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Design and Development of a New Course on Ethics in Aerospace Engineering

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Report

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BACHELOR FINAL THESIS

Agraïments

Vull dedicar aquest projecte a totes les persones que m'han acompanyat, escoltat i recolzat tots aquests mesos. A totes aquelles que són família tot i no compartir cognoms. I al Xisco, el meu amor de quatre potes.

Vull agrair a l'Ester Comellas, directora d'aquest treball, no per només guiar-me, ajudar i corregir durant tot el projecte i fer que la meva feina sigui molt més fàcil, sinó també per introduir-me en aquest nou món que era per mi l'ètica. Gràcies a la seva proposta he pogut descobrir estudiar aquesta branca sense fi la qual aplica a totes les decisions professionals i del dia a dia de tothom. No tornaré a evaluar els problemes de la mateixa manera.

També vull fer menció al Miquel Sureda, co-director, per haver volgut formar part d'aquest projecte des del principi, per tota la seva ajuda i per haver-me aportat noves idees i punts de vista els quals mai abans havia tingut en compte.

Declaration of Honour

I declare that:

- The work in this Degree Thesis is completely my own work.
- No part of this Degree Thesis is taken from other people's work without giving them credit.
- All references have been clearly cited.

I understand that an infringement of this declaration leaves me subject to the foreseen disciplinary actions by the *Universitat Politècnica de Catalunya - BarcelonaTECH.*

Patricia Tomás Peña 21st June, 2023

Project title: **Design and Development of a New Course on Ethics in Aerospace Engineering**

Abstract

The competence to apply ethics in the development of new technologies is currently not addressed in university programs for aerospace engineering at the national level. Therefore, the purpose of this project is to guide future aerospace engineers in making ethical decisions.

This project is divided into three different parts. In the first one, different teaching methodologies are studied. Active learning, which includes case studies, is concluded to be the most effective for students. In the second part, using these methodologies, the syllabus for an elective on ethics for the aerospace engineering curriculum has been developed. This syllabus covers important moral concepts in the design, development, testing, and certification processes, as well as the concept of responsibility. Finally, in the third part, a teaching guide has been developed, divided into each session, to carry out the instruction of this course.

After all, this project has successfully fulfilled all its initial requirements and developed a course that is ready to be taught.

Resum

L'aptitud d'aplicar l'ètica en el procés de desenvolupament de noves tecnologies és una matèria que, pel moment, no s'ofereix en els estudis universitaris d'enginyeria aeroespacial en l'àmbit peninsular. Per tant, aquest projecte té el propòsit de guiar a les futures enginyeres i enginyers aeroespacials a l'hora de prendre decisions morals.

Aquest projecte està dividit en tres parts diferents. En la primera, s'estudien diferents metodologies docents i es conclou que l'aprenentatge actiu, el qual inclou els estudis de casos, són les més eficients pels estudiants. En la segona part, a través d'aquestes metodologies, s'ha desenvolupat el temari d'un curs optatiu d'ètica pel currículum dels estudis d'enginyeria aeroespacial. Aquest temari tracta els conceptes morals més importants dels processos de disseny, desenvolupament, testatge i certificació així com el concepte de responsabilitat. Finalment, en la tercera part, s'ha desenvolupat una guia docent, dividida en cada sessió, per dur a terme la instrucció d'aquest curs.

Finalment, aquest projecte ha aconseguit complir totes les demandes inicials i desenvolupar un curs ja preparat per ser instruït.

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Aim

The purpose of this project is to develop a new 3 European Credit Transfer and Accumulation System (ECTS) course on Ethics in Aerospace Engineering that will be taught based on the principles of active learning, specifically through the use of case studies.

In order to carry out the present project, learning objectives, organization of the lectures, and an appropriate qualification system will be defined and included in a teaching guide. All the teaching material required to impart this course, following the principles of active learning, will be elaborated as well.

At the end of the project, this course should be a teachable subject at the Terrassa School of Industrial, Aerospace and Audiovisual Engineering (ESEIAAT) as an elective to Bachelor's and/or Master's degree in Aerospace Engineering students. It should provide learners with the main knowledge of ethical theories and codes of conduct. Moreover, all these concepts should be able to be related to aerospace applications.

Scope

In order to achieve the objectives, the project will include:

- Research on active learning and learner-centered teaching techniques and a study of the best way to apply them in the course developed.
- Research and study on ethics in aerospace engineering to select the most relevant topics.
- A proposal of a teaching guide for a course on Ethics in Aerospace Engineering including general and specific learning objectives, an activity program, and time estimated for tasks.
- A selection of bibliography proposed to students to meet the learning objectives of the subject. Also another to widen the knowledge taught.
- The analysis of different ethical issues in aeronautics based on real cases and related to each topic of this course.
- All the teaching material and learning resources necessary to impart the lectures.
- The development of the course structure in Atenea with all the teaching material and other activities. These academic resources will be organised based on the course sessions.

The project will not include:

- Development of supplementary material not directly necessary to teach the course.
- The teaching of the course developed.
- Improvement proposals based on student evaluations.

Justification

Aerospace engineering is an incredibly complex field and the ethical considerations of decisions taken by aerospace engineers are extremely important. Aerospace engineering ethics can have a profound impact on the safety of passengers and aircrew, as well as on the safety of the general public. Furthermore, ethical considerations can also play a role in the development of new technologies and the implementation of existing technologies in this industry.

Thus, a course on ethics in aerospace engineering would provide students with the knowledge and skills necessary to make ethical decisions in the engineering field. This course would give students the opportunity to learn about the ethical considerations of developing new technologies, the ethical implications of the use of existing technology, and the ethical considerations of the safety of passengers and aircrew.

By providing students with the chance to learn about ethics in aerospace engineering, this course would help ensure that future engineers are aware of the ethical implications of their decisions and actions. So, this course is essential for the development of engineers, and would help ensure the safety of passengers, aircrew, and the public at large.

Moreover, imparting a course on ethics is a great way to attract students who are looking for a career that is not just technical, but also about improving society in general. Consequently, a course on ethics will make the university program more competitive and attractive.

Overall an ethics course would be beneficial to students, society and the university itself, and should be considered a valuable addition to any aerospace engineering curriculum.

Background

At the moment of starting this project, some courses on ethics are already offered by different universities. Even so, they are not commonly available in engineering studies yet.

