommendations throughout the scenario. A similar sub-group was spontaneously created by the participants when I conducted the simulation with the Harvard undergraduates I previously mentioned in the fall of 2018. Students representing countries not directly impacted by the asteroid had a lot to say: as was the case at the PDC, some offered to welcome refugees fleeing the impact corridor, some offered technological support to assist in the design and launch of a mitigation mission. More surprisingly, some stated their desire to invade the

potentially soon to be impacted and now emptied territory, explaining that they were willing to take the risk in order to expand their frontiers. Even though such simulations were conducted on too small a number of participants to be truly representative (200+ participants per PDC, once every two years and twenty Harvard undergraduate students once a semester over a year), they nonetheless serve to illustrate the great diversity of ways an asteroid impact threat may be perceived by a plurality of actors and the kinds of unusual scenarios that may rise from them.

Other relevant questions linked to threat perception arose from these exercises regarding communication: Should or should not the general public be informed of the impact threat? Would a general panic ensue after such an announcement, and would such a panic end up being more dangerous than the impact itself?

In the three instances (the PDC scenario 2017 and 2019 and the in-classroom simulation), the participants were concerned about the public's reaction. In the classroom, the undergraduate students acting as national representatives decided not to warn the general public and refused to disclose any kind of information on the asteroid threat they were warned about. They also acted in consensus, even though they had been tasked to represent countries with different interests (some situated on the impact corridor, some not, etc.). In 2019, it seems quite unrealistic to imagine that a piece of information as openly observable by anyone with a telescope as an asteroid coming towards Earth could be hidden from the general public. This exercise, therefore, informs us of the fact that people put in a position of leadership might make an irrational decision (such as trying to hide such available information from the entire world population), when faced with the deep fear that an asteroid impact may cause a general panic.

Such a fear is not so irrational considering it has never been experienced by humankind and considering the magnitude of the emotion it might entail: if such a situation were to happen and

the general public were made aware of an asteroid impact threat, it is extremely difficult if not impossible to predict the reactions of millions, not to say billions of people. Conversely, if an asteroid were to impact the Earth, anywhere on Earth, this external threat might instead unify humans in their despair, as they would feel concerned and worried about the upcoming destruction of one of "their" regions. Or it might not.

Mass death management

In order to defeat such uncertainty, should an asteroid impact happen, Planetary Defense officials and emergency responders would have to face mass death management challenges. This domain of research has also been explored by the sociologists of natural disaster. One of their main findings comes from the observation that local populations can be deeply disturbed by the lack of cultural care during mass burials. Death management is indeed a cultural and social matter dealt with primarily by the local populations, rather than by national and international decision-makers[263]. It differs according to which countries natural disasters take place in. Death is linked to a set of rituals and beliefs of high import in any culture. Different cultures and sets of beliefs will create different behaviors when facing a disaster. In some countries, special units are created to face mass death disasters. France has, for example, a Disaster Victim Identification National Unit[264] dedicated to organizing searches to recover French citizens' corpses in the case of a natural disaster [265]. However, in a situation of natural disaster or catastrophe, corpses may not be identifiable. In the case of mass deaths, it is

[263] Cf. CORBET A., *Death and the Dead in Haiti after the January 12, 2010 earthquake, a report commissioned by the French Strategic Defense Department*, Paris, DAS (Department of Strategic Affairs)., 2011p. 100.
[264] Translated from the French: l'Unité Nationale d'Identification des Victimes de Catastrophes (UNIVIC)
[265] Cf. *Ibid*., p. 99.

sometimes impossible for the authorities to take into account the socio-cultural rites of the living regarding death management as they are acting in a state of emergency[266].

In this context, sociologists perceive death rituals as necessary to try to make sense and somehow "normalize" the disaster. A disregard for death rituals can deeply disturb sets of population. For example, the literature indicates how important it is to follow death rituals especially for violent deaths as was the case in Guede Nibo in Haiti[267]. An asteroid impact would entail a collective trauma where "the living sleep along the dead"[268] with mass graves, cities eradicated, saturated cemeteries, local cultures being totally wiped out, populations being displaced by thousands if not by millions, and mass panic[269]. Another example is to be found in some indigenous Central and Latin American cultures which strongly believe in afterlife. Populations suffering mass deaths due to an asteroid impact may be terrified of the possible retaliation of spirits blocked in limbo between two worlds, not having been buried properly or having been cast into mass graves. Consequently, when dealing with mass death management, experts recommend that collective graves nevertheless strive to respect people's individualities, religious beliefs and rights.[270]

