Brussels, we could have a problem

Future European crisis management for commercial human spaceflight

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Abstract

Currently, commercial spaceflight companies like SpaceX, Virgin Galactic and Blue Origin are developing ways to make space more accessible for the general public. While in the United States this has led to a regulatory framework for commercial spaceflight, Europe still has to formulate an answer to this development. In absence of existing policies and regulations for commercial human spaceflight in Europe, this thesis tries to explore a possible way in which a European regulatory framework can be established from the perspective of crisis management. It applies a model that prescribes the necessary elements for crisis management to spaceflight and shows how a regulatory framework with crisis management elements should be governed according to crisis management theories. Early on it became clear that a regulatory framework for commercial spaceflight should comprise of public-private cooperation. Through interviews with experts it has been determined to what extent crisis management elements should be the task of public or private actors. Existing commercial spaceflight regulations, standards and guidelines in Europe and the United States have been examined on such elements. Results show that both public and private actors should prepare, prevent, respond and manage the aftermath of accidents with manned commercial spacecrafts. Regulations for commercial spaceflight should contain requirements for private actors to be prepared for, prevent and learn from such crises. At the moment, regulations and guidelines in the United States do not contain such requirements. Based on the results this thesis would recommend the EU to ingrain space crisis management into its crisis response system and create some space safety standards and crisis prevention measures on the international level. EU policymakers should develop a regulatory framework with the EASA as the responsible regulating party. From the start the EASA should impose high-level crisis management requirements with light safety certification requirements for commercial spacecrafts in order to balance safety and innovation in an experimental market. Stricter safety standards should then be developed in cooperation with the private industry in order to guarantee safe flights when the European commercial spaceflight market opens to the general public. Crisis management and safety standards in the commercial aviation sector could serve as an example when developing commercial spaceflight standards. The ECSS standards contain useful provisions for designing safe space systems.

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Definitions and Abbreviations

Concept	Definition
1st Party persons	Individuals directly involved in operating the commercial spacecraft, i.e. flight crew/pilots
2nd party persons	Individuals not directly involved in operating the commercial spacecraft, i.e. cabin crew, ground crew, passengers
3rd party persons	The uninvolved public
Anomaly	A deviation from accepted standards
Accident	A major malfunction of a spacecraft that potentially could lead to injury or death among 1st, 2nd or 3rd party persons
Contingency	Possible event that must be prepared for
Crisis	An event, revelation, allegation or set of circumstances, which threatens the integrity, reputation, or survival of an individual or organisation. It challenges the public's sense of safety, values or appropriateness. The actual or potential damage to the organisation is considerable and the organisation cannot, on its own, put an immediate end to it.
Emergency	An event that involves a hazardous situation that needs an immediate response to prevent the loss of life or the further loss of life
Incident	A disruption of day-to-day operational activities
Issue	An condition or event, either internal or external to the organization, that if it continues will have a significant effect on the functioning or performance of the organization or on its future interests
Risk	A probability or threat of damage, injury, liability, loss, or any other negative occurrence that is caused by external or internal vulnerabilities, and that may be avoided through pre-emptive action.

Abbreviation	Description
AAIB	Air Accident Investigation Branch
AIP	Accident Investigation Plan
ALARP	As Low As Reasonably Possible
ATM	Air Traffic Management
CAA	Civil Aviation Authority
CAP	Contingency Action Plan
CECIS	Common Emergency Communication and Information System
CFSP	Common Foreign and Security Policy
CHIRP	UK Confidential Reporting Programme for Aviation and Maritime
CNES	Centre National d'Etudes Spatiales
CM	Crisis Management
CRPO	EU Crisis Response Planning and Operations
CRM	Crew Resource Management

CSDP	EU Common Security and Defence Policy
CSG	Centre Spatial Guyanais
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EASA	European Aviation Safety Agency
ECSS	European Cooperation for Space Standardization
ERCC	Emergency Response Coordination Centre
EDA	European Defence Agency
EEAS	European External Action Service
ESA	European Space Agency
ESDP	European Security and Defence Policy
ESPI	European Space Policy Institute
ERP	Emergency Response Plan
EU	European Union
FAA	Federal Aviation Authority
FAA-AST	Office of Commercial Spaceflight Transportation of the FAA
FEMA	Federal Emergency Management Agency
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Mode, Effects, and Criticality Analysis
FTA	Failure Tree Analysis
IAASS	International Association for the Advancement of Space Safety
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ITAR	International Traffic in Arms Regulations
ISS	International Space Station
JSpOC	Joint Space Operation Centre
KLM	Koninklijke Luchtvaart Maatschappij
MIP	Mishap Investigation Plan
NASA	National Aeronautics and Space Administration
NIMS	National Incident Management System
NTSB	National Transportation Safety Board
RLV	Reusable Launch Vehicle
SatCen	EU Satellite Centre
SMS	Safety Management System
SSA	Space Situational Awareness
STM	Space Traffic Management
UNOOSA	United Nations Office for Outer Space Activities
UK	United Kingdom
US	United States
US STRATCOM	United Stated Strategic Command

1. Introduction

1.1 The Dawn of the Commercial Space Race

For centuries, human spaceflight has been a dream of scientists and pioneers. Although this dream has only become a reality for a very few since the 1950's, recent developments seem to accelerate the pace in which spaceflight is being developed and is becoming available for the general public. While until now human spaceflight has been almost exclusively an endeavour undertaken by the governments of the major powers on the globe, it seems that within the field of experimental spaceflight the baton has been passed to commercial organisations. A commercial space race seems to have commenced, as multibillionaire companies like SpaceX, Blue Origin and Virgin Galactic recently have begun with testing the first prototypes of new ways of transporting humans into space. Moreover, in 2010 the first commercial spacecraft was successfully launched in to an orbit around Earth by SpaceX and returned to the surface (Kraaijvanger 2016). Since then, SpaceX has successfully delivered cargo to the International Space Station (ISS) and in 2014 has obtained a contract from the American government to deliver cargo to the station on a regular basis. This opening of space for private companies not only brings numerous new opportunities, but also many new dangers.

While delivering cargo to space stations and sending humans into space are very new undertakings for the private sector, commercial companies already have owned assets in space for decades. Today, numerous communications, scientific, military and other types of satellites orbit the earth, totalling in 1419 known satellites (UCS Satellite Database 2017). More than half of these satellites are owned by private companies. These satellites are being used for many daily activities of millions of individuals around the globe, like communications via mobile phones and the internet, weather forecasting or for scientific purposes, indicating the importance of space and the impact of any incidents with satellites in space. Furthermore, the current commercial space race that is developing includes new opportunities but also new dangers. The increasing number of artificial objects orbiting the planet already has led to collisions in space (Ianotta & Mariq 2009). Moreover, in 2014 the first casualty in commercial human spaceflight occurred when Virgin Galactic's SpaceshipTwo crashed in the Mohave Desert. This accident was the result of the combination of faulty design and human error, indicating the early state of development in the commercial spaceflight sector (National Transportation Safety Board 2014).

1.2 Political and Societal Relevance

The recent rise in space activities is not going unnoticed in Europe. In the last decade, the EU has begun to recognize that assets in space are vital for sustaining numerous critical infrastructures on the European continent. Already in 2008, the Council of the European Union declared 'that space assets have become indispensable for our economy and that their security must thus be ensured.' (The Council of the European Union 2008: 10. Also, the European Commission underlines the importance of protecting its space capacities and access to space, and thereby acknowledging the importance in managing the hazards that come with launching and operating assets in space. In its Space Strategy for Europe, the Commission names several of these: 'growing threats are also emerging in space: from space debris to cyber threats or the impact of space weather' and emphasizes that 'Europe must draw on its assets and use space capacities to meet the security and safety needs of the Member States and the EU' (The Council of the European Union 2008, 12).

Moreover, in June 2016, the European Parliament adopted a resolution on space capabilities for European security and defense purposes in which crisis management capabilities in space are addressed. In the resolution the European Parliament underlines the importance of preparing new space assets that are part of critical infrastructure like the European version of GPS, the Galileo satellite program, for evolving threats. And stresses;

> 'that the EU could play a role in making European space capabilities and services more robust, resilient and responsive; is convinced that a rapid reaction capability to replace or restore damaged or degraded assets in space as a crisis unfolds should be developed effectively through multi-state partnerships, including at European level' (European Parliament 2016: 10).

The European Parliament has urged the European Commission to improve the accessibility of space for the EU and its Member States in the event of a crisis by coordinating and developing space projects and supporting launch infrastructure, research and development, including through public-private partnerships (European Parliament 2016: 11). In October 2016 the European Commission formulated its new Space Strategy for Europe, in which its states that 'space capacities are strategically important to civil, commercial, security and defence-related policy objectives' (European Commission 2016: 8).

This narrative on resilience of space assets and crisis management in space is also present in research done by the European Space Policy Institute (ESPI), a research institute created by the European Space Agency (ESA). In a policy paper, the EPSI recommends to the policy makers in the EU to add space crisis management to the already existing terrestrial crisis management framework that is part of the European External Action Service (EEAS) mandate. The EEAS manages the EU's Crisis Platform, which includes various crisis management mechanisms (Robinson 2013: 11). The report recommends integrating space crisis management into the broader space security concerns of the EU by:

> 'Drawing on terrestrial crisis management experiences, put forward policy measures, information sharing/safeguard measures, investment strategies and other elements required for bolstering Europe's space crisis management capabilities' (Robinson 2013: 30).

It further recommends the EU to 'undertake Europe-wide space crisis management exercises' (Robinson 2013: 30). These exercises should include the political/strategic and operational/tactical levels of crisis scenarios and should make use of existing frameworks. These recommendations of this EU policy research institute show the relevance and importance of space crisis management in contemporary security policies.

While policymakers within the EU recognize the importance of making assets and activities in space secure, a regulatory framework that concretely prescribes how to achieve this, still has to be created. In any case, there are no world-wide safety standards for space activities, every spacefaring nation has developed its own set of standards, with the US, Russia, China, India, Japan and Australia developing their own safety rules. Nevertheless, it is argued that the European safety standards 'constitute the first truly international set of space safety standards' (Pelton & Jakhu 2010: 44). The European Cooperation for Space Standardization (ECSS) provides a framework in which an effective set of safety standardizations could be developed. However, these standards are only used by ESA to set standards for contracted private parties.

Still, the EU Space Industrial Policy formulated in 2013 by the European Commission shows the intentions of the EU to change this gap in legislation. In this policy, the commission expresses the ambition to 'establish a coherent regulatory framework' and specifically elaborate on the question if it should explored 'whether commercial spaceflights activities need to be embedded in a legal framework' (European Commission 2013: 13). This shows that EU policy makers do find the lack of regulation an issue and see the coming rise of commercial actors in space as a development that should deserve attention. However, it needs to be seen what effect this written policy have had on crisis management capabilities in the space sector. From interviews with experts in the field it has become clear that the EU has not taken any action in regard to regulations for commercial spaceflight since the formulation of the Space Strategy for Europe policy document. The reason for this apparent stagnation in legislative development is twofold; it happens because European policymakers do not want to interfere in the current agreement between ESA and the EU and because European policymakers tent to concentrate on economic motives for investments in space (Interview EU policy expert November 2017). According to experts this going to be a problem because Europe will lag behind on the global stage if it does not decide to invest in public-private spaceflight cooperation, as is currently happening in the United States.

Moreover, a 2013 report on the potential of the European commercial spaceflight market that has been carried out by order of the European Commission, underlines the lack of regulatory clarity at the EU-level and the need for a European regulatory framework for commercial spaceflight (Booz & Company 2013: 4). Furthermore, a study from 2014 shows that there is need within the European commercial space industry for a regulatory framework in order to give private actors some guidance in the development of new space crafts (Masson-Zwaan et al. 2014: 82).

The absence of a unified sets of regulatory rules for the commercial space industry also seem to underline the need for adequate crisis management in space, as the spacefaring industry is more prone to incidents because of its novelty. The question arises, is the EU prepared for the predicted rise of space tourism?

1.3 Academic Relevance

On the academic level, studies on the subject of crisis management in space do exist. More recent discussions on space crisis management are often done from an international relations perspective. These articles often elaborate on crises in space as national security issues (Pace 2015; Slann 2015; Petras 2002; Gallagher & Steinbruner 2008; Lynn 2011; Robinson 2013; Hildreth & Arnold 2014). They view space as a possible extension of terrestrial international politics and space crisis management as an important part of the defense policies of earthly nations. Within this framework, any crisis management measures in space are seen as efforts to protect the interests of the respective country and its citizens. However, some scholars address the issue of space crisis management from a less international relations perspective, and focus more on commercial spaceflight (Mineiro 2009; Gubby & Hoffer 2014; Langston 2016;). In both approaches of space crisis management, the authors mostly discuss the possible dangers of activities in space, thus concentrating on risk assessment. The bulk of the knowledge on space hazards are derived from unmanned spacecrafts, in particular the thousands of satellites that have orbited the Earth since the late 1950's. For example, Kallberg (2012) addresses the dangers of space debris, space weather and kinetic attacks on space assets (Kallberg 2012).

In her EPSI report of February 2013 Robinson (2013) delves deeper into space crisis management. Her report even recommends using experiences with terrestrial crisis management for developing adequate space crisis management, but does not give details on which experiences would contribute to this. Regarding to commercial human space flight, a few articles elaborate on this matter. Parallels are drawn with the early days of other forms of transportation, like cars, trains and airplane: spaceflight is seen as the new future form of human transportation and incorporates the same risks as previous pioneering modes of transportation but also new ones. At the same time, the challenges and implications for the ethics in risk awareness, assessment and governance concerning human space flight are addressed (Langston 2016: 96). Further, the ethics and liabilities within the law in the case of a commercial human space flight accidents have been examined, calling for the creation of an international tort liability scheme (Mineiro 2009: 401). Some authors have already explored a possible European regulatory framework for commercial spaceflight (Hobe 2009; Masson-Zwaans & Moro-

Aguilar 2012; Von der Dunk 2013; Masson-Zwaans et al 2014), but do not approach it from a crisis management perspective.

It seems that the academic literature on space crisis management has mainly focused on the assessments of the possible risks for manned and unmanned space flight. Based on these risk assessments there have been several recommendations for what the aim of space crisis management should be and how it should be governed. However, the literature fails to give an adequate and clear crisis management framework on both the strategic and operational level in the case of an incident in space. This is even more the case when addressing crises in commercial space activities, as this is not elaborated on at all.

1.4 A Definition of Crisis in Space

Within crisis management research, the concept of 'crisis' has been fairly ambiguous. Crises have often been defined as 'sudden, unexpected, surprising and unpredictable' (Roux-Dufort 2007: 107). The problem with these definitions of a crisis is that they underline the exceptionality of a crisis, which makes it hard to describe its overarching characteristics. A better definition of a crisis has been formulated as:

> 'an event, revelation, allegation or set of circumstances which threatens the integrity, reputation, or survival of an individual or organisation. It challenges the public's sense of safety, values or appropriateness. The actual or potential damage to the organisation is considerable and the organisation cannot, on its own, put an immediate end to it' (Sapriel 2003: 1).

However, the definition of crisis is a very subjective one, as an event will be perceived only as a crisis by those that are experiencing it as a crisis. In this respect, crises are situations where organizations temporarily lose the ability to make sense of the events that are unfolding, defining it as a result of an experience rather than a result of an event. This approach to the definition of a crisis has already been proposed by several authors (Boin & McConnell 2007; Roux-Dufort 2007; van Laere 2013; Topper & Lagadec 2013). As Roux-Dufort puts it: 'in short, the crisis has no existence by itself, it exists through the way in which it is experienced by the individuals concerned' (Roux-Dufort 2007: 110). Because of the subjective nature of the definition of a crisis, this thesis wants to define a crisis based on the scope of its impact on people, property and infrastructure. The bigger the impact of a crisis on an organization or multiple organizations, the higher level of urgency and need for coordinated response. This depends on two factors: the scope of the crisis and the organization's preparation for and experience with the crisis situation. A minor incident sometimes only needs the activation of an operational unit, a response unit. However, a minor incident could be experienced as a crisis by a small, inexperienced organization and it will trigger a larger part of the crisis organization. The same event will not have the same effect on every organization, for one organization it is an incident that can be handled easily, for the other it is a crisis that needs the management by a crisis team (Roux-Dufort 2007: 109-110).

Within the academic debate of the last decades, two different changes in narrative related to the concept of crisis can be observed. Firstly, the scope and impact of crises seems to have changed, changing from traditional crises to transboundary crises. Traditional crises and disasters are the type of exceptional situations that most people think of, like bridges collapsing, fires in public spaces, explosions in chemical factories etc. However, according to scholars it can be observed in current-day modern societies that crises increasingly do not limit themselves to one area but easily infect other sectors and functions. Transboundary crises happen 'when the functioning of multiple, life-sustaining systems, functions, or infrastructures is acutely threatened and the causes of failure or courses of redress remain unclear' (Boin 2009: 368). Transboundary crises are also transboundary in time: while traditional crises have a clear beginning and an end, transboundary crises do not have this feature. This stresses the fact that crisis management should not only prevent crisis and handle it when they occur, but should also look at the aftermath of crisis, in which longer term effects become manifest. The origin of transboundary crises cannot be easily identified and transcend borders. Crisis therefore can become transboundary in time, involving both public and private actors and might become international in character as well. Furthermore, policy makers are having difficulty coping and managing these crises, often they find it hard to make the right decision when a transboundary crisis occurs (Hermann & Dayton 2009; Zahariadis 2013). Crises and disasters in space or where space assets are involved in can be easily defined as transboundary crises, as these situations are not bounded to any geographic location on earth and have the potential to affect persons and infrastructures in different nations and continents.

Another development within the academic debate on crisis management is that crises should not be seen just as exceptional events but part of a long-time process that at a certain point fails. Traditionally, crises have been seen as exceptional events that occasionally happen and that break the line of normality. However, in the last decade, scholars are increasingly agreeing that this traditional view of the occurrence of a crisis is incorrect and obsolete in the modern-day globalised society. When one wishes to study the functioning of crisis management in organisations, then seeing crises as exceptions is not very helpful. As Christophe Roux-Dufort notes: 'crisis management is perceived as the management of exceptional or out-of-the-ordinary situations, but it does very little to help theorize the functioning of organizations' (Roux-Dufort 2007: 105-106). Within this view, the crisis is not only the actual event that triggers a disaster but more a process with an incubation period. This approach in analyzing crises was first conceived by Turner (1976) and describes a crisis having five stages: the notionally normal starting point, incubation period, precipitating event, the onset, rescue and salvage – first stage adjustment and the full cultural adjustment stage (Turner 1976: 381).

These authors try to steer the perspective on crisis as a phenomenon away from seeing a crisis only as the visible triggering event to seeing crisis as a process. Crises should be analyzed 'as a process of organizational weakening that degenerates until the point of disruption we shall call the precipitating event' (Roux-Dufort 2007: 108). By viewing crises as a process, it is possible to understand the occurrence of an incident within an organization or infrastructure better. By recognizing the existence of potential pre-crisis stages that have led up to the emergence of the triggering event, previous unidentified causes of the crisis can be addressed and linked to the triggering event. Crises thus should not be seen as a sudden disruption of the normal day-to-day activities, but should be approached as 'crisis events as the transition from one state of equilibrium to another through a massive disruption' (Topper & Lagadec 2013: 11).

Crises are thus being defined as looming, with the actual stage of emergency as the culmination of a process of failure. However, this does not mean that the traditional approach of crises, as a sudden and exceptional event, is false or irrelevant. When a small-scale accident happens, like a car crash, the traditional view on a crisis can still be useful. The process approach is rather an addition to the event approach, it tries to add a more strategic view to an operational crisis response. As van Laere (2013) puts it: 'the process view is complementary to the event view. It explains how organizational conditions build up that lay favorable ground for the crisis to be triggered' (van Laere 2013: 22). Crises happen on different scales and crisis managers should be aware that crises are being handled differently on each scale.

In conclusion, a definition of crises in space should entail an approach of crisis as a long-time process, involving public and private actors on a global scale, that eventually leads to a major accident. A crisis in space is not a sudden event that one cannot prepare for, but can be prevented with the right measures in place. Any crisis situation in space should not be seen as an isolated event on itself and these situations involving space assets, especially objects in near-Earth orbit, could potentially impact many around the globe. Any policy that tries to tackle these potential disasters in space should try to accomplish this from a process-oriented perspective.

1.5 Research Question

The recent advancements by the private sector in space flight and the lack of existing regulations and standards for commercial spaceflight within the EU highlights the relevance of this subject. As one scholar puts it: 'opening access to space to the public inherently raises novel concerns for increased risk awareness, communication, and management among commercial entities and voluntary participants' (Langston 2016: 83). Because of the lack of formulated CM policies and regulations for commercial spaceflight in Europe, the goal of this thesis will be to explore a way in which a regulatory framework for commercial spaceflight can be established in Europe. At the same time, the current state of regulations and guidelines in Europe and the United States will be examined and the parts that need improvement or are missing in Europe will be identified. Because the United States is the only Western country that has formulated actual regulations and guidelines for the commercial spaceflight industry, this thesis will examine to what extent it will be useful to serve as a baseline for future European regulations and guidelines.

This thesis will use an theoretical crisis management framework to determine the necessary tasks for space crisis management for commercial spaceflight and to examine the current state of regulations and standards in Europe and the United States in preparing for, prevention of, responding to and evaluation of potential future accidents in commercial human spaceflight. Because of the highly exploratory nature of this thesis, CM standards from the commercial aviation industry will be examined and considered as a baseline for the creation of proper regulations for the commercial spaceflight industry. The research question that this thesis will try to answer is:

What are the critical success factors for arriving at a further concretization of EU crisis management policies and regulations for commercial human spaceflight companies?

This thesis is structured as follows: in the first chapter, the theoretical framework will be laid out; while in the second chapter will elaborate on the research methodology. In the first part of the analysis the relevant existing public and private actors for crisis management in the commercial spaceflight sector will be identified. To answer the above research question, this thesis will thematically explore the desired tasks and responsibilities among public and private actors that are needed to carry out every aspect of effective crisis management and examine to what extent these tasks and responsibilities are laid out in the formulated regulations and guidelines in Europe and the United States. Where current regulations are missing crucial parts of effective crisis management, CM regulations used by the commercial aviation industry will be considered. This thesis will end with a conclusion in what way a regulatory crisis management framework for the commercial spaceflight industry in Europe can be achieved. It will make recommendations for the way that the EU could chose to successfully arrive at a further concretization of EU crisis management policies and regulations for commercial spaceflight companies.

2. Theoretical Framework

Within the discipline of crisis management, several different theoretical models of crisis management can be found. Because it has not been tried before to adapt a crisis management model to an organisation that concerns itself with spaceflight, this thesis will use a general model that prescribes effective crisis management and apply it to commercial spaceflight. Since this study is aiming for arriving at critical success factors for policy development, it will first work out the research question in theoretical respect and in this way come to an analytical framework that will be used to answer the research question. The theoretical framework of effective crisis management that this thesis will use provides the components that should be part of regulations and guidelines that prescribe CM standards for commercial spaceflight organisations. While adapting the model of effective crisis management to spaceflight, the process-orientation towards CM will be considered, approaching a crisis as a underlying process that manifest itself at a certain point.

Such a framework should not only contain the directions for handling the actual crisis situation, but also the preparation for, the prevention of, and the proper management of the aftermath of a crisis situation. These components of effective crisis management should not happen in a linear fashion, but should be seen as a cluster of activities that can happen at the same time, as will be explained. In the second part it will be explained how such a framework of crisis management should be governed. The integration of both elements will form the basis for the analytical framework of this study.

2.1 Process-orientation towards CM

As space crises are often not bound to a location or time, space crisis management should also not be limited in this way. The relational model of Jaques (2007) tries to remove this linear thinking in crisis management by offering a more holistic approach. It builds on the process approach of crises and tries to remove simplistic linear thinking in crisis management by suggesting that measures of preparing for, preventing and managing a crisis should happen simultaneously, a non-linear fashion. Thus organizational learning should happen all the time, in all levels of the organization and before, during and after a crisis.

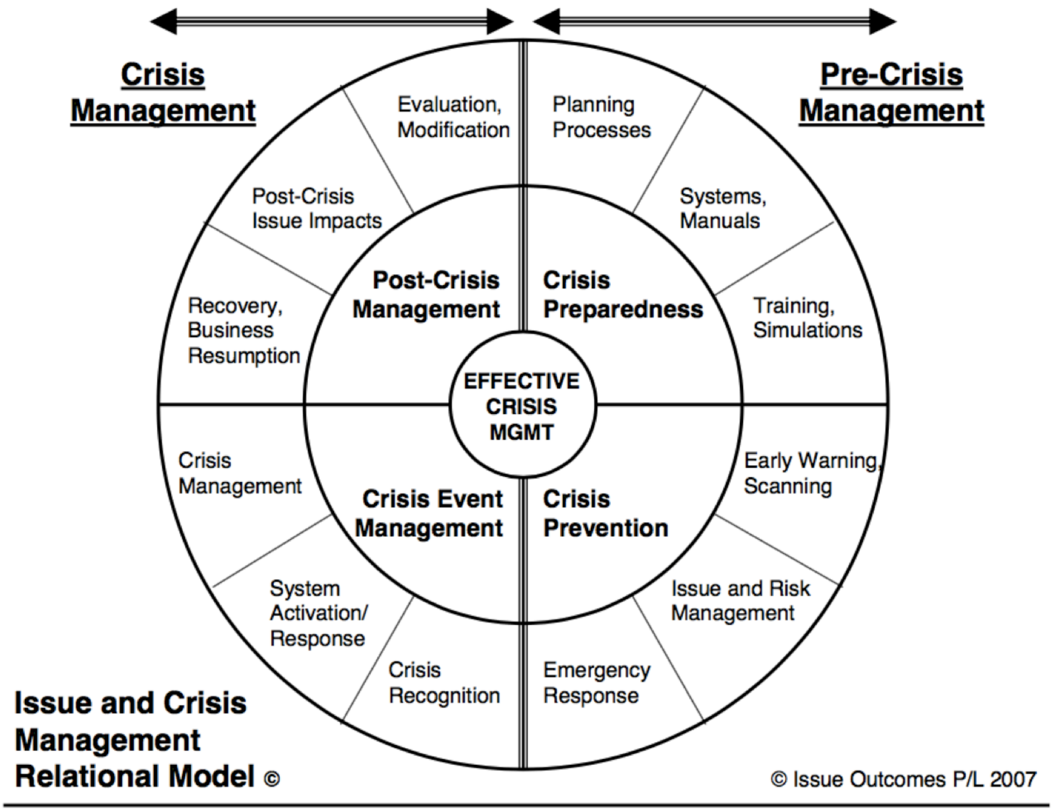

Figure 2.1: Relational Crisis Management Model (Jaques 2007: 6)

This means that the pre-crisis management and crisis management measures as depicted in figure 2.1 can happen at the same time and that new issues can arise during a crisis from which new crises can develop. In the words of Jaques (2007):

> The model's non-linear structure emphasizes that the elements should be seen as "clusters" of related and integrated disciplines, not as "steps" to be undertaken in a sequential fashion. And while the pre-crisis and crisis management hemispheres of the model have an obvious temporal relationship, the individual elements may occur either overlapping or simultaneously. In fact crisis prevention and crisis preparedness for example most often *should* happen simultaneously. Moreover, not only do some of the adjacent elements or clusters overlap but there is a substantial overlap or commonality between some non-adjacent elements, for example between early warning/scanning and crisis recognition. Similarly, the post-crisis learnings of one organization can

> provide early warning and improved crisis preparedness for *other* organizations' (Jaques 2007: 12).

By presenting a more integrated relational approach to crisis management, the model gives a better representation of the link between crisis management activities on different organizational levels (strategic, tactical and operational) and during the different phases of crises (pre-crisis, crisis and post-crisis). For example, he poses issue management as a vital part of crisis prevention, but also links it to the other elements of crisis management by seeing it as a process that really never stops. This can be explained by defining an issue as 'a condition or event, either internal or external to the organization, that if it continues will have a significant effect on the functioning or performance of the organization or on its future interests' (Regester & Larkin 2005: 43). It is the task of higher management to recognize this issue as soon as possible and act upon it. An issue can be recognized by management itself but also be presented to them by individuals other layers of the organization. In this way an issue is "an unsettled matter which is ready for decision" by the strategic level (Jaques 2007: 1). Issues can arise from operational mistakes or wrong procedures, like the handling of hazardous materials without protective clothing or the habit of personnel to easily loose their security passes to a high security area.

Issue management in this context is thus the identification and management of internal operational problems by the strategic or tactical level of an organization, after risk management procedures fail to identify or properly manage these risks in becoming an issue. From this definition of an issue, it can be derived that issue management is solving an issue within an organization before it becomes a crisis, and therefore an important part of pre-crisis management. Risk management is about recognizing and tackling mistakes and errors in the daily activities of an organization before they become an issue. This makes it the earliest chance to prevent a crisis.

By posing risk management and issue management as tools that prevent crises before they event happen, it is possible to see how they are connected to crisis management and to see what they essentially are, important parts of crisis prevention. As can be seen in Figure 2.1, the model suggests four main elements that effective crisis management should contain: Crisis Preparedness, Crisis Prevention, Crisis Event management and Post-Crisis Management. Issue and risk management can within the model be seen as part of Crisis Prevention. At the same time, it is important to recognize the fact that crises not only can arise from issues but issues also can arise from crises.

This is why issue management is also important in crisis management during the crisis response and during post-crisis phase, because often when a crisis situation is on-going or even when its resolved, new issues can arise from the situation at hand. For example, the BP oil spill in de Mexican gulf was firstly a crisis in the form of an major accident that threatened the lives of all the people on the oil platform. When this crisis was resolved by evacuating all the personnel, the pending issue of the oil leak, caused by the explosion, was not properly solved by management and it quickly led to an environmental crisis. An example of this involving a potential future crisis in space, would be the situation when a crisis is solved by evacuating a manned spacecraft that is loosing air pressure. However, thereafter the now unmanned spacecraft is at drift and threatens to collide with other space assets that are part of a vital infrastructure on Earth. In this way a new crisis can be triggered by an earlier crisis.

This changing and transboundary aspect of modern-day crises confirms the need for a crisis management scheme that is non-linear, where all the four main aspects of crisis management could potentially be at work at the same time. While some aspects of crisis management will be more relevant in certain phase of a crisis, like after care taking mainly place in the post-crisis phase, it will have effect on other aspects that are more relevant in other phases. Experiences in the response and post-crises phase will for example have effect on preparedness, as the crisis organisation will be adapted according to these experiences. It is possible that the crisis organisation will be adapted while after care is still happening. Concluding, the model of Jaques emphasises that the elements, or clusters of activities, of crisis management are not necessary bound to a certain phase or time during a crisis.

In short, the activities related to all the aspects of the four elements of effective crisis management are summarized in the following table:

	Element	Aspect	Examples of actions
Crisis	**Crisis Preparedness**	Planning Processes	❖ Putting planning in place ❖ Assigning roles and responsibilities ❖ Establishing process ownership
		Systems, Manuals	❖ Includes crisis management infrastructure, equipment, “war rooms”, resources, documentation.

		Training, Simulations	❖ Familiarizations programs ❖ Testing ❖ Table-top exercises ❖ Live simulations
	Crisis Prevention	Early Warning, Scanning	❖ Audits ❖ Preventive maintenance ❖ Issue scanning ❖ Social forecasting ❖ Environmental scanning ❖ Anticipatory management ❖ Future studies ❖ Safety Culture ❖ Space Situational Awareness ❖ Space Traffic Management
		Issue and Risk Management	❖ Identification of issues ❖ Prioritization of issues ❖ Stakeholder identification ❖ Strategy development and implementation ❖ Recognizing and mapping possible risks and failures.
		Emergency Response	❖ Emergency response infrastructure, documentation and training
	Crisis Event Management	Crisis Recognition	❖ Transition from emergency situation ❖ Objective assessment ❖ Early recognition of crisis
		System Activation/Response	❖ Activation process of response systems ❖ Effective mechanisms for call out ❖ Availability of back-ups ❖ Systems redundancy
		Crisis Management	❖ Strategy selection and implementation ❖ Damage mitigation ❖ Stakeholder Management ❖ Issue Management ❖ Media Response/Crisis Communication
	Post-Crisis Management	Recovery, Business Resumption	❖ Operational Recovery ❖ Financial costs ❖ Market retention ❖ Business momentum ❖ Share price protection
		Post-Crisis Issue Impacts	❖ Coronial inquests ❖ Judicial inquiries ❖ Prosecution ❖ Litigation ❖ Reputational damage

			❖ Media scrutiny
		Evaluation, Modification	❖ Root cause analysis ❖ Management assessment ❖ Process review ❖ Implementation of change

Table 2.1: Table of crisis management based on the model of Jaques (2007) (by author)

It is important to keep the non-linear, relational aspect of the model in mind when examining it.

As discussed above, the activities and processes of effective crisis management are clustered around four main components: crisis preparedness, crisis prevention, crisis event management and post-crisis management. In all these clusters of activities and processes there are human or automated actors that are needed to carry out these processes. At the same time, a distinction must be made between the character of the activities and processes that happen within an organisation during a crisis and when it is just carrying out its day-to-day business. This can be explained by considering time and perception as factors during crisis management.

Firstly a distinction has to be made between the situation when an organization is doing their day-to-day businesses and when it finds itself in a crisis situation. There is a difference in pace and organizational dynamics of a crisis situation compared to a non-crisis situation. It is argued that 'organizing in crisis and organizing in non-crisis in essence is more similar than different ' (Van Laere 2013: 24). Indeed, an organization in a crisis consists of the same people and resources as it had when there was no crisis at hand. However, what changes during a period of crisis is the time that is available to organize. Crises are fast-paced and require quick decision-making and fast coordination of the different people and resources within the organization to solve the crisis situation at hand. Essentially, the organization has to function in a pressure-cooker environment, it has to perform in an environment where the available time is compressed and actions and options are limited. This is why organizing during crisis needs exceptional governance and organizations need preparation for this in the form of crisis plans and training.

Another factor that is in play here is perception, namely the perception of human or automated actors that are part of the organization in crisis of their surroundings. How crises are handled or even whether they are named a crisis are heavily influenced by the perception of the ones involved. Certain situations are named crises only because those involve perceive it as a crisis. The next section will address these arguments concerning the governance of crisis management and will add known best practices from the crisis management literature and integrate it to a framework for space crisis management.

2.1.1 Crisis Preparedness

Considering the transboundary aspect and the process-view on crises has consequences for how the preparation of a spaceflight organization for crises should be structured. Information should be free-flowing within the crisis organisation and decision making should be adaptive, sometimes centralized, sometimes decentralized. This has mainly implications for how the strategic, tactical and operational layers of an organization work together.

Adequate planning for crises is a crucial part for an organisation to be prepared for a crisis situation. Empirical evidence confirms that without proper crisis planning, the chances of an organization adequately handling a crisis diminish greatly and the organisation may never recover from it (Fink 1986: 69). Much can be gained from pre-crisis determination of roles and responsibilities, the creation of crisis materials, equipment and information systems and the testing of the crisis organisation through simulations (Rosenthal and Pijnenburg 1991; ‘t Hart 1997; Boin et al. 2004).

2.1.1.1 Crisis processes and infrastructure

Traditionally, crisis management was seen as a militaristic top-down process, crisis management and authority should be centralized and the organization should have a hierarchical structure. Such a basic crisis organisation for an organization is shown in figure 2.2. This basic structure is derived from crisis management organisations within the Dutch and British governments. As it can be seen, in a basic crisis organisation there is a strategic, tactical and operational level. Practical experiences have shown that it is important that an organization develops a basic crisis management plan that is applicable to all kinds of crisis situations. This holistic crisis management plan should at least contain an executive crisis team that takes strategic level decisions and an tactical crisis team that takes tactical and operational decisions (Muller et al. 2009: 960). It should be very clear how the responsibilities, tasks and authorities are divided among the crisis teams and individuals within the crisis organization (Muller et al. 2009: 965).

Every team as a whole should know its responsibilities, tasks and authorities and every individual should know these too as part of that team. Also, these responsibilities, tasks and authorities should be written down in a crisis plan.

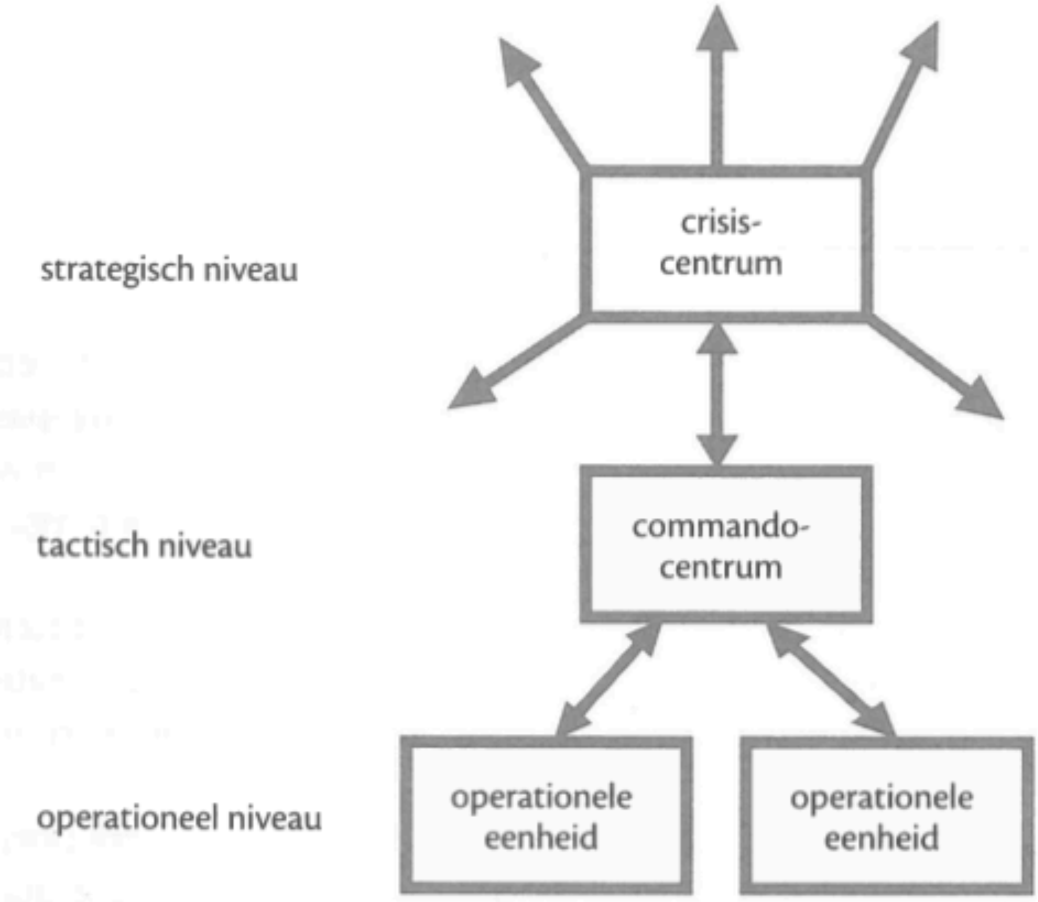

Figure 2.2: Basic crisis organization (Zanders 2012: 62)

The basic crisis organization shown in figure 2.2 has a top-down, hierarchical approach and takes the assumption that crises can be handled from purely centralized decision making. However, planning for crisis can only happen to a certain extend and proper crisis preparation can be inhibited by cultural and organizational factors. Also, from experiences in the field it can be learned that what is planned in advance often deviates a lot from what actually happens during a crisis event (Quarantelli 1988: 374). Too much top-down crisis planning can lead to organizations that are not adaptive enough to adequately respond to a crisis at hand. Several scholars already have argued for a non-centralized approach to crisis management and a leave from the militaristic central-command approach that has been proposed in the past ('t Hart et al. 1993; Boin

& McConnell 2007; Boin 2009; Muller et al. 2009; Topper & Lagadec 2013). Too much centralization can lead to crisis managers to be overwhelmed with information and decisions to be taken. Also, this can lead to groupthink, a situation where leaders make decisions not based on all available information and options. Therefore it is important to have a more decentralized crisis structure and make a distinction between strategic, tactical and operational tasks. Quarantelli (1988) elaborates on this;

> 'strategy, in general, has reference to the overall approach to a problem or objective. But there are always situational factors or other contingencies which require particular adjustments to attain a specific goal if the overall objective is to be attained. This is the area of tactics' (Quarantelli 1988: 375).