In recent years, some of the most prestigious international universities in the engineering field have started to offer courses on ethics although most of them are not mandatory in the studies curriculum. For example, the Massachusetts Institute of Technology (MIT), one of the most recognised engineering university internationally, has two electives on ethics for engineers. In these electives, ethical questions and concerns are explained through case studies. Moreover, it offers spring courses that are out of the curriculum for students who have taken the electives and want to expand their knowledge in this area.

Furthermore, other reputable engineering schools such as Harvard University, Stanford, Princeton University, and TU Delft have electives on ethics in engineering or science in their programs. Although this subject can be found in these influential schools, it is complicated to find universities which impart this elective in their STEM studies. And it is even more difficult to find these courses focused in aerospace engineering.

At a national level, the Bachelor's degree in Aerospace Engineering is offered in twelve different universities of which only one has an available elective on ethics: Universitat Politècnica de València allows its students to take an elective course on *Sustainable Development and Environmental Ethics*. So, it can be stated that a lack in the teaching of this field exists in the national territory. This lack occurs not only in bachelor's degree level but also in master's since there are ten Spanish universities that offer a master's degree in aerospace engineering but none have any course on ethics, neither compulsory nor optional [1].

On the other hand, some other institutions have free online courses on ethics. For example, an associate professor of Eindhoven University of Technology, Lambèr Royakkers, published a course in *Coursera*, a website with free courses on different areas, which is based on his book *Ethics, Technology and Engineering*. In fact, Royakkers' course has been used as main reference in the development of this project.

[1] References and websites of these universities and their courses on Ethics are shown in Appendix A.

Part I

Teaching Methods

In the first part of this project, various types of teaching methodologies such as active learning and case-based learning are studied and compared to traditional lecture-style learning.

In the field of education, there is an ongoing debate about the most effective teaching methodologies that can enhance students' learning outcomes. Thus, the aim of this part is to identify the benefits and drawbacks of each methodology and compare their effectiveness in enhancing student engagement.

Extensive research and analysis in the past years has shown that learner-focused teaching and case-based learning methods provide more advantages compared to traditional teaching methods due to educators being able to create a more stimulating and engaging learning environment that enables students to learn better and achieve academic success by using these methodologies.

As said before, the principles of these methods are the basis to develop the second and third part of the project.

· CHAPTER I.1 ·

The Importance of Teaching Methods

Teaching methods are the set of techniques used by instructors to support students to achieve learning outcomes. A correct teaching method must help students to achieve all the learning objectives of a course and to be able to apply the content in particular situations. Moreover, choosing the convenient teaching method provides knowledge while encouraging students to actively engage with the content and develop their knowledge and skills.

An alignment of what the instructor wants students to master and how they teach this topic must exist. In other words, instructors should take into account the learning objectives and the learning environment of their courses and identify the teaching method which will accurately support them [16]. For example, if a professor has to teach how to solve a complex math equation, the use of guided instruction would lead to more successful outcomes than a traditional lecture. In guided instruction, first, the instructor would facilitate learning by modeling and scaffolding, which is a method where the teacher demonstrates how to solve a problem before asking students to practice on their own. So next, students would take time to ask questions and practice applying this knowledge together and then independently. On the contrary, using a traditional lecture, students would need to process the lecture and apply principles simultaneously. As said before, this is more complicated to do and is known to lead to less successful results.

Over the years, the predominant teaching approach has significantly evolved, from the traditional lecture-based method to a more interactive and learner-centered approach. Traditional teaching methods were based on master classes and memorization. On the contrary, modern teaching is more focused on students and on the learn-by-doing methodology. It is also more activity-oriented and relies on practical collaborative methods. These modernized teaching techniques are gaining popularity since their results seem to be better than those of traditional methods [17].

In the book about teaching methods by Peter Westwood [18], he presents a classification of teaching methods. They have been divided between instructivist approaches (teacher-focused) and constructivist methods (student-centered). Examples of instructivist methods are lectures and teacher-directed lessons while experiential learning, case-based learning, enquiry-based methods and project-based learning are some types of student-centered approaches. Constructivist methods will be reviewed in the next chapter.

· CHAPTER I.2 ·

Constructivist Methods

Constructivism is a theory about human learning that states learners construct knowledge rather than just passively take in information. As people gain experience and reflect upon it, they form their own impressions and incorporate new information into their pre-existing knowledge.

Since the 1990s, constructivism has become increasingly popular, driving an educational reform and originating many new learner-centered approaches to teaching [18, 19].

Researcher and professor Peter C. Honebein [20] defines seven goals of constructivist classrooms:

- Students primarily decide how they learn.
- Multiple perspectives are incorporated.
- Material is connected to a real-world context. Students do not learn isolated facts and theories separate from the rest of their knowledge and experiences.
- Students feel empowered in their autonomy.
- Collaboration is promoted. Learning is a social activity since students and teachers work together to build knowledge.
- Learning material spans media, including text, audio and video.
- Students learn to be better learners.

Finally, some more consequences of constructivist theory can be cited [21]:

- When students are engaged in learning experiences, they learn better than if they only passively receive information. Therefore, the goal of teaching is to provide experiences that ease the construction of learning.
- It is an active process as the learner needs to do some activities in order to learn.
- Motivation is key to learning. Thus, educators need to have ways to engage and motivate learners.

I.2.1 Constructivist Models

Below, some teaching techniques based on constructivism will be explained. Nevertheless, these are broad classifications but in practice teachers usually merge them or use elements of one or the other. Plus, many of these categories actually have similar elements and may overlap with each other.

I.2.1.1 Flipped Classroom

Flipped classroom is an instructional strategy where the teaching scheme takes place in a flipped way. Unlike the traditional approach, students study new content before class and then they can practice this material at school through different activities guided by the instructor. Besides, as the content is prepared before arriving at school, if students face any doubt, they can discuss it in the class with their classmates or with the professor [17].

Some other benefits according to Harvard University [22] of flipped classroom are:

- It is more flexible than lecture-based structures.
- Students can learn at their own pace.
- Students take responsibility for their learning. Thus, learners will be better prepared for the future as they also can achieve this competence.

- It allows for greater collaboration between students.
- Instructors work more closely with students, allowing the chance to know students better and providing more useful assistance.

I.2.1.2 Enquiry-based Learning

Enquiry-based learning is an education approach that focuses on investigation and problem-solving. It is also different from traditional methods as it reverses the order of learning. Teachers start with a range of scenarios, questions and problems for students instead of presenting information. This method includes discovery learning, problem-based learning, project work, and resource-based learning [18].