Taking religion and personal beliefs into consideration may consequently be advised when dealing with mass death management from an asteroid impact. However, it can also be envisaged that an asteroid impact may deprive some people of their faith. Such was the case after the earthquake that shook Lisbon, Portugal, in 1755, killing in an instant a hundred

[266] Cf. *Ibid.*
[267] Cf. *Ibid.*
[268] Cf. SCAPIN F., VAN EECKE P., *Goudougoudou,* Polymorfilm, 2012.
[269] Cf. "Management of Dead Bodies in Disaster Situations". *Disaster Manuals and Guidelines Series N°5,* Pan American Health Organization, Washington DC, 2004.
[270] The Inter-American Court of Human Rights recognized in the Blake case "the need for preserving the cultural value of respecting the dead "as breaching that need results in intensified grief and suffering of the family members. Blake Case "reparations", Judgment of January 22,1999 Series C, n° 48, paragraph 11.

thousand people. Philosophers from all over western Europe came then to challenge the concept of divine justice, the existence of God itself and precipitated the belief of a "*secular catastrophe*"[271].

This is indeed the positioning of scientists. In scientific circles within IAWN, SMPAG and the PDCs, the question of Planetary Defense and threats of NEO impacts are approached in a secular manner. Teams of experts focus on predicting the strength and consequences of an asteroid impact in a scientific way. If some aspects of the matter verge on the psychological and on the religious, others endorse the matter-of-factness of the law.

Legal aspects of natural disasters

Various countries have passed a series of laws dealing with disaster management. For example, in France, the law passed on July 13, 1982 and entitled "The natural disaster compensation law" defines insurance requirements and the victims' compensation rights. This law acknowledges the complexity of the consequences of natural disasters and the fact that all the parties involved will enter unchartered territory given the intrinsic uncertainties of that kind of events. It acknowledges that the cost of such highly complex and unpredictable events is hard to assess, both because of the possible concatenation of events and because of the limits of standard statistical methods. Insurance premiums rarely prove to be adapted to situations characterized by such great uncertainties and where the financial reserves required for compensation go beyond the scope of insurance standards[272].

[271] Cf. LE BRETON, D., *Sociologie du risque*, Que Sais-Je Ed., Paris, 2017, p.40 : "*Le tremblement de terre de Lisbonne (1755), qui tue en un instant cent mille personnes, ruine aux yeux des philosophes toute idée de justice divine et précipite une vision laïque de la catastrophe.*"

[272] Cf. French law of July 13th 1982, "*The natural disaster compensation law*" or "*Loi d'indemnisation des catastrophes naturelles"*.

Not only are current standard statistical methods limited, as previously noted, but impact probability statistics are also helpless given that the stakes related to territorial and urban vulnerability are also linked to human presence (people, houses, economic activities, infrastructures etc.) which is hard to price[273]. Other sociologists as such Chauvin define risk as the possibility of losing what one values[274]. The difficulty of assessing damages is further compounded by the notion of human responsibility.

A human responsibility to act in disaster management?

Could anyone be held responsible for passivity in disaster management? Even though a NEO threat would be considered a natural catastrophe, if such an object were to be detected months to years in advance, legal questions would then have to be considered. Long-stretch warning systems could make it possible to take action and possibly prevent such catastrophes. Contrary to a seismic or a volcanic incident, the detection of an asteroid threatening the Earth would involve human activity in so far as the asteroid would have to be deflected to mitigate its impact. If an asteroid was detected, say, seven years prior to its impact and nothing had been done to deflect it, or if a deflection mission had changed its course, could its impact really be considered natural? In a recent, yet to be officially published report from the United Nations-mandated Space Mission Program Advisory Group (SMPAG) ad-hoc legal working group, it was assessed by international lawyers that a country conducting a mitigation mission in good faith should not be considered liable for damages if such a mission failed to mitigate the threat at all, nor should it be held responsible for the potential new damage a failed-mitigation mission could result in. This assessment was based on international law regarding liability and damage, with the