Topper & Lagadec (2013) have created a crisis management theory based on the the theory of fractal geometry. Not departing from a top-down or bottom-up approach, with the use of the theory of fractals, it is suggested that each actor or component in a crisis has its own 'autonomy, impulse and specific variability' (Topper & Lagadec 2013: 13). This has implications for the communication during the managing of a crisis: 'during a crisis event, one piece of information is received differently by the actors (partial transmission, mutation, distortion, etc.) and every single actor interprets it differently based on his local reality and acts differently' (Topper & Lagadec 2013: 13). The way an individual responds to an emerging crisis is determined by the available information and how he or she perceives it. This has implications for determining who during a crisis will have certain roles and responsibilities. The problem is that organizations that experience a crisis situation need fast-decision making while not always having the best and newest information to act on. This highlights the problem that during crises, information is often very scarce. Furthermore, crises often present decision makers with new situations in which it is not clear who is responsible and has the authority to act upon the problems presented.

Firstly this seems to implicate that responsibilities should be clearly defined before a crisis occurs within the organisation's crisis plans. At the same time authority should not be too centralized as the very nature of crises inhibits a highly centralized organisation from adequately responding to a crisis at hand. The organisation thus has to adapt its structure and governance when handling a crisis. When adding the notion of Topper and Lagadec's theory that every person on a different level within an organisation interpreters information different, the argument of transferring authority within an organisation during a crisis situation becomes even more stronger. If a person in the local, lower level in the organisation has the most relevant information and the best interpretation of a crisis situation, he should have the authority to act on this information. Asking for this authority to act in the higher levels of the organisation would cost valuable time, something that is scarce in a quickly unfolding crisis situation involving operating spacecrafts. An extraordinary situation like a crisis asks an extraordinary ability of an organisation to adapt its structure. A crisis situation asks a different structure of an organisation than during normal operations.

Thus the crisis planning of an organization should lead to a decentralized, adaptive organizational structure during a crisis. However, there is also the argument that a crisis organization should not be too decentralized, as this will lead to an uncoordinated and ineffective response. To adapt itself to a fast-paced and changing environment, an organization has to be paradoxically centralized and decentralized at the same time. This asks for the planning of a organizational crisis structure where the different components and layers all work together to solve the crisis at hand but do not have too interference from each other in a way that it inhibits making the right decisions at the right time. This is why describing the assignment of roles and responsibilities and establishing process ownership should be such an important part of crisis planning. Each team and individual on the strategic, tactical and operational level should have a clear mandate and not interfere which each other's tasks and responsibilities. At the same time, a certain level of hierarchy is maintained. An addition to the crisis organization in order to improve its adaptability is the implementation of tasks forces on the strategic and tactical level (Zanders 2012: 103). The tasks and responsibilities of these task forces should be centered around a certain aspect or problem of the crisis at hand. These task groups can be created on an ad-hoc basis on both the strategic and tactical level.

Topper and Lagadec give a solution to the problem of adequate fast-decision making in an information-scarce environment, namely the creation of a separate organizational entity that handles and disperses all the information. Their proposal is the creation of an 'information over-watch team' within the crisis-command structure:

> ‘Dispatching the information would require an ‘information over-watch’ team. This special group would be in charge of collecting all new information, evaluating its credibility and importance, and delivering it with the appropriate context to the right person on the ladder. This organizational innovation would thus reduce the loss of information from bad contextualization or improper priority rating’ (Topper & Lagadec 2013: 14).

According to the authors, this will reduce the chance that information is placed in the wrong context or is given not enough priority. Responsibly and decision making is distributed throughout the organisational layers, while ‘each layer has its own dynamics; none can have a steering role and one needs to step back to understand the complexity of the system’ (Topper & Lagadec 2013: 15). Information management is an important part of good crisis management. For proper information management a crisis organization should have clear internal agreements on how information in routed through the organization during a crisis, strong criteria on which information is selected for whom and evident judgement and dispersion of information (Muller et al. 2009: 972 - 973). The creation of an information ‘over-watch’ team or information management team that safeguards these aspects of proper information management could be a valuable improvement of a crisis organization.

A component of crisis infrastructure that greatly improves internal information sharing during crises is a crisis management system (CMS), in which all available information on the crisis is stored and shared digitally. The function of a CMS is to:

> ‘identifying, assessing, and handling a crisis situation by orchestrating the communication between all parties involved in handling the crisis, by allocating and managing resources, and by providing access to relevant crisis-related information to authorized users’ (Kienzle et al. 2010: 1).

Such a CMS could be managed and used by an information management team to disperse information throughout the organization. It would be advisable to add an information manager to each crisis team throughout the organization that monitors the incoming information from the information management team and shares it with its crisis team or operational unit in the right context (Muller et al 2010: 275).

If we visualize what is elaborated on until this point in a basic crisis organisation for commercial spaceflight organizations we come to the basic crisis structure represented in figure 2.3. Important to note is the strict separation of the strategic level with the operational units, in order to prevent micro managing. Both the strategic and tactical level have a clear mandate through well-defined roles, responsibilities and tasks. However, the extend of mandate is not the same for all crisis teams and operational units, as illustrated by the extend of the dotted sphere. Furthermore, these mandates do not interfere with each other. Both the crisis teams on the strategic level and the tactical level have the mandate to create several task groups. Examples of strategic task groups would be a judicial task group for judicial matters, a media task group for monitoring the media, a reputational task group for managing reputation or a task group for communication with a certain government or other organisation. For the tactical level it could be task groups that try to tackle certain operational problems or barriers, like certain technical problems, a group that monitors the current space weather through the CMS or a group that manages the available operational resources.

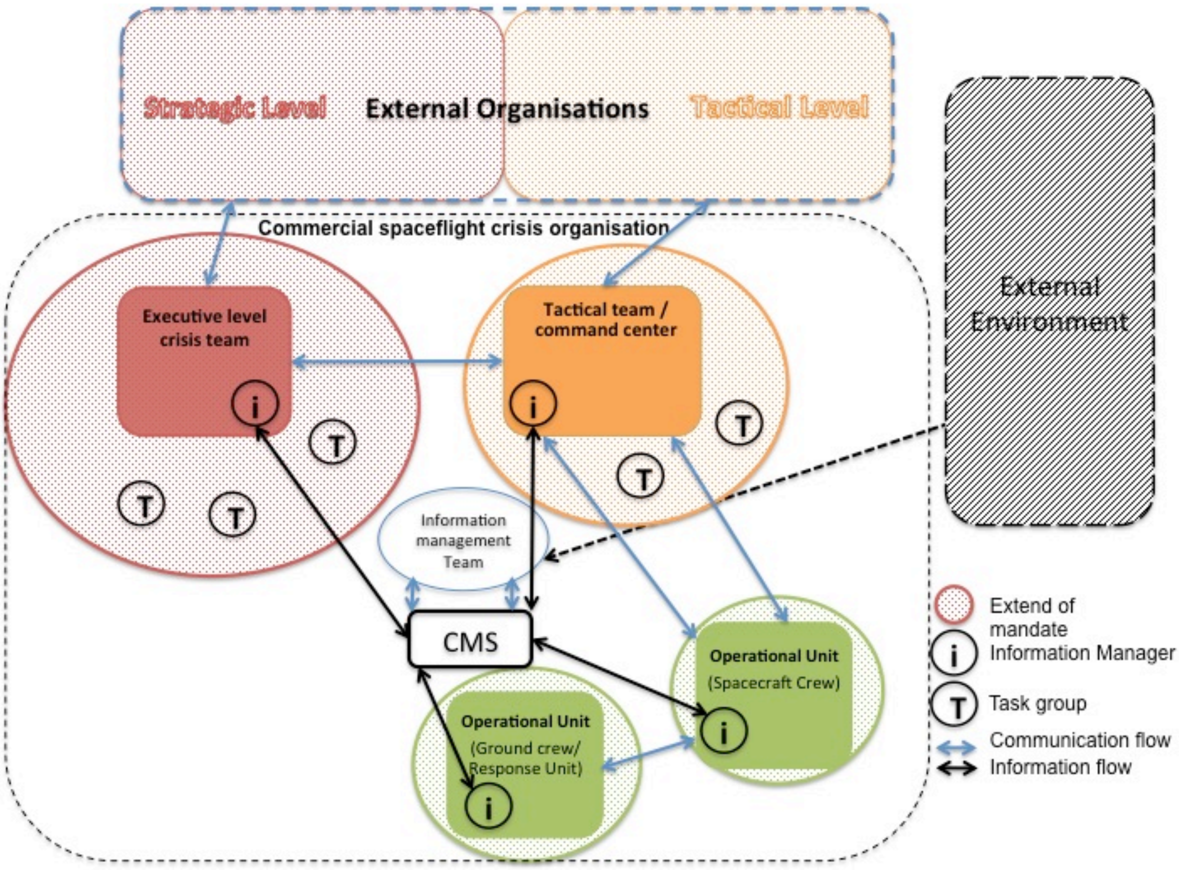

Figure 2.3: Basic commercial spaceflight crisis organization (Based on the model of Zanders (2012), adapted by author)

The model in figure 2.3 gives the most basic version of a crisis organisation. In practice, the crisis organization of each spaceflight organization will differ. Some will have more organizational layers and decide to have different crisis team for each layer or department. More importantly, not every incident or crisis asks for a full activation of the whole crisis organization. It has already been argued that this depends on the scope of the crises at hand and the experience of the organisation with dealing with such a crisis.

While every spaceflight organization should have a holistic crisis management plan that can be applied to every crisis, it is advisable to have additional crisis plans for the most probable crisis situation. This will give crisis management teams more guidance in certain situations and make their response better. From practical experience it has been observed that every organization should develop and train scenarios on these most probable crises (Muller et al. 2009: 961). For spaceflight organizations this could be for example the scenario of a manned spacecraft being stuck in a orbit that brings them in a collision course with another object, or a failed re-entry of a reusable vehicle resulting in a crash that involves fatalities on the ground in a foreign country.

Further best practices and recommendations for planning crisis processes and creating crisis infrastructures are given by numerous sources (Rosenthal et al. 2001; Muller et al. 2009; Kienzle et al. 2010; Zanders 2012; The British Standard 2014). They are in an overview in Table 2.2 with the already mentioned practices.

Crisis Processes		
Roles	**Responsibilities**	**Best Practices**

Executive Level Crisis Team
• Chairman
• Logger
• Information Manager
• Media expert
• Judicial expert
• Representatives of taskforce groups
	• Taking decisions that have influence on long term goals
	• Internal/External Crisis communication
	• Stakeholder management
	  o Public
	  o Private
	• Reputation management
	• Communication with external strategic level government
		• Informing tactical level of decisions that have influence on on-going operations
		• Refrain from micromanaging, no direct interference with operations
		• Further best practices are shown in paragraph 2.1.3.2

Tactical Crisis Team • Chairman • Logger • Information Manager • Technical experts	• Coordination of emergency response • Business continuity management • Communication with external tactical level government	• Informing strategic level on the situation on the ground • Further best practices shown in paragraph 2.1.3.2.

	• Representatives of taskforce groups	response • Communication with spacecraft flight crew	
	Information Management Team • Strategic Level Information Manager • Tactical Level Information Manager • Operational Level Information Manager • External Information Manager • Internal Information Manager	• Gather all relevant information on the crisis; • Evaluate that information in terms of quality and relevance to the crisis; • Filter, analyse and make sense of that information; • Communicate the information by dispersing them trough CMS • Present information to decision makers in an appropriate form.	• New concept, no best practices

Table 2.2: Basic components of Crisis processes (Rosenthal et al. 2001; Muller et al. 2009; Kienzle et al. 2010; Zanders 2012; The British Standard 2014)

Crisis Infrastructure
Crisis Management Plan
Contains at least; • Description of crisis organization • Description of the mandate of each crisis team or relevant operational unit. • Description of roles and responsibilities per crisis team • Key contact details of each team • Internal and external crisis communication procedures • Description of activation mechanism for crisis organization • Definitions of a crisis and an incident and the difference between them • Scaling-up of the the crisis organization • Where each crisis team is going to meet (with alternative locations) and what equipment and support are required • Key templates (such as CMT meeting agenda and logbook) • Log-keeping guidance • A situation report template which is to be used across the organization • Description of most probable scenario's and guidance for management • A designated person that is responsible for organizing and maintaining the crisis organization and updating crisis plans
Crisis Management System

	Function: • To help in the coordination and handling of a crisis; • To disperse information throughout the organization in a transparent manner and correct context • To ensure that an abnormal or catastrophic situation does not get out of hand; • Ensuring minimize the crisis by handling the situation using limited resources; • To allocate and manage resources in an effective manner; • To identify, create, and execute missions in order to manage the crisis; • To archive the crisis information to allow future analysis.
	Crisis rooms
	• Contains all the available crisis manuals • Contains basic requirements like proper lighting, air-conditioning and equipment for meetings (chairs, stools, beamers etc.) • Contains equipment for proper communication with the outside world (telephones, internet connection)

Table 2.3: Basic components of crisis infrastructure (Rosenthal et al. 2001; Muller et al. 2009; Kienzle et al. 2010; Zanders 2012; The British Standard 2014)

2.1.1.2 Crisis training and simulations

Planning crisis processes and having crisis infrastructure in place is not a guarantee for successful crisis preparedness, as without training of vital personnel and practicing through crisis simulations the crisis organization will most likely fail in practice. As Pearson and Clair argue: ‘executives and managers can develop too much faith (and a false sense of security) in their abilities to successfully prevent dangers when some level of crisis management preparation is adopted’ (Pearson & Clair 1998: 74). Without crisis training and simulations the confidence of executives and managers in the crisis preparedness of an organization will be fallacious. Moreover, it should be a requirement for a spaceflight organization to describe how the needed knowledge and competences are kept being up to date through exercises and simulations of crisis events. As is stated in the British Standard for Crisis Management:

> ‘Once the crisis management roles have been identified and specified, a training needs analysis should be carried out to confirm what crisis-specific training is required for all staff involved in implementing the organization’s crisis management arrangements. The results may be included in job specifications and performance agreements’ (British Standard 2014: 25).

It is argued that the roles and responsibilities of an individual within an organization during a crisis are not very different than during normal operations (Van

Laere 2013). This is confirmed by experiences of crisis managers, the structure of decision-making within the crisis management organization should not differ much from the structure of regular decision-making. This because decision-making will better and more efficient if the persons involved in the crisis organization are already used to the position within the crisis organization they are ought to have during crisis (Muller et al. 2009: 966). This has implications for who to select for a certain role and give them proper training. If a person normal role and responsibilities do not differ that much of the requirements of a certain role during crisis, this person should get that role.

Further, the theoretical framework of crisis management that this thesis uses teaches us that there should be separate crisis training and exercises on the strategic, tactical and operational level. Strategic level crisis management is more about recognizing organization-wide impacts of the crisis at hand and taking decisions to address those consequences. Tactical and operational crisis management is more about responding to and containing emergency situations on the ground. Crisis training and simulations should be adapted to the level within the organisation. From practice, it can be seen that roles within the crisis organization often are filled by people that do not have enough knowledge of the necessary competences for performing that role. This is why it is so important to formulate in advance what the qualifications of those involved in the crisis organization should have for their positions (Muller et al 2009: 962). Managing a crisis asks for basic managerial competences that managers already should posses for performing day-to-day managerial tasks, but it is wrong to think that this makes them prepared for managing an organization in crisis. If the crisis preparation of an organization consists of just putting a couple of managers without crisis training together in a room and calling them a crisis team, it is asking for problems (Zanders 2012: 211). Managing a crisis asks for specific managerial competences that managers do not necessarily obtain from day-to-day work.

However, defining these necessary crisis-managing competences has proven to be a challenge. Research shows that the definition of a person having certain competences differs a lot geographically and per field of work (Van der Klink & Boon 2003). Often HRM-managers use top-down standardised description of necessary qualifications for a certain position. This is however often a too generic description of a qualification, it cannot be guaranteed that a person having this competence will perform well in every crisis situation (Muller et al 2009: 401). Thus just mentioning the necessary qualifications that a person should get from crisis training for a certain position within the crisis organization is not enough for that person to be adequately prepared for a crisis. The British Standard for crisis management mentions a set of necessary crisis management skills that should be obtained through crisis training:

> ‘a) creating and maintaining shared situational awareness, with the underpinning skills in information management and analysis;
> b) analysing issues to appreciate their potential wider impacts;
> c) deconstructing problems, in order to assess their scale, potential duration, impacts, interdependencies and various dimensions;
> d) identifying and communicating effectively with stakeholders, the media and the public;
> e) identifying and countering threats (actual and emerging) to the organization’s integrity, brand, values and reputation;
> f) determining, articulating and reviewing strategy, aims and objectives, and maintaining strategic focus without being drawn into the operational detail;
> g) demonstrating visible leadership and decision-making, and providing clear, unambiguous direction to teams and people working in stressful situations; and
> h) using tools provided to assist in the performance of crisis management roles’
> (British Standard 2014: 26).

This list is already a good indication for the qualifications that a good crisis manager should have in order to properly managing a crisis. However, because every crisis situation is different, only trying to train managers in these generic skills is not sufficient. A list of these skills focuses too much on the person and not on the situation where the skills are needed. Crisis training should therefore be adapted to the type of crisis. This asks for a bottom-up approach of determining the necessary skills for crisis managers, these skills should be derived from deductive obtained knowledge (Muller et al. 2009: 425). Thus experience from real situations should determine which set of skills a crisis manager should posses. Because crisis situations do not occur often (hopefully), gaining crisis management experience through simulations of crises is crucial. Real crisis situations involving commercial spacecrafts have been scarce until now, so for private spaceflight organization, simulations of these crises would be even more important.

Therefore training in space crisis management should be tightly coupled to crisis simulations and the necessary skills should constantly be adapted through simulation experiences. By implementing feedback from evaluations of crisis simulations into crisis training, this training will be improved and the next time crisis teams will perform better during the simulation. Simulations therefore should be focussed on the testing of the skills of a certain crisis team or part of the crisis organisation and not only the crisis organisation as a whole (Zanders 2012: 220). Every spaceflight organization should have an extensive crisis training and crisis simulation program that is constantly being evaluated and adapted through crisis management experiences. Specific competences profiles for each position should be created and updated through experience. Concluding, a regulatory framework for crisis preparedness should contain requirements for the creation of an extensive crisis training and crisis simulation program by private spaceflight organisations. This also should include the description of a specific set of skills for each role in the crisis organization, while refraining from using a list of generic managerial competences as a standard.

2.1.2 Crisis Prevention

While proper preparation for a crisis is crucial for the ability of an organization to survive a crisis with minimal damage, the prevention of crises is at least an important activity as preparing your crisis organisation. By preventing crises before they even occur, it would not be necessary to activate the crisis organisation.

Prevention of a crisis can be done before and after an accident happens. The Swiss Cheese Model of Reason (1990) teaches us that there are pre-accident organizational conditions that can cause an accident. If we relate this to the model of Jaques (2007), the early warning and scanning and issue and risk management are sets of crisis prevention activities that prevent accidents from happening by identifying and mitigating risks and issues that occur because of system designs, human actions and organisational failures.

Reason (1990) illustrates this process in a 'Swiss cheese model'. In his model, the process in which the right circumstances for a crisis occurs is represented as a couple of slices of cheese with holes in it. The slices of cheese represent barriers within the organization that should prevent crises from occurring. But there are holes in the barriers, representing incidents or errors within the organization's processes that together form the steps in the buildup to a crisis situation. These holes can represent latent or active failures or in other words, system faults or human errors (Reason 1990). If enough of the holes are aligned, if enough failures and errors occur within an organization, a crisis occurs. Reasons Swiss Cheese model thus tries to explain how accidents happen and crisis situations occur, even with organizational defenses in place that should prevent failures from happening or being recognized before they do extensive damage.

An attempt has been made to adapt the Swiss Cheese model of Reason (1990) to the spaceflight industry, as shown in figure 2.4.

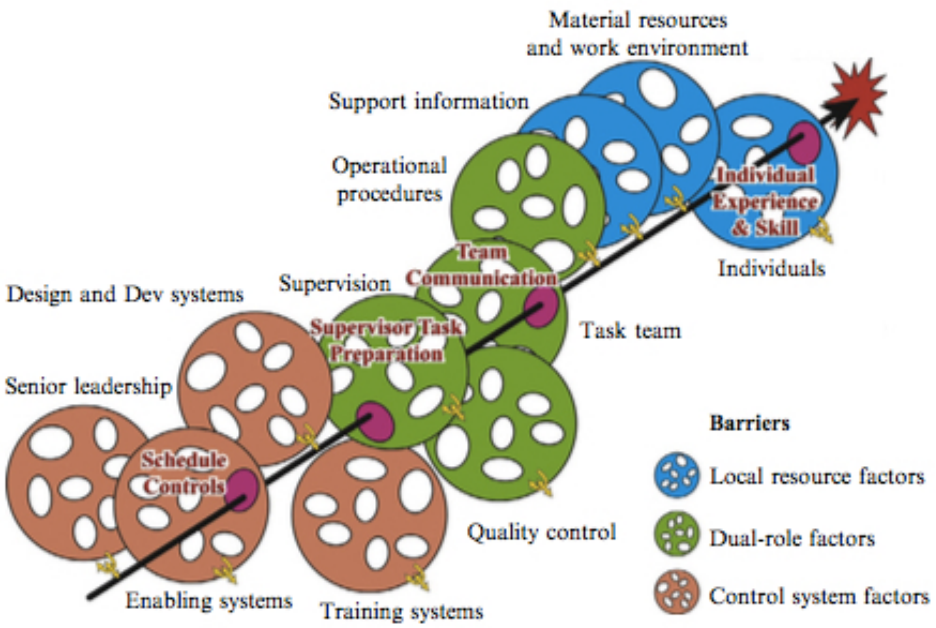

FIG. 14.1.2

Enhanced "Swiss Cheese" model with dual role barriers. Enhanced "Swiss Cheese" model with dual role barriers. Arrow indicates an event occurs because the barriers: schedule controls, supervisor task preparation, team communication, and individual experience and skills are less than adequate.

Figure 2.4: Enhanced Swiss Cheese Model (Sgobba et al. 2017)

The activities mentioned in the enhanced Swiss Cheese model of Sgobba et al (2017) are divided in to control system (latent failures), dual-role (latent and active failures) and local resource factors (active failures). This model tries to depict the changing environment in which spaceflight accidents can occur. As Reason itself puts it:

> The 'Swiss cheese' metaphor is best represented by a moving picture, with each defensive layer coming in and out of the frame according to local conditions. Similarly, the holes within each layer can be seen as shifting around, coming and

> going, shrinking and expanding in response to operator actions and local demands." (Reason 1990: 9)

All these barriers can be improved with a proper safety culture. Reason (1998) already proposed that organization's safety culture should entail a culture characterized by learning, reporting, justice, and flexibility (Reason 1998: 297). However, it is argued that the trial-and-error approach of Reason's Swiss Cheese model to organizational learning is not the most suitable for spaceflight organisations, as missions are unique and there are not much learning opportunities before an major crisis occurs (Sgobba et al. 2017: 640). Safety culture therefore should also entail a predictive wariness, or continual anticipation of trouble. It should focus on the organisational failures, the latent failures that occur because people are not working together in an adequate manner. Human error is a factor that should be anticipated on within a spaceflight organisation's safety culture. Human error should not be seen as separate from space systems engineering; 'in a proactive safety culture, system designers would take into account human capabilities and seek human factors input early in the design phase' (Sgobba et al. 2017: 641). An model that tries to incorporate human error into a safety culture is the the Human Factors Analysis and Classification System (HFACS) proposed by Reinach and Viale (2006). They introduce an update version of a human error framework that explains the relation between human error, faulty designs and organizational factors. This model shows which latent and active human errors can occur and potentially cause an accident. It connects the latent organizational factors to the active operator errors. Implementation of this model in practice during accident investigations has shown that incident and accident investigation had been improved 'by ensuring that all levels of an organization, as a

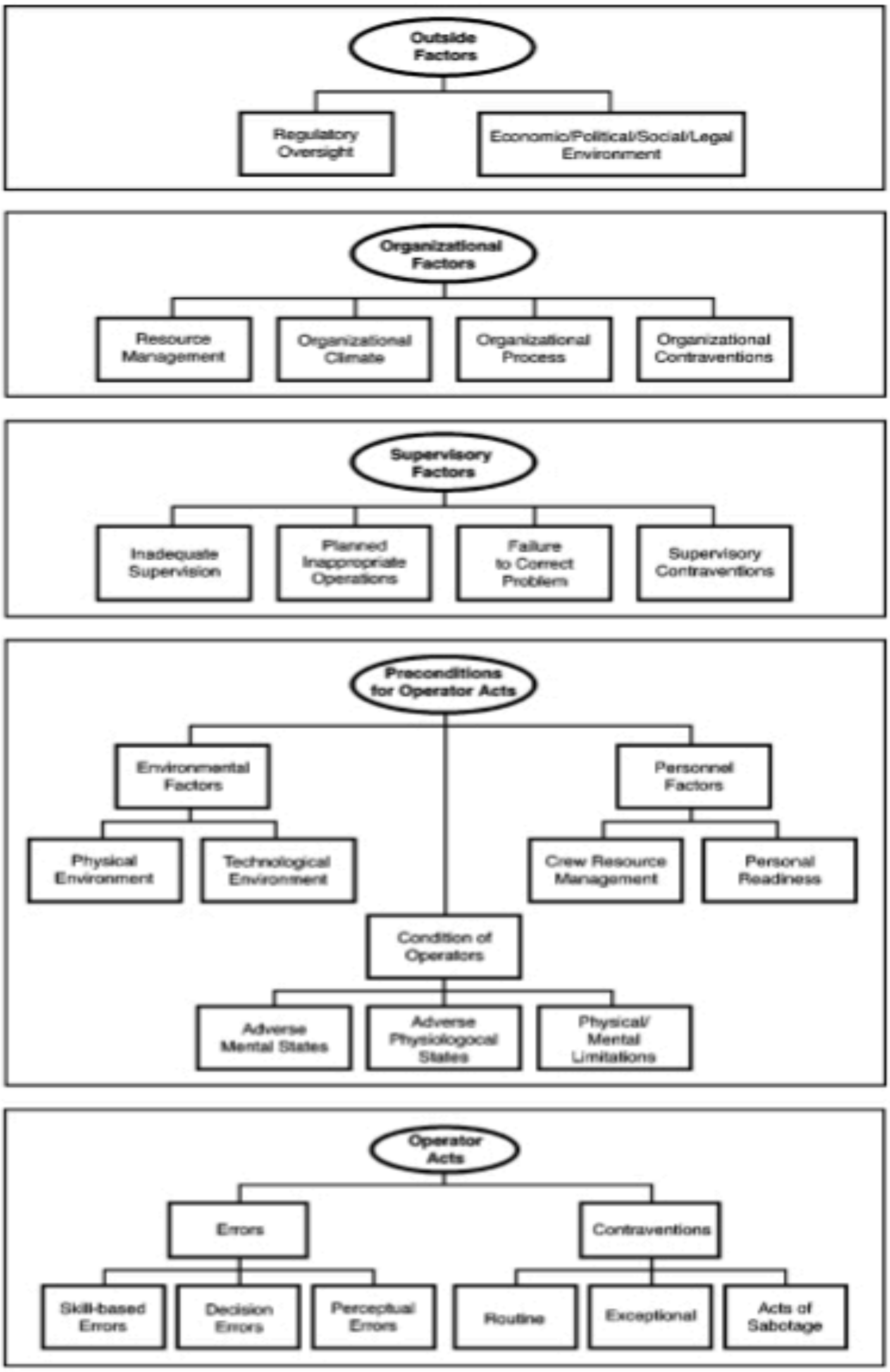

Fig. 2. HFACS-RR taxonomy.

Figure 2.5: HFACS model (Reinach & Viale 2006: 402)

system, are at least considered and explored, even if no contributing factors exist at some of these levels' (Reinach & Viale 2006: 404). The HFACS model shows the importance of the training of operators and other personnel in their skills and knowledge of their work. Also it underlines the importance of safety awareness and safety management of senior and lower management. Furthermore it incorporates the influence of regulatory oversight.

Concluding, early warning and scanning, issue and risk management for spaceflight organisations should be procedures that involve promoting a safety culture, safe designs, adequate training in safe operations and ensuring a safe operational environment. This not only should include the design of safe systems but also the consideration of human errors and organisational failures.

2.1.2.1 Early Warning and Scanning

Early warning and scanning for organizations in general can include 'audits, preventive maintenance, issue scanning, social forecasting, environmental scanning, anticipatory management, future studies' (Jaques 2007: 9) Related to the space operations of commercial spaceflight organizations this will be mainly the identification of technical issues, human errors and hazardous environmental conditions that lead to life-threatening circumstances. Identifying these factors that potentially could lead to an accident or crisis is essentially the first step of issue and risk management, namely the identification phase. Jaques recognizes this and argues:

> 'Early warning and scanning, plus the identification and prioritization phases of issue and risk management, are to a large degree overlapping clusters of activities. Both depend fundamentally on management recognizing the need for action, deciding what to do, and getting it done' (Jaques 2007: 9).

The overlapping factor here is thus the governance of identified issues and risks by management within the organization. This safety management is a crucial factor in the early recognition of issues and risks that potentially could lead to a crisis event. As Jaques elaborates;

> 'The challenge for management - greatly exacerbated by the rapidly expanding use of databases and computer-based issue monitoring - is more often not too little information but too much. And not only inadequate management of the information already to hand, but also a lack of management commitment to taking effective and responsible action on the basis of that information' (Jaques 2007: 9).

If proper safety management is generally applied throughout the organization, one could speak of an organization with a good safety culture. The International Civil Aviation Organisation (ICAO) identifies safety culture as follows;

> 'A safety culture encompasses the commonly held perceptions and beliefs of an organization's members pertaining to the public's safety and can be a determinant of the behaviour of the members. A healthy safety culture relies on a high degree of trust and respect between personnel and management and must therefore be created and supported at the senior management level.' (ICAO 2013a: 10).

Best practices show that developing a safety culture in which employees are encouraged to have high security awareness, a tendency to report mistakes and a constant alertness for danger and risk is desirable (Muller et al. 2009: 958). Without a proper safety culture issues and risks are significantly prone to not being recognized early and have a greater potential to cause a crisis. An organization can have excellent issue and risk management in place, without the whole organization being committed to a culture of safety, noting will be done about these identified issues and risks. If management decides to do nothing about a recognized issue or risk and chooses a design or procedure that is cheaper but not safe, incidents and accidents will happen.

This thesis identifies two ways of early warning and scanning of potential crises, namely internal and external. Adopting a proper safety culture is a tool for a spaceflight organization to do internal early warning and scanning of potential crises that stem from internal organizational failures. External early warning and scanning on the other hand involves the identification of potential crises that have their origin in issues or incidents that lie in the external environment. While this can involve social forecasting and media monitoring for the sake of recognizing reputational crises, this thesis will focus on what is directly relevant for operations in space, namely the early identification of hazardous space weather and potential collisions with objects in the atmosphere and in space, like aircraft, (decommissioned) space crafts, space debris and meteorites.

In order for an organization to successfully avert crises, an organizational culture of shared perspectives on safety within the organization should be present. Sharing information on issues concerning the safety during activities and processes within the organization is therefore pivotal. Best practices show that an organization should develop a strategy on how risks, threats, vulnerabilities and vital interests, processes, products and persons should be communicated internally and externally (Muller et al. 2009: 957). Every layer within the organization should engage himself in early warning and scanning, risk and issue management. At the same time, every individual should receive training in understanding and safely controlling the organizations processes. In this way, any inaccurate and inadequate perspectives on safety are quickly found and eliminated. Simultaneously, through this open dialogue, risks and issues that potentially could grow into a crisis are recognized and dealt with in a quicker and better fashion. What is safe and still complies with the common goals of the organization should not only be determined at the highest level of the organization, but should be the product of perspectives of all the levels within the organization. This requires a management that actively promotes safety and puts safety at the front when determining the organizations' long-term goals and that listens to its employees.

In order to ensure a safety culture, organizations in aviation have implemented Safety Management Systems (SMS). This thesis argues that the use of a SMS would be important for use the requirements for an SMS as set by United Kingdom's Civil Aviation Authority (CAA) as a baseline. According to the standards set by the CAA a SMS should include safety policy and objectives; safety risk management; safety assurance and safety promotion (CAA 2015: 4). This thesis wants to add safety issue management and safe operating environment to that list. An overview of the SMS requirements of the CAA as a baseline with the author's additions is given in table 2.4. This overview will be used to analyze regulations on requirements for a safety culture within spaceflight organizations.

Safety Culture

Safety Policies and Objectives

- Senior management commitment and responsibility;
  - Develop the safety policy, which is endorsed and actively supported by the accountable manager
  - Continuously promote the safety policy to all staff and demonstrate their commitment to it;
  - Specify and allocate necessary human and financial resources;
  - Establish safety objectives and performance standards for the organisation. Safety Performance Indicators (SPIs) should be established that monitor and measure the safety performance of the organisation and the effectiveness of the SMS.
- Safety policy
  - Strive to achieve the highest safety standards;
  - Comply with all applicable legal requirements, meet all applicable standards and consider best practice;

- Provide appropriate resources;
    - Determining safety as a primary responsibility of all staff especially managers;
    - Ensure that the policy is implemented and understood at all levels, both internally and externally.
- Safety accountabilities;
    - Strive to achieve the highest safety standards;
    - Comply with all applicable legal requirements, meet all applicable standards and consider best practice;
    - Provide appropriate resources;
    - Determining safety as a primary responsibility of all staff especially managers;
    - Ensure that the policy is implemented and understood at all levels, both internally and externally.
- Appointment of key safety personnel;
    - The safety manager;
        - Acts as the focal point and be responsible for the development, administration, maintenance and promotion of an effective safety management system.
        - Manage the SMS implementation plan on behalf of the accountable manager;
        - facilitates the risk management process that should include hazard identification, risk assessment and risk mitigation;
        - monitors corrective actions to ensure their accomplishment;
        - provides periodic reports on safety performance;
        - maintains safety management documentation;
        - ensures that there is safety management training available and that it meets acceptable standards;
        - provides advice on safety matters;
        - initiates and participate in occurrence / accident investigations;
        - collates, understands and disseminates information from other similar organizations, the regulator and contracted organizations.
    - Safety Review Board
        - Monitors safety performance against the safety policy and objectives;
        - Monitors effectiveness of the SMS;
        - Monitors effectiveness of the safety oversight of sub-contracted organisations;
        - Monitors corrective or mitigating actions are being taken in a timely manner;
        - Monitors effectiveness of the organisation's safety management processes.
- SMS documentation.
    - SMS records (hazard logs, risk assessments, safety cases, meeting minutes, for example);
    - Records and documentation management; c) SMS manual.
    - SMS Manual
        - Key instrument for communicating the approach to safety for the whole of the organisation.
        - Contains all aspects of the SMS, including the safety policy, objectives, procedures and individual safety accountabilities.
        - Should be constantly evolving and therefore the SMS manual should be a living document and
        - Should be reviewed regularly to ensure that it remains accurate and appropriate.

Safety Risk Management

- Hazard identification processes;
- Risk assessment and mitigation processes;
- Internal safety investigation.

	• More extensive requirements in paragraph 2.1.2.2
	Safety Promotion • Safety Training and Education • Safety Communication
	Safety Assurance • Safety performance monitoring and measurement • Continuous improvement of the SMS ○ Proactive evaluation of day to day operations, facilities, equipment, documentation and procedures through safety audits and surveys; ○ Evaluation of an individual's performance to verify the fulfilment of their safety responsibilities; ○ Reactive evaluations in order to verify the effectiveness of the system for control and mitigation of risk e.g. incidents, accidents and investigations; ○ Tracking organisational changes to ensure that they are effective. ○ Regular review of the organisation's safety performance and safety action plans.
	Safety Issue Management • Issue identification processes • Open dialogue on solutions for issue • Issue reporting an logging • More extensive requirements in paragraph 2.1.2.2.
	Safe working environment • Correct and safe mental processes of work • Training of personnel in their day-to-day work.

Table 2.4: Basic components for a safety culture

Concerning external early warning and scanning, this thesis will focus on the recognition of hazardous space weather and possible collisions with objects within the atmosphere or outer space. When launching a spacecraft, either with a vertical or horizontal take-off, it is important that collisions with aircraft or other spacecrafts are avoided. This calls for the implementation of space traffic management for the launch and reentry phase of spacecraft, something that already has been suggested by several authors (Yehia & Schrogl 2009; Pelton et al. 2010; Masson-Zwaan & Moro-Aguilar 2012). The management of traffic going to and flying in outer space is called Space Traffic Management (STM) and defines as; 'the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical and radio-frequency interference' (Yehia & Schrogl 2009: 1622). A STM regulatory framework will comprise of the securing of the information needs, a notification system, concrete traffic rules and mechanisms for implementation and control (Yehia & Schrogl 2009: 1623). In order to adequately manage space traffic and avoid collisions, a sound Space Situational Awareness (SSA) should be established. Space Situational Awareness (SSA) consists of 'three interdependent tasks: discovery of new objects, tracking of detected objects, and characterization of tracked objects' (Hussein et al. 2012: 2065). Or as Kaiser (2014) elaborates;

> Space situational awareness is generally considered as the understanding and maintained awareness of;
>
> - man-made objects orbiting the Earth, including spacecraft, rocket bodies, mission-related objects and fragments;
> - the space environment, comprising natural objects, including near Earth objects and meteorites, man-made effects on the space environment and space weather, including solar activity and radiation; and
> - possible threats, including risks to humans and property on the ground and in the air space due to accidental or intentional re- entries, on-orbit explosions and release events, on-orbit collisions, and capabilities disrupting missions and services (Kaiser 2014: 5-6).

For the analysis of external early warning and scanning, this thesis will look for the existence of a STM regime, coupled with SSA that includes the monitoring of objects in space and hazardous space weather.

2.1.2.2 Issue and Risk Management

As already has been argued, issue and risk management are vital activities for an organization to prevent crises. If we apply this to private spaceflight organizations, the identification, prioritization and management of risks to safety during manned or unmanned spaceflight is the one of the first crucial steps in preventing accidents and crises during spaceflight. As the British Standard argues:

> 'Crisis management is inextricably related to the management of risks and issues (real or perceived) of potential significance to the organization. For example, the failure of an organization to respond to what ought to have been a foreseeable risk is likely to call into question its competence, with strong potential for a crisis to emerge' (The British Standard 2014: 9).

Safety risk management tries to 'assess the risks associated with identified hazards and implement effective and appropriate mitigations' and should also include risks that come from human error (ICAO 2013a: 47-48). This thesis will use the following more comprehensive definition of risk management; 'risk management is a systematic approach to setting the best course of action under uncertainty by identifying, assessing, understanding, acting on and communicating risk issues' (Berg 2010: 81). Risk management should be done from an organization-wide perspective. In this way not only environmental risks are identified, but also risks that stem from organizational processes are identified. In this way, system errors and human mistakes can be identified before they even occur. The overall steps in risk management can be seen in Table 2.5, along with other necessary components of risk management. These added components are extracted from the work of Quinn (2013), who has conducted an extensive research into safety management systems in both spaceflight and aviation.