Besides, this technique prioritises problems that require critical and creative thinking. Thus, students can develop abilities to ask questions, investigate, interpret evidence and communicate their results.

The most important skills that enquiry-based learning promotes according to a publication by the Australian Department of Education [23] are:

- Social interaction. This method encourages students to generate their own ideas and debate in group discussions.
- Exploration. This allows students to investigate, design, imagine and explore, therefore developing curiosity and resilience.
- Argumentation and reasoning. It encourages students to generate questions, formulate resolutions and make decisions.
- Positive attitudes to failure. The iterative and evaluative nature of many problems means failure is an essential part of the problem-solving process. A healthy attitude to failure encourages reflection, resilience and continual improvement.

I.2.1.3 Case-based Learning

With case-based teaching, students develop skills in analytical thinking and reflective judgment by reading and discussing complex, real-life scenarios.

Case studies are stories used as a teaching tool. Students must be able to apply theory and contents learned to real situations. Two types of cases exist and should be treated differently: cases can be fact-driven and deductive where there is a correct answer, or they can be context-driven where multiple solutions are possible. Besides, good cases generally are contemporary, create empathy with the main characters, are relevant to the reader, serve a teaching function, and require a dilemma to be solved [24].

I.2.2 Comparison of Learner-centered with Instructor-centered Learning

Over the years, many studies have been developed to test the effectiveness of student-centered techniques versus traditional lecture-based methods. In this section, some studies that compare the results of applying techniques shown above with these of traditional methods will be presented.

Karabulut et al. [1] analysed 30 studies carried out between 2010 and 2015. All of them compared student learning in traditional classrooms with learning in flipped classrooms. The outcome of this article (see Fig.I.2.1) was that 13 studies exclusively reported that students in the flipped classroom outperformed their counterparts in the traditional classrooms. Of these, 7 studies reported the statistical significance of their findings. In others, the authors reported an increase in average scores, but did not report a statistical analysis investigating the significance of the observed difference.

To see if there was any difference between student performance in flipped and traditional formats, an analysis of variance was performed based on the mean scores reported in 25 studies. The results indicated that the mean score for the flipped method was higher than for the traditional format. Although, this difference only was statistically significant when they controlled for the author as a clustering effect. That is to say, they took into account whether the studies analysed were from the same author since a person could tend to give similar outcomes in different investigations.

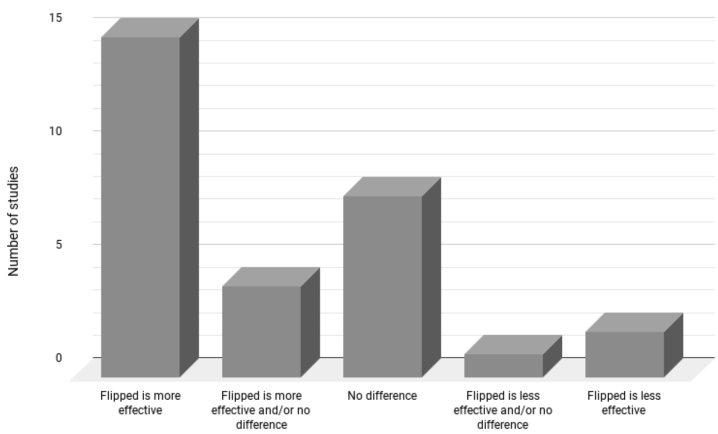

Figure I.2.1: Findings of articles comparing flipped approach to traditional approach. Source: [1]

The results of this synthesis indicated that flipped-learning provided various benefits and challenges for students and instructors. As said before, the benefits can be listed as flexibility, improvement in interaction, professional skills, and student engagement. On the other hand, as with any new approach, flipped-learning brings some challenges for instructors and students. The biggest challenge for instructors was the heavy workload prior to and during class. Converting a course from a traditional teaching approach to a flipped format required a reasonable amount of front-end investment from faculty members. Moreover, challenges for students included uninteresting material, technical issues and insufficient knowledge about the new topic. Other researchers found that students could easily skip some of the materials in this methodology. Finally, student resistance was another challenge that flipped-learning instructors faced as they felt overwhelmed when faced with a new approach that require them to actively participate in the learning process. Hence, they might opine that they were not being taught; rather, they taught themselves.

Similar conclusions are shown in other studies. For instance, Summerlee and Murray [2] reported qualitative findings demonstrating that students who attended an enquiry-based course in a first year seminar program had greater confidence in their academic abilities, were more engaged and were better prepared for upper year courses. Besides, they presented results to expose that these students not only feel more confident about their knowledge but also do perform at a significantly higher level compared with members of the control group who did not experience this kind of teaching method. These results are presented in Fig.I.2.2, which shows the average grades of 3 different control groups of students in all semesters.

In this study, it is notable that the students having an enquiry-based learning have a trend to have higher average grades over the semesters compared with the other groups. Moreover, by graduation, the difference between these groups had increased to an average of 8.9 per cent grade points.

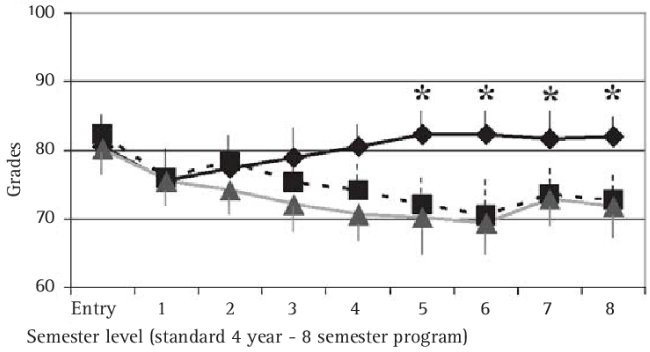

Figure I.2.2: Average grade in all courses completed. Students taking classes using enquiry-based learning are indicated with black diamonds, students taking seminars taught in a traditional way are indicated with black squares and students having standard didactic lectures are indicated with gray triangles. The mean and standard error of the mean are shown for each group. Source: [2]

Furthermore, in this article, they studied changes in resource-seeking patterns of the enquiry-based learning group. They developed a more sophisticated research repertoire including consulting scholarly articles, specialized websites of research institutions, general and specific encyclopedias, and online data-bases. A comparison of sources consulted before and after the course appears in Fig.I.2.3. Students appear to have developed more independent research capability and confidence since they relied less on family, friends, professors, and teachers. Moreover, they reported a significant increase in the frequency with which they consulted reference librarians to help to identify appropriate sources. Hence, there was a clear shift in the behaviour of students.