[273] Cf. PIGEON, P., REBOTIER, J., *Les politiques de prévention des désastres, Penser et agir dans l'imperfection*, ISTE Ed., London, 2017.
[274] Cf. CHAUVIN, B., *Risk perception, the input of psychology in the identification of the determinants of perceived risk*, Ed. De Boeck, Paris, 2014.

understanding that countries should not be deterred from trying to mitigate an asteroid threat because of a fear of liability in case of failure. Also, as not every country has the same clout and capabilities the following question may be raised: Do spacefaring nations have the moral responsibility to take action on behalf of non-spacefaring nations? But conversely, what is the moral responsibility of any country trying to prevent or block an international endeavor to deflect a NEO? SMPAG members asked its ad-hoc legal working group to conduct research on the international responsibility and limitations in the case of an asteroid set to impact a country with no space capabilities. If we were to look at the same situation from an anthropological perspective -- which would take into consideration the beliefs of the threatened populations-- what would happen if the targeted country decided not to act, purposefully? Could other nations choose to intervene and defend the country anyway in order to avoid a large impact on the Earth global economy? Would that interference be tolerated from a legal and political point of view? Such a question was deliberated upon at the very end of the 2017 Planetary Defense Conference. Japan was the targeted country of a small size asteroid which was predicted to likely wipe out that nation. In a role play where world leaders represented more or less the United Nations Security Council, some representatives of spacefaring nations such as the United States, Russia and others, decided that the best course of action was to send nuclear explosive devices to try to change the trajectory of the asteroid. However, the Japanese representative decided against the use of Nuclear Explosive Devices (NEDs), explaining that Japan had historically been traumatized by nuclear bombs and refused their use. He agreed on the use of impactors. However, it was largely agreed upon among the experts that, in this specific scenario, impactors would likely not be enough. Consequently, the choice of the Japanese representative was over-ruled by the rest of the group and NEDs were sent (and successfully mitigated the threat).

Conclusion

Reaching out to socio-anthropologists of Natural Disaster Management would allow the Planetary Defense community to take into account **social, cultural and psychological aspects** of a potential asteroid impact such as:

1) mass deaths management and local practices

2) possible population displacements (and resistance to them)

3) the scotomization effect: Most people might go into denial when faced with the warning of an asteroid impact.

It would also help the Planetary Defense community begin building preparadness and management capacities in the following areas:

4) Provide psychological support to the affected populations

5) Set up long-term policies resilient to change (between the moment they are written and the moment the impact may occur)

6) Involve socio-anthropologists in PDC scenarios for the scientists and new Planetary Defense managers to increase their knowledge of local problematics (depending on the impact region and size of impact) and design their NEO mitigation plan.

7) Share with the Planetary Defense community the methodologies from sociology of science and STS which may enable them to turn a critical eye on their own new and rapidly growing structure, practices (such as the way they are controlling their transdisciplinary interactions) and decision-making responsibilities.

One key lesson to be remembered is the importance of not underestimating the social, cultural and psychological impact a space catastrophe could create. It will be necessary to provide psychological assistance to the populations in order to help them deal with shock, loss, massive disappearances of friends and family and the emergence of both rational and irrational fears. To prepare addressing the psychological hardships the populations are likely to experience, I am inclined to recommend inviting anthropologists and religious experts in the design phase of crisis management planning, in future Planetary Defense conferences and similar venues. The objective will be to build awareness among policy makers of a given population's needs so that the emergency responders operating under their authority may provide adequate help in a way that will be best received locally, rather than follow political plans designed in a way that may be dismissive of the local specificities of a country or a territory[275].

Moreover, it would be important to keep in mind that the efficiency of an international humanitarian governance endeavor may be challenged when that governance ignores the specificities either of the culture or local resources[276]. Historically, collective risk has been managed by the State.[277] But it remains to be seen how a trans-border catastrophe as that of a large asteroid impact could be managed. Should such a collective global risk be managed by the United Nations or by a transnational system yet to be developed? In order to be efficient any intervention should be locally rooted. Top/down systems should be avoided as they are eventually poorly adapted to local needs or do not know or take into consideration local practices[278]. However, such transnational catastrophes might occur in places with differing political models/regimes: in democratic or totalitarian countries; complying or not with UN

[275] Cf. JAMES, J.W, FRIEDMAN, R, *The Grief Recovery Handbook*, Harper Perennial Ed., New York, 1998.
[276] Cf. *Ibid.*, p. 27.
[277] Cf. *Ibid.*, p. 64.
[278] Such as the way a local population will deal with its dead.

conventions/treaties, etc. This would force or block the implementation of top/down systems and would create one more hurdle that would have to be taken into consideration and overcome. Detailed knowledge of international relations and local regimes would be consequently quite important to set up cross-border space risk management systems.