Safety Risk Management

Should comprise of the following risk management steps:

1. Establishing goals and context (i.e. the risk environment),
2. Identifying risks,
3. Analysing the identified risks,
4. Assessing or evaluating the risks,
5. Treating or managing the risks,
6. Monitoring and reviewing the risks and the risk environment regularly, and
7. Continuously communicating, consulting with stakeholders and reporting

Should consist of the following activities and tools:

- Definition of Risk
- Risk Analysis
  - Risk analysis tools
  - Human Factors Integration,
  - Organizational failure, using models like the HFACS model.
- Risk Identification
  - Identification of organizational risks
- Hazard management
  - Hazard identification and analysis
    - Occupational
    - Environmental
  - Hazard analysis tools
- Risk assessment
- Risk mitigation
- Risk acceptance
- Communication of known and potential risks throughout the organization and with relevant external stakeholders

Table 2.5: Basic components of safety risk management (Berg 2010; Quinn 2013)

Requirements for safety risk management should be clear and well-described in every part of the life-cycle of a spacecraft and include multiple ways of identifying, assessing and managing risks. An example of such a thorough risk assessment is given in figure 2.6:

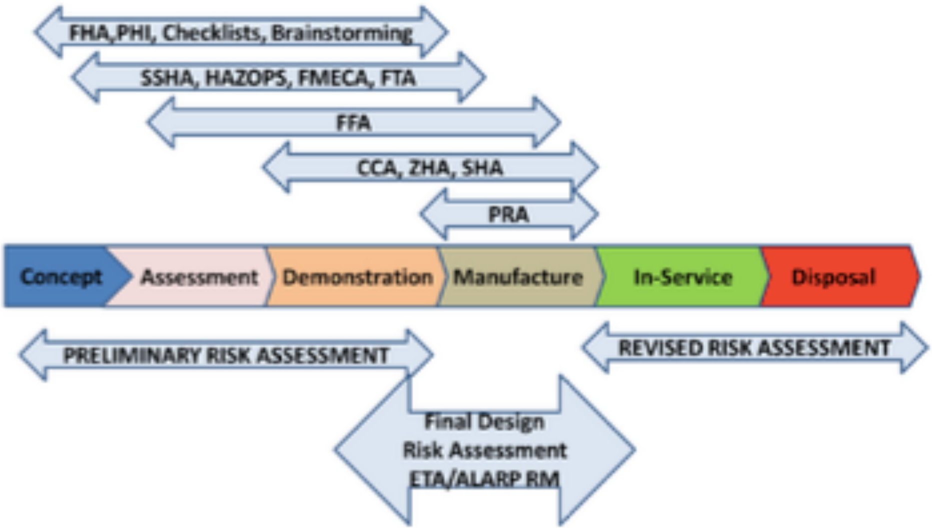

Figure 2.6: Example of risk management throughout the life cycle of a spacecraft (Quinn 2013: 34)

While safety risk management is about recognizing risks that possibly can create an issue, incident, accident or even an crisis, safety issue management is about the identification, prioritization and managing of system failures, human errors or faulty procedures that already have occurred. These are issues that safety risk management activities have failed to mitigate or recognize. Issues can arise during the development, testing or during normal operations of spacecraft. Issues often arise from bad decisions being taken during one or more of these phases.

Perception of what issue could potentially lead to a crisis can greatly differ within an organization. As Boin argues: 'Before a crisis or disaster becomes manifest, public leaders and their staffs usually find it hard to recognize (from vague, ambivalent, and contradictory signals) that something out of the ordinary is developing' (Boin 2009: 372). So consensus within an organization on which issues should be given attention to in order to prevent a crisis is important. However, this consensus should contain perceptions from people from all the layers of the organization. This is why identification and prioritization of issues is part of crisis prevention. For example, in the case of the crash of the Colombus space shuttle in 2003, the crash could largely be attributed to the mistake of NASA's management in reaching a consensus on that there was not a issue with the shuttles O-rings that potentially threaten the lives of the crew, despite the continued perception of several lower level engineers that it was an issue that could cause a disaster (Kauffman 2005; Boin & Smith 2006). Eventually, malfunction of these O-rings was later on pointed out as the direct cause of the crash. This highlights that the organizational culture of an organization should permit that all the relevant information on issues should flow freely throughout the several layers of an organization and reach the relevant decision makers. This is something that several scholars already have proposed before (Turner 1976; 't Hart el al 1993).

So it is equally important that all relevant issues are known at each layer in order to reach the right decisions concerning safety aspects. From what has been discussed an analytical framework for safety issue management can be made and is presented in Table 2.6:

Safety Issue Management

Should consist of:
 	
• Definition of an issue
  ○ Determined by an organization-wide input
• Issue identification
  ○ On the operational level
  ○ On the tactical level if relevant
  ○ On the strategic level if relevant
• Issue prioritization
  ○ On severity
  ○ On potential to cause a crisis
• Issue management
  ○ Mitigation
  ○ Countermeasures
 	
• Issue communication and logging
  ○ Free flow of information on known issues
  ○ Maintain database on known issues, either solved or unsolved.
  ○ Log actions taken on issues

Table 2.6: Basic components of safety issue management (by author)

2.1.2.3 Emergency Response

In the model of Jaques, emergency response is part of crisis prevention because an adequate emergency respone can prevent an accident growing into a crisis situation. However, emergency response will continue if the situation is declared a crisis, so it also can be seen as part of crisis event management. For clarity, it will remain part of crisis prevention. Jaques elaborates on emergency response being part of crisis prevention;

> 'Not every crisis is triggered by an emergency, but enough are to demonstrate that emergencies badly handled can lead to crises. While an organization well versed in crisis preparedness and management can handle emergencies routinely, a good emergency response process does not substitute for a proper crisis management capability…it is essential from the overall strategic perspective to recognize that a serious emergency can trigger a crisis, and that as such, prompt and effective emergency response is a core element in crisis prevention' (Jaques 2007: 10).

Emergency response to emergencies that involve manned spacecrafts would involve responses on two levels: response by the flight crew to an emergency on board or the response by parties not directly involved with the operation of the spacecraft. Firstly a definition of an emergency should be established. This thesis will use its own definition of an emergency; namely an event that involves a hazardous situation that needs an immediate response to prevent the loss of life or the further loss of life.

Emergency response by the flightcrew themselves would first consist of containing the effects of the emergency on board by executing contingency procedures. If contingency procedures fail, the flight crew should switch to emergency procedures to prevent the loss of life or, if one or more fatalities already have occurred, prevent the loss of more life. Contingency and emergency procedures should be well established and known by the crew onboard the spacecraft. Similar to crisis processes, roles and responsibilites should be clear for contingency and emergency procedures (Muller et al 2010: 45). Roles, responsibilities and necessary procedures should be all well documented in manuals and checklists on-board. These should address emergencies during launch, operation in space and reentry of the atmosphere. All crew on board should have received emergency training.

Emergency response by personnel not involved in the operation of the spacecraft should mainly involve response from ground personnel to emergencies during the launch or response from recovery crew after reentry. Private organizations in the Netherlands who conduct business operations that have a certain level of hazards are required to have their own private fire-fighting service (Zanders 2012: 68). Public emergency services come in play if the emergency affects third parties on the ground.

Procedures for coordination between private and public emergency responders should be in place, roles and responsibilities being clear for all parties.

Emergency response during launch and reentry is quite clear-cut, as it should be the responsibility of the operating company, operating spaceport and the government on whose territory the emergency takes place. For emergencies in space, responsibilities for response are not that evident, as these emergencies do not take place within the zone of a certain public authority.

Emergency response
In-flight emergency response

Should consist of;
 	
• Contingency procedures
  ○ Clear roles, responsibilities and procedures for crew on board
  ○ Training of contingency procedures
• Emergency procedures
  ○ Clear roles, responsibilities and procedures
    ▪ For crew
    ▪ For spaceflight participants
    ▪ Mission control

External emergency response

Should consist of;
 	
For private personnel not involved in the operation of the spacecraft;
 	
• Contingency procedures
  ○ Launch
  ○ Re-entry
• Emergency procedures
  ○ Launch
  ○ Re-entry

Table 2.7: Basic components for spaceflight emergency response capability (by author)

2.1.3 Crisis Event Management

When crisis prevention measures do not succeed in preventing a crisis from occurring, the classic form of crisis management comes in play. When a crisis situation does develop, a quick and adequate crisis response is crucial. This begins with the early recognition of a pending crisis, followed by the swift activation of the crisis management organization and management of the crisis at hand.

2.1.3.1 Crisis Recognition and Systems Activation/Response

As already has been argued, the recognition of pending crises can be hard until an emergency situation actually takes place. It is important that management recognizes the crisis on time. As Jaques (2007) argues; 'early warning and scanning are important in helping prevent a crisis - either chronic or acute - but they are of no value whatever if management ignores, denies or tries to suppress the warnings' (Jaques 2007: 11). Management should be constantly aware of the possibility of the development of a crisis and not be overconfident by the organizations crisis prevention capabilities. They should have 'a recognition that crises can develop regardless of the effectiveness of existing controls and that the organization needs to be prepared to manage these effectively' (The British Standard 2014: 9).

The early recognition and management of the transition from an incident or accident to a crisis is important in order to start mitigating any damage to persons inside and outside the organization as soon as possible. Early recognition can be improved through the prior establishment of a definition of a crisis (Zanders 2012: 88).

Related to this is the crisis process of scaling-up of the crisis organization. Because not every incident is a crisis, not every incident needs the activation of the whole crisis organization. How much of the crisis organization is needed depends on the level of coordination that is required (Zanders 2012: 101). For example, an incident that has an impact on persons and assets outside the organization does need more coordination. This scaling-up of the crisis organization to the tactical or even the strategic level should be well described in an organizations' crisis plan. When an incident becomes a crisis and needs the scaling-up of the crisis organization is highly subjective, as it depends on the views of the persons handling the situation at hand.

The activation of the crisis organization should be well-planned. It should be clear when this activation takes place and who decides upon the activation and who should be informed when activation occurs. Warning and alarming the critical persons within the crisis organization should be done within realistic period of time. The way in which the crisis organization is activated and the extend of activation depends on the specific organization and the scope of the identified crisis at hand (Muller et al 2009: 963). An example of this activation process is given by Zander (2012):

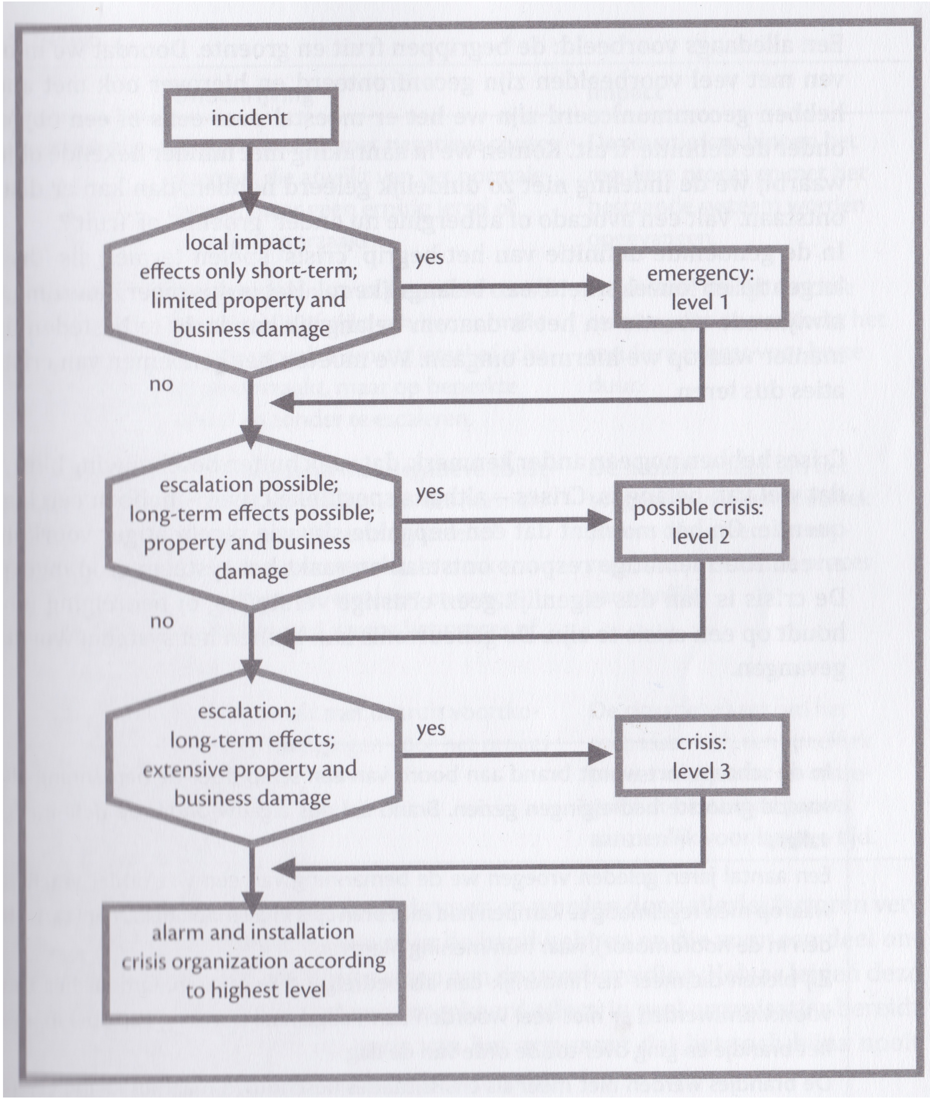

Figure 2.7: Example of crisis organisation activation process and levels (Zanders 2012: 25)

The level of activation of the crisis organization depends again on the perception of the ones experiencing the crisis situation. If the situation is perceived as a major crisis that threatens the survival of the organization, the whole crisis organization up until the executive level could be activated. If the situation is perceived as a minor incident or accident, minimal or no activation can be considered. The structure of the crisis organization activation process can differ per organization, but it is important for an organization to have one. An organization should acknowledge the difference in impact that each event could have on the organization and prepare a proportional response to that impact.

2.1.3.2 Crisis Management

The management of the crisis at hand is well described within crisis literature and many best practices are known. In overall, crisis management comprises of 'strategy selection and implementation, damage mitigation, stakeholder management, media response' (Jaques 2007: 11). As already discussed, a strategic level crisis team should only occupy itself with organization-wide impacts of the crisis at hand and damage mitigation on the strategic level. Because of the extent of known good practices for crisis management teams, the most important ones are selected and presented in table 2.8. Crisis event management best practices comprise of overall activities that can be implemented in each organization, no matter the sector it operates in and the type of crisis it is dealing with (Muller et al. 2009: 78). Therefore the following list is also applicable to crisis management for commercial spaceflight.

Crisis Management Best Practices
CM Best Practices – overall
• Crisis management leaderships should be clear; it should be evident who has the lead on the strategic, tactical and operational level • Identify issues, make decisions, assign actions and confirm the implementation and results of actions. • As a crisis management team, hold meetings on a regular basis during a crisis and have a disciplined discussions cycle. • When making decisions, make a distinction between strategic, tactical and operational decisions. Only occupy yourself and your team with making decisions on matters that are within the mandate of your own layer of the crisis organisation. • Make a distinction between centralized and decentralized decisions. Leave operational decision authority to the ones closest to the situational arena. • Guard and maintain the cooperation with other vital public and private organisations and stakeholders during the crisis. Coordinate roles, responsibilities and tasks effectively between the activated crisis organisations. • Be aware of both the short-term and long-term consequences of the crisis at hand. • Take decisions, go further than solely the coordination of the crisis organisation • Log decisions. In this way it can be monitored if decisions taken are actually executed and lead to the desired outcome. • Learn to take decisions in uncertainty • Achieve situational awareness, with the team confirming their (individual and shared) understanding of the situation and its dynamics, and continuously reviewing it. • Define (and continuously reviewing) the strategic direction of the response. • Identify issues, make decisions, assign actions and confirm the implementation and results of actions. • Make a clear distinction between facts and rumors • Operate in accordance with the following decision model: collect information, verify information, assess information, formulate advice, take decisions, execute decisions and confirm. • Managing meeting agendas and ensuring brevity.

• Confirming, monitoring and reviewing internal and external communications and strategy. • Examining the impact and management of the crisis on business as normal. • Carrying out a continuously reviewed analysis of interested parties, to ensure that the right people receive the right messages and information, and that their views, advice and assistance are actively sought. • Regular communicate developments internally. • Communicate in a quick and transparent manner to the relatives of victims • Be aware of closure, groupthink and entrapment within the own crisis team and the crisis organization as a whole.
CM Best Practices – strategic level
• Reviewing and monitoring the work of the crisis management organization as a whole, to ensure that priorities are understood clearly and that its performance, and the flow of information, are appropriate to the demands of the situation. • Monitoring and reviewing continuously the objectives and effectiveness of any teams managing incidents at other levels of the response, with particular focus on making sure that their activities are in harmony with the strategic crisis response and conflicts of interest or resource are managed • Ensuring that strategic planning for recovery starts as early as possible. • Establish a sound internal and external crisis communication strategy • Pay sufficient attention to communication with the media and briefing of the public • Distinguish which stakeholders and audiences should be informed on a regular basis and take care of organizing this. • Organize an permanent media-watch team
CM Best Practices – Tactical Level
• Set an operating rhythm for the response, so that meetings, briefings, information dissemination, press releases, conferences, etc., can be arranged coherently. • Coordinate with external tactical level response – public or private

Table 2.8: Crisis management best practices (based upon best practices by Muller et al 2009; Zanders 2012; The British Standard 2014)

2.1.4. Post-Crisis Management

When a crisis is averted either through proper crisis event management by the involved organizations or through some other external factor the crisis situation ceases to exist, it does not mean that there is nothing left to manage. The proper management of the aftermath of the event that triggered the crisis is just as important as managing the crisis itself. This because a crisis can trigger new incidents and issues or even a new crisis if an organization does not properly manage the long-term effects of a crisis. Mitigation of damage does not stop when the emergency that caused the crisis is solved and the 'flames stop burning'; practical experiences have shown that most damage mitigation is done in the aftermath of a crisis (Zanders 2012: 199).

2.1.4.1 Post-Crisis Issue Impacts

An important component of post-crisis management is the management of issues that arise in the aftermath of a crisis (The British Standard 2014: 14). Issue management should still be done as the previous crisis could expose or trigger new issues. For instance, the crisis could expose a wrongly implemented safety culture within the organization or design faults within the design of a spacecraft. Judicial inquiries of the crisis could expose these issues to the public and trigger an reputational crisis: 'crisis-induced "blame games," take place in a fuzzy context: officeholders always have a prior reputation, other pressing issues may gain salience, symbolic incidents may unleash a media frenzy' (Kuipers & 't Hart 2014: 596). Such a reputational crisis could threaten the existence of the organization in the way that they loose all their customers and suppliers because of bad reputation.

Another issue in the aftermath of a crisis involving human space operations would be the aftercare for wounded and/or deceased and their relatives. If not properly handled, this also could lead to a reputational crisis. The aftercare of victims can entail medical and psychological aftercare. While aftercare long has been seen as the most final stage of post-crisis management, practical experiences show that it should be seen as one of the most important crisis management processes (Zanders 2012: 206). Next to moral obligations, psychological and physical damage among employees can cause high long-term financial costs as these employees can be not able to work for a long time. Moreover, a traumatized pilot could experiences psychological problems for years to come if aftercare is not given sufficient. This could lead to higher level of human errors during future flights if the pilot would resume his job with psychological problems that have not been addressed.

The crisis management literature gives several best practices for managing post-crisis issues. Just as crisis management best practices during response, these post-crisis issue management are applicable to every kind of crisis and for every kind of organisation. These are summarized in table 2.9:

Post-Crisis Issue Management
Post-Crisis Issue Management Best Practices
• Plans and protocols should recognize the importance of a definitive transition and handover marking the progress from the response phase to the recovery phase of crisis management.

- Recovery planning could be directly affected by decisions made as part of the response, and longer-term recovery objectives and issues may inform response managers who are making decisions on immediate issues.
- Develop a plan and a project organization for dealing with the aftermath of a crisis. For each aspect or theme of the aftermath a separate project team should be created which handles this part of the aftermath.
- Designate a person within the organization who could function as a crisis recovery manager, who would plan for the aftermath of a crisis in advance and who would organize the management of post-crisis issues during that aftermath.
- As an organization experiencing an aftermath of a crisis, take care of permanent internal and external communication. Employees should be informed of the progress being made in managing post-crisis issues. Communication to external parties like the media and third-party victims would entail communication about damages and causes of the crisis that has transpired.
- Organize commemoration and grieving (with or without cooperation of external parties) of employees and third-party victims.
- Organize physical relief and treatment for victims and their relatives.
- Organize psychosocial relief and treatment
- Organize and guide investigations and evaluation, either in cooperation with public authorities or not.
- Organize giving accounts and responsibilities for the crisis that has occurred.
- Guide the closure of post-crisis juridical and financial issues and impacts.

Table 2.9: Post-crisis issue management best practices (based upon best practices by Muller et al 2009; Zanders 2012; The British Standard 2014)

2.1.4.2 Evaluation and Modification

Evaluation of a crisis and creating and implementing modifications to the own organization through lessons learned are maybe the most important aspects of post-crisis management. An organization should evaluate and adapts its organization to the extent that the crisis can be avoided in the future. As the British Standard for CM argues;

> 'Finally, recovery presents an opportunity to regenerate, restructure or realign an organization. The essence of recovery is not necessarily a return to previous normality. It might mean moving towards a model of business and organizational structures that represent a new normality, confronting harsh realities and realizing potential opportunities that might have been revealed by the crisis.' (The British Standard 2014: 15).

While evaluation and modification should happen in every phase of crisis management (including prevention and preparedness), a post-crisis situation gives particularly a fertile ground for genuine organizational learning and organizational-wide modification (Jaques 2007: 12). Through continuously learning and adaptation of the own organization, private spaceflight organizations would make themselves increasingly resilient to spaceflight accidents and crises. While doing evaluation of the cause and the management of the crisis that has transpired, it is important to look at the whole process that has led up to the event that triggered the crisis. Evaluation of the whole spectrum of crisis management processes (i.e. crisis preparedness, crisis prevention, crisis event management and post-crisis management) should be done. Evaluation and modification and implementation of changes should be an integral and continuous process (Jaques 2007: 12-13). This is a vital process for organizational learning from crises, as the crisis organization, crisis training and simulations should be adapted through the lessons learned during and after a crisis.

2.2 Governance of CM in Space

The crisis management framework of cooperation between organizations in the field of commercial spaceflight would in theory consist of both public and private actors. Because of the transboundary character of a crisis involving commercial spaceflight, the preparation, prevention, response and managing of the aftermath of such a crisis would quickly lead to a need for cooperation on an international scale between public and private actors. Just as the crisis organization of a single organization should be both centralized and decentralized at the same time, preferably the cooperation between multiple organizations would be the same. Roles and responsibilities should be defined properly before a crisis in space happens.

Crisis situations in space are especially hard to manage on a tactical and strategic level, as the distance between managers of the crisis situation on Earth and the actual incident in space is even bigger than in the case of an incident on Earth. In this way, information is even more scarce and harder to obtain. In line of the theory of Topper & Lagadec, the effect of information distortion will be even bigger; each actor or component are even more prone to having a different interpretation of information that is being received. A person that is at the location of the incident in space will have a different interpretation of the situation than a person on Earth. Therefore, the transboundary character of a crisis in space makes it hard for crisis managers to make sense of the emerging and evolving crisis at hand. In the words of Boin: 'During a disaster, they often find it problematic to develop a so-called "common operational picture." It is hard to collect, analyze, and comprehend the necessary information to make sense of a crisis situation' (Boin 2009: 369). Further on he elaborates more on this:

> 'All this is compounded by the fragmentation of authority that is inherent to crises and disasters. A crisis brings unique problems that rarely fall neatly within the domain of one agency or leader. A crisis thus typically has multiple "owners"—or no owners at all. An effective crisis response is to a large extent the result of a naturally evolving process. It cannot be managed in a linear, step-by-step, and comprehensive fashion from a single crisis center, however full of top decision makers and equipped with state-of-the-art information technology. There are simply too many hurdles that separate a leadership decision from its timely execution in the field ('t Hart et al., 1993). An effective response depends on such variables as previous interaction and trust between network parties' (Boin 2009: 373).

Because authority during a crisis in space is not clear, it needs cooperation between public and private actors. It can be argued that private actors in space should develop some basic crisis management capabilities in order to effectively cooperate with public actors.

Several studies confirm that responding to a transboundary crisis needs a multi-agency response, as it quickly impacts multiple geographical areas and sectors (Boin et al 2013; Boin & Lodge 2016). The argument of having a strong network of partners within a crisis response is strengthened by a study into multi-agency incident response, that confirms that leadership should interact a lot with other stakeholders (Devitt & Borodicz 2008). As it is argued;

> At all levels of crisis handling, and particularly where the crisis is hallmarked by inter-agency response, relationships with stakeholders and operational partners have to be given careful consideration, not just in the planning stages, but during the incident and after in the recovery stage (Devitt & Borodicz 2008: 212).

A public-private partnership in crisis management should thus be extended to all clusters of activities that prescribe effective crisis management. As it is already argued, a purely command-and-structure does not work effectively in a crisis response. This is also the case for a public-private crisis management response;

> 'An effective response is flexible and networked, recombining the joint potential of the response network. The authorities should limit themselves to making critical decisions, which are the decisions only they can make' (Boin & Smith 2006: 302).

This strengthens the argument of making sure that commercial spaceflight organisations develop some capacity for responding to incidents and not only make this a public responsibility. However, the argument has already been made that a too decentralized response would also be effective.

The question is, to what extent would it be desirable to regulate the aspects of effective crisis management proposed by Jaques (2007) in an upcoming and experimental industry like commercial spaceflight? It has been argued that the commercial spaceflight market has high entry barriers and undeveloped product markets;

> 'Since space technology is unreliable until tested and proved in outer space, investment in outer space industries is risky.' Moreover, most products manufactured in space will have undeveloped Earth markets, posing additional risks to investors' (Freeman & Inadomi 1985: 821).

While this has been argued decades ago and applied to the commercial spaceflight market in the United States at that time, the same can be said for the current situation of the commercial spaceflight market in Europe (Booz & Company 2013). These existing barriers already present public and private investors with difficulties for entering the commercial spaceflight market, illustrated by the lack of operators in Europe. Any companies currently entering the market would do this because of pioneering, scientific or long-term investment reasons. Adding a lot of governmental control in the form of overregulation would pose an extra barrier for future European commercial spaceflight companies. This is reflected by the opinion of currently existing manufacturers in the spaceflight industry. During a study involving a questionnaire about a possible future European regulatory framework that was answered by important stakeholders in the European spaceflight industry, respondents overwhelmingly responded that this framework at the start should have a 'light touch' (Masson-Zwaan et al. 2014: 76). However, in the same study most of the respondents, which also included possible regulators, declared that the EU should regulate the market on some basic level in order for the European commercial spaceflight market to develop (Masson-Zwaan et al. 2014: 77).

The preference of current manufactures in the European space industry for lighter regulation would possibly create tensions with the basic interest of the EU to protect its citizens. As a public entity, it should have the inherent desire to ensure a safe environment for its people, products and vital infrastructure. Moreover, current existing international space law under the Outer Space Treaty could be interpreted in a way that the country from which a spacecraft is launched is responsible for the activities of that spacecraft (UNOOSA 1967a). This gives even more incentive for public entities to ensure that launching private spacecraft from their soil is done in a safe manner and to develop capabilities for when something went wrong. This would suggest that public entities like the EU would prefer a stricter regulatory framework. It seems that there is a possible area of tension between public and private actors within the European commercial spaceflight sector.

A possible balanced governance model is provided by Christensen et al (2016), who argue that 'hybrid arrangements combining hierarchy and network might be a promising way forward' (Christensen et al. 2016 : 887). They use an organization theory-based institutional approach in order to understand how governments deal with wicked crises that are transboundary, unique and characterized by a high degree of uncertainty. This will be the case with accidents in an experimental industry like commercial spaceflight, especially in the first few years of development. While their model is created for cooperation among public actors, it also could be applied to public-private cooperation. Christensen et al. argue that 'crisis management is not just a matter of technical containment and logistics but also involves conflicts and raises issues of power, trust, and legitimacy' (Christensen et al. 2016: 888). In order to create a well-functioning governmental crisis management system, both governance capacity and governance legitimacy are needed. Organizational arrangements as well as the legitimacy of government bodies affect the performance of crisis management (Christensen et al. 2016: 887). Christensen et al further divide governance capacity into coordination capacity, analytical capacity, regulation capacity and delivery capacity and governance legitimacy into input (resources), throughput (procedures) and output (results), as is shown in figure 2.10:

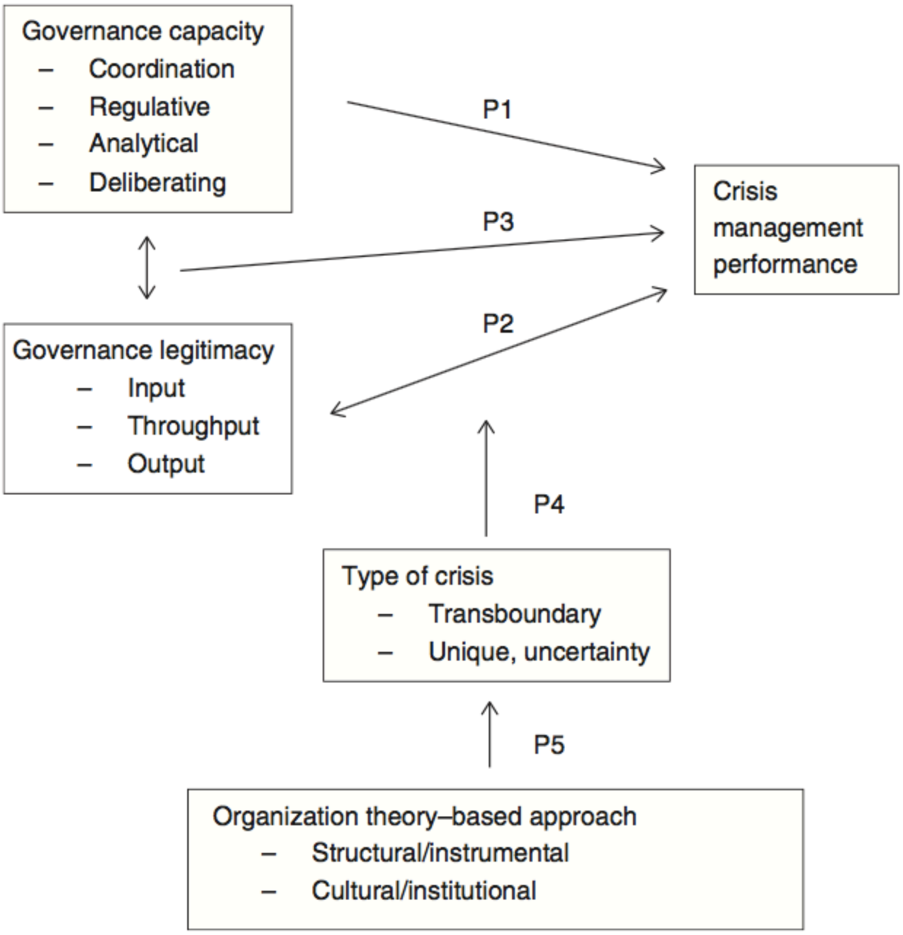

Figure 2.8: Model of Analysis for crisis management performance (Christensen et al. 2016: 890)

As is depicted in the model, the amount of governance capacity is related to the amount of governance legitimacy. For a public entity to receive legitimacy, its citizens and stakeholders should perceive it as legitimate; their acceptance, perceptions, participation, and support are crucial and constrain capacity and instrumental action (Christensen et al. 2016: 894). If this is applied to public-private cooperation in relation to crises management, the governance model works the best if there is high trust by both the public and private actors in resources and procedures that operate the governance model. Studies have shown that within public-private cooperation, 'social capital', (e.g. trust, reciprocity and commitment to the collective) is crucial in creating and sustaining this cooperation in order to achieve effective crisis management (Chen et al. 2013: 140). Furthermore, private actors themselves also should enjoy some legitimacy among the general public, if they want to sell their product. Vise-versa, good governance capacity increases governance legitimacy through good crisis management performance.

As stated earlier, Christensen et al (2016) divide governance capacity into four components:

- '*Coordination capacity* is about bringing together disparate organizations to engage in joint action;
- *Analytical capacity* is about analyzing information and providing advice as well as risk and vulnerability assessments;
- *Regulation capacity* is about control, surveillance, oversight, and auditing;
- *Delivery capacity* is about handling the crisis, exercising power, and providing public services in practice' (Christensen et al. 2016: 888).

If this is related to the model of Jaques (2007), it can be observed that these capacities involve and are affected by elements of all four crisis management aspects. For example, the coordination capacity of a governance model is affected by the level of crisis preparation and event management of all network partners, in the sense that every actor should have adequate crisis plan and trained crisis managers. Further, the regulation capacity is affected by the level of crisis prevention, the public actors controlling, surveying and auditing the regulatory framework and the private actors accepting and complying to those regulations. Thus in order to perform well, a governance model for crisis management should ensure that all four aspects of Jaques (2007) model of effective crisis management are present among the actors in the network.

From a crisis management perspective, in order to adequately prevent crises a regulatory framework for commercial spaceflight thus should prescribe the basic elements of effective crisis management for all actors but at the same time maintain a level of trust among public and private actors. As it is argued: 'alignment of incentives between public and private sector partners is important. Alignment of objectives can be achieved through incentives, both positive and negative' (Chen et al. 2013: 141). Furthermore, both public and private actors within this regulatory framework should enjoy some level of legitimacy in the eyes of the general public, otherwise no one will make use of the possibility of a commercial flight into space if this framework cannot prevent accidents and crises in space. Customers should have trust in the government and commercial spaceflight organizations that they are adequately prepare for, prevent, react to crises in space and deliver after care, justice and learn from crises.

In order for governance of crisis management to be effective, Christiansen et al (2016) thus propose a hybrid form of cooperation, creating a network of partnership were actors have some autonomy but at the same time are coordinated by one or more actors. An example that is given is the 'lead agency approach', were 'a lead agency is responsible for organizing interagency oversight of the day-to-day conduct of policy and activities related to a particular operation' (Christensen et al. 2016: 893). However, there is not a particular way of hybrid cooperation that is the most effective. As a study suggests, in Europe alone there are several different ways of governance of crisis management that involve a combination of hierarchy and network (Christensen et al. 2015).

In absence of an existing European regulatory framework for commercial spaceflight, several ways in which one can be created have been suggested. Among some European manufactures there is the preference for adopting the same type of regulatory framework as the one currently in existence in the United States (Masson-Zwaan et al. 2014). Other stakeholders in the European spaceflight industry would prefer a more commercial aviation-like approach, with a restricted type of certification approach that currently is used by the European Aviation Safety Agency (EASA) for 'unusual designed' aircraft (Masson-Zwaan et al. 2014). Others have suggested that a new form of regulatory framework should be created with international space law at its basis, which borrows only some elements from commercial aviation (von der Dunk 2013). From a crisis management perspective, it can be suggested that this regulatory framework for commercial spaceflight should incorporate a hybrid form of public-private governance with adequate crisis management capacities, which possesses legitimacy in the eyes of its stakeholders and the general public.

2.3 An analytical framework for space crisis management

After explaining what spaceflight organisations need for effective space crisis management and how such a framework that deals with crises in space should be governed, this thesis will examine the current and desired state of space crisis management governance for commercial spaceflight in Europe and answer the main research question. This will be done by answering the following sub-questions:

1. Which public and private entities currently exist or are foreseen within the EU and the United States that concern themselves with the implementation of strategic, tactical and operational functions of crisis management for space tourism?
2. To what extent is it envisaged that these public and private entities should concern themselves with the tasks that the CM framework by Jaques (2007) proposes?
3. In what way could an European regulatory framework for commercial spaceflight be created that has the support of both public and private stakeholders and ensures both a safe and a innovative and competitive European space flight market; in other words what are the critical success factors for arriving at a further concretization of EU crisis management policies and regulations for commercial spaceflight companies?

The next chapter will elaborate on the methodology of this thesis, before moving on to the analysis in which the current state of regulating commercial spaceflight in Europe will be examined.

3. Methodology

3.1 Design of the study

The aim of this thesis is to explore a possible way in which a European regulatory framework on crisis management for commercial spaceflight organisations can be created. To attain this goal, this thesis will try to answer its research question through a qualitative research method. This thesis will be have a exploratory nature, as from interviews with experts it has been deduced that no European commercial spaceflight organization exists that has produced, tested and operated a fully functional commercial spacecraft or even developed crisis management procedures in the case of an accident. Most interviewed experts agree that no fully commercial European spacecraft will be developed for at least ten to fifteen years (Several interviews with experts November and December 2017). Therefore a case study of the current status of crisis management among European spaceflight organisations is not feasible.

Because of this lack of real-world cases that can be examined, the design of the study will thus be of an exploratory nature. It will begin with exploring the current division of CM tasks in commercial spaceflight among public and private actors. Each following chapter of the analysis will address one of the four element of effective crisis management; crisis preparedness, crisis prevention, crisis event management and post-crisis management. It first will be determined for each element of crisis management in what way it is desirable to divide roles and responsibilities among public and private actors. It then will examine any formulated policies and regulations for commercial spaceflight in the EU on mandatory CM tasks for private actors. Early on in the process of writing this thesis it became clear that crisis management elements for commercial spaceflight are non-existent or marginal at the least in European policies and regulations. Therefore it has been decided to look at the most extensive formulated regulations and guidelines for commercial spaceflight organizations, that of the United States. The practical outcome of these policies will be examined through interviews with American-Dutch commercial spaceflight organisation, XCOR and interviews with other experts. The exploration of formulated CM regulations and guidelines in the EU and United States will be done in a thematic manner, per element of crisis management.

3.2 Data collection

In order to answer the research question, empirical evidence has been gathered. Data has been be collected for this purpose in two different ways: through the study of the available literature in the form of policy papers, written legislature, academic papers, handbooks and journalistic articles and through interviews with experts in the field of crisis management, EU policy makers and employees of space organisations that involved with the crisis management within that organisation. With this combination of written and perceived truth, this thesis will try to triangulate in to what extent certain CM aspects should be the responsibility of private actors and should made mandatory through regulations. This is the most feasible way in absence of an actual truth, a real-world case. It then will try to determine to what extent the current European and American policies and regulations are complete enough to ensure effective management of future crises involving commercial actors in space.

Several experts have been interviewed, most of them are working at an organization occupies itself activities that are related to spaceflight. Two space safety experts from the International Association for the Advancement of Space Safety (IAASS) have been interviewed. Also an employee of American commercial spaceflight organisation XCOR and an expert on European space policy from the European Space Policy Institute (EPSI) have contributed their views to this research. A consultant specialized in aviation law and regulations and who is currently is creating regulations for commercial spaceflight from the island of Curacao has been interviewed for insights into similarities and differences between aviation and spaceflight. For expertise in the field of crisis management a crisis management consultant as an expert on crisis management in general and an expert on crisis management within spaceflight from ESA have been interviewed. Each expert has been interviewed with the same interview protocol, which consists of questions about the current state of CM policy and regulations for commercial spaceflight organisations in Europe and the United States and the institutions that govern these policies and regulations. Furthermore, experts have commented on the aspects of CM that have been put forward by the theoretical framework.

3.3 Data analysis

This thesis follows a qualitative paradigm and the analysis of the data will be carried out accordingly. Empirical evidence from the analysis of documents and interviews will be obtained and analysed in a comparative manner. The analysis will be done through the theoretical framework presented in the previous chapter. The overall qualitative analysis will be divided in the four components of effective crisis management. Each component will be analysed in separate chapters. As already has been stated, in each chapter it will first be determined for each element of crisis management in what way it would be desirable to divide roles and responsibilities among public and private actors. This will be determined based on the comments of interviewed experts. After this, the existing European regulations and guidelines for commercial spaceflight will be examined on existing CM requirements. The analysis will resume with an examination of regulations and guidelines in the United States. This part will rely mostly on the analysis of available documents and will be complemented with comments of interviewed experts. Each chapter of the main analysis will end with a conclusion in which the desirable division of tasks and responsibilities of the examined element of crisis management will be summarized.

Interviews have been done by face-to-face interviews in person or via Skype. These interviews gave the opportunity for more in-depth insights into the current state of crisis management policies and regulations for commercial spaceflight organizations in Europe and the United States. By adding first-hand experiences of experts in the field this thesis gains a lot more validity and insights into the current situation in practice. The interviews were structured with help of an interview protocol, the interview results can be found in appendix A. The interview protocol has not been followed too precise, allowing for the interviewee to venture through their thoughts and come up with deeper insights into the current situation and possible ways forwards. When sometimes the interviewee went too astray while expressing their thoughts, the interview protocol helped the interview to get back on track.

3.4 Reliability and validity

Through the analysis of both the current legislative situation in Europe and the United States, this thesis has come up with some interesting comparative insights between the various policy and legislative documents on both continents. This multi-case approach gives it quite some external validity. Furthermore, the interviews with several experts in the field have given first-hand insights in the current situation concerning the development of crisis management policies and regulations in Europe and the United States. However, because of the exploratory nature of this thesis, there are some limitations in validity and reliability of the research.

3.4.1 Validity

Internal validity is about the validity of the research itself, is it based on representative samples or is there much bias in the research? Are there no confounding factors in the study? (Drost 2011: 115). The means of measurements, the study of policy documents and expert interviews give the research some internal validity, as the comparison between what is formulated on paper and what is being done in practice give some valid insights into the relation between theory and practice. However, because interviews are used as the main source of current practice, it is prone to some level of bias. Because the number of interviewees is not very high, personal opinion and biased views can influence the outcome of this thesis. However, it is the view of the author that not much more experts could have been interviewed in the given time for conducting the research, as there are not much experts to be found in the specific field of crisis management for commercial spaceflight. Moreover, the collection of data from the field has been hindered by limited number of commercial spaceflight companies in the United States and especially in Europe. The limited approachability of major companies like SpaceX and Virgin Galactic has prevented this thesis to collect more valuable data. Furthermore, because of the sensitive nature of crisis management documents and also because of protocols and treaties that prohibits the exchange of these kinds of sensitive security data and technical details of rockets (for example ITAR), it has been even more difficult to extract valuable data from the field. However, it is the opinion of the author that the extracted data and insights obtained through the conducted interviews give the research quite some level of internal validity.