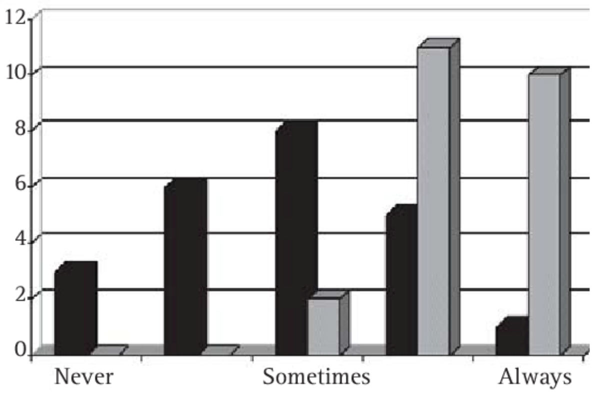

Figure I.2.3: The impact of an enquiry-based course on access to original scholarly articles. The responses of students before the course indicating how often they accessed journal articles in preparing to write an essay or make a presentation is shown in black. The response at the end of the course is shown in grey. Source: [2]

Also, Khalid and Azheem [3] presented similar results in one of their studies. They compared the grades of two different groups at the beginning and after the course. The control group took traditional lectures while the experiment group received instruction through student-centered approaches. Finally, in Fig.I.2.4 significant improvements can be witnessed in the results of the second group with respect to these of the control group.

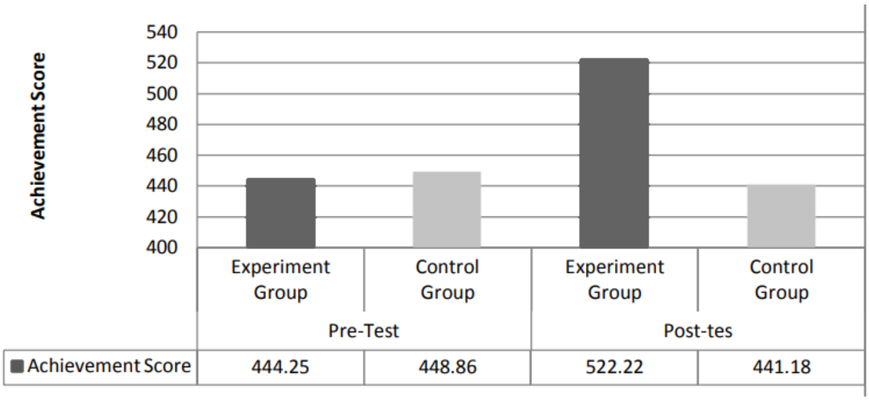

Figure I.2.4: Comparision of control and experimental groups in achievement score on pre-test and post-test. Source: [3]

In conclusion, according to different recent studies, learner-focused teaching seems to have more benefits for students than traditional models. When constructivist methods were used, students achieved higher confidence in themselves and were more engaged in the subject. Because of this engagement, students developed more autonomous and sophisticated research skills over the course. Besides, they obtained higher average grades in comparison with students that took traditional courses.

· CHAPTER I.3 ·

Active Learning

As justified before, modern teaching methods are the best system to meet the demands of today. Since times have changed, learners require different techniques to acquire knowledge which provide them not only with theoretical education but also with practical knowledge, new skills and the ability to face any kind of challenges.

Therefore, active learning has to be taken into account since it is another important learner-based technique. Besides, it can be applied in all teaching methods in order to increase student attention and engagement with classes. In a report by Felder and Brent [25], active learning is defined as *a method which consists of short course-related individual or small-group activities that all students in a class are called upon to do, alternating with instructor-led intervals in which student responses are processed and new information is presented.*

Active learning is demonstrated to increase student performance in science, engineering and mathematics. For example, in a study by Freeman et al. [4], a decrease in the failure rate in the same course, under active learning versus traditional lecturing was proved. Their results are shown in Fig.I.3.1. This study is a comprehensive meta-analysis of 225 science, engineering and mathematics education studies and states that active learning can significantly increase course grades over didactic methods and is particularly effective in small classes of 50 students or fewer. In their analysis, students in courses without active learning were 1.5 times more likely to fail the course than students in courses with active learning.

Moreover, Barnes [5] suggests that active learning contributes to a better understanding of topics and proposes the learning structure in Fig.I.3.2. This structure supports that doing, analyzing and applying are better for remembering and learning new information than just reading or listening about a topic.

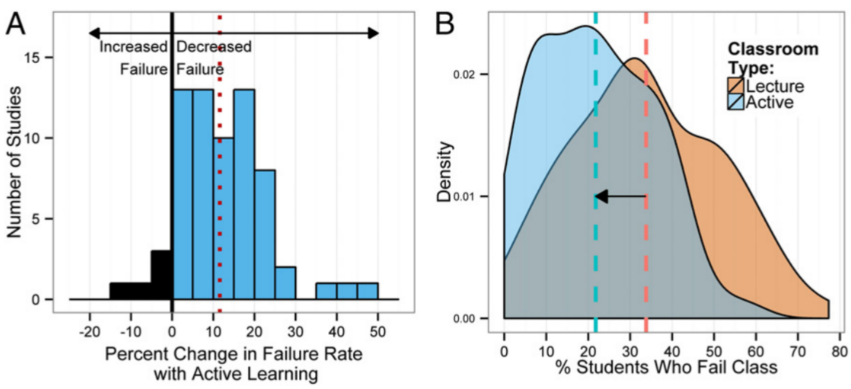

Figure I.3.1: Changes in failure rate in active learning vs traditional learning classrooms. (A) Data plotted as percent change in failure rate in the same course, under active learning versus lecturing. The mean change (12%) is indicated by the dashed vertical line. (B) Density plots of failure rates under active learning and under lecturing. The mean failure rates under each classroom type (21.8% and 33.8%) are shown by dashed vertical lines. Source: [4]