As humankind has had so far no direct experience with the consequences of a large asteroid impact, it relies for argumentation's sake on what it knows, namely natural disasters. Be they earthquakes, hurricanes, landslides, volcanic eruptions, tsunamis or wildfires, natural disasters are generally considered a-political, "Nature" possibly being the one to blame. We can note that in some circumstances, when natural disasters are linked to issues such as climate change and human industrial activity, such disasters may be more politically charged. Moreover, in two other instances natural disasters can be linked to political responsibility: disaster prevention and ways governments deal with the aftermath[279]. Natural disaster related relief and assistance efforts can create substantial tensions among populations, international organizations and government institutions. These conflicts can reveal different visions of and assumptions about relief and assistance as well as the often-unquestioned representations of risk and vulnerability that each group supports[280].

[279] *Ibid.,* p. 62.
[280] BIRKMANN J., *Measuring Vulnerability to natural hazards towards Disaster Resilient Societies*, United Nations University Press, Tokyo, 2006.

CONCLUSION

The organizational study of Planetary Defense today as it is currently exemplified by SMPAG and its ad-hoc legal work group has revealed that Planetary Defense is indeed a scientific field whose decision-making processes are led by scientists. Even though it has expanded and evolved into a three-pronged system (science, policy and management), it remains a technically-led field in charge of the design of its own organization and interactions with external actors whether they be other governmental agencies or the general public.

Through the SMPAG ad-hoc legal working group on Planetary Defense case study, I was able to observe first-hand Planetary Defense managers' willingness to explore transdisciplinary partnership, as long as these complied with their technical structure where scientists -- informed by law, economics and communication -- remain the sole Planetary Defense Management decision-makers.

In this conclusion, before establishing some recommendations, I will now consequently summarize my research findings to answer my research objective and hupotheses: 1) Why is PD experiencing rapid growth? 2) How is PD transforming into a managerial structure? 3) How is it adapting and responding to its new managerial responsibilities? 4) Why and how can Sociology of Disaster Management help the field of Planetary Defense?

From my empirical and ethnographic research, I am concluding that Planetary Defense is a growing field in transformation, muting into a full managerial structure with, as explained in my third chapter, dedicated budget, policies, staffed offices and even specialized conferences where its members' role play decision-making exercises. All of these factors play an important part: with the increased visibility of NEOs resulting from technological advancement in NEO detection, usefulness of addressing the possibility of a NEO impact, there has been an

emergence of national and international policies, which were then supported by dedicated budgets and the construction of dedicated managerial structures. These scientifically-led structures have embraced more and more responsibilities for example coordinating scientific efforts, including acting as first responders and warning system to the rest of the decision-making chain within national governments. In order to adapt to these newly assigned responsibilities, I have argued that this scientifically-led system reached out to some Social Science experts to benefit from their outside knowledge, and yet at the same time carefully monitored such new interactions so as to remain the sole decision-makers. Finally, from my theoretical research, I have demonstrated that an asteroid impact could be considered a natural disaster and, in my final chapter, analyzed some Sociology of Natural Disaster Management literature; I concluded that valuable managerial lessons learned extracted from it could be applicable to Planetary Defense Management. These lessons learned could help prepare the design of mitigation missions by factoring in the challenges that may face this scientifically-led structure when it will interact with impacted and non-impacted populations before, during and after an asteroid impact. Such new examples of transdisciplinary and collaborative efforts could inform Planetary Defense Management of preemptive steps that can be taken against the social complexities usually emerging during natural disasters.

Thus this research confirmed my three hypotheses: 1) The scientific field of Planetary Defense has grown into a national and international managerial structure; 2) Planetary Defense has grown into a decision-making structure by progressively reaching out to other forms of expertise and monitoring such interaction; 3) An asteroid impact could be considered a natural disaster of unprecedented proportions and lessons learned from Sociology of Natural Disaster Management literature may be applicable to this new form of natural disaster.