External validity is about the extent to which a study can be generalized to other persons, settings and times (Drost 2011: 120). The multi-case approach, by examining both the situation in Europe and the United States, gives some external validity to this thesis. When not changing the time and settings in which this study has been conducted, the external validity is quite high, as there are currently not much other settings in which commercial spaceflight is currently developing. This limited number of cases gives the thesis in the current situation a high level of external validity. The current developed policies and regulations for commercial spaceflight in the United States are by far the most advanced in the world and the US is currently the only country where the commercial spaceflight industry has matured to any significant level. However, because the present situation within commercial spaceflight is changing rapidly, with new many initiatives being set up in the US and other countries, over time the finding of this thesis will become less valid. Moreover, when in the future in other major spacefaring countries like Russia, China and India a commercial spaceflight industry arises, it begs the question if the development of these industries will go the same way as the United States and Europe and will encounter the same problems. Political and cultural differences will probably steer the development in a different direction and it probably will encounter different problems.

3.4.2 Reliability

The reliability of a study is about the extent in which the results of this study are repeatable if the same measurements are done by different persons, on different occasions, under different conditions with allegedly different instruments (Drost 2011: 106). The reliability of the results of this thesis is limited through the means of data collection (interviews) and the rapidly changing environment in which this data is collected. Because in-depth interviews with experts are prone to subjective factors like biased views of the interviewee, the mood of the interviewee at the time of the interview or the understanding of the interviewee of the questions that are being asked it is possible that repeating these interviews with other interviewees will give different results. Furthermore, the interviewee's statements are prone to the interpretation of the person conducting the interview. However, the interviews show similar reappearing responses to the questions of the interview indicating that if currently repeated, this study will show the same results. Nevertheless, because commercial spaceflight is an industry wherein the situation is changing very quickly over the months and years, in time the repetition of this study will probably give different results.

4. Analysis

As explained before, this thesis will explore a possible way in which a European regulatory framework for commercial spaceflight can be created. For this, an analytical framework has been developed in chapter two. A crisis management model for space crises has been presented that could in theory help create a regulatory framework for commercial spaceflight organizations that includes requirements for proper crisis management for these organizations. This framework is built on four elements that should be seen as part of an integrated structure. In line of this crisis management model by Jaques (2007), the analysis will be divided into the four main elements of effective crisis management; crisis preparedness, crisis prevention; crisis event management and post-crisis management. Each aspect of crisis management will be discussed in a separate chapter.

Before analysing current standards and regulations in Europe and the United States, it will be examined which public and private entities in Europe and the United States currently exists that occupy themselves with the crisis management elements of the model of Jaques (2007). After this, four chapters will each examine how each element of crisis management could be governed in Europe and to what extent this element should be made mandatory for private actors through regulations. Existing European standards and national legislations for commercial spaceflight shall be examined on each of the elements. Because of the lack of a European regulatory framework for commercial spaceflight, the second half of each chapter will examine the regulations for commercial spaceflight in the United States and use this as a reference for the European situation. It will be examined to what extent American regulation could be used for a European regulatory framework for commercial spaceflight.

4.1 Currently existing crisis management framework for space in Europe and the United States

4.1.1 Public and private stakeholders in Europe

In Europe, there are currently three main European space actors; the European Member States and their national space agencies, the European Space Agency (ESA) and the European Union (Asbeck 2015). The European States and their national space agencies can develop their own national space policy and own 150 satellites that are currently in orbit, both civilian and military (Asbeck 2015). On the national level, it is the governments of the member states and the national space agencies that are the source of governance for European spaceflight. A schematic overview is shown in Figure 4.1.

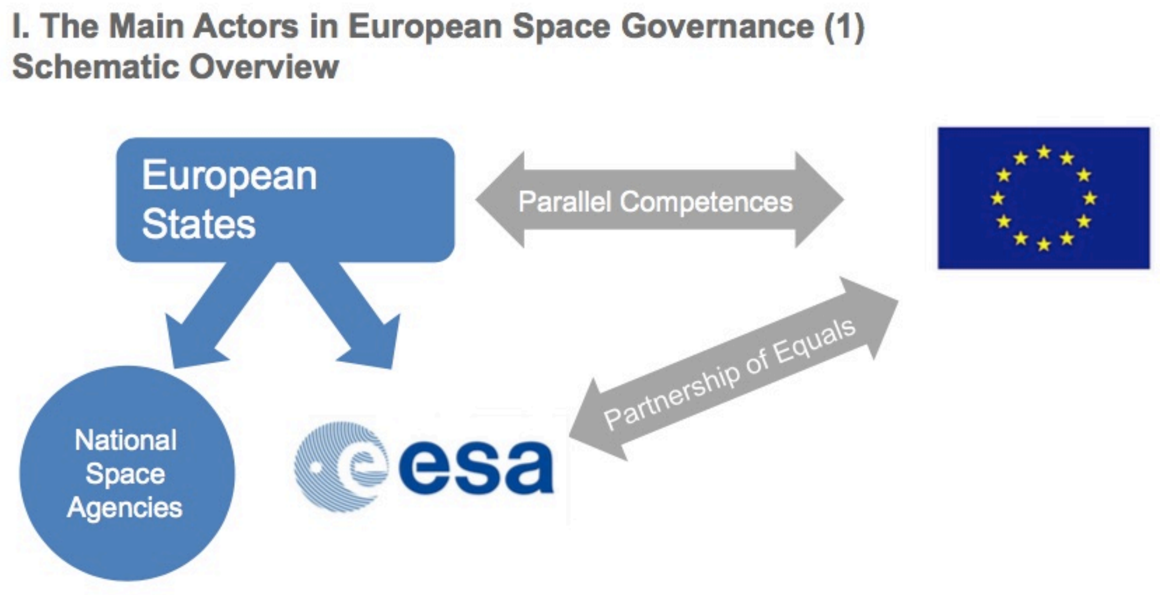

Figure 4.1: Schematic overview of the main actors in European Space Governance (presentation by Rolf Densing, DLR German Aerospace center 2015)

On the European level, the EU and ESA are thus the main actors that govern space policy in Europe. Next to the national space agencies and policies of the Member States (MS), the ESA is the organisation in which the MS cooperate in the fields of research and technology for peaceful purposes. The ESA was established in the 1975 ESA Convention as an intergovernmental organisation and out of the need for massive technological development in the European space sector and need of coordination between European states in order to achieve this (Kaltenecker 1977: 39). As it is stated in the Convention; 'To provide for and promote, for exclusively peaceful purposes, cooperation among European states in space research and technology and their space applications' (ESA Convention 1975). Since then, the landscape of the European space sector has changed, as currently there is much expertise in the development of satellites and launchers in the European space industry. The ESA is cooperating closely with private space actors, which are contracted for the development of space technology and applications (Lebeau et al 2013: 198).

The cooperation between the EU and the ESA as the main space actors on the European level is governed by the EU-ESA Framework Agreement that came into force in May 2004. In this framework it is stated that 'the need for greater operational efficiency, symmetry in defense and security matters, political coordination and accountability can only be resolved, in the long term, through the rapprochement of ESA towards the European Union' (European Commission 2014). This framework establishes the ESA and the EU as two separate entities with their own mandate, with the ESA as a Research and Development space agency, and the EU occupying itself with security matters in space. Within this framework, the EU and ESA are conducting ministerial level meetings in the EU/ESA Space Council. Furthermore, the EU sees the ESA as the main partner for the implementation of their space policies and space programme (European Commission 2014). Within the EU, the most important space actors and space policy treaties are depicted in figure 4.2;

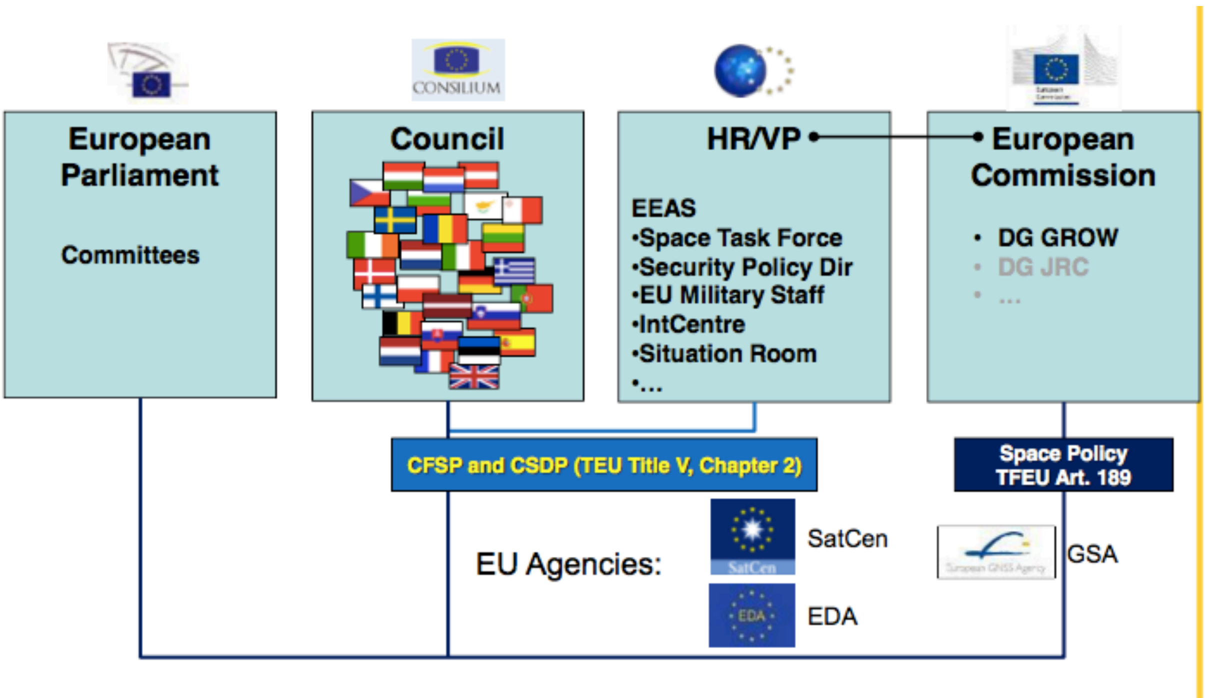

Figure 4.2: Schematic overview of the main space actors within the EU (Asbeck 2015)

As it can be seen, the four main space actors within the EU are the European Parliament, the European Council, the European External Action Service (EEAS) with its Space Task Force and the European Commission. Any new space policies or amendments to existing ones are proposed by the European Commission and need to be accepted by the European Parliament and the European Council. The EEAS and the European Council further decide on Common Foreign and Security Policy (CFSP) and Common Security and Defence Policy (CSDP), which include the EU's common space security policies. The EU crisis management activities, which under its mandate would include space crisis management, fall under the umbrella of its CSDP (Robinson 2013: 9). These activities are supported by two agencies, the EU Satellite Centre (SatCen) and the European Defency Agency (EDA). SatCen provides support for EU crisis management activities by generating satellite imagery and other Earth observation activities (Asbeck 2015). The EDA main task is to 'support the Member States and the Council in their effort to improve European defence capabilities in the field of crisis management and to sustain the European Security and Defence Policy (ESDP) as it stands now and develops in the future' (Remuss 2009: 64). The security-related space activities of the EU, like the Galileo and Copernicus programs, are coordinated and procured by the ESA (Robinson 2013: 26).

When examining the space cooperation framework within Europe for crisis management elements, it can be observed that the EEAS is the main actor that manages and implements the crisis management capabilities of the EU. The EEAS crisis management response is governed by the EEAS Crisis Response System, which consists of the EU crisis platform, EU Situation Room and Crisis Management Board (EEAS website 2018). When examining the structure of the EEAS crisis response system, several elements that the model of Jaques prescribes can be found. A study has found that the EU has developed a high capability to detect and creating a common operational picture in different sectors and categories of transboundary crises (Backman & Rhinard 2017: 4-5). Also the EEAS Crisis Response System has a lot of coordination power and some decision-making power. Moreover, meaning-making/communication is established at the EU level and some accountability mechanisms are established (Backman & Rhinard 2017: 6-7).

If we translate this to the elements of crisis management proposed by Jaques' (2007) model, it can be examined that the EU currently has established a CM framework that addresses quite some crisis preparedness and crisis event management elements, a moderate level of crisis prevention elements and some post-crisis management elements (Backman & Rhinard 2017: 8). For example, early warning and scanning capabilities are vested in different EU and national agencies for each type of crisis, who have different levels of capabilities for the detection of upcoming crisis. On the other hand, crisis event management capabilities are more centralized within the EEAS Crisis Response System. This is quite logical, as most elements of effective crisis event management are the same for every type of crises (Several interviews December 2017 & January 2018).

However, all the current crisis management capabilities of the EU concern themselves with 'terrestrial' crises, thus the crises that happen on Earth and are not space related. Currently, the main European space actors have developed or are developing some capabilities for space crisis management but these focus on tackling terrestrial crises that could be aided by using space assets (Robinson 2013: 27). For example, the EU is currently trying to develop a capability for Space Situational Awareness (SSA), in order to manage the hazards and threats to space assets (Asbeck 2015). This is however not related to a possible future rise of commercial spaceflight activities and not to the management of this future traffic. Next to the absence of regulations and guidelines for commercial spaceflight, it seems that the EU, as the actor who concerns itself with space security on the European level, has hardly developed capacities to specifically deal with crises involving commercial spaceflight activities. This is confirmed by interviews with experts, in which it became clear that the EU has some basic capabilities to respond to a crisis on Earth, but does not posses the expertise needed specifically for responding to accidents with commercial spacecraft on the ground, let alone accidents that happen in space (Several interviews with experts).

The lack of crisis management capabilities of the EU for crises that involve commercial spacecraft can partly be blamed to the fact that currently there are no European commercial operators in existence and the development of European commercial spacecrafts is in a very early stage. Experts confirm the lack of private actors in Europe and argue that European commercial spaceflight is still in an embryonic stage (Interviews safety experts November, December 2017). The current European space industry mainly consist of private actors like Ariane Space, Dassault Aviation, Airbus Space and Swiss Propulsion Laboratory that are contracted by the ESA to build launchers and space applications. Next to these contracted parties, there are some European start-ups that strive to build a commercial spacecraft like Bristol Spaceplanes, Starchaser Industries and Reaction Engines, but these actors are still in the early days of development (Interview safety expert November 2017).

None of these European private actors concern themselves with elements of crisis management, except for the fact that contracted parties by ESA have to comply with the safety standards prescribed by the European Cooperation for Space Standardization (ECSS) (Several Interviews with experts November, December 2017 and January 2018). The ECSS is used by the ESA to set safety standards for their projects and their contractors, effectively acting as a regulatory authority for the European space industry in public-private cooperation. However, These standards only apply to designers and manufactures of space systems and not to launchers (Interview EU policy expert November 2017). Nevertheless these standards are widely accepted by the most important public and private actors in de European space sector and have the intention to not only cover safety in design (Pelton et al. 2010: 44). Because of the familiarity of the European space industry with the ECSS standards, it could be argued that these standards could be used and adapted for a single European regulatory framework. This has already been suggested by the European Commission while formulating its EU Space Industrial Policy in 2013 (European Commission 2013: 14). Some interviewed experts however, have objections to this as this would diminish the competitiveness of the European space market with other markets (Interview EU policy expert November 2017). This also has been recognized by the European Commission, stating that it has the intention to increase competiveness of the European space industry and the observation that;

> 'some European industry stakeholders call upon the EU to put in place a stricter regulatory framework, with adequate certification rules derived from aeronautic best practices, to better guarantee passenger safety. Industry argues that the predictability of the regulatory framework is key for private investors, since it will drive the technology used and the development activities. Other European stakeholders call upon the EU to put in place a more innovation-friendly regulatory framework' (European Commission 2013: 14).

It has been observed that next to the absence of a coherent European regulatory framework for commercial spaceflight, the EU has developed some capabilities for overall crisis management of transboundary crises but not specifically for crises involving commercial spacecrafts. As Robison (2013) argues;

> 'The EEAS, which defines the coordination and resourcing mechanisms associated with the use of space for terrestrial crisis management and "external

action", has not, as yet, systematically integrated space crisis management into its operations (Robinson 2013: 26).

Because many crisis management elements for space prescribed by the model of Jaques (2007) are absent among public actors and non-existent among private actors, further in-depth analysis of each of the four main aspects of effective crisis management will revolve around what would be an desirable allocation of these elements of CM among public and private actors in the space sector. As several interviewed experts argued, 'desirable' in this case means balancing crisis management standards and requirements with the accessibility and competiveness of the market (Interviews EU policy expert, both CM experts).

The allocation of these space crisis management tasks in the form of roles and responsibilities will include determining the desirable crisis management standards and regulations for private actors and determining the allocation of roles and responsibilities for crisis management among public entities. In other words, what aspects of space crisis management should be mandatory for private actors in order to create a European governance of space crisis management that results in both a safe and an innovative and competitive commercial spaceflight market? Because space standardization efforts have been attempted with the establishment of the ECSS, these standards will be examined on crisis management elements and its usefulness for a coherent European regulatory framework will be determined. Another possible source for crisis management regulations and standards for European space are the MS and their national space agencies. From interviews with experts it has been determined that some national governments are already examining the need to develop regulations for commercial spaceflight from their territories. Most notably in the United Kingdom the UK Department for Transport in collaboration with the UK space agency currently has proposed a Bill that will lay down a national regulatory framework for commercial spaceflight (Interview safety expert November 2017). This UK Space draft bill will also be examined on useful crisis management elements for a European regulatory framework.

With the analysis of the current existing allocation of space crisis management elements related to commercial spaceflight among public and private actors in Europe, the first sub-question has been partly answered. In order to be able the main research question and the remaining sub-questions, the possible allocation of roles and responsibilities of all four aspects of space crisis management in Europe will be examined. Next to the usefulness of ECSS standards and the UK Draft Space Bill, the regulatory framework for commercial spaceflight in the United States will be investigated. Therefore a short overview of the currently existing public and private actors in the commercial spaceflight sector of the United States will be given in the next paragraph, before moving on to the more in-depth analysis. In these paragraphs that explore a possible European regulatory framework, a comparison with the current American regulations for commercial spaceflight will be made.

4.1.2 Public and private stakeholders in the United States

In the United States, the Federal Aviation Authority (FAA) acts as the regulating body for commercial spaceflight. Its spaceflight department, the Office of Commercial Space Transportation (FAA-AST), in particular occupies itself with the creation, implementation and auditing of commercial spaceflight regulations. Public crisis management tasks mainly lie at state-level, with each state equipped to respond to a state-wide crisis. The crisis response system in the United States is very decentralized, as would be expected from a decentralized federal political system. As Tierney et al (2001) argue; 'in the U.S., we believe that allowing responsibility for managing emergencies to reside at the local level provides the best way of ensuring that emergency management organizations act in ways that are responsive to local needs' (Tierney et al. 2002: 85). Because of this, emergency response in the United States has been fragmented for years, with the local governments having the primary responsibility for emergency management. In 1979 the Federal Emergency Management Agency was created to solve the very fragmented crisis response on the national level (Tierney et al 2002: 235). The FEMA comes in action when states are overwhelmed by the crisis that happens within or across state's borders. Still, almost every federal agency at the national level has its own emergency response department, showing that at the federal level, there also is a high level of fragmentation.

To overcome the highly fragmented emergency response, the National Incident Management System (NIMS) has been created, which coordinates the preparation, response and handling the aftermath on the national, state and local level (Annelli 2006: 225). The NIMS also provides for public-private cooperation in crisis management, with relevant private actors being part of the NIMS response system. The NIMS system seeks to activate the relevant public and private actors for each type of emergency. Local authorities will first handle crises that involve commercial spacecraft, if the crisis happens on U.S. soil. Federal agencies like the FEMA will be involved if the crisis extends local and state capabilities. It is however not clear what the precise procedures for crises involving commercial spacecrafts will be. From the regulations for commercial spaceflight organizations, it can be derived that the National transportation Board (NTSB) will be involved in such crises as they have the authority to investigate transportation related accidents (FAA-AST 2017). The FAA will obviously be involved in their function as regulator. From interviews with experts it can be concluded however that the FAA does not poses the necessary expertise on spaceflight to handle and investigate accident with commercial spacecrafts (Several Interviews November and December 2017). It is probable that the National Aeronautics and Space Administration (NASA) will have this role with their expertise in the field of spaceflight.

In the United States there are several private actors that operate or have plans to operate commercial spacecrafts. At the moment none of these actors operate manned spacecrafts, but several, like SpaceX, Blue Origin and Virgin Galactic, are planning to bring astronauts and eventually passengers to space in the near future (Belfiore 2017). Several private actors have been contracted by NASA to contribute to or even preform unmanned space missions for years. Notably SpaceX and United Launch Alliance (consisting of a cooperation between Boeing Space and Lockheed Martin Space Systems) have provided launch services to NASA the past decade.

4.2 Crisis Preparedness for commercial spaceflight in Europe

As is discussed above, crisis preparedness should entail the planning of processes, adequate systems and manuals for crisis situations and training of personnel and crisis simulations. As there is currently no separate European regulatory framework on crisis preparedness for commercial spaceflight, the existing public actors and regulations for private actors will be analysed on planning of processes, systems and manuals for crisis situation and training of personnel for spaceflight in general. After this, the regulations for private actors in the United States will be examined. Both the analysis on the situation in Europe and the United States will be divided in two parts. The first on planning for crises and implementing these plans into tools that can be used in the event of an crisis, while the second will cover training of personnel and the simulation of crisis events. Important note to make here that the distinction between emergency and crisis will be maintained; crisis preparedness in this case will mainly concern the preparation of a private spaceflight organization above the operational level. Emergency and contingency planning for example are part of emergency response, which will be elaborated on in the chapter on crisis prevention.

4.2.1 European public institutions and regulations for private actors

4.2.1.1 Crisis processes and infrastructure

The planning of processes and the creation of tools that can be used to execute these plans during a crisis situation is one of the crucial aspects of being prepared for a crisis situation. Crisis plans include roles, responsibilities and procedures for the tactical and strategic level of the organisation. In other words, how does an organisation as a whole respond to an emergency situation that leads to a crisis and not only should be handled by a quick response of flight crew or emergency personnel on the ground, but also by the involvement of higher layers of the organization? This part of crisis preparedness thus refers to the human component of being prepared for crises, who is within the spaceflight organisation responsible for which tasks and processes during an incident involving a private suborbital or orbital spaceflight? The second part is more about crisis infrastructure, what tools does an organisation have in place in order to respond properly to a crisis situation?

Currently the European Union has laid out crisis processes in the form of roles and responsibilities and some crisis infrastructure in place. The EU's crisis management tries to use a 'comprehensive approach', which means using a crisis management strategy that 'seeks to use all instruments available to the EU for crisis management, combining political, diplomatic, economic/financial, development aid-related activities, as well as civilian and military tools' (Robinson 2013: 11). This approach shows that the EU understands how to tackle possible transboundary crises such as a crisis in space.

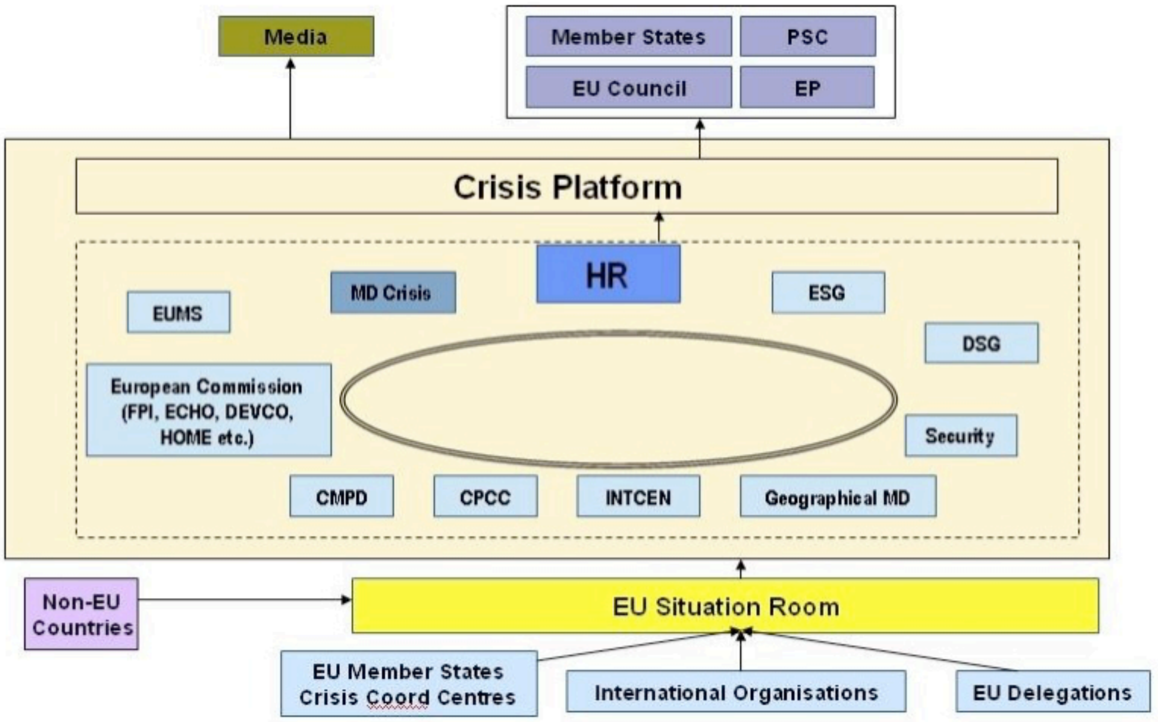

Figure 4.3: Organisational chart of the EEAS Crisis Response System (EEAS website 2014)

The main EU department which provides for the EU's crisis preparedness is the Crisis Response Planning and Operations (CRPO), which is tasked 'with the overall planning, organisation and coordination of crisis related activities, including preparedness, monitoring and response' (EEAS website 2018). It also coordinates the EU Crisis Platform, which is a platform to bring together the right organisations and services from within and outside the EU together during a crisis. The basic components of the EU Crisis Platform are depicted in figure 4.3. The composition of the EU Crisis Platform depends on the type and scope of a crisis, as the Platform;

> 'can be convened on an ad hoc basis and is a crucial mechanism that is activated to guarantee EU responsiveness during external crises. The Platform provides the EEAS and Commission services with a clear political and/or strategic guidance for the management of a given crisis' (EEAS website 2018).

Until now, the EU crisis management capabilities are designed to respond to conflicts on Earth. Like in 2011, when the EEAS Crisis Response System was activated the first time during the revolutions of the 'Arab Spring' (EEAS website 2018). The lack of integration of a response to crises in space is illustrated by the fact that no space agency like the ESA is mentioned as a potential organisation that would participate in the EU crisis platform. This is probably the case because a crisis in space has not yet happened on a scale that it would be relevant to the EU. It has be questioned by one interviewed experts if responding crisis involving commercial spacecraft would be foremost the responsibility of the EU, arguing that it would be first the responsibility of the state were the spacecraft has launched from (Interview spaceflight CM expert January 2018). However, because crises in space are external to the territory of the EU and because the Member States of the EU want to maintain a shared foreign policy under the EEAS, it would be more logical to respond to a crisis in space involving commercial spacecraft through the EEAS.

A crises involving commercial spacecraft can both happen in space and on Earth, with spacecraft exploding and crashing into the ground during launch or experiencing an accident in space and crashing down into Earth. External crises are one of the types of crises which the EU considers a situation which it should respond to. According to Boin et al (2013), which acquired this knowledge trough interviews with policymakers, there are three types of crisis which the EU finds relevant; national crisis (Type I), external crisis (Type II), and transboundary crisis (Type III) (Boin et al. 2013: 7). Responding to external crises is thus seen as part of the common foreign policy. Type III transboundary crises are crises that play out on 'the transnational level, affecting more than one member state at the same time, often with an impact on multiple sectors or systems' (Boin et al 2013: 9). The EU quickly takes on a coordinating role when such a crisis happens above the national level, coordinating the response between member states. Experts argue that an accident involving a commercial spacecraft would quickly lead to transcend borders and affect multiple sectors, especially in a area with tightly interlocked infrastructure and that is relatively heavily populated like in the European

Union (Interviews both safety experts and aviation consultant). The European national governments may not be overwhelmed quickly in their crises response (which would justify the involvement of the EU with a Type I crisis) but quickly need to coordinate with other member states as the chance that the debris field of a crashed-down spacecraft from orbital or suborbital flight would quickly transcend their borders is high. Not to mention the impact a malfunctioning spacecraft could have on vital infrastructure on Earth and in space that potentially could affect multiple countries at once.

Thus it is confirmed by most experts that it would be justified having the EU develop the capability to respond to crises involving commercial spacecraft, next to the crisis response capabilities of the national governments of the Member States. A component of the EEAS Crisis Response System that could be vital in responding to emergencies involving crashed-down commercial spacecraft is the EU Civil Protection Mechanism. The EU Civil Protection Mechanism seeks to foster cooperation among national civil protection authorities across Europe. On their website their activities are explained more in detail;

> 'Civil protection assistance consists of governmental aid delivered in the immediate aftermath of a disaster. It can take the form of in-kind assistance, deployment of specially-equipped teams, or assessment and coordination by experts sent to the field. Yet, disasters know no borders. A well-coordinated response at a European level is necessary to avoid duplication of relief efforts and ensure that assistance meets the real needs of the affected region' (European Commission website 2018).

Until now, operational integration of managing space crises into the EU crisis response has not been done (Robinson 2013: 9). So it could be suggested that adding space experts a EU civil Protection Mechanism in the case of a crises involving a crashed spacecraft would be advisable. The EU Civil Protection strengthens its potential in handling such a crisis on the tactical level because of the existence of a Emergency Response Coordination Centre (ERCC), which monitors emergencies around the globe 24/7 and the Common Emergency Communication and Information System (CECIS), which is in fact a Crisis Management System used by the whole response organisation (European Commission website 2018).

It seems that the EEAS Crisis Response System has most of the crisis tools and systems in place to respond to a crisis. However experts argue that the EU currently doe not have the technical expertise and experience with spacecraft disasters to adequately respond to crises involving spacecrafts (Interviews safety experts). Moreover, in the case of an emergency with a commercial spacecraft, the government quickly would need the expertise of someone of the company that has made the spacecraft, as these spacecrafts would have a unique design, especially in the early days of commercial spaceflight in Europe (Interview spaceflight CM expert January 2018). Technical expertise from the private space industry would thus be necessary for the EU and/or national governments to respond to a crisis. Without the ability of a private actor to adequately coordinate their crisis response with public entities, public-private cooperation would be difficult and time consuming.

Crisis preparedness for private actors

The fact that cooperation with commercial spaceflight organisations would be necessary during crises involving commercial spacecraft, gives incentive to ensure that these private actors also have a proper crisis organisation in place so that public-private cooperation would run smoothly. Most experts confirm that it would be desirable to have some basic requirements for a crisis organisation for private spaceflight actors (Interviews safety expert, aviation consultant and both CM experts). However, it is also argued that private actors would already have enough incentive to develop these crisis organisations themselves, as an accident involving human casualties would quickly lead to people not wanting to fly with that organisation (Interviews both CM experts). Meanwhile this does not mean that it is guaranteed that every commercial spaceflight organisation would develop their crisis preparedness without any regulations giving them the incentive to do so. Some experts argue that such an organisation would always choose the most profitable way of conducting business, not giving priority to safety and the development of a crisis organisation as this would result in more expenses (Interviews safety experts). Another argument for creating high-level crisis preparedness requirements is that current commercial spaceflight operators are already busy with this aspect and there will not be much resistance to regulations that prescribe this (Interview spaceflight CM expert 2018).

Nevertheless, the responses from interviews with experts give enough motivation to say that it is desirable for public entities to develop some requirements for private actors to develop a crisis organisation. If ECSS standards, UK space legislation or other European legislation would be considered as inspiration for a European regulatory framework, these should contain some requirements for creating a crisis organisation. However, these regulations and guidelines contain few and unclear requirements for planning CM processes and creating CM systems and manuals.
The ECSS standards contain some requirements for the planning for incidents for operators and ground facilities. The documents containing standards for space product assurance includes one establishing a safety programme and safety technical requirements for all European space projects that are carried out that are authorized by ESA.

The ECSS elaborate on the implementation of emergency plans. However, these are solely requirements for plans that handle the response to an emergency situation and not the response to an organization-wide crisis. For example, in the paragraph on 'operational safety', the ECSS states that: 'Responsibilities, rules and contingency procedures shall be established prior to operation for hazardous "limit" conditions that can occur during ground and in-flight operations' (ECSS-Q-ST-40C Rev.1 2017: 43). Also, when referring to hazardous operations on the ground, the document states that 'Where necessary, contingency and emergency plans or procedure shall be established and verified prior to the commencement of the operation' (ECSS-Q-ST-40C Rev.1 2017: 45). While these passages in the ECSS text describe crucial requirements in handling emergency situations, these plans are more about the prevention of crises, as these describe only the procedures that involve responding to the initial incident that triggers the crisis. The same can be said for the spaceflight legislation that at the moment is being developed in the United Kingdom. These only contain requirements for emergency response plans. These will be elaborated on in the next chapter, as these plans are part of crisis prevention.

From discussions with experts, it became clear that there might be a discrepancy in the definition of a 'contingency plan' (Interview safety expert December 2017). While from a crisis management perspective contingency planning is seen as being part of business continuity management and tends to focus on the response on the operational level, in the spaceflight sector a contingency plan could be defined as a crisis management plan (Interview safety expert December 2017). This would define a contingency response plan as a crisis management plan, which would mean that the contingency plans that the ECSS documents mentions could be seen as crisis management plans. However, what is meant with ‘contingency response plan’ in the ECSS documents is not explained. If it entails only operational procedures or a clear-cut allocation of roles and responsibilities for every layer of the organisation cannot be deduced. Without this certainty, it cannot be said that the ECSS documents contain requirements for implementing crisis management plans.

The only existing description of requirements for plans that not only describe the initial response to an emergency are found in the handle organisational crises are found in the Centre Spatial Guyanais (CSG) Safety Regulations that have been developed by CNES, the French space agency, for the European launch site in Kourou, French Guyana. When examining these regulations, the difference between the requirements for emergency plans that the ECSS and UK regulations describe and more extensive crisis plans can be seen. To begin with, the document makes a distinction between prepared scenarios for minor accidents, which include emergency measures or plans. And for disastrous accidents, which includes an Emergency Operations Plan (POI) or a Particular Intervention Plan (PPI) (CNES 2006: 34). The description of the plans for minor accidents describe the ‘conventional intervention measures’ that include that ’it must be possible to sound the alarm quickly (emergency switch, etc.) and activate devices to prevent the extension of the accident’ (CNES 2006: 34). These intervention plans should be prepared by the CSG fire-fighting and should deal with each type of accident. This part obviously describes emergency response plans with the necessary early response to an accident.

The part on disastrous accidents describes plans that include crisis management procedures;

> ‘The POI shall be applied by the operating company concerned by the accident. If the accident extends beyond the boundaries of the establishment, the CSG POI shall be triggered under the responsibility of its Manager or his representative. In the event that the consequences of the accident extend beyond the boundaries of the CSG, the PPI shall be triggered and placed in application under the responsibility of the Prefect’ (CNES 2006: 35).

The document states that the creation of the POI should be done by the operator, while the PPI is created under the responsibility of the local government. It does not particular mentions the word crisis, but by stating that management should be involved by activating the POI, it suggests that the scope of the emergency has surpassed normal emergency procedures and it should be recognized as a crisis. The next step, the activation of the PPI does with little doubt classify as a crisis plan, as the management of the accident and its consequences now falls on the responsibility of the Prefect, the regional French Government Authority. In crisis management terms, the impact of the emergency situation has such wide consequences that the higher strategic level is needed to coordinate and solve the situation. Here a classification of a 'crisis' by CNES can be seen, namely if the consequences of the accident stretch beyond the boundaries of the CSG.

While the CNES has created the most complete regulations concerning crisis management for spaceflight organizations, its description is still incomplete for effective crisis preparedness. For example, it does not describe crisis management infrastructure, other than the creation of the POI and PPI plans.

The lack of requirements for crisis preparedness in existing European regulations and standards for spaceflight begs the question what these minimal requirements should entail. Experts agreed that the proposed allocation of roles and responsibilities by the analytical framework of this thesis would constitute in a properly working crisis organisation (Interviews safety expert, both CM experts). Experts further agreed that there should be a clear distinction between the roles and responsibilities of senior management and that of those coordinating the response to the crisis. Main reason for this separation of the operational response from senior management is the technical expertise that is needed for this response, which senior management often does not have. As on safety expert argued: 'You don't put the top manager to coordinate the field the action of response to the crisis. This is not the guy who has to contact the operation, he asks the people to contact the operation, he has to play his own part' (Interview safety expert December 2017).

Following this line of reasoning, it can be suggested to put the technical expertise in a crisis management team that coordinates the response on the tactical level, while adding a technical liaison in the strategic level crisis team, giving them an update of the response and the situation on ground. Some experts agree that the crisis organisation should not have a hierarchical structure, letting the tactical crisis team have their own mandate (Interview safety expert December 2017). However, it is also argued that the structure of a crisis organisation should be hierarchical to an extent, as the decision making during a crisis situation should be fast-paced and there is limited time for consultation within the crisis organisation (Interview CM expert January 2018). A command-and-control structure would be desirable in order to react quickly, but micro-managing can be avoided by established well defined roles and responsibilities. It must be clear which problems are strategic, tactical or operational problems and should be tackled by the correct layer of the crisis organisation (Interview CM expert January 2018). Furthermore, a crisis management system is seen as a crucial tool to ensure a common operational picture and thus an asset for information management during a crisis (Interviews both CM experts). It is however not necessarily desirable to place the task of interpretation of the available information only with an information management team, every crisis management team in the organization should be able to interpret information and place it in a context in order to determine its relevance for the own layer of the crisis organisation (Interview CM expert January 2018).

Some experts confirmed that it would be a good idea to look into crisis management requirements that are being used in the commercial aviation sector and derive basic standards for crisis organisations for commercial spaceflight organisations (Interviews aviation consultant & spaceflight CM expert). Another suggestion that has been done is that crisis preparedness standards should be created on a global scale, with the same regulatory system that is being used in commercial aviation (Interview CM expert January 2018). These options will be further explored in the chapter on crisis event management. More elaboration on possible requirements of crisis organisation for private actors will be done in the sub conclusion of this chapter. In the next sub-chapter the regulatory system in the United States will be first be evaluated on requirements for crisis preparedness.

4.2.1.2 Crisis training and simulations

Training for and exercising crisis situations is as crucial as having crisis processes and crisis infrastructure in place. An organization may have a proper planned crisis processes and excellent crisis infrastructure in place, but without adequately trained personnel its crisis response will inevitably fail. It is confirmed that without the simulation of crisis situations in the form of live exercises, it will never be certain that implemented crisis plans will work in practice until a crisis event occurs (Interview CM expert January 2018).

It has been concluded that it would be desirable to require commercial spaceflight organisations to create a basic crisis organisation. Requirements for proper crisis training and simulations of crisis situations would also be desirable as these are crucial for a well-functioning crisis organisation. For public actors in the EU this would mean training personnel on the strategic, tactical and operational level in dealing with space crises. Most of these crisis management skills for strategic and tactical level crisis teams would be capabilities that can be used in any type of crisis (Interviews both CM experts). Simulations are crucial in developing better crisis organisations and crisis training for personnel as it points out weaknesses within the crisis organisation and improves crisis training. Without simulations you will never know if your organisation is prepared for a crisis before a crisis actually hits (Interview CM expert January 2018).

While examining the ECSS standards and UK space policy under development, it can be concluded that no specific requirements for crisis training are mentioned in the documents, only some requirements for emergency training of personnel. The ECSS documentation mentions a requirement for the training of personnel for the 'special procedures' that can include emergency and contingency procedures during mission operation (ECSS-Q-ST-40C Rev.1 2017: 32). The definition of these 'special procedures' is vague, only stating that these apply to situations were there is a deviation from nominal procedures (ECSS-Q-ST-40C Rev.1 2017: 34). The document also mentioned safety training for personnel working with system elements that have hazardous properties. This training only focuses on safe procedures to prevent hazardous conditions and does not mention procedures in response to an hazardous event. The document further does not mention any form of simulation of crisis events.