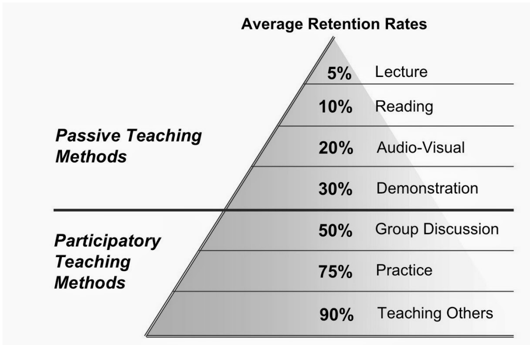

Figure I.3.2: Active learning in front of passive learning structure by Barnes. Source: [5, 6]

To conclude, the main advantages of active learning are:

- It is more interactive and students are not just passive listeners. The interest of students is maintained through animations, videos and also through participatory activities in class.
- Learning-by-doing allows the memorization of concepts more quickly and for a longer retention period than reading.
- It improves collaboration skills. Instead of simply listening to an instructor lecture, this type of learning encourages collaboration and social interaction to learn and solve problems.
- It promotes creativity and innovation. Because of the need for everyone's commitment and collaboration, learners are encouraged to use their imagination and broaden their creativity to make a great contribution in class. Active learning also broadens their perspectives as they have to debate other students' opinions.

CHAPTER I.4

Teaching Methods Chosen for the Course

For all the reasons presented above, this course will follow constructivist principles to engage students. Moreover, following these models, they will learn how to apply the Ethics knowledge they will acquire in real cases. It is important that students achieve this skill as the main purpose of this course is for engineers to be able to analyze and solve future problems taking into account the basis of ethical theory.

Every class will be different, although they will follow a similar structure, shown in Fig.I.4.1. First of all, flipped classroom methodology will be used in this course. Before a class, the main topics of the lecture will made available on Atenea so students can become familiar with the syllabus and then class activities can be carried out in a more dynamic way. Besides, sometimes students will have to complement this material by consulting other sources. Hence, they also will develop their research capability. Finally, student preparation before the session may be evaluated, either before the class through Atenea or at the beginning of it using participatory activities.

In the class, all the supplementary theory needed will be exposed by the teacher. During these lectures, principles of active learning will be applied and some activities will be performed in order to encourage students to follow the class and understand the theory.

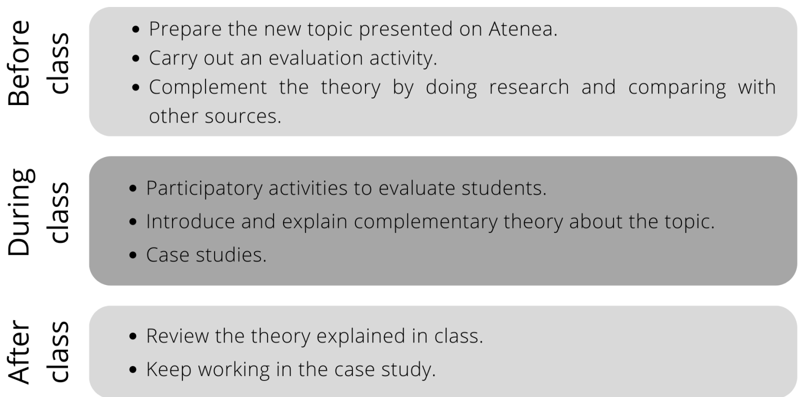

Figure I.4.1: Scheme of a session structure of this course.

Then, as said before, study cases will be developed in some classes and students must be able to know how to apply the theoretical knowledge to provide solutions to these real situations. The cases introduced in class not only will belong to aerospace industry or a closely-related sector but also will be related with the ethical topic developed in each session.

I.4.1 Addressing Disadvantages of Active Learning

To handle the potential disadvantages of active learning some measures proposed by the University of Minnesota [26] will be taken into account.

To prevent students from resisting to participate in activities:

- The concept of active learning and its benefits will be introduced in the first session and students will be told that they are expected to actively participate.

- Active learning techniques will be used in all sessions and they will be varied.
- Clear instructions will be given in the proposed activities.
- Start with short and simple activities. As students gain experience, these activities may be more elaborate.

To ensure activities do not take too much time:

- Learning objectives will be considered carefully so non-essential content may be removed.
- The content that students will be able to cover outside of class by themselves will be taken into account so it will not be incorporated in class activities.

Part II
Ethics

In this second part of the project, the selected topics for the course are thoroughly studied. Additionally, a detailed guide is developed for each case study included in the course.

These topics are divided in two different modules:

1. Introductory module and the main elements of the ethical cycle.
   (a) Unit 1: The Responsibilities of Engineers.
   (b) Unit 2: Codes of Conduct.
   (c) Unit 3: Normative Ethics.
   (d) Unit 4: Normative Argumentation.
   (e) Unit 5: The Ethical Cycle.
2. Specific ethical issues in engineering and technology.
   (a) Unit 6: Ethical Questions in the Design of Technology.
   (b) Unit 7: Ethical Aspects of Technological Risks.
   (c) Unit 8: Distribution of Responsibility.

· CHAPTER II.1 ·

The Responsibilities of Engineers

Responsibility is a fundamental value in engineering ethics that emphasises accountability and reliability in decision-making and actions. In the engineering profession, ethical responsibility involves being responsible for one's work, the safety and well-being of the community, and the impact of one's actions on the environment. The concept of responsibility also involves having a duty to act with integrity, honesty, and transparency. The importance of this value cannot be overstated as it plays a crucial role in ensuring that engineers meet the highest ethical standards and maintain the trust and confidence of society.

This chapter will explore the concept of responsibility through the following topics:

- Differences between passive and active responsibility.
- Conditions of blameworthiness.
- Conflict between professional responsibility and responsibility as an employee.
    - How to deal with the issues arising from this conflict: separatism, technocracy, and whistle-blowing.

References

All the information presented in this chapter is based on the following references unless otherwise specified:

- Poel (2011) *Ethics, Technology and Engineering: an Introduction*, Wiley-Blackwell [14]
- Hoppe (2011) *Ethical Issues in Aviation*, Routledge [27]

Definitions of Key Concepts

There are some terms that need to be understood beforehand for the proper comprehension of this chapter. These terms are as follows:

- **Moral responsibility**: It concerns the extent to which a person believes that another individual or group is blameworthy and ought to be accountable for violating standards of conduct by either behaving in an unacceptable manner or failing to behave in an acceptable manner [28].
- **Causal responsibility**: It is the kind of responsibility that derives exclusively from the fact that an agent brought about a certain state of affairs, no matter their intentions or beliefs [29].