Recommendations:

Using my position as both observer and insider I consequently recommend that:

1) The Planetary Defense community reaches out to socio-anthropologists expert in Natural Disaster Management, possibly inviting them to the biennial Planetary Defense Conferences organized by the International Academy of Astronautics and the NASA-FEMA annual exercises, to help the construction of the decision-making structure and improve preparedness by taking into account:

- Local knowledge and problematics
- The understanding of risk/threat perception by the different populations
- The need to prepare for the "scotomization" effect

2) To socio-anthropologists, I would suggest that they take on the opportunity to look at a recent field and new form of natural disaster (i.e. an asteroid impact) and share their expertise with the Planetary Defense community to improve their preparedness efforts, learn about and understand local problematics and consequently better communicate with local populations. Socio-anthropologists may also inform Planetary Defense experts of their possible biases and help introduce sociology of science and STS methods and tools for this recent and fast crowing community to reflect upon its own development using social science analysis. They could help educate the Planetary Defense community about how to think differently about complex and uncertain societal issues and its reflexivity by drawing attention to their own values and assumptions such as assumptions about how to establish trust with the public.

3) To all I would recommend developing transdisciplinary work and enhancing the field of Social Science and Humanities of Space expertise and literature.

There are, however, remaining challenges in Planetary Defense Management, namely that it is a relatively new and scientifically-led field with recent structures with no social science feedback (as of yet) to help reflect on its own nature, growth and decision-making process. It is also a domain vulnerable to political changes, with, for example, budgets dependent on this year's ESA's Ministerial Council, Nov 26-27th 2019 and the US elections in 2020 which may or may not continue its investment in space security (the umbrella Planetary Defense falls under).

My main recommendation would consequently be that space science experts connect with sociologists who have an expertise in natural disaster management, like Revet, so as to discuss jointly what possible academic research could be conducted to reflect on and plan the most adequate ways to interact with populations under a potential asteroid impact threat.

A core set of transdisciplinary discussions could be ignited as well, therefore bringing to the table space social scientists to address the social, legal and ethical aspects of asteroid threat management. The commonalities thus found could help draft new international Planetary Defense policies, which may afterwards be used to pursue and extend the study of other space hazards, such as that of Space Weather or, man-made hazards, such as those of Space Debris.

In terms of lessons learned from sociology of disaster management, one of the key recommendations from most authors has been to plan for the scotomization effect and to take into account the fact that most people might go into denial when faced with the information of an asteroid impact. Information about the specific communities and local resources at risk should also be gathered and psychological support for the affected populations would need to be provided. In the same vein, it is important not to underestimate the diversity of ethnic and socio-cultural backgrounds so as to be prepared to face the local reality of the disaster. It would

also be necessary to root policies in the "long-term" in order to best assist disaster-stricken or merely affected populations. Some needs will have to be defined in socio-cultural contexts that will be changing and evolving over unknown stretches of time, namely from the time policies will be written to the time the disaster will occur. This could span decades or more, and such lengths of time will be a challenge as they imply a large number of unknown parameters. This will also imply the necessity of putting into place evolving policies and decision-making structures, resilient and adaptable to the long-term approach required by emergency systems.

Consequently, in addition to coordinating with FEMA and other governmental emergency response teams, SMPAG, the PDCO, European Planetary Defense Office or any other Planetary Defense Managerial structure located in an impacted area could seek the help of anthropologists and sociologists, expert urban planners and geographers in addressing movements of population and supporting populations "at risk" in order to plan adapted assistance to the various communities.

I would also recommend that Planetary Defense Management continue being developed in a way that enables it to be passed down to the next generations so as to help them face a hazard potentially beyond the scope of typical human lifetimes. In addition, Planetary Defense management would also have to ensure the trust of the populations so that their warnings be heard and listened to should such warnings be sent out. To that end, communication campaigns should be started to get these institutions to be better known to the general public. Such communication campaigns could be extended through educational exercises, organizing in-classroom Planetary Defense Exercises, following the Planetary Defense Conference Scenario model.

Finally, this research could be continued by exploring other types of lessons learned from UNSDR to inform SMPAG and IAWN on best practices to apply to the kind of natural disaster an asteroid impact might represent.

Moving forward in a prospective way, one might also imagine that other space threats such as solar flares, coronal mass ejections or cosmic radiation could also be considered new forms of natural catastrophes yet to be linked to the domain of natural disaster management.

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