Crisis management experts confirm that training personnel and doing crisis simulations would be essential for a good crisis organization. If you want to make sure that private actors in spaceflight have adequate crisis organization, requirements for regular crisis training and exercises are crucial (Interviews both CM experts). By letting private actors do exercises, the state of the crisis organization can be checked, and with that it can be checked to what extent an organization is prepared for crises. When making requirements for crisis training and simulations, it is important however to make sure that these regulations do not only contain the amount of training and exercises an organization should have. These requirements should also prescribe that personnel can show that they have certain skills in crisis management and that the organization as a whole should show some level of performance during a crisis exercise (Interview CM expert January 2018). In this way you avoid a regulatory system for crisis preparedness that has a tick-in-the-box culture with normative requirements, in which only showing the frequency of training and exercises is enough and no performance is checked. Most interviewed experts agree that a type of regulatory system where only having certain safety and crisis management elements is enough to obtain a license to operate, while the performance of these is elements is not tested by some authority, is something that you should avoid (Several interviews November, December 2017 and January 2018).

The way in which the basic structure of such performance-based regulations should be created is explained in a presentation of space safety expert Andy Quinn and is depicted in figure 4.4;

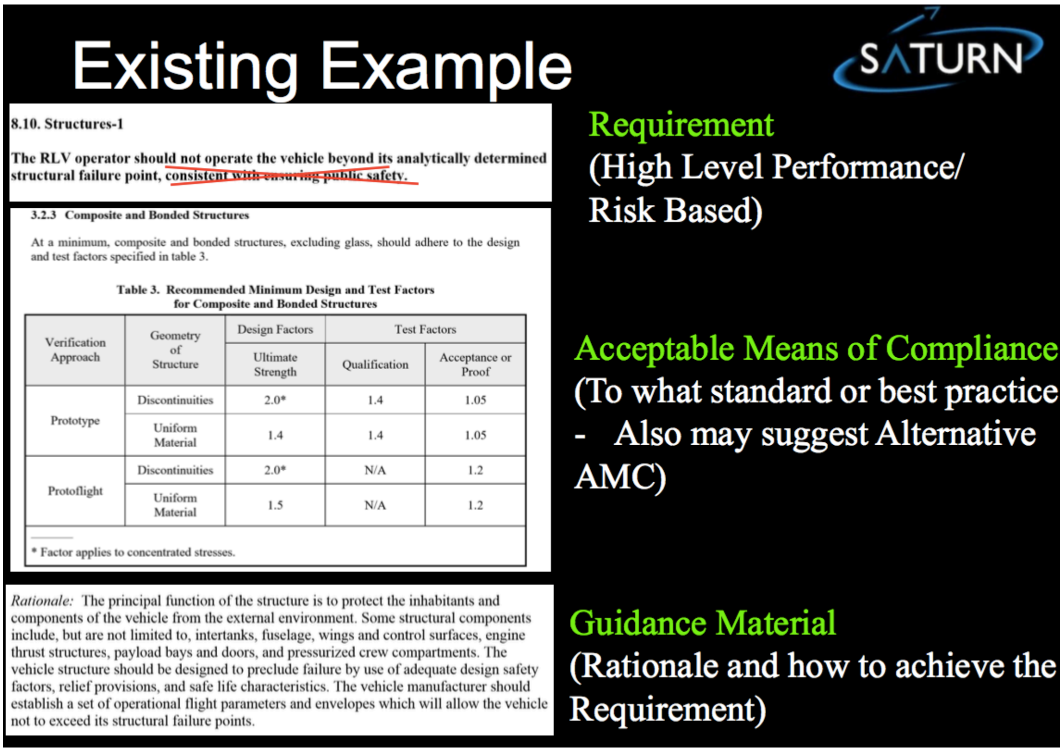

Figure 4.4: Basic structure of performance-based regulations (Presentation Andy Quinn 2017)

As it can be seen, the basic structure should consist of high-level performance requirements, with acceptable means of compliance that explain what is needed to meet the high-level requirement. This is complemented with guidance material on how to achieve the requirement. For crisis preparedness it is advisable to create a list of competences and knowledge that each crucial personnel should posses after receiving crisis training, in order to adequately execute his or her role and responsibilities during a crisis (British standard 2014: 34). This list of skills could act as one of the acceptable means of compliance for the high-level requirement of a certain level of performance in crisis preparedness. Experts agree that simulations should be done to identify any faults or unskilled employees within the crisis organization (Interviews safety expert, CM expert). Also, for a crisis plan to be proven to be all-hazard, different scenarios should be practiced (Interview CM expert January 2018).

While the regulation of crisis preparedness thus should be done in a qualitative way, and not ruled by a tick-in-the box normative culture, experts also have argued that the current and near-future state of the European commercial spaceflight market would ask for crisis preparedness regulation that should not very strict from the beginning. It has been suggested to establish crisis preparedness standards for the commercial spaceflight in cooperation with the industry, trough deliberation with the private stakeholders in Europe (Interview CM expert January 2018). In order to not put too much regulatory pressure on a developing European market, high-level performance requirements like 'prove to the regulating party that you have a well-prepared crisis organization with personnel that understand the crisis organization working and their own tasks' could be a start for imposing crisis preparedness requirements on private actors in a small and experimental market (Interview CM expert January 2018). Acceptable means of compliance then would then be developed in cooperation with the industry.

Both the ECSS standards and the UK draft space policy do not mention specific crisis management training for personnel and do not mention crisis exercises or simulations at all. Maybe the current regulatory system in the United States does give some better requirements for crisis preparedness. This is going to be explored in the next sub-chapter.

4.2.2 Regulatory status in the United States

4.2.2.1 Crisis processes and infrastructure

Because it has been observed that crisis preparedness requirements for commercial spaceflight is almost non-existent in European standards and regulations, the American regulatory system will be analysed on the existence of such requirements.

Since the SpaceShipTwo accident in 2014 the Office of Commercial Space Transportation has updated existing regulations quite extensively. The FAA-AST regulations define several separate licenses for different actors in commercial spaceflight; launch licenses, license to operate a launch site, reusable launch vehicle mission licenses, licenses to operate a re-entry site, re-entry license and experimental permits (FAA-AST 2017: 1). For an operator to obtain these license, for each license there are some requirements that should be met that can include creating crisis plans and describing crisis processes. An overview of these can be found in Figure 4.5.

Only certain plans are relevant for our crisis model. What could be regarded as plans that are part of crisis preparedness for operator licenses are the Accident Investigation Plan (AIP), Mishap Investigation Plan (MIP), Emergency Response plan (ERP) and Launch Site Accident Investigation plan. However, these plans only describe requirements for procedures concerning emergency response and not procedures for the activation of other layers of the organisation. In the sections describing the contents of the above-mentioned plans, it is only stated that the consequences of the incidents, accidents and mishaps should be 'minimized and contained'. What minimizing and containing of these emergency situations entails is not made clear. This leaves a lot open to interpretation. No description of procedures and responsibilities for when the scope of an emergency needs the involvement of and coordination by higher levels within the organization is given. Or the procedures for coordination with outside parties for that matter. A spaceflight organization is only required to report the accident or mishap to the US

Launch licenses

- Accident Investigation Plan
- Flight Safety Plan
- Ground Safety Plan
- Launch Safety Plan
- Launch support equipment and instrumentation plan
- Flight termination system electronic piece parts program plan
- Local agreements and public coordination plans
- Hazard area surveillance and clearance plan

License to operate a launch site

- Launch site accident investigation plan
- Explosive site plan

Reusable launch vehicle mission licenses

- Communications plan
- Mishap investigation plan and emergency response plan

Licenses to operate a re-entry site

- None

Re-entry license

- Same as reusable launch verhicle license

Experimental permits

- Mishap investigation and response plan.

Figure 4.5: overview of plans required by FAA-AST regulations (by author derived from FAA-AST regulation)

government; no description of procedures for eventual cooperation with the government during a crisis is required. Further requirements for having a crisis infrastructure in place are also not mentioned.

From talks with XCOR, an American-Dutch commercial spaceflight start-up, it can be concluded that quite some safety inspection is being done by the FAA-AT among private spaceflight companies. In practice, private spaceflight companies have to set up detailed emergency and contingency plans, which contain a extensive checklist for the operator of the spacecraft and several scenario's for the failure of each crucial component of the spacecraft (Interview XCOR November 2017). Also, the start-up followed or was planning to follow standard military testing protocols for safety and emergency procedures. These protocols included the formulation of clear roles and responsibilities in the event of emergency situations between the test pilot and the ground control center, thus planning processes for the operational and more tactical level. However XCOR did not have plans in place for the handling of a crisis situation of a larger scope and that would require organization-wide response with coordination at the strategic level (Interview XCOR November 2017). This shows a gap in what would be proper crisis preparation and confirms that until now, preparation for crisis situations has been limited to emergency and contingency planning.

However, one expert mentioned during the interview that from his experience Virgin Galactic concerns itself with crisis planning and thus has some crisis preparedness in place (spaceflight CM expert January 2018). This is probably part of the reaction to the crash with SpaceShipTwo in 2014. It then can be argued that it seems that commercial spaceflight companies would only concern themselves with crisis planning after a fatal accident already has happened. This gives even more incentive to create requirements for these organizations to have some crisis preparedness in place.

The FAA-AST regulation for commercial spaceflight organizations does elaborate on contingency plans, which again could be interpreted as crisis management plans. But here the same inconsistency and vagueness in terminology as in the ECSS standards can be found, as the required contents of these contingency plans are not described. Experts confirm that the FAA-AST regulation does not contain any crisis preparedness requirements for private actors (Interviews safety expert and aviation consultant). Moreover, the requirements of the FAA-AST mainly elaborate on 'contingency abort plans' and 'contingency landings', indicating that this entails only operational procedures during flight.

Further requirements or guidelines for preparation of cooperation with public entities are described briefly. As part of an Emergency Response Plan (ERP), a re-entry vehicle licensee should do the following things;

> 'Notification to local officials in the event of an off-site or unplanned landing so that vehicle recovery can be conducted safely and effectively and with minimal risk to public safety. The plan must provide for the quick dissemination of up to date information to the public, and for doing so in advance of reentry or other landing on Earth to the extent practicable' (FAA-AST 2017: 574).

The only other requirement for an ERP that is mentioned is;

> 'A public information dissemination plan for informing the potentially affected public, in laymen's terms and in advance of a planned reentry, of the estimated date, time and landing location for the reentry activity' (FAA-AST 2017: 574).

These requirements describe some very basic components of what could be named a crisis management plan, basically a short description of external communication during a 'off-site or unplanned landing' and thus falling short to qualify as requirements for a basic crisis management plan.

For obtaining a launch license there are also some requirements for emergency procedures, with requirements for describing external communication lines. These requirements are however again marginal. These requirements for launch licensees are satisfying 'the local agreements and plans of the launch site operator' or 'develop and implement any agreements and plans with local authorities at or near the launch site whose support is needed to ensure public safety' (FAA-AST 2017: 125). Further the requirements only state that the licensee should 'coordinate with any other local agency that supports the launch, such as local law enforcement agencies, emergency response agencies, fire departments, National Park Service, and Mineral Management Service' (FAA-AST 2017: 126). These are again vague descriptions of coordination with public entities in the event of an accident or crisis. At last, for every type of license there is the requirement for cooperation with the FAA and the NTSB in the post-crisis phase. Further more extensive description of requirements for cooperation with the FEMA or another emergency response organization that could be in play during a crisis involving commercial spacecraft is not mentioned. This could be expected if a basic level of crisis preparation is desirable.

After examination of the FAA-AST regulations, it can be concluded that requirements for crisis processes, systems and manuals are marginal at the least. The few parts that describe some requirements for external cooperation are short and leave a lot open for interpretation. Requirements are not performance-based; these only require licensees to have plans in place and not stating how the organization should perform while using these plans.

4.2.2.2 Crisis training and simulations

Developed regulations and guidelines in the United States have some training requirements for spaceflight personnel and participants. Next to training for normal operation, the crew of a spacecraft must have received training for abort scenario's and emergency operations. This includes training 'in procedures that direct the vehicle away from the public in the event the flight crew abandons the vehicle during flight' (FAA-AST 2017: 647). However, specific crisis training requirements for personnel throughout the organisation are not mentioned in the document. Without clear requirements for the creation of crisis plans this is not unexpected. Experts have argued that the FAA-AST commercial spaceflight regulation is not extensively descriptive and mainly contains requirements for private actors that prescribe only having certain emergency equipment and do not describe about how these personnel should perform using these elements (Interviews both safety experts and aviation consultant). This also can be said for elements of crisis preparedness. FAA-AST requirements for crisis plans, systems and manuals are already almost non-existent, and personnel using these 'plans' do not need to have certain skills. This again confirms that FAA-AST requirements are mostly normative, and not based on performance.

The lack of performance-based requirements in FAA-AST regulation can also be seen when examining the requirements for crisis simulations. As part of familiarization training with launch sites, flight safety crewmembers have to participate in launch simulations exercises of system failure modes, including nominal and failure modes. Furthermore, an applicant for a launch license has to file 'dress rehearsals' procedures in order to prove its readiness for flight. These dress rehearsals should 'ensure crew readiness under nominal and non-nominal flight conditions; contain criteria for determining whether to dispense with one or more dress rehearsals; and verify currency and consistency of licensee and Federal launch range countdown checklists' (FAA-AST 2017: 78). Non-nominal flight conditions could be interpreted as crisis situations, but the document does not give any clarification on what non-nominal flight conditions entail. Nevertheless, the FAA regulations document does have a separate section on dress rehearsal. In this section, there is a part that describes an emergency response rehearsal for during launch operations:

> 'A launch operator must conduct a rehearsal of the emergency response section of the accident investigation plan required by §417.111(h)(2). A launch operator must conduct an emergency response rehearsal for a first launch of a new vehicle, for any additional launch that involves a new safety hazard, or for

> any launch where more than a year has passed since the last rehearsal.' (FAA-AST 2017: 134)

This is part is the most extensive description of a simulation that can be found in the FAA regulations. However, this passage only applies to operations during launch. For rehearsals of crisis situations during flight, the section is quite vague as it states requirements of dress rehearsals during 'abnormal' or 'non-nominal' flight conditions.

It can be seen that FAA-AST regulations are also vague in what crisis simulations should entail and what personnel should learn. Basically a launch licensee only is required to hold a minimum of one launch rehearsal per year, with almost no requirements for the content and goals of that rehearsal or what personnel should learn. Furthermore, it does not specifically describe organization-wide rehearsals.

4.2.3 Subconclusion on Crisis preparedness for Europe

It has been determined that in order to ensure that Europe is adequately prepared for crises involving commercial spaceflight, an European regulatory framework should assure that both the public and private actors have prepared their response to such events. Most interviewed experts would agree that crisis preparedness is foremost the responsibility of public entities, but also would agree that regulations which prescribe some basic level of preparation for commercial spaceflight organisations are desirable.

As a big part of the responsibility for crisis preparedness lies with the public actors, the EU and its Member States should develop some space crisis preparedness. As there is a big chance that space crises would cross over or even take place outside the national borders of Member States, the EU specifically should integrate space crisis management in its already existing crisis planning framework. It should obtain technical knowledge and expertise from the space sector, from organisations like the ESA or SatCen. Furthermore, most experts would agree that it would be desirable that the EU should develop regulations that make a basic level of crisis preparedness for private spaceflight actors mandatory. Most experts would agree that such regulations on crisis preparedness should be regulated by an agency specialized in spaceflight. It has been suggested that a separate department within EASA for commercial spaceflight should be created, in line of the American regulatory model (Interviews safety expert, XCOR employee, spaceflight CM expert).

After examining the existing regulations and guidelines in Europe on planning crisis processes and implementing crisis infrastructure in commercial spaceflight organisations, it can be determined that specific requirements for crisis plans and procedures are scarce or non-existent. Moreover, requirements of crisis training and crisis simulations for the strategic or tactical level are non-existent. Safety regulations made by the CNES do make a more clear distinction between emergencies and crises, albeit not using this terminology.

The FAA-AST regulation gives an indication how crisis preparedness for commercial spaceflight organisations could be regulated in Europe. However, most of the expert respondents felt that the crisis preparedness that American regulation prescribes would alone not be sufficient for an implementation in Europe. As one safety expert argued: 'So in Europe, were they say the UK and Italy will follow the FAA when doing things, I hope what they really mean is that they will take the best bits of the FAA and then any other bits will come with their own requirements and regulations' (Interview safety expert November 2017). However, the interviewed XCOR employee was confident that FAA-AST could serve as a base for regulating crisis preparedness for commercial spaceflight in Europe. His main argument was that the FAA-AST regulation is realistic and feasible in a way that it would not impact the development of new commercial vehicles too much (Interview XCOR November 2017). This is a valid point, but several of the other experts felt that the language of the FAA-AST regulations is not concise enough on the contingency and emergency plans that they describe. Some would even argue that there are no crisis management requirements at all (Interviews both safety experts and aviation consultant). Examination of FAA-AST regulations confirms that these are marginal.

Looking at what already has been formulated within commercial spaceflight regulations and standards in Europe and the United States, there are few parts in existence that can be used within a framework for crisis preparedness of commercial spaceflight organizations. The safety requirements for operators launching from the European Spaceport in Kourou, French Guyana contain the only crisis preparedness requirements, albeit having a very limited description. In the United States, the FAA-AST regulations does contain some requirements for developing emergency and contingency procedures and plans, but these cannot be called requirements for adequate crisis plans. Moreover no requirements that would ensure proper crisis training and simulations can be found, thus missing the essential part for the implementation of a proper crisis organisation.

It can be concluded that the EU should further develop its space crisis preparedness and create regulations that make sure that private actors in Europe develop some basic level of crisis preparedness. These regulations on crisis preparedness should be made according to crisis management standards. How these standards should be created is up to debate. Most of the interviewed experts agreed that the American regulations are not a good source for creating such crisis preparedness regulations for Europe. Crisis preparedness in the commercial aviation industry has been named as a possible source of inspiration for creating crisis preparedness standards for the commercial spaceflight industry, something that will be explored later on.

Nevertheless, crisis preparedness requirements for the European spaceflight industry should not only elaborate on having the right distribution of roles and responsibilities throughout an spaceflight crisis organisation and the creation of reliable crisis management systems and manuals, but also on making sure that the right personnel is adequately trained and do practice crisis situations often. In this way, regulations on crisis preparedness will be performance based and it will be more certain that private actors are prepared for crises not only on paper, but also in practice.

4.3 Crisis Prevention for commercial spaceflight in Europe

The paragraphs on crisis prevention for commercial spaceflight organizations in Europe and the current regulations in the United States will be divided in line of the theoretical framework that was presented in chapter two. These include the three main components of crisis prevention; early warning and scanning (internal and external), issue and risk management and emergency response. After determining what the desired distribution of each aspect of crisis prevention among public and private actors would be, both existing European standards and guidelines and the American regulations will be evaluated.

4.3.1 European public institutions and regulations for private actors

4.3.1.1 Early Warning and Scanning

4.3.1.1.1 Internal Early Warning and Scanning

If the theoretical framework of Jaques (2007) is applied to commercial spaceflight, two forms of early warning and scanning can be identified; internal and external early warning and scanning. It has been established that internal early warning and scanning in commercial spaceflight would entail creating a safety culture within the organization of a private actor that would ensure the timely identification and mitigation of risks and issues within the design, test and operation phase of commercial spacecrafts. From interviews with experts it can be concluded that this is a task that would be carried out by the private actors themselves. However, experts also argue that it would be the responsibility of public entities to create rules and regulations for private actors that ensure safe designs and safe operations for commercial spacecrafts (Interviews both safety experts).

Experts also elaborated on how a safety culture should work within a spaceflight organization. They noted that higher management should only involve themselves with operational issues on an exceptional basis. Higher management should only intervene when decisions need to be taken that involve not fully pre-determined processes (Interviews safety expert and spaceflight CM expert). Thus it should be very clear which role management has when decisions need to be taken on issues concerning the design and operation of spacecraft. Also, senior management should clearly understand the issue at hand, which can be difficult because often some technical expertise is needed (Interview safety expert November 2017). In this way, senior management can take a better position on how to manage the safety issue in respect to other strategic priorities like cost-reduction and reputation management. Furthermore, personnel that has the responsibility for guarding the safety culture within an organisation should also be able to influence senior management in their decisions in a way that senior management will always keep safety at the forefront (Interview CM expert January 2018). In this respect, there should be clear rules and responsibilities for the daily management in upholding safety as the pinnacle within the own organisation. An SMS would create the right safety culture within the daily management of an organisation.

However, from interviews with experts it also has become clear that the level of mandatory crisis prevention for commercial spaceflight in the form of regulations that ensure safe designed spacecraft and safe operation of those crafts is the most debated on among stakeholders in the commercial spaceflight industry. It has been argued that creating too much requirements for the design and operations of commercial spacecraft will have a profound negative effect on the accessibility and competiveness of the European commercial spaceflight market (Interviews XCOR, EU policy expert and spaceflight CM expert). At the same time, some experts have argued that Europe should ensure safe commercial spaceflight by creating its own safety standards (Interviews both safety experts).

Nevertheless, most experts would agree that Safety Management Systems used like in commercial aviation would be an asset to improve safety in the commercial spaceflight sector. It has been agued that having a safety organisation with a proper safety culture would be a minimal requirement for commercial spaceflight organisations. Safety culture is called a 'necessary devil', because it is at the same time seen as crucial for preventing organizational failure, but also causing some level of bureaucracy (Interview safety expert December 2017). Furthermore, the expectation is that imposing an SMS on commercial spaceflight organisations would not encounter resistance among private actors because it would be in the interest of private the actors to have a SMS. Furthermore, most private actors would already have a level of safety culture because it is an experimental industry with a low tolerance on deviations in performance (Interview spaceflight CM expert 2017).

Airworthiness and Spaceworthiness

According to some experts, Europe should establish its own safety standard requirements that should be embedded in a mandatory SMS. It is suggested that Europe should establish their own standards on airworthiness and spaceworthiness for commercial spacecrafts (Interview safety expert November 2017). Experts have warned that without proper airworthiness and space worthiness requirements, commercial spacecraft will start to malfunction and blow up. As one interviewed safety expert argues;

> 'In aviation you have 90 per cent human error and 10 per cent vehicle error, that because the vehicles are certified, whereas in spaceflight the vehicles are not going to be certified because there are no airworthiness and spacewortiness standards they have to follow. So that 90-10 is going to be massively different. Is it going to be 50-50? It is going to be more, a lot of human error because you are going faster higher and etc. into a more turbulent environment. Arguably the vehicles are not certified so there are going to be more vehicles errors. So engines are going to blow up' (Interview safety expert November 2017).

It has been argued that in order for commercial spaceflight to be safe an expected casualty rate standard has to be established (Interview safety expert November 2017). In aviation, the allowed probability for a catastrophic event (loss of aircraft and crew) is set at not greater than $1x10^{-7}$ per flight hour (Janssens 2013: 92). This standard would be too strict because human commercial spaceflight involves operations that are mostly still experimental. To put in perspective, the casualty rate of NASA's space shuttle was $1.5x10^{-2}$ per flight hour (Janssens 2013: 93). Therefore it can be suggested that safety standards for commercial spaceflight should be somewhere between these. Adding to this, in making a safety standard for European commercial spaceflight, a separate casualty expectancy for 1st, 2nd and 3rd parties should be established (Quinn 2013: 145). This has also been suggested by several interviewed experts (Interviews both safety experts, aviation consultant). To aid the regulator in setting spaceflight safety standards, the International Association for the Advancement of Space Safety (IAASS) has proposed to create an independent institution for space safety in Europe. The idea is that verification of compliance to safety standards should be done on a peer-to-peer basis:

> 'Government organizations are more detached with technology developments. They cannot pretend that they are as good controllers of this technology. The best is thus to have someone from industry, that is independent from the specific project to. That can be called on a case-to-case basis as a sort of peer-review to check if everything is well done. This is the idea around the institute, to have a third party that can one side issue performance safety requirements and provide the necessary skills to make the verification.' (Interview safety expert November 2017).

However, it is also argued not to follow too strict safety standards for commercial spaceflight, because this will reduce competitiveness (Interview EU policy expert November 2017). Creating a lot of requirements for safety in design and safe operations would establish a lot of barriers for development of an experimental market that already has a lot of financial barriers (Interviews EU policy expert, XCOR, both CM experts). For example the ECSS standards have been named as a good starting point for spaceworthiness of commercial vehicles As Thomasso Sgobba argues: 'the ECSS has been invented for a specific use as a standardization tool but includes also the application to human spaceflight. ECSS is very modern and very revolutionary and very visionary' (Interview safety expert November 2017). However, other would argue that ECSS standards are not applicable to launchers and imposing them would be 'be cumbersome and very detrimental to the competitiveness of the industry' (Interview EU policy expert November 2017).

Imposing a SMS with lighter airworthiness and spaceworthiness requirements during the experimental phase

One solution to this problem of too strict safety standards creating to much regulatory pressure that has been suggested by experts could be to create regulations that focus on preventing organizational failures by prescribing SMS requirements and less on setting strict requirements for safety in design and safe operations. To start off with ensuring a safety culture within private actors, you can guarantee a level of safety within commercial spaceflight without enforcing strict safety rules. An interviewed expert tried to explain this by referring to Reason's Swiss cheese model. Instead of creating a lot of rules that should clog the holes in the Swiss cheese that represent the faulty designs and human errors, and in this way creating a lot of regulatory pressure, you could obligate private actors to inspect their Swiss cheese on regular basis for the existence of any holes (Interview CM expert January 2018).

Imposing high-level safety requirements for a SMS used like in aviation would be desirable (Interview spaceflight CM expert January 2018). Imposing an SMS in commercial spaceflight would however be different than in commercial aviation. In aviation commercial operators broadly use the same type of airplanes, choosing from a limited number of manufactures. A defect or anomaly in the design or operation of an aircraft of one operator quickly leads to a change in all the aircrafts in the same type as there is much exchange within the industry on safety issues through their SMS's. There is thus a lot of self-regulation in commercial aviation (Interview safety expert December 2017).

However, in commercial spaceflight, every actor will have a different designed spacecraft with different ways to operate it, as there are no global standards on designing such crafts. The industry thus will be more fragmented and exchange of safety issues will be lower (Interview spaceflight CM expert January 2018). The willingness of private spaceflight actor to exchange the technical details of their uniquely designed spacecraft with competitors will be low. Furthermore, several experts note that international exchange of technical details in commercial spaceflight is thwarted by national laws that prohibit the exchange of information on rocket technology, like the International Traffic in Arms Regulations (ITAR) of the United States (Interviews safety expert, EU policy expert and spaceflight CM expert). Several experts have suggested that public actors can act as a facilitator of the exchange of safety issues by creating certain basic safety requirements that would at least tackle organisational failures and stimulating the creation of space safety standards by bringing important industry stakeholders together (Interviews safety expert, both CM experts).

As already has been argued for crisis preparedness, several experts argue that the private actor should also be able to prove his crisis prevention performance to the regulator trough a qualitative assessment and not by quantitative assessment (Interview both safety experts, aviation consultant, both CM experts). This means that a safety culture is not guaranteed by only having a safety officer, the performance of the organisation in safety should be checked. This also does not mean that regulators should solely check the performance of the safety officer. This assessment by the regulator should not be an assessment of the performance of the person that is tasked with safeguarding the safety culture within the organisation of the commercial spaceflight organisation, but should be more a cooperation with this safety officer in checking the safety culture of the organisation (Interview CM expert January 2018).

Nevertheless, the need for innovation during the experimental phase does not mean that commercial spacecrafts should not be certified at all from the beginning. Some European operators and manufactures have declared that they would prefer to set up a complete regulatory regime from the beginning (Masson-Zwaans 2014: 80). Moreover, with Europe having on average a denser population than the United States, accidents with commercial spacecrafts during launch or re-entry have a higher chance on making a deadly impact (Interviews safety experts). Thus a good way forward for a European regulatory framework would be to start off with 'light' regulations containing basic but not too strict airworthiness and spaceworthiness qualifications and include requirements for an adequate implemented SMS with proper issue and risk management. In this way you would weave out design faults and human operating errors without having very strict specification barriers from the start. If we relate this to the basic structure of performance-based regulation as is depicted in the presentation of Andy Quinn (2013), this would mean creating some high-level performance requirements for commercial spacecrafts with basic guidelines how to achieve them. The acceptable means of compliance, the required standards, would then be not too strict from the start and further developed as the market grows.

Implementing safety requirements in phases

While requiring the implementation of a safety culture, safety standards in design and human operation for spacecrafts can be developed in cooperation with the European space industry. It has been proposed to change the level of standards and regulations in a developing European commercial spaceflight industry according to the level of development and size of the European market (Interview spaceflight CM expert January 2018). Currently, the European commercial human spaceflight market does not exist, as there are companies performing flights from the European continent. It is the expectation that somewhere in the next decade the first flights will be offered, but these will not be accessible for the general public and will involve sending astronauts into space or ferrying the richest people on the planet to space (Interview spaceflight CM expert January 2018). In this market with a highly experimental character and low demand, per flight an accident will have a higher probability of occurring. But because of the low number of flights and people using these services deadly accidents will occur less frequently and have less of an impact. Accidents during the first generation of commercial human spaceflight, that will commence operation in the coming years, will involve only a few astronauts and billionaires and will not quickly lead to public demand for safer commercial spaceflight. During this phase, a more lightly regulated commercial space industry will have legitimacy (Interview spaceflight CM expert). This is a sentiment that is present among a sizable part of the stakeholders in European spaceflight, as became clear during a workshop in 2014;

> 'Concerning the characteristics that a future European regulatory framework for commercial spaceflight could have, a step-by-step approach is the option preferred by most stakeholders, in order to go along with the technical evolution and to facilitate the industry to emerge. A flexible framework for development, testing and initial operation would be desirable at this point, in order not to constrain innovation and enable a level playing ground with respect to US companies. Almost all stakeholders seem to agree on having a "light-touch" approach to regulation as long as the market remains small.' (Masson-Zwaans 2014: 80).

However, when in the more distant future commercial spaceflight will develop itself and become a more accessible market and therefore has a higher demand and more frequent flights, a more stricter regulatory system will be desirable in the eyes of the public. This is the development the global commercial aviation sector went through and several experts envision that the commercial spaceflight market will go through the same development (Interviews safety expert and both CM experts).

In order to be prepared for a probable rise in demand, stricter safety standards should be developed from the experiences of private actors with developing, testing and operating their spacecrafts (Interview spaceflight CM expert January 2018). It would be the responsibility of the regulating entity to further develop standards for airworthiness and spaceworthiness in cooperation with the private industry, in order to have decent standards when the European market is starting to open to the general public (Interview spaceflight CM expert January 2018). The creation of a safety institute as proposed by the IAASS with a peer-to-peer review would help standardization and encourage self-regulation among private actors next to regulation from above.

Possible regulating authority

Most experts agree on which organisation would be a good agency on that could fulfil the role as the regulator of commercial spaceflight in Europe, namely the European Aviation Safety Agency (EASA) (Several Interviews November, December 2017 and January 2018). It would require an independent agency, detached from and minimally be influenced by private interests (Interview spaceflight CM expert January 2018). The EASA could play the same role as the FAA in the United States, with or without a separate department for commercial spaceflight (Interviews both safety experts and spaceflight CM expert). However, the EASA currently does not posses much knowledge and expertise on spaceflight, which is the same problem that the FAA in the US currently has (Interviews safety expert, XCOR and aviation consultant). Thus it would be important that EASA obtains this knowledge when creating a department on commercial spaceflight, which could be obtained in cooperation with the ESA.

It also has been suggested to create safety standards for commercial spaceflight, on a higher, global level. This would be something in line of the current international regulatory system in commercial aviation, with the ICAO being the organisation setting the international standards (Interview spaceflight CM expert January 2018). For commercial spaceflight, an organisation like the ICAO or a space safety division in ICAO itself could be created.

It has been established that a European regulatory framework on crisis prevention should focus on preventing organisational failure among private actors through safeguarding a safety culture. This can be done through make Safety Management Systems mandatory for private actors. Now the ECSS standards and UK legislation in development will be analysed on safety culture requirements.

Safety culture in the ECSS Standards and UK legislation

The ECSS standards contain some provisions for the implementation of a safety culture for internal early warning and scanning. In the ECSS standard on safety, a chapter on the implementation of a safety program exists. The safety programme plan's purpose and objective are described in Annex B of the document:

> 'The plan defines:
>
> - the safety programme tasks to be implemented;
> - the personnel or supplier responsible for the execution of the tasks;
> - the schedule of safety programme tasks related to project milestones;
> - safety programme activity interface with project engineering and with other product assurance activities;
> - how the supplier accomplishes the tasks and verifies satisfactory completion (by reference to internal procedures as appropriate).' (ECSS-Q-ST-40C Rev.1 2017: 61).

And adds to this:

> 'The safety programme plan shall include a description of the project safety organization, responsibilities, and its working relationship and interfaces with product assurance disciplines (reliability, maintainability, software product assurance, parts, materials and processes and quality assurance according to ECSS-Q-ST-10, -20, -30, -60, -70 and -80), with configuration management according to ECSS-M-ST-40, system engineering according to ECSS-E-ST-10, design and other project functions and departments of organizations.' (ECSS-Q-ST-40C Rev.1 2017: 61).

Also the plan should describe how the following provisions of the ECCS-Q-ST-40 document are implemented: Safety programme and organization; Safety engineering; Safety analysis requirements and techniques; Safety verification; Operational safety' (ECSS-Q-ST-40C Rev.1 2017: 62). These required contents of an ECSS safety program seem to include many aspects of a Safety Management System (SMS). For example, key safety personnel in the form of a safety manager with specific access and authority is described in the document (ECSS-Q-ST-40C Rev.1 2017: 18-19). One remarkable feature is the extensive description of safety program tasks and reviews per project phase (including mission analysis, feasibility analysis of the project, preliminary definition, detailed definition, production and qualification testing, utilization and disposal) (ECSS-Q-ST-40C Rev.1 2017: 20-24).

However, there are some elements of a SMS missing or not elaborate enough to qualify the ECSS safety program as a complete SMS to ensure a safety culture. For example, the document fails to describe the commitments and the responsibilities of senior management. Furthermore, no Safety Performance Indicators (SPI's) are created and safety promotion requirements are under the level of the qualifications of a SMS. Safety training is included in the document, but only entails training for persons working with hazardous materials in safely handling of the materials and general awareness of hazards surrounding these materials (ECSS-Q-ST-40C Rev.1 2017: 25). No training on overall safety throughout the organisation is described. While the documentation of safety issues and hazards is well described in the document, there is no description of requirements for the communication of safety issues throughout the organisation.

An overview of the existence of requirements for an SMS in the ECSS standards is given in Table 4.1;

SMS requirements status in the ECSS standards		
Safety Policies and Objectives	I	Insufficient. Certain aspects are insufficient or absent.
Senior management commitment and responsibility	✕	Absent.
Safety policy	I	Insufficient.
Safety accountabilities	I	Insufficient.
Appointment of key safety personnel	S	Sufficient. Safety manager and Safety boards with tasks and responsibilities described. However, tasks of safety personnel could be extended to math SMS standards more properly.
SMS documentation.	S	Barely sufficient.
Safety Risk Management	✔	Good. Well-described and documented safety risk management processes and tools.
Safety Promotion	I	Insufficient. Safety training and communication requirements do not math SMS standards.
Safety Training and Education	I	Insufficient. Safety training only for personnel working with hazardous materials or systems.
Safety Communication	I	Insufficient. Should be extended to safety communication for

		the whole organisation. Communication tools need to be added
Safety Assurance	I	Insufficient
Safety performance monitoring and measurement	I	Insufficient.
Continuous improvement of the SMS	I	Insufficient.
Safety Issue Management	I	Insufficient. Safety Issue Management do not match SMS standards.

Table 4.1: Overview of SMS requirements present in the ECSS documentation (by author)

When examining this overview, we can see that certain SMS components are present in the ECSS standards but many are insufficient or even absent. The ECSS standards describe proper risk management, safety and hazard analysis and reporting and the assignment of key safety personnel, but fail to describe requirements that ingrain safety into the whole spaceflight organisation. More extensive and better-described requirements are needed if the ECSS standards on safety would be used as a basis for requirements that should guarantee a good safety culture among commercial spaceflight organisations.

United Kingdom's spaceflight legislation that is in development elaborates quite extensively on requirements for the implementation of SMS's. As a minimum the regulations will contain requirements that prescribe the appointment of a safety manager who will be responsible for the development, administration and maintenance of an effective safety management system (Department for Transport & UK Space Agency 2017: 9). This will be a requirement for both spacecraft operators and spaceport operators to obtain a license. An SMS is described as; 'the organizational structure, policies, procedure and accountabilities for ensuring safety' (Department for Transport & UK Space Agency 2017: 22). A extensive description of the contents of such prescribed SMS is not provided. However, experts feel that the UK will follow CAA requirements for risk assessments and SMS's (Interview safety expert November 2017). If they do so, it would be the first European national legislation that includes aviation standards in their regulations for commercial spaceflight organizations.

4.3.1.1.2 External early warning and scanning: Space Situational Awareness and Space Traffic management.

Most interviewed experts would agree that Space Traffic Management (STM) and Space Situational Awareness (SSA) are important activities in preventing collisions between commercial spacecrafts and other objects that are placed within their operating range. The risk of collision or damage from other environmental hazards depends on where a spacecraft is going and how far it is going (Interview spaceflight CM expert January 2018). For example, suborbital flights, which in general do not go much further than the official boundary (100 km) between the atmosphere and space, mainly only intersect with air traffic and almost never cross the orbital path of other objects (Interviews safety expert and spaceflight CM expert). Furthermore, humans on board would be exposed to minimal space weather hazards such as radiation. If you decide to launch a rocket that would head for the moon, however, you would go through all the layers of orbiting objects such as (abandoned) satellites, stations and debris (Interview spaceflight CM expert January 2018). The on-board crew is then exposed to much more hazardous spaceweather as they move out the Earth's protective magnetic sphere. So the level of potential external hazards changes when going higher and further.

Space situational awareness is thus an important component of Space Traffic Management. In order to manage traffic to and from space, you need to know where all the potential collisions and other dangers are located. Among experts who elaborated on this subject, it is a common opinion that SSA should be an international endeavor and ideally be achieved through global cooperation (Several interviews December 2017 and January 2018). Ideally a global organization that manages SSA activities should be established (Interview Sgobba December 2017). Currently, the United States is the country that has developed the most accurate SSA capabilities and effectively is responsible for global SSA (Interview safety expert December 2017). Kaiser (2014) elaborates on this;

> 'the Space Surveillance Network (SSN) operates a worldwide sensor network and provides the information to the Joint Space Operations Center (JSpOC) under the superior command of the U.S. Strategic Command (US STRATCOM). With these data inputs, the JSpOC catalogues Earth orbiting man-made objects and combines them with other information to provide space situational awareness' (Kaiser 2014: 6).

In 2009 US STRATCOM started to provide global SSA service as it took responsibility for the 'SSA Sharing Program', which provided 'space situational awareness services and information to, and obtaining the same from, foreign States and U.S. and foreign commercial entities' (Kaiser 2014: 6). Currently Europe is looking into developing European-wide SSA capabilities, but does not have implemented it yet (Interview safety expert December 2017). The ESA has implemented SSA as an optional ESA program until 2019 with 'the current activities running to 2020 place increased emphasis on developing space weather and NEO services, while research, development and validation activities continue in the domain of space surveillance and tracking' (ESA website 2018). Other major spacefaring nations like Russia and China also have some separate SSA capabilities (Interview safety expert December 2017). It thus would is desirable to create one global SSA system. Kaiser (2014) identifies three major elements that SSA includes;

- 'the collection of data and information, typically including the detection and tracking by ground-based and space-based optical and radar sensors, and collection by other sources, like registration information and exchanges with other public and private bodies including satellite operators;
- the arrangement of the collected information in a systematic manner, typically by keeping and updating a data base or catalogue of all space objects and space debris, including their orbital parameters; and
- computer processing capacity to predict the status, events and threats in the future, most importantly to issue reliable conjunction information, i.e. predicting with a useful probability collision conflicts among man-made and possibly also natural space objects.' (Kaiser 2014: 6).