II.1.1 What is Responsibility?

An intrinsic part of human moral practices and interpersonal relationships is to make judgments about whether someone is morally responsible for their behaviour.

Responsibility means being held accountable for one's actions and for the effects of these actions. Some types of actions are the making of choices, the taking of decisions but also failing to act. Responsibility is often linked to the role that someone has in a particular situation. People often have to fulfil a number of roles simultaneously such as those of friend, parent, citizen, employee, engineer, and so on. Each role brings with it certain responsibilities. For example, a friend is supposed to give support in both good and bad times, or a parent is expected to care for their child. In the role of employee it is expected that people will execute their job properly. Moreover, an engineer is expected to perform their work in a competent way. Thus, the professional responsibility of an engineer is based on the role of professional engineer as long as it remains within the limits of what is morally permissible.

On the other hand, moral responsibility should be distinguished from causal responsibility. It is often fairly clear that a person is causally responsible for some outcome. However, the capacities required for moral responsibility are not the same as an agent's causal powers. Due to this fact, moral responsibility cannot be assumed from an assignment of causal responsibility. For example, if someone causes an explosion by flipping a switch but they had no reason to expect such a consequence from flipping the switch. Although they can be said to have causal responsibility in this example, their moral responsibility and their blameworthiness might be questioned [30].

There are different kinds of responsibility that can be distinguished. A common distinction is between active responsibility and passive responsibility.

- **Active responsibility** is responsibility before something has happened. It requires individuals to act proactively instead of just reacting to situations. This means being aware of what needs to be done and taking the initiative to make it happen. It is also important for teams and organizations to function effectively, as everyone needs to take active responsibility for their roles and tasks in order to meet common goals and achieve success.
- **Passive responsibility** is applicable after something undesirable has happened. This type of responsibility is often associated with negligence. The person who is held responsible of an action must be able to provide an account of why a particular course of action and certain decisions were followed. This type of passive responsibility is also called *accountability.* Passive responsibility usually involves not just accountability but also blameworthiness.

II.1.2 Conditions of Blameworthiness

Commonly, philosophers declare two necessary and sufficient conditions for a person to be morally responsible for an action: a control condition, also called freedom condition, and an epistemic condition, also called knowledge, cognitive, or mental condition. The control condition is about whether the person possessed an adequate degree of control or freedom in performing the action, whereas the epistemic condition is concerned with whether the agent's cognitive state was such that they can properly be accountable for their actions. That is to say, while the first condition can be considered asking if this person was acting freely when they did this action, the second condition induces to ask if they were aware of what they were doing and its consequences [31].

On the other hand, in the business world four conditions need to be applied in order to blame someone for the consequences of their actions or their actions themselves.

1. **Wrong-doing**: In order to blame an individual or an institution, some norm must have been violated or something wrong has to be done. This can be a legal or moral norm, or that is common in the organisation.
2. **Causal contribution**: The person who is held responsible must have made a causal contribution to the consequences for which they are blamed. Not only an action but also a failure to act may be considered a causal contribution.
3. **Foreseeability**: Whoever is held responsible for something must have been able to know the consequences of their actions would result in violating a rule. That means that someone cannot be held responsible when the consequences of their actions were totally unexpected.
4. **Freedom of action**: The blamed person must have had freedom of action. That is, they must not have acted under compulsion. Individuals are either not responsible or responsible to a lesser degree if they are, for

instance, coerced to take certain actions. Hence, the debate is what exactly counts as coercion. For example, someone can be manipulated to work on the development of some project under the threat that if they do not cooperate their chances of promotion will not exist. In this case, this person is not coerced to work on the project so they can still act differently. Although this person remains responsible for their actions their responsibility could be said to be smaller than in the case where they had freely chosen to be involved in the project.

II.1.3 Handling Professional Responsibility and Responsibility as Employee

Above, questions of responsibility when something has gone wrong have been considered. However, responsibility is also something that comes into play beforehand, if nothing has yet gone wrong. This has been termed active responsibility. When someone is actively responsible for something they are expected to act in such a way that undesirable consequences are avoided as much as possible and so that beneficial consequences are realised. Therefore, this kind of responsibility is not only about preventing the negative effects of technology but also about realising certain positive outcomes.

Mark Bovens, who is a professor of public administration at Utrecht University since 2000 and a member of the Scientific Council for Government Policy since 2013, suggests the following features of active responsibility [14, page 13]:

1. Adequate perception of threatened violations of norms.
2. Consideration of the consequences.
3. Autonomy. That is to say, the ability to make one's own independent moral decisions.
4. Display conduct that is based on a valid and consistent code.
5. Taking role obligations seriously.

As said before, since a person has different roles in life, their role responsibilities are different. Thus, one role may have responsibilities that conflict with the responsibilities associated with another role. So there are cases where professional responsibility as engineer may conflict with the responsibility as an employee.

In consequence, three models of dealing with this potential engineer-manager discord are separatism, technocracy and whistle-blowing.

II.1.3.1 Separatism

Separatism is the notion that scientists and engineers should apply the technical inputs, but appropriate management and political organs should make the value decisions. It implies that the professional responsibility of engineers is restricted to engineering matters and all decisions are made by managers and politicians. Therefore, according to this view the formulation of the design assignment and the way in which the technology is used and its consequences are not considered to be part of the responsibility of engineers.

The disadvantage of this model is that engineers may end serving immoral goals and lose sight of the engineering ideal of public welfare.

II.1.3.2 Technocracy

Technocracy proposes that engineers should appropriate the role of managers of companies and that of politicians. Thus, this proposal would lead to the establishment of a technocracy, that is, government by experts. According to this model, engineers would be those who make decisions depending on what they consider best for a company or for society. But the role of technocrats is questionable for different reasons.

First of all, it is not clear that engineers could claim to the role of technocrats legitimately. Engineers do have specific technological knowledge but when it comes to the goals that should be pursued by a company or the acceptable levels of risks they are not more valid than others.

A second objection to technocracy is that it is undemocratic and paternalistic since the decision-making is made on someone else's behalf on the assumption that one knows better what is good for them than they know themselves.

II.1.3.3 Whistle-blowing

Whistle-blowing can be defined as the voluntary and intentional release of non-public information into the public domain, as a moral protest, by a member of an organisation about illegal or immoral conduct in the organisation that is opposed in some significant way to the large public interest. This conduct not only includes the endangerment of public health, safety or the environment but also intolerable offences, violation of the law and of legislation, deception of the public or the government, corruption, fraud, and so on. Thus, whistle-blowers act to raise concerns about suspected impropriety within their place of employment, in good faith and in the public interest. The goal is to try to alert people to pay attention to what is happening or is about to happen, and to take action immediately.

The decision to whistle-blow on a colleague, an employer, or a company is never an easy one and unless there is a legal obligation to report, it should be considered as an option only when all else has failed. This is due to the fact that whistle-blowing may well lead to conflicts with the employer. In fact, whistle-blowers often suffer negative consequences including not only the possibility of losing their job but also the very difficult task of getting hired again. Moreover, whistle-blowing becomes more complicated to carry out because since childhood people are told that being a tattletale is wrong.

In this way, since whistle-blowers may be exposed to charges of disloyalty, disciplinary action, freezes in job status, forced relocation, and even dismissal, it is reasonable to consider the extent to which it will endanger one's well-being. So, to what extent will rational self-interest override moral obligations? The possibility of many people getting hurt if an employee has an excuse to refuse to whistle-blow should be taken into consideration.

On the other hand, a study concluded in 2004 of whistle-blowers in the US [27, page 75] found that:

- 100 percent were fired and most were not able to find new jobs.
- 90 percent reported emotional stress, depression, and anxiety.
- 80 percent suffered physical deterioration.
- 54 percent were harassed by peers at work.
- 17 percent lost their homes.
- 15 percent were subsequently divorced.
- 10 percent attempted suicide.

Finally, for the cases that whistle-blowing is morally required, business ethicist Richard De George [14, page 24] proposes the following guideline:

1. The organisation to which the would-be whistle-blower belongs will, through its product or policy, do serious and considerable harm to the public (whether to users of its product, to innocent bystanders, or to the public at large).
2. The would-be whistle-blower has identified that threat of harm, reported it to their immediate superior, making clear both the threat itself and the objection to it, and concluded that the superior will do nothing effective.

3. The would-be whistle-blower has exhausted other internal procedures within the organisation (for example, by going up the organisational ladder as far as allowed) – or at least made use of as many internal procedures as the danger to others and their own safety make reasonable.

4. The would-be whistle-blower has (or has accessible) evidence that would convince a reasonable, impartial observer that their view of the threat is correct.

5. The would-be whistle-blower has good reason to believe that revealing the threat will (probably) prevent the harm at reasonable cost (all things considered).

Although whistle-blowing may sometimes be inevitable, it is an unsatisfactory way for dealing with the tension between engineers and managers as it usually forces people to make big sacrifices which may not be legitimate to be expected from an average professional. In second place, the effectiveness of whistle-blowing is often limited because as soon as the whistle is blown the communication between managers and professionals has inevitably been disrupted. So it would be much more effective if at an earlier stage the concerns of the professionals were to be addressed but in a more constructive way. Thus, this demands a role model in which the engineer as professional is not necessarily opposed to the manager so they have to be able to recognise moral questions and discuss them with other parties.

II.1.4 Case Study: The Challenger

This 25th launching of the space shuttle was to be something special. There was, therefore, more media attention than usual on this launching. On the launch morning, when the mission controllers' countdown began it was almost four degrees Celsius below freezing point. And after 73 seconds the Challenger exploded at an altitude of 11 kilometres. All seven astronauts were killed.

After the accident an investigation committee was set up to establish the exact cause of the explosion: they concluded that this disaster was due to the failure of the rubber sealing ring, the O-ring (see Fig.II.1.1 and Fig.II.1.2). This component was unable to function properly at low temperatures, so fuel started to leak from the booster rocket. Then, the fuel caught fire causing the Challenger to explode.

A year before the explosion, Roger Boisjoly, an engineer at the Morton Thiokol company, a NASA supplier responsible for the construction of the Challenger rocket boosters, had aired his doubts about the reliability of the O-rings. In July 1985 he had sent a confidential memo to his company management board. In that memo he had expressed his concerns about the effectiveness of the O-rings at low temperatures:

"I am really afraid that if we do not take immediate steps we will place both the flight and the launching pad in serious danger. The consequences would be catastrophic and human lives would be put at risk."

His memo led to a project group being set up in order to investigate the problem. However, this team received from the management insufficient material and funding to carry out its work properly. Finally, one of the project group managers sent another memo headed *"Help!"* and ended with *"This is a red flag!"*. No concrete actions were actually undertaken.

On the day of the flight the launching was delayed five times for weather-related reasons. The night preceding the launching it froze to minus 10 degrees Celsius. NASA engineers confessed to having heard that it would not be safe to launch at very low temperatures. Therefore, they decided to have a conference on the eve of the launching between NASA and Morton Thiokol representatives, Boisjoly also participated. Morton Thiokol initially recommended that the launch should not be allowed to go ahead since the solid rocket booster joints with the O-rings had never been tested in sub-zero conditions. Moreover, the weather forecast indicated that the temperature would not rise above

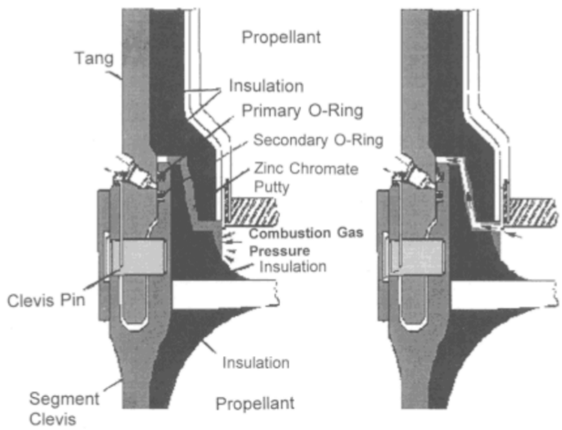

Figure II.1.1: Solid rocket booster joint that failed. The left illustration shows the hot gases (arrows) being shielded from the joint with zinc chromate putty. The right illustration shows what happened. The pressure caused a blowout in the putty, the gases penetrated through to the O-rings, eroding them and causing their failure. Source: [7, page 139]

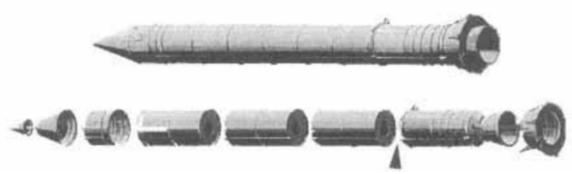

Figure II.1.2: Solid rocket booster assembly. The arrow shows the Challenger point of failure. Source: [7, page 139]

freezing point on the morning of the launch.