Experts identify one big hurdle in creating a global effort in these SSA elements, namely the fact that part of the SSA data would be classified military data (Interviews safety expert and EU policy expert). It would be difficult to reach global agreements on sharing this data world-wide, as it would be against national security interests of spacefaring nations. As the interviewed EU policy expert elaborates;

> ‘If you want to achieve space traffic management in order to avoid collisions then you need to share information then you have a problem. Because you need to have access to a number of data’s that are restricted, that are really military. Because much of the traffic in space is related to military programs. And this you will not get easily agreements to fully and openly share this data’ (Interview EU policy expert November 2017).

From interviews with experts it can be concluded that Space Traffic Management (STM) is something that currently not has been developed and of which it is not entirely clear how it would work in practice. While SSA is about knowing the situation and possibly informing spaceflight actors of collisions, STM is about interfering and making sure actions are taken (Interview safety expert December 2017). The experts that commented on STM all agreed that STM also should be done through global cooperation (Interviews safety expert, EU policy expert and spaceflight CM expert). When considering creating STM capabilities you first have to create rules that govern STM, which currently do not exist. From interviews with experts it can be derived that the way that these rules would govern STM would depend on the height on which the space traffic is located and the type of space traffic.

One distinction that has been made by an expert is based on altitude; firstly all launched spacecraft will first cross airspace (up until 20 km), then an ‘intermediate’ area (from 20 until about 100 km), and then into space, which is above the Karman line of 100 km (Interview safety expert December 2017). However, there are countries which regard their airspace reaching up until 100 km. Currently Curacao is developing legislation for spaceflight operation from the island, and developers have decided to extent airspace up to 100 km (Interview aviation consultant December 2017). When operating in airspace it would not be difficult to establish rules for spacecraft, as these would be similar to rules for air traffic. It has been suggested to integrate space traffic in this area with existing Air Traffic Management (ATM) (Interviews safety expert and EU policy expert). STM on this level would thus be the responsibility of the local ATM authority. However there are still a lot of technical difficulties to be considered. For example, air traffic managers can only track spaceplanes to a certain height, as radar and transponders do not work higher up in the atmosphere. Also one should consider the damage that a rocket powered airplane does to regular runways (interview aviation consultant December 2017). Furthermore a distinction has to be made between managing suborbital and orbital traffic. As one safety expert states while answering the question if STM should done in a same manner as ATM;

> 'Suborbital yes, orbital not because of the speed that you need a lot of elaboration. Suborbital is to a certain extent a slow business, you go up to like for 4000 km per hour. To be orbiting you have to go 28.000 km per hour, so the speed is different. On the one hand there is the management of traffic, on the other hand the management of bullets. You cannot manage in real time the prevention of a collision of a rocket' (Interview safety expert December 2017).

Orbital space traffic, launching or re-entering thus cannot be managed in the same way as air traffic, 'which de-conflicts air traffic at a short-term tactical level' (Kaiser 2014: 11). Managing this kind of traffic needs a more strategic approach, planning and anticipating ahead and creating launch and reentry corridors to avoid collision with air traffic. Thus suborbital flight could be integrated with air traffic management. For orbital spaceflight, new rules should be established, as this would take a more strategic approach.

It has been suggested that rules for STM would be managed by a global agency like ICAO does with air traffic management (Interviews safety expert, EU policy expert and spaceflight CM expert). While integrating STM in airspace with ATM, this global STM organization would be responsible for the STM above airspace (Interview EU policy expert November 2017). An attempt was made to create a code of conduct for space operations, which would create a centralized organization for the exchange of data and space traffic management. But this attempt failed because of conflicting military interests (Interview safety expert December 2017). On the European level, STM standards for private actors could be implemented by EASA (Several interviews). It has been suggested that for suborbital flights from and to Europe, the same organization that manages air traffic could manage suborbital traffic (Interview safety expert December 2017).

Experts agree that STM and SSA would mainly be a task for public actors. Private actors obviously need to comply with STM rules and it would be expected that these would be included within regulations when STM is created globally or regionally. For now, STM is absent and private actors need to plan their trajectory way ahead of the launch, based on data provided by JSpOC. It has been suggested that a middleman between the launch vehicle and SSA data providers should be created, a kind of space traffic operator controller (Interview safety expert December 2017). Operators of satellites or other spacecraft most of the time have better information on the location of their own spacecraft than SSA providers like JSpOC, as this organization tries to achieve SSA with radar (Interview safety expert December 2017). This middleman within the organization would then combine the data of their own spacecraft, that of operators of spacecraft in the vicinity and that of JSpOC. This would call for SSA cooperation between commercial operators and public SSA providers.

SSA or STM requirements are scarce in existing European standards and legislation for commercial spaceflight, which is not strange, as it has been established that these are very new activities. The ECSS documentation does not yet contain documentation for external warning and scanning. A space sustainability branch has been created that would include space situational awareness and tracking space debris, but no real standards have been formulated on these aspects. In the UK legislation in development, external early warning and scanning in the form of space traffic management (STM) and space situational awareness (SSA) is elaborated on in the form of the establishment of 'ranges for spaceflight activities' and this means 'a zone that is subject to restrictions or exclusions for keeping it clear, at the relevant times of persons or things that might pose a hazard to those activities, and persons or things to which those activities might pose a hazard' (Department for Transport 2017: 4). The document also provide for a license of a 'range control licenses' for an organization that would provide range control services. This is effectively the establishment of an authority who would determine the flight paths for commercial spacecrafts and would manage the spaceflight traffic.

However, while examining the policy scooping notes it becomes clear that many aspects of this form of STM are still not certain and how they would work in practice is still up to debate. The document recognizes that international precedent for the licensing of range control services is absent and that proper requirements are going to be a product of decade-long debate between governments and the industry in the coming decades (Department for Transport & UK Space Agency 2017: 18). Concluding, it can be examined that the UK is trying to explore possible STM standards in a world without proper international STM standards.

4.3.1.2 Issue and Risk Management

Experts have already argued that commercial spaceflight organizations should develop an adequate safety culture within the organization and should tackle organizational failures. Implementing Safety Management Systems in those organisations would be a good way to achieve this. Part of these SMS's would be issue and risk management, identifying, prioritizing, assessing and managing risks and issues that occur during designing, testing and operating commercial spacecrafts. Next to organizational failures, which would include latent failures like bad management, these would include issues and risks involving faulty designs and operational failures. It has been argued that safety standards should not be too high from the start. Before stricter standards are being developed, it is important to have adequate issue and risk management for private actors, on which the ECSS and UK legislation will be examined. In order for safety requirements to be performance-based, the risks have to be known. One aspect that has been named important by experts, is considering the risks of commercial spaceflight for both 1^{st}, 2^{nd} and 3^{rd} parties while performing risk management (Interviews both safety experts)

The ECSS standards are quite extensive on early warning and scanning of technical issues and possible human errors during the development phase. They contain separate documents on risk management and hazard analysis, and an overview of the safety analysis process is given in the document on safety. The documents depict risk management as a continuously and imbedded process during design, testing, operating and the disposal phase. The risk management process prescribed as by the ECSS standards is shown in figure 4.6;

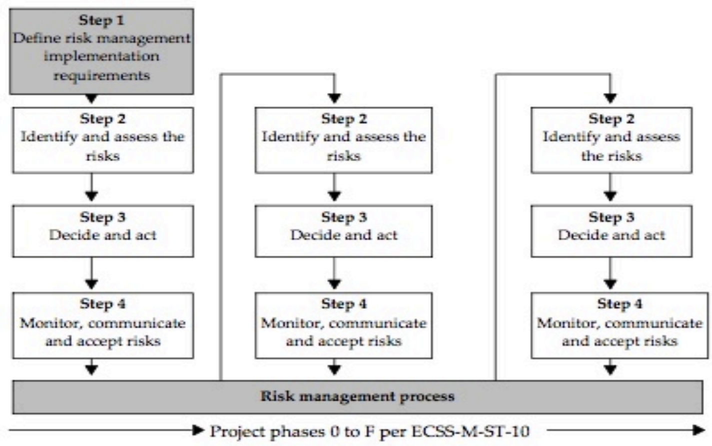

Figure 5-1: The steps and cycles in the risk management process

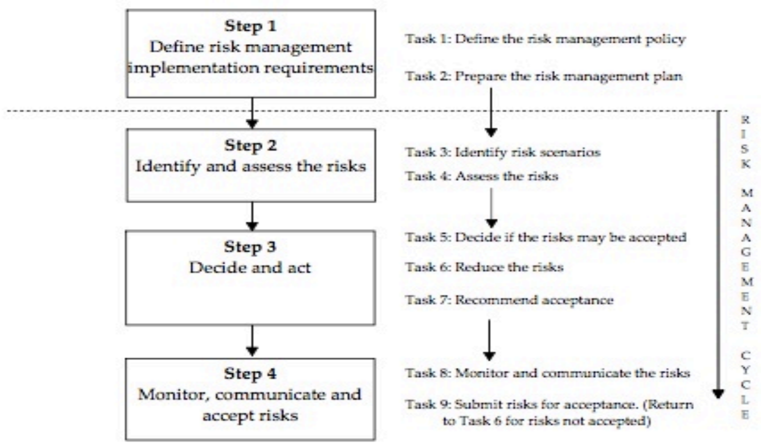

Figure 5-2: The tasks associated with the steps of the risk management process within the risk management cycle

Figure 4.6 : Risk Management process as depicted by the ECSS standards (ECSS-M-ST-80C 2008: 14)

All the necessary steps of risk identification, assessment, and management are present. The document on hazard analysis also contains some hazard analysis tools.
The ECSS standards also try to set standards for designing reliable systems which incorporate identified risks and hazards (ECSS-Q-ST-30C Rev.1). The management of hazards by designing safe systems is called 'dependability' by the ECSS standards. This document on dependability of space systems contains several hazard analysis tools. Proper failure modes analysis tools for products and processes are elaborated on in a separate document (ECSS-Q-ST-30-02C).

One remarkable document is the 'human dependability handbook', which tries to incorporate some form of human factors integration in the overall risk management process. As the document states:

> 'Human dependability captures the emerging consensus and nascent effort in the space sector to systematically include the considerations of "human behaviour and performance" in the design, validation and operations of both crewed and un-crewed systems to take benefit of human capabilities and to prevent human errors.' (ECSS-Q-HB-30-03A 2015: 7).

The documents describes failure scenario's that integrate human errors, three levels of human performance as proposed by Quinn (2013) and extensive description of a human error analysis method.

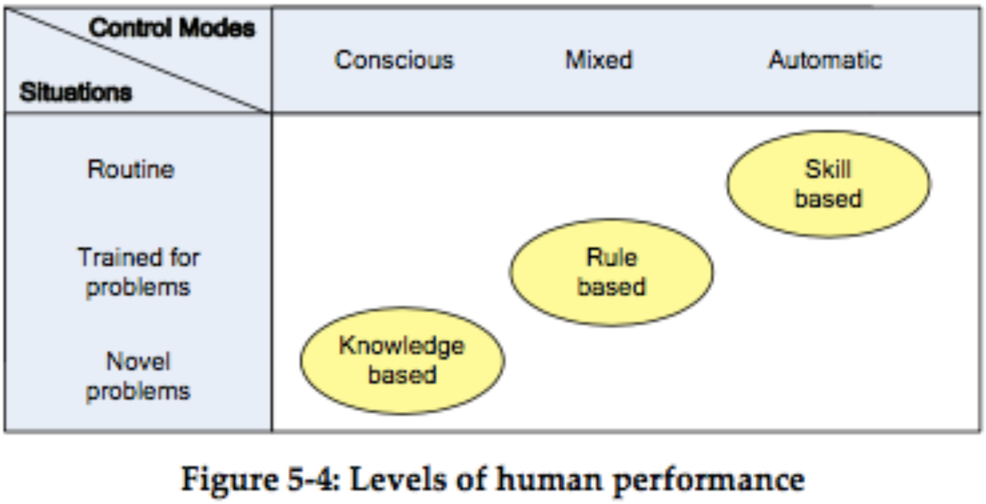

Figure 4.7: Three level of human performance (ECSS-Q-HB-30-03A 2015: 22)

The standards set by the handbook on human dependability are to an extent in line of human factor integration as proposed by Quinn (2013). It even gives an extensive human error management method that includes the different stages of development, operation and disposal of spacecrafts. This human error management process mimics that of the overall risk management process steps and cycles (ECSS-Q-HB-30-03A 2015: 47-54). It even quite extensively elaborates on organisational factors that lead to human failure. It names these influences 'performance shaping factors' (PSFs) and divides them into two categories; external PSFs and internal PSFs:

- **External PSFs** that are external to the operators divided in two groups: organizational and management (O&M) factors and job factors,

- **Internal PSFs** that can be part of operators' internal characteristics, also called personal factors (ECSS-Q-HB-30-03A 2015: 18).

The document further recognizes that these PSFs can influence each other and name a whole range of different external and internal PSFs (ECSS-Q-HB-30-03A 2015: 19-20). Among the O&M factor PSFs and job factor PSFs, it incorporates factors as deviating mental processes, safety cultures and training for the task at hand. Lack of personal commitment and of commitment of management to safety are also mentioned. Moreover, it adds a model that could help with analysing organizational influences on human errors, the Human Factors Analysis and Classification System (HFACS). Adding to the HFACS model the document names three different organizational influences :

- 'Resource and acquisition management: this category refers to the management, allocation and maintenance of organizational resources (human or monetary) and equipment/facilities.
- Organizational climate: this category refers to a broad class of organizational variables that influence worker performance and in general is the usual environment within the organization. This category is related with the Safety Culture or the definition of policies and rules.
- Organizational process: this category refers to the formal process by which things are done in the organization and includes definition of operations and procedures and control of activities' (ECSS-Q-HB-30-03A 2015: 21).

Furthermore it names four main categories of negative supervision or managerial influences:

- Inadequate management and supervision: this category refers to those times when management results are inappropriate, improper or cannot occur at all.
- Planned inappropriate operations: this category affects to the appropriate planning of operational schedule or selection of operators.
- Failure to correct a known problem: this category refers to deficiencies affecting personnel, equipment, training or procedures that are "known" by the management, but yet they are allowed to continue uncorrected.
- Management and supervisory violations: this category refers to situations when managers disregard existing rules and regulations (ECSS-Q-HB-30-03A 2015: 21-22).

The thing that misses in regard to Quinn's recommendations are human error probability values (Quinn 2013: 66-67) and a model linking these human errors to the design of the system, making a safe operating- safe system feedback loop (Quinn 2013: 144). Moreover, proper human factors integration would include models that examine the integration between humans and complex electronic elements (Quinn 2013: 165). An overview of the analysis of safety risk management standards in the ECSS documents is shown in Table 4.2:

Safety Risk Management requirements status in the ECSS standards		
Definition of Risk	S	Sufficient: undesirable situation or circumstance that has both a likelihood of occurring and a potential negative consequence on a **project.** It would be recommended to add a emphasis on humans as the object of negative consequences.
Risk Analysis	✔	Good. Well-described process.
Risk analysis tools	✔	Good. Failure Tree Analysis (FTA), Failure Mode and Effects Analysis (FMEA) and Failure Mode, Effects, and Criticality Analysis (FMECA) included.
Human Factors Integration	I	Insufficient, the addition of human error probability values, the use of HFI models and a safe operation- safe design model would be recommended.
Risk Identification	✔	Good.
Organizational Risks	✔	Good. Organisational factors as risks are identified: Internal organizational aspects; public image; political constraints; risk sharing between actors; etc. PSFs recognized and HFACS model introduced.
Hazard Management	✔	Good. Well-described identification, analysis and management of potential hazards requirements.
Hazard identification and analysis	✔	Good.
Hazard analysis tools	✔	Good. Includes: Preliminary hazard analysis (PHA), Subsystem hazard analysis (SSHA), System hazard analysis (SHA), operating hazard analysis (OHA), Zonal analysis (ZA), Hardware-software interaction analysis (HSIA), Contingency analysis, Common-cause analysis, Worst case analysis (WCA), Part stress analysis, Failure Detection Isolation and Recovery

		(FDIR) analysis, Maintainability analyses, Availability analysis, Human error analysis.
Risk Assessment	✔	Good.
Risk Mitigation	✔	Good.
Risk Acceptance	✔	Good.
Risk Communication	✔	Good. Valid safety verification and communication methods of risks.

Table 4.2: Overview of Safety Risk Management requirements present in the ECSS documentation (by author)

While the ECSS standards make a valid attempt to integrate human factors and organizational failure into safety risk management, it maintains it focus on identifying design faults. Experts would confirm that the ECSS standards focus mainly on the design phase (Interviews safety expert and EU policy expert). This is not strange as the standards are mainly used for the design of space systems by private actors. It does not provide for proper risk management throughout the life cycle of a spacecraft, as proposed by Quinn (2013). Furthermore, a safety model that includes safe operation and safe design loop as proposed by Quinn (2013) is also not included.

Issue management is not explicitly mentioned in the ECSS standards, but in the standard on Safety there are some requirements mentioned that could include issue management. For example the document mentions that the safety manager should have 'unimpeded access to any management level without organizational constraint on any aspect of project safety ' (ECSS-Q-ST-40C Rev.1 2017: 18). Issues concerning spaceflight likely manifest themselves for the first time during the test phase of a spacecraft. For the testing phase, the document states that there should be accident-incident reporting and investigation. All incidents and accidents should be logged and mentioned to the safety representative of the organization (ECSS-Q-ST-40C Rev.1 2017: 26). Also, for the operating phase the document sets requirements for the creation operational safety plan, to 'identify and monitor hazardous operations', the evaluation of any 'anomalies for impact to safety' and 'investigate safety related anomalies and trends' (ECSS-Q-ST-40C Rev.1 2017: 23- 24). Finally, the document mentions the requirement of the 'use of a safety lessons learned' with the 'assessment of a all malfunctions, accidents, anomalies, deviations and waivers.' In the Human Dependability Handbook, we can see that bad issue management is recognized as a factor that influences human error, as the documents states that 'failure to correct a known problem' is a negative management factor (ECSS-Q-HB-30-03A 2015: 22). In paragraph 6.3.3.2 of the document, titled 'Steps of human error reporting and investigation', a process is described that could be interpreted as issue management. In order to report and investigate human errors the document identifies the following 5 steps:

- 'Establish a system to log incidents during operations on a project;
- Log incidents;
- Review logs for their completeness and comprehensibility;
- Identify criticality and urgency and classify logs;
- Establish anomaly review board: review incidents and define classification of incidents. In case of human error involved in the incidents proceed with Step 2.' (ECSS-Q-HB-30-03A 2015: 44).

The whole process of human error reporting and investigation is depicted in Figure 4.8.

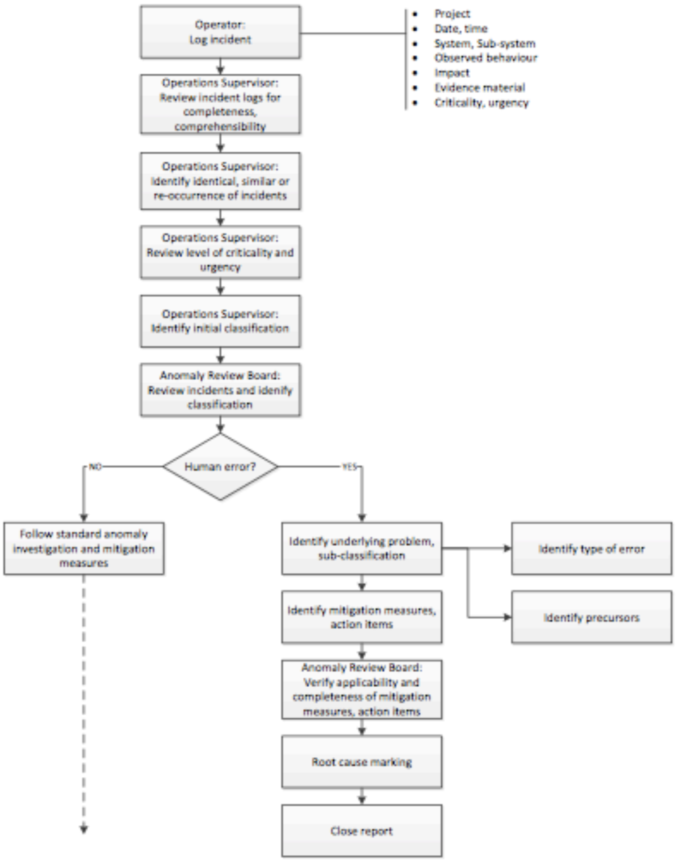

Figure 6-4: Human error reporting and investigation process

Figure 4.8: Human error reporting and investigation process (ECSS-Q-HB-30-03A 2015: 45)

The figure actually describes roles and responsibilities when doing issue management. It includes operations management. However, this process focuses only on the technical issues and the mitigation oft them. It identifies the need to search the root causes of the problem in managerial and organizational problems, shown as 'identify precursors', and identifying how to tackle these problems by 'identify mitigation measures, action items'. In the section on 'reducing human errors', the document tries to describe tackling these precursors for human error. It gives the description of implementing a step-by-step process to identify, prioritize, implement, verify and track human error reduction (ECSS-Q-HB-30-03A 2015: 41). This process is however not described extensively, the document gives a few examples of solutions for tackling precursors, but does not name a process to tackle managerial and organisational issues. Furthermore it gives no guidelines for who would be responsible for tackling these underlying problems.

The amount of safety issue management requirements set by the ECSS standards is summarized in Table 4.3;

Safety Issue Management requirements status in the ECSS standards		
Definition of a Issue	×	Absent, the word issue is not present in the standards. The word anomaly is used but a definition is not given.
Determined by an organization-wide input	×	Absent.
Issue identification	I	Insufficient. Not clear enough requirements issue identification processes.
On operational, tactical and strategic level.	I	Insufficient. Only partly described, only for operator and operations management.
Issue prioritization	I	Insufficient. Only briefly mentions the prioritization of issues as assessing human errors.
On severity and potential to cause a crisis.	S	Sufficient but could be more elaborate.
Issue management	I	Insufficient. Does not describe roles and responsibilities in this process. Focuses mitigation and solutions at the operational level. No role for management described in this processes.
Mitigation	I	Insufficient. Only describes the identification, prioritize, implement, verify and track of human error reduction in a short manner.

Counter-Measures	I	Insufficient. Briefly mentions some counter measures.
Issue communication and logging	I	Insufficient. External communication with customers and other space system designers mentioned and no organization-wide internal communication procedures on issues mentioned.
Free flow of information on known issues, Maintain database on known issues, either solved or unsolved, Log actions taken on issues	I	Insufficient. No mention of internal flow of information on issues. Only supplier- customer information flow mentioned. Database of safety lessons learned mentioned.

Table 4.3: Overview of Safety Issue Management requirements present in the ECSS documentation (by author)

The described issue management processes in the Human Dependability Handbook are to an extent quite elaborate in identifying, prioritizing and managing issues related to human error. While it mentions tackling organizational and managerial issues as the underlying problems of these human errors, it does not give guidance on how to do so and who has to do this. Responsibilities and roles of management or senior management not mentioned at all.

UK Legislation in development

The legislation being developed by the UK Space Agency and the CAA does elaborate on some parts of an organisation-wide risk management scheme. For operator licences, the applicant should show having made proper risk assessments for risks to third parties. Such a risk assessment would involve the identification of risks for all persons directly or indirectly involved in the operation of the aircraft, such as flight crew, spaceflight participants and ground crew (Department for Transport & UK Space Agency 2017: 28-29). Important to note is that the risks identified are required to be managed to according to the 'low as reasonably practicable' (ALARP)-principle. This means that all risks have to be mitigated and managed to a minimum for all persons directly or indirectly involved in the operation of the spacecraft and third-parties. This with the high possibility of adopting the SMS standards already set by the CAA, seem to predict that the UK will set a good standard for safety risk management within commercial spaceflight. During interview, a safety expert agreed that the tendency of the UK to follow aviation risk management process standards is a good development. In his words:

‘In the UK they are going to follow the risk management process that the aviation follows. I agree with that. In the UK we have the ALARP principles so we have a level of tolerability of risk for a vehicle’ (Interview safety expert November 2017).

4.3.1.3 Emergency Response

From interviews with experts it can be derived that at the moment, the responsibilities for the emergency response to an accident involving commercial space activities are not very clear. In the case of an accident during the launch or a crash of a spacecraft during re-entry, the responsibilities for emergency response are not very difficult. Experts would agree that it is foremost the responsibility of the government on which territory the accident takes place to coordinate an emergency response (Interviews safety expert, both CM experts and aviation consultant). Thus for emergencies with spacecrafts on Earth, responsibilities will be the same as any other major accident. In the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, adopted and ratified by all members of the United Nations in 1967, the responsibilities between states when an object from space crashes on Earth are summarized;

> ‘If, owing to accident, distress, emergency or unintended landing, the personnel of a spacecraft land in territory under the jurisdiction of a Contracting Party, it shall immediately take all possible steps to rescue them and render them all necessary assistance. It shall inform the launching authority and also the Secretary-General of the United Nations of the steps it is taking and of their progress. If assistance by the launching authority would help to effect a prompt rescue or would contribute substantially to the effectiveness of search and rescue operations, the launching authority shall cooperate with the Contracting Party with a view to the effective conduct of search and rescue operations. Such operations shall be subject to the direction and control of the Contracting Party, which shall act in close and continuing consultation with the launching authority.’ (UNOOSA 1967b).

This would be the same for space debris falling from the sky through a collision in orbit. It would require space crisis management of public authorities as it established was earlier established.

However, the responsibilities for providing emergency services to crew and passengers in space are not clear. The space outside Earth's atmosphere is not owned by any government or organisation, as stated in the Outer Space Treaty (United Nations Office for Outer Space Affairs). The existence of this power vacuum makes it hard to determine who is responsible for managing a crisis in space involving assets that are owned fully or partially by commercial entities. Boin (2009) elaborates on this:

> 'The combination of geographical and functional "spread" can easily create a power vacuum as it is not clear who "owns" the crisis and who must deal with it. This authority vacuum allows familiar tensions to play up and feed off each other: nation states versus international organizations; central authorities versus local first responders; public organizations versus private interests; state concerns versus citizen fears' (Boin 2009: 368-369).

The Outer Space Treaty does however state that the country from where the spacecraft has been launched is responsible for the spacecraft (Interview aviation consultant December 2017). This however was determined in the time that space activities were solely a national non-private endeavour. The treaty states that 'the activities of non-governmental entities in outer space, including the moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty' (UNOOSA 1967a). It is not clear if 'non-governmental' extents to commercial entities and who the 'appropriate State Party' is. Further it only states that the 'State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air or in outer space' (UNOOSA 1967a). Precedents on the responsibility for the rescue of astronauts in outer space have already been made, but the document is not very clear:

> 'If information is received or it is discovered that the personnel of a spacecraft have alighted on the high seas or in any other place not under the jurisdiction of any State, those Contracting Parties which are in a position to do so shall, if necessary, extend assistance in search and rescue operations for such personnel to assure their speedy rescue. They shall inform the launching authority and the Secretary-General of the United Nations of the steps they are taking and of their progress' (UNOOSA 1967b).

This part can be interpreted as that any country should provide assistance to the emergency response from Earth. However by using the line ‘those contracting parties *which are in a position to do so*’, it begs the question, when is a country in a position to perform such an operation? Experts argue that at the moment there is hardly any capacity to quickly rescue stranded astronauts or passengers in space (Interviews safety expert, aviation consultant and spaceflight CM expert).

The Treaty is clearly written in a time without purely commercial spaceflight, as it does not clearly name commercial entities as actors who is responsible for rescuing persons experiencing an emergency while flying with a commercial spacecraft. The language in the Treaty can be interpreted as such that the launching country is responsible, but this is not clear-cut. It is already stated that the Outer Space Treaty and the Rescue Agreement are out-dated and suggested that they quickly need to be revised in order to be applicable to the current situation where private actors increasingly become more relevant (Interview EU policy expert November 2017).

For emergency operations for commercial spacecraft on Earth, the distribution of responsibilities between public and private would not differ much than what already is being done in public spaceflight and other high-risk industries (Interviews safety expert, both CM experts). If the accident takes place on privately owned grounds, like during the launch from a commercial launch site, the first response would be done by emergency personnel of the private actor, with assistance from public entities if necessary. If it takes place in the sky or in space and debris falls outside the private owned ground, it would obviously be the other way around. Responsibilities for emergency operations to outer space, as we already have seen, are less clear.

Experts would expect that rescuing the crew and passengers of a commercial spacecraft in outer space would mainly be the responsibility of a public entity (Interviews safety expert en spaceflight CM expert). It is however quite possible this would be a joint public-private effort as no country has real rescue capabilities, as such a country should have a spacecraft standing by that could come in action within hours in a case of an emergency and at the moment there is no country that has this (Interview spaceflight CM expert January 2018). You could make it mandatory for the private actors to have an own spacecraft standing by for rescue operations, but this would be difficult. Another argument for joint public-private rescue operations is the fact that each commercially designed spacecraft would have its own unique design, which specification would be only known to the operator (Interview spaceflight CM expert January 2018). Public entities would need to work together in their rescue operations with the private actor in order to safely enter and rescue persons out of the spacecraft. Moreover, it would also mean that you would require private actors to build in ways to rescue persons out of the spacecraft, like an emergency hatch (Interview spaceflight CM expert January 2018).

It seems that there are incentives to require private actors to have some emergency response capabilities, also for emergencies in space. The fact that at the moment it is not entirely clear who is responsible for rescue operations for stranded astronauts in space gives an incentive to create regulations that contain requirements for training of flight crew and ground crew in emergency response. Furthermore, experts believe that requirements for on-board emergency equipment and emergency training for passengers should be included in regulations (Interviews both safety experts). Because emergency response after an accident by third parties is not always sure, it better prevent such a situation in the first place. Therefore adequate emergency response capabilities on-board and on the ground for a commercial spaceflight organisation could be made mandatory.

ECSS standards

The ECSS standards give some requirements for emergency and contingency planning. It can be seen that contracted operators according to the ECSS standards should have some form of preparation for dangerous situations in the form of planning the processes needed to contain it. As is stated in the section on 'special procedures': 'When it is not possible to reduce the magnitude of a hazard through the design, the use of safety devices or the use of warning devices, special procedures shall be developed to control the hazardous conditions for the enhancement of safety' (ECSS-Q-ST-40C Rev.1 2017: 32). These special procedures can include emergency and contingency procedures. Besides, the document does not give exact instructions for what these responsibilities, rules and procedures for hazardous situations should entail.

The ECSS standards also have a separate document for safety assurance for spaceflight test centers, which actually describe the requirement of accident, incident and emergency procedures. This is the most extensive description of emergency response planning requirements that can be found in the ECSS documentation. While this can applied to private test centers, it does not cover emergency response plans for the operations of the space vehicle when it is in actual service or for spaceports.

UK legislation in development

The Bill does elaborate on some mandatory aspects of emergency response. One of mandatory actions for reducing the risk of spaceflight in order for an operator to obtain a license is to have a suitable emergency response plan in place (Department for Transport & UK Space Agency 2017: 30). The policy scooping notes do not try to clarify further what these emergency response plans should entail.

The document elaborates on what an emergency response plan should contain, namely it should set out how an emergency situation or incident involving a spacecraft that takes place at the site or nearby would be managed effectively in order to minimize the effects it may have on life, property and spaceport operations (Department for Transport & UK Space Agency 2017: 35). It seems that UK legislation is going to make emergency plans mandatory and gives a short description of what it should entail. It has to be seen if this would not include a tick-in-the-box culture, and review of emergency plans will be done performance based.

A separate clause that accounts for the development of training requirements for spaceflight crew and participants can be found in the legislation that is currently being developed in the United Kingdom. Specifically these training requirements apply to individuals 'taking part in, or otherwise engaged in connection with, spaceflight activities or the provision of range control services; or working at sites used for, or in connection with, spaceflight activities or the provision of range control services' (Department for Transport & UK Space Agency 2017: 45). This definition gives commercial spaceflight operators the incentive to expand training requirements to not only the crew but also spaceflight participants.

However, the document is not conclusive yet on what specific training the crew of the spacecraft should get. On the flight crew it mainly states that they should 'come from a military fast jet or fixed wing test pilot background or can demonstrate an equivalent level of experience', have training in high 'G' environments, a complete syllabus of training for the spacecraft to be flown, must provide demonstration of competences on a regular basis over time and hold a medical certificate (Department for Transport & UK Space Agency 2017: 46). According to one expert, this is crucial as a military test pilot that has experience with high performance environments would be crucial for safe operation of the jet (Interview safety expert November 2017). For the rest of the crew, for example cabin crew, the document states that it is not clear yet what specific training they should get other that high 'G' training and medical training. For emergency situations within the spacecraft it is relevant that the flight crew is required to hold a International Civil Aviation Organisation (ICAO) Class 1 medical certificate or equivalent, which means that they require the same medical fitness as commercial airplane pilots.

Concluding, the UK legislation in development has more content that addresses emergency response training and plans than the ECSS standards. However, both the ECSS and UK legislation do not elaborate on emergency responses into space or the coordination with public authorities on the ground.

4.3.2 Regulatory status in the United States

4.3.2.1 Early Warning and Scanning

4.3.2.1.1 Internal warning and Scanning

In the FAA-AST regulations and guidelines for commercial spaceflight organisations, Safety Management Systems are not elaborated on, as the word does not appear anywhere in the documentation. The regulations do mention requiring applicants for a launch license and for a RLV license to have a safety organisation in place. For the operator of a RLV the requirement of having a safety organisation entails:

> 'An applicant shall maintain a safety organization and document it by identifying lines of communication and approval authority for all mission decisions that may affect public safety. Lines of communication within the applicant's organization, between the applicant and the launch site, and between the applicant and the reentry site, shall be employed to ensure that personnel perform RLV mission operations in accordance with plans and procedures required by this subpart. Approval authority shall be employed to ensure compliance with terms and conditions stated in an RLV mission license

and with the plans and procedures required by this subpart' (FAA-AST 2017: 566).

Also a launch or RLV operator is required to appoint a safety official, whose task it is to 'examine all aspects of the applicant's operations with respect to safety of RLV mission activities and to monitor independently compliance by vehicle safety operations personnel with the applicant's safety policies and procedures' (FAA-AST 2017: 566). His responsibilities are further 'monitoring and evaluating operational dress rehearsals' and to 'ensure the readiness of vehicle safety operations personnel to conduct a safe mission under nominal and non-nominal conditions' (FAA-AST 2017: 567).

While this seems to be a safety manager like the one prescribes by a SMS scheme but the one prescribed by the FAA-AST has less required tasks. For example, the FAA-AST does not require a safety manager to manage the safety management training. Further there are guidelines for safety management in the form a advisory circular on 'Reusable Launch and Reentry Vehicle System Safety Process' that provide guidance on 'applying a systematic and logical system safety process for identification, analysis, and control of public safety hazards and risks associated with the operation of reusable launch vehicle (RLV) and reentry vehicle (RV) system' (FAA-AST 2005: 1). This could be seen as the FAA-AST version of guidance on creating a SMS for commercial spaceflight organizations. There are some requirements that would guide commercial spaceflight organizations to safer operations. Most notably the anomaly reporting requirement, which obliges the operator to document, analyze and report anomalies to the FAA-AST (FAA-AST 2007a: 14). This is further elaborated on in a separate guideline on anomaly reporting. An overview of the identified requirements in FAA-AST regulations and guidelines for a safety culture as prescribed by a standard SMS are shown in Table 4.4:

SMS requirements status in FAA-AST regulations and guidelines		
Safety Policies and Objectives	I	Insufficient. Certain aspects are insufficient or absent.
Senior management commitment and responsibility	✕	Absent.
Safety policy	I	Insufficient. No determination of safety as a responsibility for all staff. Responsibility lies entirely with the safety official.

Safety accountabilities	I	Insufficient. Poorly defined requirements for lines of safety accountability throughout the organisation.
Appointment of key safety personnel	I	Insufficient. The appointment of only a safety official is required. Roles and responsibilities of safety official are not extensive enough.
SMS documentation.	I	Insufficient. Only
Safety Risk Management	I	Insufficient. Focuses on risks for the public and therefore on risks of debris falling back to earth.
Safety Promotion	I	Insufficient.
Safety Training and Education	I	Insufficient. Safety training focuses on training for personnel to understand and practice operations that protect public safety. No training for specific layers of the organisation or key personnel are mentioned.
Safety Communication	I	Insufficient. Regulations and guidelines only mention the establishment of 'lines of communication' between certain critical parts of the organisation for mission decisions that affect public safety. No communication of adequate safety culture is mentioned.
Safety Assurance	I	Insufficient.
Safety performance monitoring and measurement	I	Insufficient.
Continuous improvement of the SMS	X	Absent. No requirements or guidelines for continuous improvement of the system safety program of the FAA-AST is mentioned.
Safety Issue Management	I	Insufficient. Safety Issue Management do not match SMS standards.

Table 4.4: Overview of Safety Management System requirements present in the FAA-AST regulations and guidelines (by author)

Most of the requirements for a proper SMS are missing in the guidelines. For example, the system safety process seems to focus on operators, not making a clear distinction between designers and operators of spacecraft vehicles (Quinn 2013: 88). Moreover, only describing the lines of communication for approval authority on safety does not guarantee that personnel will use these lines of communication in the way that is intended or use it at all. This requirement is not based on performance; something that experts would say is missing in most of the FAA regulations for commercial spacecraft. (Interviews both safety experts, aviation consultant and spaceflight CM expert).

From talks with XCOR it can however be concluded that the FAA-AST is quite involved in monitoring the safety organization (Interview XCOR November 2017). The interviewed employee of XCOR was quite confident about a safety culture being stimulated and monitored by the FAA. He mentioned that a safety board was established to review the safety in the entire project before they commenced testing of their space plane. He stated that this is not mandatory but a custom that stems from standards in military flight testing; 'Only after a safety board the approval for testing is given. It is an unwritten rule that every flight test program should organize a safety board with independent experts who have a lot of knowledge of safety and systems but who do not have a direct connection to the company' (Interview XCOR November 2017). However, he would affirm that the FAA is mainly concerned with safety for the public as a third-party. The FAA is fine with a commercial company testing a new spacecraft as long they are aware of the risks for their own employees and risks to the public are brought to a minimum.

Despite the confidence of the XCOR employee in the safety culture in his company, and XCOR seemingly concerning itself with safety, it is the opinion of several experts that it is not guaranteed that private actors would implement an adequate safety culture without proper performance-based regulations for safety. It is argued that the FAA-AST does not talk about safety culture and just requires commercial spaceflight organisations to have a safety official without proper explaining what this person would do (Interview safety expert November 2017). This does not mean that the industry does not care about safety but standards can be improved, as it has been argued that this would be in the interest of private actors themselves. Experts would argue that current FAA-AST regulations leave too much to the commercial spaceflight organisations themselves while implementing a safety organisation and do not give clear and extensive enough requirements. As Quinn (2013) argues:

> 'The FAA are leading the way and do not want to stifle the new ventures by imposing too strict a criteria. However, the author considers the FAA is being too liberal in its use of the 'flexible' approach.' (Quinn 2013: 110).

While from interviews with XCOR it can be concluded that FAA has been stricter in monitoring the safety culture within American commercial spaceflight organisations since the crash of Virgin Galactic's SpaceShipTwo in 2014, an European regulatory framework should provide more strict requirements for a safety culture. In order for commercial human spaceflight to be safe, it should have a very solid safety organisation (interview safety expert November 2017). Therefore it would not be desirable to derive safety culture requirements for commercial spaceflight from FAA-AST regulations.

4.3.2.1.2 External early warning and scanning: Space Situational Awareness and Space Traffic management.

The FAA-AST regulations contain some parts that elaborate on managing the flight path of the commercial spacecraft as part of traffic management. For a license to operate a launch site the regulations state that:

> 'Except as provided by paragraph (c) of this section, an applicant shall complete an agreement with the FAA Air Traffic Control (ATC) office having jurisdiction over the airspace through which launches will take place, to establish procedures for the issuance of a Notice to Airmen prior to a launch and for closing of air routes during the launch window and other such measures as the FAA ATC office deems necessary to protect public health and safety.' (FAA-AST 2017: 498).

Here the FAA Air Traffic Control (ATC) seems to act as the authority that manages spacecraft traffic and prevents collisions with aircrafts or other spacecrafts. For an RLV operator, the document states that a written agreement between the operator and the responsible Air Control authority must be established. (FAA-AST 2017: 601). This includes requirements for the operator to be in contact with ATC during all phases of flight, communicating all aspects affecting the safety of the flight (FAA-AST 2017: 602).

The regulations further prescribe requirements for collision avoidance analyses for all operating license applicants. For each launch a collision avoidance analysis must be obtained from United Strategic Command and should in general contain the following:

> 'A flight safety analysis must include a collision avoidance analysis that establishes each launch wait in a planned launch window during which a launch operator must not initiate flight, in order to protect any manned or mannable orbiting object. A launch operator must account for uncertainties associated with launch vehicle performance and timing and ensure that any calculated launch waits incorporate all additional time periods associated with such uncertainties. A launch operator must implement any launch waits as flight commit criteria according to §417.113(b).' (FAA-AST 2017: 150).

The regulations do not make a distinction between a orbital and suborbital flight, for both it is required to establish launch waits to ensure that the spacecraft, any jettisoned compartments or payload does not come within '200 km with other manned or mannable objects' (FAA-AST 2017: 150-151). However, a collision avoidance is not needed when the spacecraft does not fly above the lowest known orbiting object. Section A417.31 of Appendix A of the FAA-AST regulations elaborates extensively on the implementation of collision avoidance analyses for launch operators. This includes describing the screening of potential collisions with objects within 200 km during flight. A launch operator is obliged to describe all the manoeuvres that the spacecraft is going to take and describe its position in proportion to other orbiting objects at that time (FAA-AST 2017: 221-222). This seems as a quite extensive preparation for potential collisions with other object during suborbital or orbital flight. However, this includes only describing the expected chance of collision with other object and not the actual management of a potential collision, something expert respondents would see as crucial (Interviews safety expert and spaceflight CM expert).

In absence of clearly established international STM rules and combined global SSA capabilities, the FAA-AST regulations try to do a valid attempt in establishing requirements for private actors to plan collision avoidance, keep in contact with SSA providers, while establishing the FAA as the manager of space traffic. However they do not make a difference in managing the traffic of suborbital and orbital, as this would be different. For now, the FAA regulations seem to the best reference for the avoidance of collision for commercial spaceflight in the absence of international STM rules.

4.3.2.2 Issue and Risk Management

According to experts, there are several major problems with the safety requirements within the FAA-AST regulations for commercial spaceflight. Firstly there are no specific airworthiness or spaceworthiness requirements for commercial spacecraft present within the regulations (Interviews both safety experts and aviation consultant). This is a mayor concern for safety experts. A discussion that relates to this is if a European regulatory framework should use the 'licensing' approach that the FAA-AST uses in its regulations. Several experts would feel that this approach would not be the best way, as it is not based on high-level performance requirements (Interviews both safety experts and aviation consultant). Others would feel that it would a good way forward to ease the regulatory pressure (Interviews XCOR and EU policy expert). Secondly, FAA-AST regulation is build to minimize the risks and damage to 3rd parties, i.e. the public. The regulations do not require managing or minimizing the risks for 1st and 2nd parties, i.e. the crew or passengers. Crew and passengers are required to sign waivers in which they state that they acknowledge the risks of experimental spaceflight and waive all their rights to sue the government in the event of an accident (FAA-AST 2017: 629). Several experts do not find this system acceptable for the long-term and would expect that this waiver system will not be use in Europe because it conflicts with the European value of solidarity (Interviews both safety experts). Others see it as a good way to contribute to the prevention of too much regulatory pressure for a European commercial spaceflight market (Interviews EU policy expert, XCOR and spaceflight CM expert).

The waiver-system could be useful when the market is still small and not accessible for a major part of the general public. If the US waiver system is going to be used, proper risk assessment for all involving parties should be done in advance. As one interviewed safety expert argues;

> 'I think the regulator at least have a duty of care for trying to understand what level of risk is involved so you can inform people that sign those informed consent waivers. Without knowing what level of risk is involved how can they make a informed decision?' (Interview safety expert November 2017)..

Experts argue that the FAA-AST regulations do not contain suitable risk management requirements (Interviews both safety experts and aviation consultant). When examining the FAA regulations on risk management requirements, this can be confirmed. The FAA-

AST regulations and guidelines do try to establish standards for safety risk management. Here there is a strong emphasis on risks for the public, even naming safety risk management 'public risk management' and stating that operators should 'control the risk to the public from hazards associated with normal and malfunctioning launch vehicle flight' (FAA-AST 2017: 141). The regulations mention the requirement of a risk assessment that must demonstrate the risk to the public and;

> The analysis must account for the variability associated with:
> (i) Each source of a hazard during flight;
> (ii) Normal flight and each failure response mode of the launch vehicle;
> (iii) Each external and launch vehicle flight environment;
> (iv) Populations potentially exposed to the flight; and
> (v) The performance of any flight safety system, including time delays associated with the system (FAA-AST 2017: 141).

The guidelines on safety system processes describe the way the FAA would envision that commercial spaceflight operators should reduce the risk to the public to a minimum. They try to couple system safety, safe operations and an expected casualty rate to determine the risks to the public and keep them to a minimum.

The document further elaborates on system safety engineering and includes hazard analysis and risk assessment processes, including Fault Three Analyses and FMEA and FMECA. However, the document does not provide an adequate risk management process that includes managing risks that stem from organizational failures. A risk management process as seen in the ECSS standards cannot be found in the guidelines. Also, the hazard analysis guidelines give a form of hazard analysis that is simplistic.

Safety Risk Management requirements status in FAA-AST regulations		
Definition of Risk	S	Sufficient: a measure that accounts for both the probability of occurrence of a hazardous event and the consequence of that event to persons or property.
Risk Analysis	I	Insufficient. No HFI is being done, focus on analysis of risks of system failure.
Risk analysis tools	✔	Good. Failure Tree Analysis (FTA), Failure Mode and Effects Analysis (FMEA) and Failure Mode, Effects, and Criticality

		Analysis (FMECA) included.
Human Factors Integration	✗	Absent. Human error as a risk only briefly mentioned in the regulations and guidelines.
Risk Identification	I	Insufficient. Only risks concerning the public are identified.
Organizational Risks	✗	Absent. Organisational risks not considered.
Hazard Management	✔	Good. Well-described identification, analysis and management of potential hazards requirements.
Hazard identification and analysis		Good.
Hazard analysis tools	✔	PHL, PHA, ETA, FTA, Mishap Data, Industry Guidelines
Risk Assessment	S	Sufficient.
Risk Mitigation	S	Sufficient.
Risk Acceptance	I	Insufficient. Required risk Acceptance procedures not described.
Risk Communication	✗	Absent.

Table 4.5: Overview of Safety Risk Management Requirements present in the FAA-AST regulations (by author)

The FAA-AST regulations and guidelines do not explicitly mention safety issue management, but elaborate on 'anomaly reporting', which could be interpreted as a form of safety issue management. There is a whole separate guideline on anomaly reporting, a process that according to the guideline can unearth clues that exist before a mishap happens. The analysis of anomalies can:

- help warn of impending mishaps;
- provide risk data, including potential consequences and the likelihood of the hazard and the condition that need to be controlled to mitigate public risk
- help identify risk mitigation approaches
- assist in the validation and verification of risk mitigation measures and;
- assist in establishing new structured processes and improving existing processes (FAA-AST 2007a: 3).

The FAA guideline on anomaly reporting foresees the following anomaly reporting process:

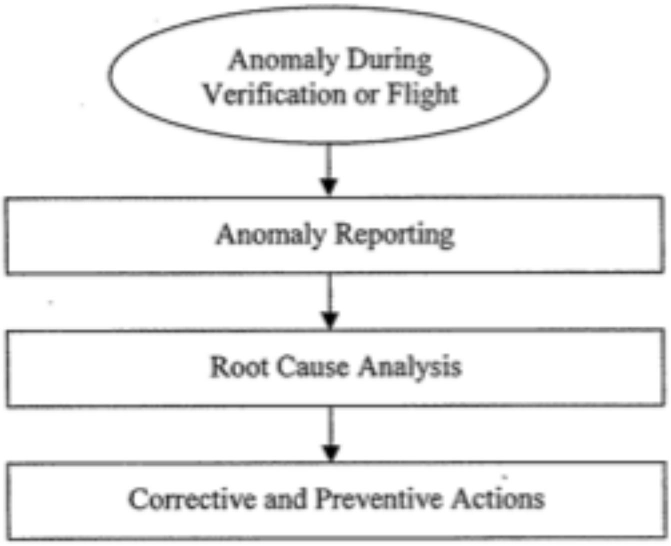

Figure 4.9: Anomaly reporting and corrective action process (FAA-AST 2007: 4)

The part describing the root cause analysis is quite extensive and includes the possibility of human errors and organisational factors causing the anomaly, implicating an organisational wide approach to anomaly reporting. The document also describes several tools that can assist in root cause analysis like FTA and FMEA (FAA-AST 2007a: 6). Furthermore, regulations state that a RLV operator should report any anomaly and the corrective actions for that anomaly to the FAA, indicating that anomaly reporting is seen as important by the FAA (FAA-AST 2017a: 602). The part on corrective and preventive actions is however quite thin, as it only describes in a simplistic way that proposed corrective and preventive actions should be validated, implemented and verified (FAA-AST 2007a: 6). No description of roles and responsibilities are given and to what extent management should be involved in this process. In overall, the anomaly reporting that the FAA prescribes contains some elements of proper safety issue management but lacks issue prioritization, describing the involvement of management, communication of issues. The management of anomalies is poorly described.

Safety Issue Management requirements status in FAA-AST regulations		
Definition of a Issue	S	Sufficient. While the word issue is not used, an anomaly is defined as: 'A problem that occurs during verification or operation of a system, subsystem, process, facility, or support

		equipment.'
Determined by an organization-wide input	✗	Absent.
Issue identification	✔	Good. Well-described issue identification process plus tools to analyze issues
On operational, tactical and strategic level.	✗	Absent. Distinction between issue identification and management by the different organizational layers is not present.
Issue prioritization	✗	Absent. No prioritization of issues is mentioned
On severity and potential to cause a crisis.	✗	Absent.
Issue management	I	Insufficient. Anomaly corrective actions are described but does not state by whom or were the responsibilities are in this process.
Mitigation	I	Insufficient. Mitigation process is not well-described.
Counter-Measures	I	Counter-measures are mentioned but not it is not described which counter-measures should be taken and when
Issue communication and logging	I	Insufficient. Logging of anomalies and reporting them to the FAA is mentioned. But no internal communication of known issues is described.
Free flow of information on known issues, Maintain database on known issues, either solved or unsolved, Log actions taken on issues	S	Sufficient to the extent that anomalies and actions taken are logged in a database. Flow of information on known issues internally is not described.

Table 4.6: Overview of Safety Issue Management requirements present in the FAA-AST regulations (By author).

Concluding, it can be argued that risk and issue management are not properly addressed in the FAA regulations. Even when disregarding the fact that the regulations do not contain requirements for risk management for 1st and 2nd parties, risk management guidelines do not contain guidance for preventing human error or organisational failures. Also, the guidelines for issue management are underdeveloped.

4.3.2.3 Emergency Response

The FAA-AST regulations and guidelines describe on several occasions requirements for emergency response. As already have seen, there are some requirements for emergency plans and exercising emergency situations, which do not consist of performance-based requirements. As part of a ground safety plan this entails: 'generic emergency procedures that apply to all emergencies and the emergency procedures that apply to each specific task that may create a public hazard, including any task that involves hazardous material' (FAA-AST 2017: 122). Here the inclination of the US government to only occupying itself with protecting the safety of the public as a third party comes again to the forth. For launch emergencies the document further describes requirements to plan coordination with local authorities (FAA-AST 2017: 125-126). An operator of a RLV has to file two separate crisis plans: a Mishap Investigation Plan (MIP) and an Emergency Response Plan (ERP). It has already been argued that the requirements for an MIP and ERP are not very elaborate. Furthermore, the requirements of the ERP are again built on the perspective that mainly the safety of the public as a third party should be guaranteed. While it is important to minimizing risk to the public, there are no requirements for a response that involve taking care of the flight crew or participants.

Recommended Practice	Section
Emergency Survival Equipment and Supplies	1.1.6
Emergency Response to Contaminated Atmosphere	1.2.9
Emergency Response to Loss of Cabin Pressure Integrity	1.2.10
Emergency Response – Abort and Escape	1.2.11
Emergency Occupant Location Post-Landing	1.3.13
Emergency Communication with Rescue Personnel	1.3.14
Emergency Control Markings	1.4.14
Emergency Equipment Access	1.4.15
Emergency Lighting	1.4.16
Emergency Vehicle Egress	1.4.17
Occupant Survivability Analysis	1.5.4
Emergency Operations Management	3.3.20
Emergency Survival Equipment Training	3.5.8

Figure 4.10: overview of recommended emergency practices (FAA-AST 2014: 3)

More qualifications of in-flight emergency plans are provided in the recommended practices for Human Spaceflight Occupant Safety of the FAA. An overview of these practices can be seen in figure 4.10. The sections on emergency response shown in figure 4.10 recommend the necessary equipment that should be on board to response to the mentioned emergency situations and give a rationale why these are necessary. A more general description of the management of emergency situations is found in section 3.3.20:

> 'An operator should develop and execute a plan to manage system emergencies, including: Launch escape, if applicable; Occupant rescue and recovery; Contacting, and providing necessary vehicle information to, emergency responders to aid in preserving life and treating the injured; and preservation of data and physical evidence for use in any anomaly or accident investigation' (FAA-AST 2014: 43).

While this gives recommendations for operators to implement emergency plans that provide occupants of their spacecraft more chance of survival, it does not give a description of the necessary specific roles and responsibilities for the response on the ground. Recommendations for establishing authority for safety-critical systems during launch, flight and post-flight are given and also recommendations for establishing final decisions authority on the spacecraft are elaborated on (FAA-AST 2014: 36). However this does not qualify as an extensive description of roles and responsibilities for emergencies.

The guidelines elaborate on specific training requirements for spaceflight crew and participants. The crew with a safety-critical should have a FAA second class airman medical certificate issued. This is in contrast with UK legislation, which require a class 1 medical certificate requirement. Experts argue that this is another major shortcoming of FAA regulations, as the high-stress environments of suborbital or orbital flight should require for a class 1 pilot medical certificate (Interview safety expert November 2017). The training requirements for spaceflight participants are shortly summarized in the following; 'an operator must train each space flight participant before flight on how to respond to emergency situations, including smoke, fire, loss of cabin pressure, and emergency exit' (FAA-AST 2017: 651).

The recommended practices for human spaceflight do describe some basic necessities for adequate emergency response, like emergency equipment and training for crew and passengers. However these requirements are not mandatory and not very extensive. For example it only describes emergency equipment for after the vehicle crashes and some poorly described response to certain emergency scenario's. Expert respondents confirm the lack of clarity and completeness of the document. For example, there are no requirements for providing flight crew and participants with a parachute, oxygen or the vehicle itself with a parachute (Interview safety expert November 2017). The document itself even states that it lacks extensive recommendation, stating that

> 'NASA commercial crew requirements are much more exhaustive, and address mission assurance and other mission needs in addition to occupant safety. NASA also addresses verification and incorporates a number of government and industry standards that AST has yet to address.' (FAA-AST 2014: 7).

The document states that it tries to do recommendations on a performance based approach, stating a safety objective to be achieved, and leaving the design or operational solution to the designer or operator (FAA-AST 2014: 5). However the recommendations made in the document are not clear and extensive enough to guide commercial spaceflight organisation to an adequate safety objective.

In practice, FAA inspectors join flight crew during training in flight simulators, in which the flight crew have to demonstrate that they know and can reproduce the necessary emergency and contingency for certain scenarios in which components of the spacecraft fail (Interview XCOR November 2017). Where before the crash of Virgin Galactic in 2014 private spaceflight companies only had meet with a checklist of the FAA on safety, FAA inspectors now are an integral part of the development of experimental commercial space crafts. XCOR already had developed some contingency plans for different scenario's, including emergency situations outside the atmosphere and had started to train flight crew in these procedures (Interview XCOR November 2017).

A useful training in the guidelines is crew resource management (CRM) training. This entails training for flight crew and ground controllers that include 'clear definitions of roles and responsibilities, use of a defined communications protocol, and crew resource management techniques' (FAA-AST 2014: 48). CRM techniques could be a crucial part of training for emergency situations within spacecraft, as CRM techniques would ensure the proper operationalization of prior defined roles and responsibilities of flight crew during crisis situations. As the guidelines of FAA-AST state:

> 'Lack of clarity concerning roles and responsibilities of flight crew and ground controllers, as well as poor communication among the flight crew and ground controllers, can lead to unsafe operations. This is especially true during dynamic, complex, or high stress situations. Crew resource management training helps the flight crew and ground controllers make good informed decisions using all available resources' (FAA-AST 2014: 48).

CRM is a form of training that pilots of commercial airplanes have been given for years. Thus here the FAA-AST has taken relevant experience from the commercial aviation sector and implemented it into their commercial spaceflight regulations. Experts confirm that CRM could be a minimum requirement for spaceflight crew as a necessary tool to create good relationships between the crewmembers and make them effective in what they are ought to do (Interviews safety expert, aviation consultant and spaceflight CM expert). This would be relevant in spacecraft with a bigger crew, many current designs only provide for one or two crew members. However, it is emphasized that the CRM used in aviation should be adapted to spaceflight, as CRM is not applicable in the same way in spaceflight emergencies as in aviation (Interview safety expert December 2017). This because from the beginning of human spaceflight, parts of a spaceflight mission (mainly the launch) are automated and many parts are managed by the mission control centre on Earth. However, CRM would also become relevant for emergency situations when the spacecraft goes further from Earth. The farther the spacecraft goes from Earth, the more the flight crew are ought to operate autonomously because of the delay in communication with the mission control centre on Earth. As one interviewed safety expert argues:

> 'The day when you will go to Mars because of delay in the communication with the ground center there would be more autonomous operations. So over there the organization of communication such that the words are not misinterpreted and addressed is fundamental' (Interview safety expert December 2017).

4.3.3 Subconclusion on Crisis Prevention for Europe

Currently, in Europe crisis prevention for commercial spaceflight is nearly non-existent. Safety regulations have to be developed and the EU has to develop its crisis prevention capabilities. Crisis prevention in commercial spaceflight will be a public-private effort, with a big role for the private actors themselves in adequately implementing a safety culture within their organisations. It is up to public authorities to create regulations that will guarantee the implementation of a safety culture among private actors. It has been argued that the amount of regulatory pressure for private actors in the early stages of the development of the European commercial spaceflight market should be balanced between guarantying safe flights and an innovative and competitive market. It would be desirable to develop regulations based on the size and accessibility of the market. Stricter regulations would then be implemented in phases.

Most experts argued that there should be a basic level of safety that can be guaranteed from the start. Regulators should provide for some basic level of airworthiness and spaceworthiness requirements while stricter standards will be developed in cooperation with the European private industry. It was the opinion of most interviewed experts that it should not take the FAA-AST regulations as an example for safety requirements. FAA-AST regulations do not contain any airworthiness and spaceworthiness requirements, while safety culture, risk management and issue management qualifications and guidelines are ill described. Also, requirements for safety for human occupants could be more clear and elaborate. The lack of current emergency capabilities in outer space would give incentive for proper emergency training of commercial crew and passengers. This is something that the FAA regulations lack. Experts argue that the for safety and emergency training in the human space flight occupant safety requirements are not enough to guarantee the safety of the occupant. Furthermore, these are just guidelines so private actors are not obliged to follow them.

It would be desirable to implement Safety Management Systems as used in commercial aviation. The ECSS standards do not contain provisions for a fully SMS implementation. However the ECSS standards contains good guidelines for safety risk management and some basic issue management that could be considered while implementing SMSs. However, the ECSS standards have their limitations. For example, human factors are not integrated enough within safety risk assessment and issue management is focussed on human errors in the design phase. Furthermore, managing human error and organizational failure should be integrated better into these standards.

All experts would agree that the inclination of the FAA-AST to focus on public safety while regulating commercial spaceflight would be a bad starting point for European regulation. European regulations for commercial spaceflight should provide clear requirements for all participants in commercial spaceflight. It would be important to implement risk management that also adequately determines the risk for 1st and 2nd parties and desirable to use the ALARP principle that is being implemented in the UK when doing risk management. EASA has been named as the most suitable agency to act as the regulating party for commercial spaceflight in Europe.

Public actors should work towards establishing a worldwide SSA capability and global STM rules. From interview with experts it can be concluded that establishing a sound STM and SSA for Europe can only be done in an international context. The current biggest problem for STM is that there are no established international rules for this. At the moment, the global SSA is in the hands of the US, of which United States Strategic Command keeps track of all orbiting objects and informs any spacecraft of the possibility of collision. It would be desirable to integrate STM with air traffic management, while making a distinction between managing suborbital and orbital flights. It is argued that an international body should be created that establishes and monitors global STM rules. In absence of currently established STM rules, the FAA-AST regulations try to establish collision avoidance requirements, which could be taken as an example for a European regulatory framework. SSA further could be a more public-private cooperation, as private actors have the best data on the position and heading of their own satellites.

Emergency response to accidents with commercial spaceflight would also be a public-private effort. The emergency response for accidents on Earth or a with direct impact on Earth's surface can be done in the same manner as responding to any major emergency on Earth. The public authorities of the countries that have been impacted will be in the lead, while other public actors and private actors will give support if necessary. However, roles and responsibilities for emergency operations in outer space are not clear. Existing space treaties do not provide clarity and it is suggested that these should be updated in order to be applicable to the current situation. Public-private cooperation in emergency response will foremost be necessary in the early stages of the development of the global commercial space market because of the lack of emergency response capabilities to space of the public actors and the unique design that every commercial spacecraft in this stage will have.

4.4 Crisis Event Management for commercial spaceflight in Europe

The chapter on crisis event management will not be divided in a European part and an American part because both the regulations and guidelines for commercial spaceflight in Europe and the United States do not contain any crisis event management requirements or guidelines. Because of the lack of requirements and guidelines in commercial spaceflight regulations and standards, commercial aviation regulations will be examined on crisis event management requirements and guidelines. Crisis event management is something that should be done by both public and private actors, of which the distribution of tasks already is determined within the process of crisis preparedness.

4.4.1 Public institutions and regulations for private actors

4.4.1.1 Crisis Recognition and System Activation/Response

Both in Europe and the United States there are no requirements or guidelines on crisis recognition and response for spaceflight organisations in existence. The ECSS standards and UK legislation do not mention specific requirements or guidelines on the recognition and activation of the crisis organisation. Also the FAA-AST regulations do not mention anything like this. The FAA-AST only mentions notifying the FAA in the case of a mishap and does not elaborate on steps to be taken by management of the commercial spaceflight. Crisis event management is something that every organization with a crisis organization should do properly, but in practice it can be done in different ways (Interview CM expert January 2018). It has already been argued that it would be desirable for private actors in commercial spaceflight to have a certain level of crisis preparedness. Furthermore experts would agree that while creating a crisis organisation, roles and responsibilities should be clear for both the operational, tactical and strategic level of the organization. Part of this would be determining how and when to activate the crisis organisation and to what extent.

Experts agree that it is important to determine in advance how and when to activate the crisis organisation (Interviews both CM experts). Furthermore, it would be important to coordinate this activation with external parties, thus between public and private actors (Interview CM expert January 2018). In order to improve cooperation between public and private actors, you could create some high-level requirements for the activation of the crisis organization. In order to activate the crisis organisation in a proper manner, an organization should determine which event is seen as a crisis in which is not (Interview CM expert January 2018).

It would then be important for each private actor to determine its own definition of a 'crisis'. Because the definition of a crisis is very subjective and depends on the size and experience of an organisation with crisis situations, this definition is different for every organisation. The definition of crisis, or 'mishap' in the FAA-AST regulations are not that clear. When turning to §401.5 of the document, which is a section of the definitions used within the document, it can be examined that;

- The definition of an *incident* is the 'unplanned event during the flight of a launch (or reentry) vehicle, other than a launch (or reentry) accident, involving a malfunction of a flight safety system or safety-critical system, or a failure of the licensee's or permittee's safety organization, design, or operations' (FAA-AST 2017: 6-8).

- The definition of an *accident* is the 'An event that causes a fatality or serious injury (as defined in 49 CFR 830.2) to any person who is not associated with the flight; An event that causes damage estimated to exceed $25,000 to property not associated with the flight that is not located at the launch site or designated recovery area …. For a launch that takes place with a person on board, a fatality or serious injury to a space flight participant or crew member' (FAA-AST 2017: 6-8).

- The definition of a mishap is ' a launch or reentry accident, launch or reentry incident, launch site accident, failure to complete a launch or reentry as planned, or an unplanned event or series of events resulting in a fatality or serious injury (as defined in 49 CFR 830.2), or resulting in greater than $25,000 worth of damage to a payload, a launch or reentry vehicle, a launch or reentry support facility or government property located on the launch or reentry site' (FAA-AST 2017: 6-8).

While the differences in definitions between incidents, accidents and mishaps seem to give the impression that the document tries to make a distinction between an emergency and a crisis, there is no distinction in the description for the requirements of the response to an incident, accident or mishap. Moreover, the definition of an accident and mishap seem broadly the same. When examining the contingency plans of the NASA it becomes clear that the FAA-AST has derived its classification of mishaps from this organization. It has been mentioned by experts that that the NASA, just like the ESA, has its own standards for contracted private actors and that it has been proposed to transform these standards to standards for the commercial spaceflight industry in the US (Interview safety expert November 2017). The crisis management plans of NASA are called 'contingency action plans' (CAP's) and contain some clear crisis management procedures. In the CAP the procedures for activation of the plan are described with a description of who notifies who of the crisis situation, as well an extensive description of roles and responsibilities for the key positions throughout the organization (NASA Contingency Action Plan 2003: 1-9). In the NASA CAP a crisis is defined as a mishap and recognizes three levels of mishaps. The recognition and activation criteria of the CAP are summarized in Figure 4.11.

APPENDIX A

CONTINGENCY CRITERIA SUMMARY

Classes of Unexpected Events	**Damage to Property, Facilities, or Equipment**	***AND/OR*** **Injury/Death**	**Investigation/ Analysis**
Type A Mishap	Equal to or greater than $1M	Death	Administrator or AA/SMA (AA/OSF if Administrator and AA/SMA decline) appoints mishap investigation board*
Type B Mishap	Equal to or greater than $250K but less than $1M	Permanent disability of 1 or more persons, or hospitalization of 3 or more persons.	AA/OSF or Center Director appoints investigation *
Type C Mishap	Equal to or greater than $25K but less than $250K	Occupational injury or illness that results in a lost workday case.	Center Director appoints investigator or investigation team depending on significance of mishap*
Incident	Equal to or greater than $1,000 but less than $25K	Injury of less than Type C Mishap severity but more than first-aid severity.	Same as Type C mishap*
Mission Failure	A mishap of whatever intrinsic severity that prevents the achievement of primary NASA mission objectives as described in the Mission Operations Report or equivalent document.		An investigation board is required and Type A or B Mishap investigation procedures are followed*
Close Call**	No equipment/ property damage equal to or greater than $1,000.	No injury and no significant interruption of productive work	Investigated in accordance with its potential*

* If event involves more than one Center or has significant public interest, the AA/OSF, or delegated agent, may recommend that the Administrator activate the International Space Station and Space Shuttle Mishap Interagency Investigation Board .

** Event that possesses high severity potential for any of the previous types of mishaps.

Figure 4.11: Mishap classification used in the NASA CAP for Human Space Operations (NASA CAP 2003: 4)

The document further mentions the following definition of a mishap:

> 'A SFO mishap is defined here as any mishap, mission failure, incident, or high visibility close call that causes or may cause a major impact to space flight operations or prevents accomplishment of a primary mission objective involving OSF-controlled personnel, hardware, support equipment, or facilities or any personnel, hardware, software, equipment, or facilities that have been integrated with OSF-controlled flight related systems' (NASA 2003: 5).

It seems that the NASA uses a subjective definition of a mishap, talking about a mishap that has a major impact on a primary NASA mission objective. Experts argue that the NASA CAP for space operations mostly concentrates on the post-crisis part of crisis management, setting out the roles and responsibilities when putting up the investigation (Interview CM expert January 2018). From talks with experts it could be assumed that this is the overall view in the spaceflight sector of what 'contingency' plans, and thus crisis plans, for the strategic level should cover. It was the view of one expert that the strategic level of an organization only comes in play in the days and months after a crisis, and thus only in the post-crisis phase (Interview safety expert December 2017).

The contingency criteria summary in the NASA CAP would confirm this, as the classifications of mishaps only show the activation of the crisis organization in terms of setting up an investigation into the accident. From a crisis management perspective, this would not be an adequate crisis plan on itself, as it only covers a small part of the response to a crisis. Crisis management experts would argue that the NASA CAP is not a holistic crisis management plan, it is mainly a well described action plan for the post-crisis phase and thus should be seen a small part of a overall crisis plan (Interview CM expert January 2018). The classification of mishaps and non-mishap on itself is not bad, as there the distinction between an accident, an incident, an a 'close call' is being made. The distinction of a close call as something that should be investigated is something that is desirable (Interview CM expert January 2018). Furthermore, the definitions are based on the amount of impact the event has. It seems that the crisis typology used in the NASA CAP could be used as an example, but only if the activation process described would not only entail of setting up an investigation.

However, it would be important for a crisis plan to be more all-hazard and cover the response of every layer in the organization in the short term (crisis event phase) an on the long run (post-crisis phase) (Interview CM expert January 2018). It has already been suggested that crisis management as being used in commercial aviation could serve as a basis for crisis management in commercial spaceflight. Crisis planning and event management guidelines are a mandatory part of a SMS in aviation, in the form of an Emergency Reponse Plan. When examining the ICAO's guidance for establishing an ERP, it can be observed that it contains a lot of elements that a crisis management plan would have. This gives another incentive to translate SMS requirements form aviation to the commercial space sector, something that most expert respondents feel would be a good thing (Interviews both safety experts, aviation consultant, both CM experts). For example, the guidance material names clear requirements for roles and responsibilities for key personnel and the establishment of crisis teams. The document actually states that it should be seen as a crisis management plan:

> 'An emergency response plan (ERP) outlines in writing what should be done after an accident or aviation crisis and who is responsible for each action. Among different product and service providers, such emergency planning may be known by different terms such as contingency plan, crisis management plan and continuing airworthiness support plan.' (ICAO 2013a: 208).

The document is only not clear on how the criteria for activation should be established. It mentions that it should contain who is going to be notified in a case of an emergency, who makes external notifications and by what means (ICAO 2013a: 209). It further only states that a 'Emergency Management Centre, an EMC (normally on standby mode) may be established at the organization's headquarters once the activation criteria have been met'. What these activation criteria should be, it doesn't say. Furthermore does not mention criteria for describing the activation of other layers of the organization or crisis teams if that would be necessary. However, the International Air Transport Association's (IATA) introduction to Safety Management Systems guidance gives the establishment of the following crisis teams as a guidance criteria;

- A Emergency Management Center (EMC) at its headquarters
- A Local Incident Control Center (LICC) at the accident location to coordinate activities with company headquarters and the local authority EMC

- A mobile support and investigation team to assist local investigators and victim support services (IATA 2009: 43).

In practice, airlines go often further than only establishing only these three crisis teams, as can be seen in the case of Dutch airliner KLM. Obtaining these emergency response plans from airlines has proven to be quite difficult as these are often confidential. However from a presentation of KLM that can be accessed online, one can get an impression of the crisis organization the company uses. The company has developed a '3-tier command system' as the basis of its crisis organisation, with a local, tactical and strategic level. The basic crisis structure of KLM is depicted in figure 4.12

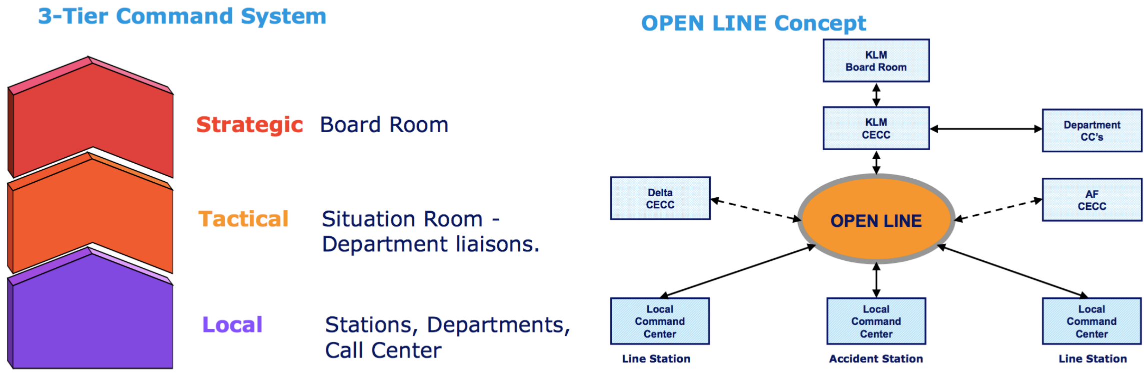

Figure 4.12: Structure of the crisis organisation of KLM (presentation by Kees van der Louw 2013)

Form an interview with an aviation consultant, who worked for KLM a couple of years, can be concluded that this crisis organization of KLM includes a certain activation protocol, that prescribed the extent of activation which depended on the severity of the crisis. It was the aviation consultant's feeling that such crisis response plans and activation procedures would be suitable for commercial spaceflight organizations (Interview aviation consultant December 2017).

It seems that the KLM crisis organization goes further than the IATA guidelines, adding a strategic level crisis team in the boardroom. It thus would be desirable to use this kind of preparation as an example for commercial spaceflight. These examples could be improved with overall crisis management standards. Experts felt that the crisis organization as proposed by this thesis in the theoretical framework chapter in overall complies with crisis management standards in practice and would be suitable for a commercial spaceflight organization (Interviews both CM experts). There were some remarks however, for example as it has been already argued; the proposed information management team in essence would be a good idea but it would maybe more desirable to leave the task of interpretation of information with each crisis team (Interview CM expert January 2018). Furthermore, in spaceflight organizations, the information management is done by the tactical level, which most of the time is the mission control center of the launching company (Interview spaceflight CM expert January 2018).

When making the crisis recognition and system activation part suitable for a commercial spaceflight crisis organization, one should consider certain aspects of crises in space that are different than crises in aviation. As in aviation, one should determine per individual crisis to what extent the crisis organization should be activated and take in consideration the impact of the crisis. One factor that would have an influence on the impact of the crisis is the location of the spacecraft emergency. The interviewed aviation consultant elaborates on this;

> 'in aviation it {determining the extent of activation} is easy, the aircraft crashes down somewhere on Earth, but if you are on the way to the Moon, you don't need such a big of a crisis organization. An good example would be the case of Apollo 13, in that case they had also some sort of a layered activation but they couldn't do much, they couldn't go there as is would be the case of an aircraft crash.' (Interview aviation consultant December 2017).

Because crisis management in commercial spaceflight is not exactly the same in as in commercial aviation and for the sake of not having too much regulatory pressure, it has been suggested that the private spaceflight industry could set it own crisis management standards, in line of high-level CM requirements set by the regulator and thus for a part self-regulate (Interview spaceflight CM expert January 2018). The same has been done in aviation, as the ICAO has set high-level CM requirements and the IATA, which an organization that represents the stakeholders in the commercial aviation industry, has developed the standards and best practices. Developing crisis preparedness and crisis event management standards in commercial spaceflight by the industry would work better than developing safety standards, as it would not involve exchanging any technical details of commercial space crafts (Interview spaceflight CM expert January 2018).

Nevertheless, it would be desirable to create some high-level crisis recognition and crisis organization activation requirements and turn to the commercial aviation industry for some crisis preparedness and crisis event management standards and best practices. These standards could be improved with standards and best practices from the general field of crisis management.

4.4.1.2 Crisis Management

Next to the lack of crisis recognition and system activation requirements or guidelines, the European and American regulations and standards for commercial spaceflight also do not contain any parts on crisis management during the response phase. Experts argue that proper crisis event management, i.e. responding to the crisis at hand, is something that can differ per organisation in practice and regulations should not strictly dictate to private actors that it should be done in a certain manner (Interviews both CM experts). There is no business sector where a certain conduct of crisis event management is imposed by regulations (Interview CM expert January 2018). Furthermore, each crisis demands a different response of an organization (Interview CM expert January 2018). However, regulations could impose some high-level requirements that for example dictate that a private spaceflight actor should have adequately worked out its crisis communication organization (Interview spaceflight CM expert January 2018). The crisis communication with the public authorities should for example be prepared and known by private actors (Interviews both CM experts).

High-level requirements for crisis event management should only cover requirements that ensure proper cooperation between public and private organisations. It should not dictate how the private actor should communicate to its customers, as this would only frustrate the crisis response. It is in the own interest of each commercial spaceflight organisation to have a good interaction with it customers, so enforcing rules for this interaction would not be necessary and desirable (Interview spaceflight CM expert January 2018). However, it would be desirable to create guidelines in how crisis managers within private organisations should react to the crisis and manage the organisation during a crisis (Interviews both CM experts). This could be done in order to give guidance to commercial spaceflight organizations in how to achieve an acceptable crisis event management standard.

Both the ECSS standards, UK legislation, FAA-AST regulations and guidelines do not elaborate on any recommended practices of crisis management during a crisis situation. The NASA CAP however, contains some checklists for stakeholder management, listing internal and external stakeholders that possibly would be needed to be reached (NASA 2003: 18-22). This is however the only part of the CAP that could be interpreted as a tool to encourage good crisis management practice. No further guidelines or recommendations on proper crisis management are mentioned in the document.

Within aviation regulations and guidelines concerning Safety Management Systems recommendations that encourage good crisis management practices can be found. The guidelines on emergency response planning of the ICAO contain high-level requirements and recommendations on the conduct of proper crisis management. To begin with, it identifies that the Emergency Response Plan should ensure 'proactive identification of all possible emergency events/scenarios and their corresponding mitigation actions, etc' (ICAO 2013a: 207). Furthermore, it encloses a list with the most important internal and external categories of stakeholders who should be contacted in the event of a crisis. It names the following stakeholders;

> 'State authorities (search and rescue, the regulatory authority, the accident investigation board, etc.); local emergency response services (aerodrome authorities, fire fighters, police, ambulance, medical agencies, etc.); relatives of victims (a sensitive issue that, in many States, is handled by the police); company personnel; media; and legal, accounting, insurers, etc.' (ICAO 2013a: 209).

Also, it gives a couple of basic questions that the crisis management team should think about when sending the initial response team to the site were the triggering event has occurred. Lastly it gives some crisis communication recommendations including; which information would be classified and should not be disclosed, the designation of a spokesperson at the head office and the accident site, the preparation of media statements, timing and content of the initial company statement and regular updates of the media.

The International Air Transport Association (IATA) gives a more extensive guideline of best practices in crisis communication for the airline industry. It elaborated extensively on proper external crisis communication timing and give a list of possible necessary ways and sources for external communication during the first days of the crisis (IATA 2016: 10-11). Furthermore the document gives comprehensive description of a proper social media strategy and using online channels like the companies website and twitter for crisis communication (IATA 2016: 17). The document further continues with a lengthy description in recommended crisis communication practices of the different parties in the airline industry like operating carriers, aircraft manufactures and airport operators. It concludes with a guide for the creation of proper crisis communication plans and an overview of a recommended crisis communication organizational structure, which is shown in figure 4.13.

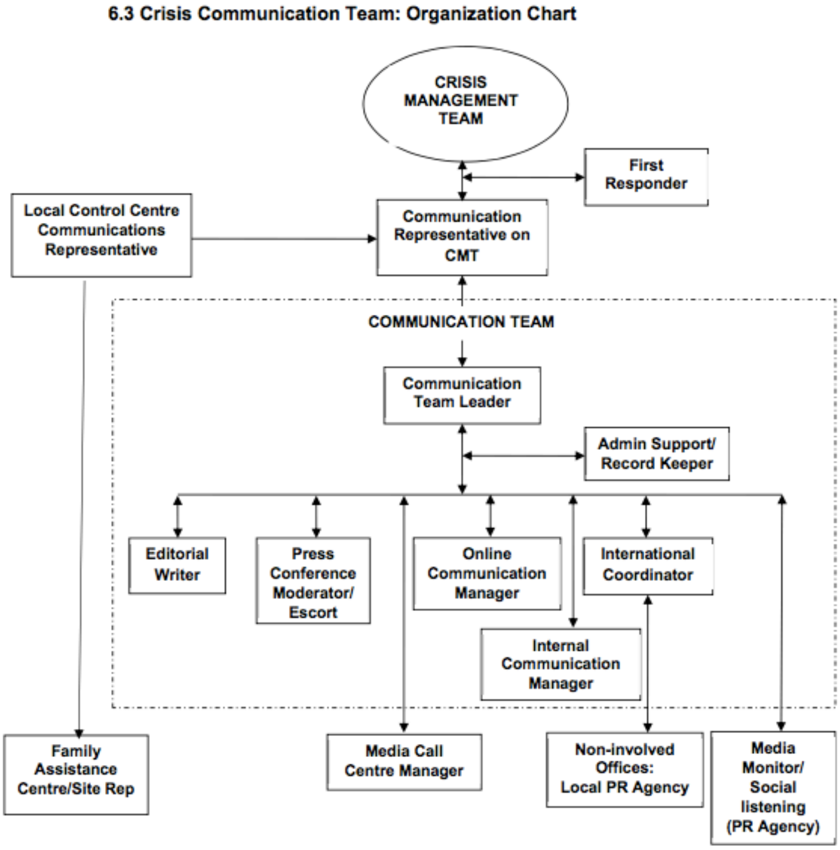

Figure 4.13: Recommended crisis management organization for the aviation industry (IATA 2016: 32)

It seems that commercial aviation regulations and guidelines contain some basic high-level requirements and guidelines for crisis event management that can be used for commercial spaceflight. These could be improved with high-level requirements that contribute to public-private crisis response. Furthermore, experts would confirm that the best practices for crisis event management that this thesis has put forward in its theoretical framework consist of actual best practices in crisis event management and could serve as a basis for a guideline for crisis event management in commercial spaceflight (Interview spaceflight CM expert January 2018).

4.4.2. Subconclusion on Crisis Event Management for Europe

High-level requirements and guidelines in crisis event management do not exist in European and American regulations and standards for commercial spaceflight. It would not be desirable to create very extensive requirements for crisis event management, as each crisis demands a different response. Dictating on the micro-level how a private actor should respond to a crisis would only frustrate the crisis response as it would make the crisis organisation very rigid and ineffective in its response. However, while this is the case, it would be desirable to create some high-level crisis event management requirements that would improve public-private cooperation during a crisis.

Private actors in spaceflight organisation should adequately define what events its personnel should see as a crisis and which not. This would improve the activation process and make the private actors crisis response quicker and more effective. Related to this, the activation process should be described and known by personnel. Furthermore, some high-level requirements that would improve stake holder management and crisis communication between public and private actors would be desirable. At last, it would be desirable to create guidelines on crisis event management for private actors in commercial spaceflight. Standards and guidelines from the aviation sector could be used to serve as a basis for commercial spaceflight. These could be improved with crisis event management standards from the general field of crisis management.

4.5 Post-Crisis Management for Commercial Spaceflight in Europe

The chapter on post-crisis management for commercial spaceflight in Europe is also divided according to the theoretical framework that was presented. First the desired distribution of post-crisis issues tasks between public and private actors will be determined, after which regulations, standards and guidelines in Europe and the United States will be examined. Because it will become apparent that these are scarce on post-crisis management requirements, post-crisis management for private actors in the commercial aviation industry will be examined.

4.5.1 European public institutions and regulations for private actors

4.5.1.1 Post-Crisis Issue Impacts

Interviewed experts have argued that tackling post-crisis issues is both a task for public and private actors (Interviews safety expert, aviation consultant, spaceflight CM expert). In general, the most pressing post-crisis issues for a private actor are judicial inquiries, prosecution, litigation managing reputation and communication with the media (Interview CM expert January 2018). Several of these, like reputation management and communication with the media would be the responsibility of public and private actors towards themselves and thus would be done out of self-interest. Like some crisis event management aspects, it would be of no interest to regulate these activities, as it does not necessarily improve public-private cooperation. However, some for some post-crisis activities it is desirable to have public-private cooperation. In the case of an accident involving a spacecraft, these post-crisis issues are the aftercare of victims and investigation into the accident (Interviews both safety experts and both CM experts).

Aftercare of victims is a post-crisis issue that in the first place is the responsibility of a public authority, but also should to an extent be the responsibility of private spaceflight actor (Interviews safety expert and spaceflight CM expert). For private spaceflight actors it would be in their own interest to perform aftercare for victims, as it is a high-profile business that would be much affected by negative public opinion (Interview spaceflight CM expert January 2018). It would however be desirable to make a support organisation for victims mandatory for private actors (Interview spaceflight CM expert January 2018). Experts felt that for a system of aftercare for commercial spaceflight, one could look at the commercial aviation industry for inspiration (Interviews aviation consultant and spaceflight CM expert). In the commercial aviation industry, most airlines and operators have an extensive aftercare and support organisation for victims. This has evolved in such a way because in the United States it is foremost the responsibility of private actors to establish aftercare, while public actors concentrate on post-crisis investigation.

In Europe, public actors provide more after-care and this is more of a joint public-private task. But because of American standards, most European operators and airliners also have a sizable post-accident support system (Interview spaceflight CM expert January 2018). Experts would expect that this cultural difference between the Europe and the United States would also manifest itself in commercial spaceflight, thus that in Europe the governments would feel having more responsibilities for the well-being of its citizens (Interviews both safety experts, XCOR, both CM experts).

It has been suggested to copy ICAO policy on the aftercare of victims (Interview spaceflight CM expert January 2018). The ICAO Policy on Assistance to Aircraft Accident Victims and their Families contains recommendations for public and private actors on how to develop policies and how to provide aftercare (ICAO 2013b). This could serve as a basis for aftercare policies in commercial spaceflight. These could be extended with general best practices in post-crisis aftercare, as these would apply to any sector (Interview CM expert January 2018). Nonetheless, one aspect of aftercare, namely liability and post-accident financial claims, would at the moment not work the same in commercial spaceflight as in commercial aviation. This because commercial spaceflight is a small and non-accessible for the general public, and commercial flight is a widely used means of transportation. At the moment, it would make no sense to create full financial compensation for victims, as private actors would barely be able to pay the enormous price of a ticket back to customers as a compensation (Interview spaceflight CM expert January 2018). The way in which liability will be regulated depends also on the question if Europe will adopt the waiver-system as used in the FAA-regulations. In a workshop with commercial spaceflight stakeholders on the creation of a European regulatory framework, this problem was elaborated on;

> 'Insurers need however an understandable, predictable liability regime. So far, only the US has a national regulation with the CSLAA and related rules, and it is

> an incomplete regulation. Passengers can probably not sue the FAA, but it is not clear whether passengers could sue the operator, because of the informed consent rule. Only if such passengers' claims are possible will insurance for operator's liability make sense: otherwise, liability insurance is not necessary. In the rest of countries, no regulation at all is in place yet. The evolution of the liability regime will be key to finding long-term stable solutions' (Masson-Zwaans et al. 2014: 81).

It would thus be important for the EU to create legislation on a liability regime for commercial spaceflight, in line of the US informed consent regime or making operators liable for accidents with their commercial spacecrafts. Some experts argue that the latter would be more preferable, certainly when more people are going to fly with commercial spacecrafts from Europe (Interviews both safety experts).

Public-private cooperation would even more be necessary in the case of the investigation of accidents with commercial spacecrafts. It would be foremost the responsibility of public authorities to investigate accidents with commercial spacecraft (Interviews safety expert and spaceflight CM expert). Authorities need the cooperation of private spaceflight actors because they need their technical expertise in investigating accidents with their uniquely designed spacecraft (Interview spaceflight CM expert January 2018). Several problems arise when trying to achieve this. Firstly, there is the problem of responsibility for the investigation of an accident of a commercial spacecraft in outer space. As has been argued earlier, international rules can be interpreted as that the State where the spacecraft is launched is responsible for the actions of the craft. But the Outer Space Treaty says noting on the responsibilities for the investigation of an accident (UNOOSA 1976a). On Earth this may not be a problem, as the authority on which territory the accident occurs will start an investigation, but for an accident in outer space responsibility might not be taken.

Another problem in investigating accidents with commercial spacecrafts are the barriers in the exchange of technical details. As already was argued, private actors might not be too willing to share the technical details of their uniquely designed spacecrafts and foreign operators would be restricted by treaties like ITAR. As public authorities need the technical details of the spacecraft, this could pose a major barrier to a successful investigation (Interview spaceflight CM expert January 2018). Regulators could oblige private actors to share the detail of their spacecraft, but this may not contribute development of the market. A solution could be that investigators would need to sign a secrecy clause, prohibiting them from sharing technical detail with third parties (Interview spaceflight CM expert January 2018).

It was the opinion of interviewed experts that in Europe it would be the EASA that should be the authority that should bear responsibility for investigation of accidents with commercial spacecrafts on European soil (Interviews safety expert, aviation consultant, spaceflight CM expert). However, in order to successfully perform this function, an investigative authority should obtain general technical spaceflight knowledge and expertise from spaceflight organisations like ESA or national spaceflight organisations (Interview spaceflight CM expert January 2018). This is something the EASA does not posses at the moment and thus need to obtain if it wants to perform investigation into accidents with commercial spacecrafts.

Several experts have suggested to also take the commercial aviation sector as an inspiration for creating an accident investigation system for commercial spaceflight (Interviews aviation consultant and spaceflight CM expert). Annex 13 of the Convention on International Civil Aviation that elaborates on Aircraft Accident and Incident Investigation could be adapted to fit spaceflight accident investigation (Interview aviation consultant December 2017). It seem that in the UK, the government is seeking to do just this. The ECSS standards requirements on handling post-crisis issues consists only of a brief mentioning of accident-incident investigation and reporting. Because the ECSS standards are made for commercial designers contracted by ESA, the requirements for accident-incident investigation only describes reporting and investigation by the contracted party of accidents that affect space system elements and designs. Accidents involving humans is not elaborated on. The UK space legislation in development does however have a more extensive section on accident investigation.

In this section the document states that 'it is the intention of the government to provide, by regulations, arrangements for the investigation of accidents involving spaceflight activities' (Department for Transport & UK Space Agency 2017: 52). Thereby it uses the CAA regulation Investigation of Air Accidents and Incidents of 1996 as a basis and will adapt it to developments in space law if necessary. These regulations will establish the Air Accident Investigation Branch (AAIB) as the authority that will perform investigations to accidents and incidents in commercial spaceflight (Department for Transport & UK Space Agency 2017: 52-53). It seems that the UK is trying to take regulations on post-crisis management in aviation as a basis and adapt it to be suitable to spaceflight. Further guidelines on the management of post-crisis issues are however not created yet.

4.5.1.3 Evaluation and Modification

Experts would agree that evaluation and modification is a vital component of post-crisis management. A lessons-learned program should be implemented in the organisation of any private actor in the spaceflight industry and is indispensable in preventing and preparing for crises (Interviews both safety experts, aviation consultant, both CM experts). It would be desirable to make such a program mandatory for private spaceflight actors, as it would be in everybody interest (Interviews aviation consultant spaceflight CM expert). An investigation into an accident with commercial spacecraft should be done with the goal of public and private actors learning from the event (Interview aviation consultant December 2017). Furthermore, the safety culture of an organisation is based on the lessons learned from incidents and accidents (Interview safety expert December 2017).

Part of this lessons learned program would be the creation of a database in which each anomaly, incident or accident would be logged and kept for evaluation. It would be desirable to make this mandatory for private actors (Interview spaceflight CM expert January 2018). If a public authority wants to make a lessons-learned program mandatory, it should create high-level requirements that prescribe learning goals and interaction with the authorities (Interview spaceflight CM expert January 2018). In this way, a regulating party can keep track of the amount of organizational learning that a private actor does and if improvements are actually implemented.

It has been suggested to implement a lessons-learned system like currently being used in the commercial aviation industry (Interview aviation consultant). This is another argument for the implementation of an aviation-like Safety Management System, as logging and evaluating any issues, incidents and accidents is part of such a system. However, when trying to implement such a system in a developing spaceflight industry, you immediately encounter the problem of limited possibilities of the exchange of technical information. The system of industry-wide self-learning that is used in commercial aviation would currently not work in the commercial spaceflight sector.

In the ECSS standards, some provisions for a lessons-learned programme are present. The main part on evaluation and modification in the ECSS Standards can be found in the ECSS Safety Standard and describes the logging of accidents and malfunctions and how the project organisation has learned from them;

- 'Safety lessons learned shall be collected and used during the project, as far as they are relevant, considering as a minimum:
- the impact of newly imposed requirements;
- assessment of all malfunctions, accidents, anomalies, deviations and waivers;
- effectiveness of safety strategies of the project;
- new safety tools and methods that were developed or demonstrated;
- effective versus ineffective verifications that were performed;
- changes proposed to safety policy, strategy or technical requirements with rationale' (ECSS-Q-ST-40C Rev.1 2017: 28)'

Next to these requirements, the document states that all safety lessons learned should be available to the customer and other suppliers (ECSS-Q-ST-40C Rev.1 2017: 28). The document does however not elaborate on how to extend this availability to other private actors in the industry.

A study by Christensen (2017) evaluates existing safety and incident reporting systems in commercial aviation and other logistic industries for their applicability to the commercial spaceflight sector. The most important argument of this study is that such a system should comprise of multi safety reporting structures, both mandatory and voluntary reporting systems (Christensen 2017: 232). For example, in British aviation, next to the mandatory reporting system imposed by the CAA, there is a voluntary system called UK Confidential Reporting Programme for Aviation and Maritime (CHIRP). CHIRP is an independent, totally confidential reporting system for all persons employed or associated within the aviation industry, in which the reporters' identification information is not passed to investigators or regulatory agencies (Christensen 2017: 230). This feature, combined with another element that can be found in some voluntary systems, namely a neutral third-party to operate the system, could be a solution for the barriers of information exchange in the commercial spaceflight industry. This kind of organization shows similarity with the Space Safety Institute proposed by the IAASS (Interview safety expert December 2017). This would imply that this proposed Space

Safety Institute could function as a third-party that would operate a confidential voluntary safety and incident reporting system.

4.5.2 Regulatory Status in the United States

4.5.2.2 Post-Crisis Issue Impacts

The FAA-AST regulations and guidelines mention some requirements for the investigation of accidents and incidents for commercial spaceflight organisations. The foremost accident related requirement for launch and RLV operators is the requirement of an Accident Investigation plan (AIP) and a Mishap Investigation Plan (MIP). According to the regulations the Accident Investigation Plan must contain: 'A launch operator must implement a plan containing the launch operator's procedures for reporting and responding to launch accidents, launch incidents, or other mishaps, as defined by §401.5 of this chapter.' (FAA-AST 2017: 124). The requirements for these procedures are more or less the same for both the AIP and MIP. Both require the operator to notify the FAA of the accident or incident and the submission of a preliminary report of the accident. Furthermore, cooperation with the National Transportation Safety Board (NTSB) is required. Also, these reports should contain 'delineated responsibilities, including reporting responsibilities, for personnel assigned to conduct investigations and for any unrelated entities retained by the licensee to conduct or participate in investigations' (FAA-AST 2017: 514).

It seems that the FAA-AST requires a licensee to investigate the accident themselves and in cooperation with the NTSB. However, there are no standards in how to investigate accidents and how to cooperate with the NTSB, showing that the FAA-AST does not provide for performance-based requirements of handling post-crisis issues by private spaceflight actors. Moreover, no requirements or guidelines for the after-care of victims can be found.

4.5.2.3 Evaluation and Modification

The FAA-AST regulations and guidelines do not contain requirements for evaluation and modification after major accidents or crises. While the guidelines give some guidance on evaluation and modification in the crisis prevention phase, it does not prescribe requirements for a lessons-learned program. The regulations do contain the requirement to log all anomalies, incident and accidents properly, but this is only required in order for the FAA and the NTSB to have proper data for their investigations (FAA-AST 2017: 217). This is not required for the sake of organizational learning after incidents and accidents. There are no required standards or guidelines in how to implement change in the own organization and improve its crisis prevention and crisis preparedness. It can be concluded that the FAA-AST regulations do not encourage commercial spaceflight organisations into organizational learning after crises, despite having recognized the failures in the Virgin Galactic incident.

4.5.3 Sub conclusion on Post-Crisis Management for Europe

Post-crisis management in commercial spaceflight is both a responsibility for public and private actors. In Europe, aftercare for victims would be a public-private endeavour, while investigation of accidents would be mainly a task for public authorities but needs the cooperation of private actors. Experts confirmed that the evaluation and modification after crises is a task for every private actor and implementation of lessons learned should be mandatory.

After examination of current regulations, standards and guidelines in Europe and the United States for commercial spaceflight, it can be concluded that these do not contain good examples of requirements for post-crisis management. Regulations and standards from the commercial aviation industry could better serve as an example for post-crisis elements in a European regulatory framework. Regulations should provide for proper public-private cooperation in handling aftercare for victims and investigation of the accident. Experts agree that high-level requirements, standards and guidelines for the creation of a support organisation and cooperation with public authorities during investigation should be created. Post-crisis management standards and guidelines can be improved with best practices from the general field of crisis management.

EASA is seen as the most promising agency to bear the responsibility of investigating accidents with commercial spacecrafts in Europe, if it would obtain the necessary technical knowledge and expertise in spaceflight from ESA or other public spaceflight organisations. Currently, investigations into commercial spaceflight accidents would be hampered by limitations in the exchange of technical details of commercial spacecraft. This could be solved by giving private actors the possibility of making technical details confidential and not being revealed to third parties during investigation. On the international level, the Treaty on Outer Space has to be amended to make it more clear which party is responsible for investigating accidents with commercial spacecrafts in outer space. Air law on investigations could be used as an example and adapted to commercial spaceflight for accidents on Earth, making both the operator and public authorities of the territory where the accident has taken place responsible.

Experts agree that a lessons-learned system would be vital to improve crisis prevention and crisis preparedness by proper evaluating incidents and accidents with commercial spaceflights and implementing the lessons learned from them. It would be the responsibility of each private actor to implement such a lessons-learned program and the responsibility of the regulating party to check the implementation of such a system. Proper high-level requirements, required standards and guidelines should be created that ensure that each private spaceflight actor implements a lessons-learned system and achieves effective organisational learning from crises. Part of this would the implementation of a SMS with its safety and incident logging, evaluation and modification parts. Best practices in organizational learning within the commercial aviation industry could serve as a basis for commercial spaceflight. The combination of a mandatory and voluntary industry-wide safety and incident reporting system would be desirable, in order to overcome commercial interests. The voluntary system could be confidential and operated by an independent third-party like the Space Safety Institute that has been proposed by the IAASS.

4.6 Conclusion

At the moment, the capabilities in Europe to effectively manage a crisis involving an accident with a commercial spacecraft are minimal. The European Union and its Member States do have a crisis management framework in place but the management of crises in space or from space is not integrated into this framework. Furthermore, a European regulatory framework for private actors is absent, thus there are no crisis management requirements or guidelines for potential European commercial spaceflight organisations.

It was the goal of this thesis to answer the question: *what are the critical success factors for arriving at a further concretization of EU crisis management policies and regulations for commercial human spaceflight companies?* In absence of an existing space crisis management framework in Europe, this thesis has tried to determine a possible way in which a European crisis management regulatory framework for commercial spaceflight can be established by the review of existing regulations, standards and guidelines in Europe and the United States for commercial spaceflight and by interviews with experts from the field of spaceflight and crisis management. It has been established that a European crisis management framework for commercial spaceflight ideally would comprise of cooperation between public and private stakeholders with both public and private bearing responsibilities for various crisis management tasks. The division of responsibilities between public and private would differ per element (preparedness, prevention, event and post-crisis) of crisis management, with some aspects being foremost the responsibility an public authority, others mainly the responsibility of private actors themselves, while other would be a more equal responsibility for both public and private.

It has been determined that crisis preparedness tasks are both the responsibility of public and private actors. Both public and private actors should establish a well-working crisis organisation by creating a clear distribution of roles and responsibilities for each individual and layer of the organisation, while creating a reliable crisis infrastructure. Preparing the public-private crisis cooperation is a crucial part of this. Adequate personnel should be trained and the crisis organisation should be tested and improved through regular exercises. It is desirable to guarantee a level of crisis preparedness among private actors to ensure an effective public-private cooperation during the crisis response. Therefore regulations for private spaceflight actors should ideally contain performance-based crisis preparedness requirements.

The division of responsibilities in crisis prevention is more ambiguous. There is a principal responsibility of public authorities in creating emergency capabilities and carrying out an emergency response that also needs the cooperation of private actors in the event of an accident with a commercial spacecraft. Also setting up Space Situational Awareness capabilities and creating Space Traffic Management rules and capabilities would be a task for public authorities, in which there is a minor role reserved for private actors. Meanwhile, it is the responsibility of private actors themselves to design safe vehicles, ensure safe operation and create and implement a safety culture within the organisation. It is then the responsibility of public authorities to create requirements that would ensure these things and guide them in achieving an acceptable level of safety through proper risk and issue management.

Both public and private actors would do crisis event management. It is however not desirable to create rules for private actors in how to respond to a crisis, except for some high-level requirements that would improve cooperation with public authorities. These would include determining how the crisis organisation is activated, proper stakeholder management and crisis communication. Nevertheless, it would be desirable to create guidelines for private actors in how to adequately perform crisis event management. Post-crisis management, like crisis preparedness, would be a joint public-private responsibility. Post-crisis issues caused by accidents with commercial spacecraft like aftercare for victims and investigation would be best tackled by cooperation between public and private organisations. The creation of a lessons-learned program would be the responsibility of private actors themselves, while oversight in this process by public authorities is needed.

The desired division of crisis management tasks and responsibilities tells us which crisis management activities should be made mandatory for private actors and which not. This thus shows the desired level of regulation for a future European commercial spaceflight market. This would be the ideal level of regulation from a safety and crisis management perspective. In what way then could an European regulatory framework for commercial spaceflight be created that has the support of both public and private stakeholders and ensures both a safe and a innovative and competitive European space flight market? From interviews with experts it has been established that because a European regulatory framework for commercial spaceflight would ideally consist of a lot of public-private cooperation, it would be important that both the public and private actors see this framework as legitimate. Furthermore, because the European commercial spaceflight market still needs a lot of development, it has been argued that innovation and competiveness should be promoted by not putting too much regulatory pressure on private actors. In opposition to this stands the argument that the European spaceflight industry would profit from clear regulations and guidelines by giving them guidance how to develop reliable spacecraft.

As a compromise between ensuring safety in commercial spaceflight activities and creating room for innovation and competiveness in an immature and developing European commercial spaceflight market, it is suggested to develop crisis management regulations and standards in accordance to the size and accessibility of the market. European public authorities would set the basic high-level requirements and create some standards and guidelines for private actors to follow from the beginning. While the market develops itself, the regulating body would then take the lead in developing stricter requirements and standards in cooperation with the private actors. In the meanwhile, the EU and its Member States should develop space crisis management capabilities and prepare their crisis response to and post-crisis management of crises involving accidents with commercial spacecrafts, while carrying out their crisis prevention responsibilities.

Most experts agreed that a new European regulatory system should include minimal crisis management requirements from the start, including a level of crisis preparedness, basic crisis prevention requirements and guidelines, some high-level crisis event requirements and post-crisis requirements and guidelines. In order for the regulatory system to be effective, it would be crucial to create performance-based crisis management requirements, creating high-level performance requirements with required standards and best practices that tell what it would need to comply with these requirements and guidance material and how it is advised to meet these requirements. This is in contrast to current regulations for commercial spaceflight in the United States; which barely contains crisis management requirements, while existing requirements have a normative nature, and also are lacking established standards and guidance material. Furthermore the requirements and guidelines of the FAA-AST regulations are incomplete and often vague in their language, leaving much open to interpretation.

Therefore, most experts would argue not to copy or use the FAA-AST regulations as an example for an European regulatory system, except maybe for the parts on collision avoidance and Crew Resource Management. It would be more desirable to use the ECSS standards, UK legislation and the regulatory system used in commercial aviation as precedents for a European regulatory system for commercial spaceflight. The ECSS standards would mainly contribute to establishing standards and best practices in safely designed space systems and risk management in the design phase. UK legislation is exemplarily in the intention of authorities to require private spaceflight actors to implement aviation-based Safety Management Systems and the ALARP principle. For inspiration for standards and guidelines in other elements of crisis management, European regulating authorities could look at the regulatory system of the commercial aviation industry.

5. Reflection and Recommendations

5.1 Reflection on results

The results of this exploratory research have shown that like the industry itself, existing policies and regulations for commercial human spaceflight are still of an experimental nature. For policy makers in the West commercial spaceflight is a new and unknown industry that triggers difficult legislative and regulatory questions on which the answers are not that clear-cut. From a crisis management perspective a lot has to be done on the national, supranational and global level in order to guarantee future commercial human spaceflight that is safe. Looking at the current state of policies and regulations for the commercial human spaceflight sector from the perspective of crisis management has proven to be unique and valuable. Through this method it has highlighted several areas of concern that should get attention if policymakers do not want to see human casualties in commercial spaceflight occurring any time soon.

The results of this thesis have shown the gap in Europe in policy and regulations for the commercial spaceflight sector and the urgency for developing these in the near future. While currently the European commercial human spaceflight sector still is in an embryonic state, commercial spaceflight is on the rise and it would be important that European policy and legislation is prepared for the opening of the European market. Furthermore, crises in space or from space will quickly have a regional or even global impact, showing that even without a European commercial spaceflight market, it would be desirable that the EU and its Member States should develop their space crisis management capabilities.

Using the current legislative framework in the United States as a point of reference for a possible European framework has proven to be valuable. The examination of the only regulatory framework for commercial spaceflight in the world has demonstrated a way in which a soft regulatory regime could be established but which would not be desirable for Europe. When looking from a crisis management perspective, the FAA-AST regulations lack a lot of essential crisis management elements or do not address these in a proper manner. Also including the framework in the United States has highlighted cultural differences between Europe in the United States. It has been argued by experts that Americans prefer a free and competitive commercial spaceflight market with minimal regulatory restrictions, while in Europe the perspective of the government having more the role of a care-taker will probably drive European policymakers to more stricter safety requirements.

It has been confirmed by experts that the theoretical crisis management model presented in chapter two contains appropriate crisis management practices and of which most aspects could be included in a regulatory framework for commercial spaceflight. The results of this thesis have confirmed that space crisis management should be achieved by public-private cooperation and that a regulatory framework for commercial spaceflight should have a level of legitimacy through the eyes of its stakeholders and the general public as laid down by the CM governance model of Christensen et al (2016). Governance of space crisis management should include the capacity to bring public and private actors together in joint action, the capacity to analyse the environment on potential dangers, the capacity to regulate the commercial spaceflight sector in a proper manner and the capacity to deliver an adequate crisis response through public-private cooperation. Interviews with experts have shown that including most aspects of the presented theoretical CM framework for spaceflight, based on the model of Jaques (2007), in regulations, standards or guidelines would contribute to creating a resilient and safe commercial spaceflight market, in which fatal accidents are prevented or were the effects are effectively brought to a minimum. Looking at accidents involving spacecraft from a process-viewpoint has highlighted the main tasks and activities that should be carried out in preventing crises involving commercial spacecrafts from happening.

The biggest limitation of this study has been the absence of a European commercial human spaceflight market and therefore it could not test its theoretical CM framework on an existing case. Therefore it was forced to rely on the views from experts in the fields of spaceflight and crisis management, and not observing actual practice. It has to be seen if the results and recommendations of this thesis would work out in practice. However, by relying on the views of experts from the field, it has achieved the highest level of validity that is possible at the moment and it gives a strong indication of what would be a desirable way forward for Europe to prepare for, prevent, respond to and learn from accidents with commercial spacecrafts in the future. One other limitation of this thesis was that no European private spaceflight actors have been interviewed due to the underdeveloped state of the European commercial spaceflight market. Therefore the vision of the European private industry on regulation has not directly been examined through interviews. However, this has been compensated by interviewing experts from different fields, some having a more pro-safety viewpoint, while others giving more value to an innovative and competitive European market. Therefore this thesis has reached a more balanced result, it has identified a possible way forward in creating a European regulatory framework for commercial spaceflight that it regards as favourable for both public and private actors.

Through interviews with experts and the study of documents this thesis has shown that at the moment, Europe is unprepared for a possible future advent of commercial human spaceflight from the continent, either through European spaceflight start-ups or American-based companies expanding their activities overseas. Currently, commercial spaceflight would be an unregulated business, prone to accidents and having the potential to wreck havoc to European cities and landscapes when malfunctioning spacecrafts would come crashing down from the sky. While this is may be a scenario that would currently be unimaginable to many, it should be the interest of public authorities to secure a future where commercial human spaceflight is a safe business for both crew, passengers and those on the ground and where crises are avoided by proper preparation, prevention, response and organisational learning.

The EU should create its own space crisis management capabilities in cooperation with its Member States. In practice, this might be difficult to achieve at the moment, as through interviews with experts it has become clear that space is not high on the agenda among European policymakers at the moment (Interview EU policy Expert). However, there are numerous stakeholders, among several industry players and the EASA who have urged the European Commission to begin with formulating policy on in this area (Masson-Zwaans 2014). Another obstacle in the formulation of policy on space security could be the Member States themselves, as space security related policies need unanimity from the Member States in order to be implemented. Furthermore, the EU and other major spacefaring nations should establish international spaceflight standards, which include safety, SSA and STM standards and make an organisation like the ICAO responsible for governing these standards. Creating these standards is at the moment difficult because of national interests, as the major spacefaring nations are hesitant in sharing their suborbital and orbital designs and SSA data.

The main point of action is the creation of a European regulatory framework in which the interests of the public and the private actors are represented. To an extent this will not be difficult, because it is in the interest of both the public and the private actors to have a certain level of safety when performing commercial human spaceflights. However, there is a possible area of friction where safety interests meet financial interests. Nevertheless, the EU should formulate policy that establishes the foundations of such a European regulatory framework and designate a European regulator that would govern such a framework. With the EASA having urged EU policymakers for years to establish it as the regulating authority for suborbital flights this should not be a difficult task if policymakers are willing.

5.2 Policy Recommendations and future study

The results of this study have shown that there are several policy changes that should be considered by European policy makers and regulators. These changes are needed to ensure that both public and private actors would perform their tasks and responsibilities within a European crisis management regulatory framework for commercial spaceflight. These policy changes should happen both on the European level and the international level.

Firstly, some policy recommendations and institutional changes on the global level are recommended;

The EU should try to establish a global SSA network and create international STM rules in cooperation with the space-faring nations of the world. Create an international organisation like the ICAO that governs STM rules globally. Differences in managing suborbital and orbital traffic should be acknowledged. Management of suborbital traffic can be integrated with ATM.

This thesis has shown that SSA and STM should foremost be established on a global scale, in order to safely manage suborbital and orbital traffic. Space traffic happens at such a speed and in an area that literally spans the globe, that is would be necessary to know on a global scale where all the objects in near-Earth space are positioned. This is mainly the case for orbital space traffic. Furthermore, STM only works when all the spacecraft follow the same rules and it is implemented by every nation on Earth. One major barrier in the international exchange of SSA data is that these data often include sensitive military data that States are not keen on sharing. Achieving the establishment of a global SSA network is probably not something that will be done in the near future.

Facilitate the exchange of technical information on commercial spacecrafts by adapting international arms regulations like ITAR

Currently, the international exchange of technical information of commercial spacecrafts is hampered because commercial spacecrafts are often defined as rocket technology that falls under national interests. This would hinder the international exchange of safety issues that could help improve the global safety of commercial spaceflight and the investigation into accidents with foreign spacecrafts.

Adapt the Outer Space Treaty or create a new one in which the responsibilities for commercial activities and emergency response to commercial spacecraft in distress are described.

Currently it is not clear whose responsibility it is to set up an emergency response to commercial astronauts and passengers stuck in space. This could potentially lead to inaction and confusion among public actors in the case of an emergency involving a commercial spacecraft. Therefore it is important to engrain the roles and responsibilities for States and private actors in the case of emergencies in space in international treaties and law. Adapting the current Outer Space Treaty could be an option.

Further, several institutional changes within the EU are recommended;

The EU should create EU space crisis preparedness and response capabilities by integrating space crisis management into the EEAS Crisis Response System on the strategic, tactical and operational level. Also it should establish crisis response networks with private actors.

With the EEAS as the platform for terrestrial crisis management, it would be only logical that it should be the agency that would coordinate the EU space crisis response. Policies and procedures should be created that bring the relevant space and spaceflight stakeholders together on the strategic level within the Crisis Platform of the EEAS in the event of a crisis in space or from space. A Space Crisis Management cell as proposed by Robinson (2013) could be established to coordinate the response during a space crisis. For the terrestrial response, the EU Civil Protection Mechanism could be outfitted with the technical expertise needed when responding to crashed space crafts. These technical expertise can be obtained from ESA. Also, as it has been suggested by Robinson (2013), it would be important to 'undertake Europe-wide space crisis management exercises' (Robinsion 2013: 30), in order to check the space crisis preparedness of the EU. Private actors should be included in a network of space crisis response.

The EU should develop rapid emergency response capabilities for emergencies in outer space and/or require private actors to develop this capacity

Currently there is no country in the world that has the capability to quickly respond to an emergency in outer space. Rapid response would be necessary in the case that a life-threating situation develops aboard a commercial spacecraft operating in outer space. This would involve making sure that a rescue spacecraft is on standby in all times with the necessary skilled crew. Another option is to require private actors themselves to having a response unit standing by in the case of an emergency in outer space.

The EU should further develop SSA capabilities on the European level by developing ESA's SSA programme in to actual EU-wide SSA capabilities and integrate it with STM. Designate the EASA as the future European STM authority and integrate STM with ATM.

While establishing SSA and STM should be a global effort, the space traffic departing from or coming to Europe should partly be managed locally. Space traffic intersects with air traffic and therefore needs integration on the regional level. Furthermore, global SSA exchange is something that probably will not be achieved in the near future, so it would be beneficial for Europe to develop its own SSA capabilities. Because STM needs to be integrated with ATM, the EASA would be the best candidate to create these rules on the European level. Actual management of EU-wide space traffic could be done by an organisation like EUROCONTROL, that currently also manages the air traffic.

The EU and its Member States should establish a European regulatory framework that would minimize the chances of a crisis occurring to as low as reasonably possible in an experimental market while giving room for innovation and competiveness with foreign markets. Create performance-based high-level requirements that would ensure basic crisis preparation, prevention, event management and post-crisis management capabilities from the start that would compensate the low certification requirements for experimental commercial spacecrafts.

Next to institutional changes that would allocate the necessary crisis management tasks and responsibilities to European public actors, a regulatory framework has to be established that ensures that private actors will perform their tasks and responsibilities in preventing crises. It has been determined that this should be done by establishing a European regulatory framework for commercial spaceflight that ensures a level of crisis management capabilities among private actors but still allows for innovation and competitiveness when the market is still small and not accessible for the general public. This would comprise of high-level crisis management requirements that should be met in order to be allowed to launch and operate commercial spacecraft from EU territory. At the same time, some basic but light airworthiness and spaceworthiness requirements like an acceptable expected casualty rate should be established. Commercial spacecrafts would be certificated as having a minimum level of safety that would be acceptable in an experimental market that requires a level of innovation. The low certification standards would be compensated by ensuring that private actors would be adequately prepared for responding to accidents and an organisation-wide safety culture that weeds out the faulty designs and human and organisational errors during the design, test and operational phase of a commercial spacecraft. This would be achieved by implementing at least the following requirements;

- A crisis organisation with a hierarchical structure but some decentralized decision-making capacities, as has been put forward in chapter two.
  - Clear roles and responsibilities for the strategic, tactical and operational levels of the organisation, especially with technical issues.
  - No micromanaging from higher management in the other layers of the crisis organisation.
  - Decentralized information management that is supported by a crisis management system
- Proper crisis infrastructure like an all-hazard crisis plan, crisis rooms and a crisis management system.
- A set of required skills that people within the crisis organisation should obtain via training and that stems from crisis management experiences.
- Regular crisis exercises that will check the level of crisis preparedness of the organisation and reveal the necessary skills that personnel should have for managing the crisis at hand.
- A aviation-like Safety Management System that will ensure a proper safety culture among private actors
- STM rules and SSA requirements
- Risk management that includes human factors and organisational failures, that identifies, assesses and manages risks throughout the life cycle of commercial

spacecrafts, that manages risks for 1st, 2nd and 3rd parties and uses the ALARP principle.

- Issue management that is being done throughout the organisation, with clear roles and responsibilities for individuals in each layer of the organisation.
- Emergency equipment and training for crew and passengers
- Crisis response capabilities to emergencies on Earth or in outer space
- Stakeholder management and crisis communication that improves cooperation with public actors or other private actors
- Clear definition of a incident, accident and crisis in order to aid the proper activation of the crisis organisation
- Guidelines containing crisis management best practices during the response phase
- Setting up a support organisation for after care of victims
- Setting up a lessons-learned program with a database of incidents and accidents with the goal of improving the organisation's preparation of responding to accidents and its capacity to prevent accidents.
- Rules and guidelines how to cooperate with public authorities during the investigation of an accident.
- Create a liability regime for operators, either adopting the US-waiver system or making operators more liable for their passengers and crew.
- Guidelines containing post-crisis management best practices

The EU should establish EASA as the regulating authority for commercial spaceflight in Europe. In doing so, the EASA should obtain the necessary technical spaceflight knowledge and expertise from ESA or other spaceflight organisations.

It has been established that there is a preference for EASA being designated as the regulating authority for suborbital and orbital commercial spaceflight in Europe. This would be analogue to the role the FAA currently has in the United States. It would develop and implement regulations for commercial spacecraft and lead the investigation into accidents with commercial spacecrafts. It has been argued that the FAA currently lacks technical knowledge on spaceflight. This is should be avoided by the EASA and it should attract the necessary expertise on spaceflight from ESA or other spaceflight organisations.

After establishing a European regulatory framework with basic CM requirements, the regulator should take the lead in develop standards and best practices in cooperation with the industry. This in order to develop stricter regulations with fully certified and safe spacecrafts for when the market grows and opens to the general public. An independent Space Safety Institute could be established to aid the regulator in establishing space safety standards and investigating accidents with commercial spacecrafts.

By developing standards and regulations in cooperation with the industry while being the governing authority in this framework, the regulator can impose its authority on private actors in a way that it is seen legitimate by these private actors. By developing regulations with a level of cooperation and consent of the private spaceflight industry, standards and best practices can be created that stem from experience and there will be a higher chance that private actors will actually implement these. By creating this hybrid form of hierarchy (the regulator as the governing authority) and network (cooperation by relevant industry stakeholders), legitimacy within the public-private cooperation is high and standards stems from actual experience. In this way, commercial spaceflight will remain safe and innovative during the development phase and will have acquired a level of safety that is acceptable when the market opens to the general public. Establishing a independent Space Safety Institute with a third party peer-to-peer review of the safety within commercial spaceflight organisations, as proposed by the IAASS, would help with objective auditing of private actors and increase their compliance with regulations. Also it could serve as an independent third-party that operates a voluntary safety and incident reporting system next to a mandatory reporting system governed by the EEAS.

While developing standards and best practices for the commercial spaceflight industry, regulators could use safety and crisis management standards and best practices from the commercial aviation industry as an example and adapt it to fit to commercial spaceflight. The ECSS standards could be used as a basis for designing safe space systems and proper risk management. Best practices from the general field of crisis management could also be considered.

While developing regulations for a new European regulatory framework, regulators do not have to re-invent the wheel. Already more than 50 years of experience with designing and launching space systems into space exist in Europe, which has partly been transformed into the ECSS standards. These could serve as a basis for developing standards in designing safe commercial space systems and adequate risk management. Also, safety management standards and best practices in commercial aviation like the Safety Management System could serve as a basis for implementing regulations that ensure safe designed spacecrafts and the safe operation of these commercially developed spacecrafts. Furthermore, the commercial aviation industry has developed some crisis management standards and best practices that also could be useful for the commercial spaceflight industry.

This thesis has identified in its exploratory examination of the current regulatory situation in Europe and the Untied States concerning commercial spaceflight several areas of concern that should be addressed by policymakers in the EU. Further research is necessary for determining the technical details of the proposed policy and institutional changes. Building on the results of this thesis, it can also be explored what the current vision in Europe among the most important spaceflight industry stakeholders is on a possible European regulatory framework and to what extent they agree with the results of this study. It also could be examined more in detail how safety and crisis management standards in commercial aviation could be translated to commercial spaceflight. Also it could be examined in more detail to what extent ECSS technical standards should serve as an example for commercial spaceflight. Also, in what way public-private cooperation during response to crises in space can be achieved, could be explored. Nevertheless, the successful maiden voyage of the Falcon Heavy Rocket by SpaceX last February marks a new milestone in the development of cost-effective spaceflight and shows the quick development that the commercial spaceflight industry at the moment is experiencing (Luscombe 2018). This again urges the need for policymakers in Europe to take action and secure a future in which commercial spaceflight is safe and accessible for European citizens.

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Appendix A: Interview results