The people at NASA claimed that this data did not provide a sufficient argument for them to declare the launching unsafe. Then, a brief consultation session was convened so that the data could once again be checked. While the connection was interrupted a few minutes, the General Manager of Thiokol said that a managerial decision had to be made. Boisjoly felt that people were not listening to his arguments because a possible contract extension with NASA could exist so for Thiokol it was too much of a political and financial risk to postpone the launch. So, the four managers present, the engineers excluded, put this decision to vote. When they were reconnected, Thiokol announced to NASA its positive recommendations concerning the Challenger launching. As agreement had been reached, the whole problem surrounding the inadequate operating of the O-ring at low temperatures was not passed on to NASA's higher management level.

A Presidential Commission determined that the whole disaster was due to inadequate communication at NASA. At the same time, they argued for a change in the system that would ensure transparency and encourage whistle-blowing.

As a consequence, the entire space program was stopped for two years so that the safety of the Shuttle could be improved. Morton Thiokol did not lose its contract with NASA but helped to fix the O-ring problem. Engineers were given more of a say in matters and, in the future, they would be given the power to suspend a flight if they had their doubts.

II.1.4.1 Development of Study Questions

In this section, some questions related with the theory of this chapter and following the case of the Challenger disaster are presented. Also some justifications are developed as a guide for the in-class debate.

Could someone be blamed for the Challenger disaster according to the four conditions of blameworthiness?

1. **Wrong-doing**: NASA could be accused for the violation of the norm that a flight had to be proven to be safe.
2. **Causal contribution**: Since not only an action but also a failure to act may be considered a causal contribution, in the case of the Challenger the failure to stop the launch might be blamed. Therefore, both the NASA project team and the Morton Thiokol management team made a causal contribution to the disaster because both could have postponed the launch.
3. **Foreseeability**: In this case engineer Boisjoly, the Morton Thiokol management team and the NASA representatives could all have expected the Challenger disaster as all three were aware of the risks of erosion when the O-rings were exposed to low temperatures and a safe launching could not be guaranteed under such conditions.
4. **Freedom of action**: The NASA project team was under pressure since the launch had already been postponed several times. Morton Thiokol might also have felt the pressure of NASA because they were interested in further cooperation with NASA and a negative recommendation to launch could have resulted in the termination of their contract. On the other hand, Boisjoly was limited since the only thing he could have possibly done was inform the press but that would have had negative consequences for him and his family. Even though, in all three cases the pressure was probably not strong enough to say that they lacked freedom of action. Nevertheless, the negative consequences expected could be argued to diminish their responsibility, especially in the case of Boisjoly.

Boisjoly had both roles as an employee and as an engineer. What was he expected to do according to each role at the meeting to decide whether the launch was approved?
As an employee he was expected to be loyal to his company and to listen to his superiors, who eventually decided to give the go-ahead to launch.
As an engineer he was expected to give technically sound advice taking into account the possible risks to the astronauts and, in his view, this implied a negative to launch.

If the separatism model or technocracy had been the methodology adopted to manage the Challenger project, had the consequences been different? If they would lead to the same disaster, would the blameworthiness criteria be the same?
According to separatism, as the management team would be who decided whether the launch was approved or not, the same outcome would have occurred. Although, then Boisjoly could not be blamed at all for this case as the role of engineers is restricted to engineering affairs. On the other hand, if they had been organised under technocracy, this launch probably would not had been approved but other bad decisions about management could had been taken since engineers are not necessarily more valid than other professionals, so some other disaster might had occurred.

If Boisjoly had decided to whistle-blow, would he had met the guideline exposed by Richard De George for whistle-blowing?
In this case, criterion 1 is met since the harm of future disasters was serious and considerable. Besides, Boisjoly had reason to believe that reporting his concerns to his superiors would not be enough to bring about required changes, given his past experience. Therefore, criteria 2 and 3 are met. Given the facts of the Challenger disaster, his statement would probably convince an impartial observer that something should be done to solve the O-ring

problems. So criterion 4 is met as well.

On the other hand, taking into account criterion 5, the fact that he had strong evidence for assuming that making this information public would prevent such harms in the future is much more doubtful.

Therefore, it can be concluded that from the point of view of De George's criteria, Boisjoly's whistleblowing was justified but not required [9, pages 86-93].

What consequences could Boisjoly had suffered if he had decided to whistle-blow? Would they had been worth it?
He could had suffered not only social and emotional consequences but also career repercussions. For instance, a lot of whistle-blowers are fired. Some may need to move to another state or another industry to find a job, and they may not find a job at the same level [32].

Whether these consequences are worth it or not depends on the whistle-blower since many of them say that, in spite of the pressure, they still consider they did the correct action by trying to bring about a positive change. Moreover, for many people, the costs and consequences of ignoring illegal activity may be much higher than what they would face by making the issue public.

Extra credit question: Do research into the theory of the justification of whistle-blowing by Michael Davis. According to this theory, did Boisjoly have the obligation of blowing the whistle?
Michael Davis proposed a different theory of the justification of whistle-blowing. He stated that whistle-blower's obligation has to be understood as a need to avoid complicity in wrong-doing rather than from the ability to prevent harm. The complicity theory and the standard theory differ in that the former is solely focused on identifying situations where whistle-blowing is morally necessary, whereas the latter also includes scenarios where whistle-blowing is morally allowed but not required.

David formulates his complicity theory in the following way [33]:

- **C1.** What you will reveal derives from your work for an organisation.
- **C2.** You are a voluntary member of that organisation.
- **C3.** You believe that the organisation, though legitimate, is engaged in a serious wrong.
- **C4.** You believe that your wokr for that organisation will contribute - more or less directly - to the wrong if - but not only if - you do not publicly reveal what you know.
- **C5.** You are justified in beliefs C3 and C4.
- **C6.** Beliefs C3 and C4 are true.

Therefore, the analysis of whether Boisjoly was required to whistle-blow or not according to the complicity theory results in the conclusion that he had an obligation to report his concerns about the O-ring failure to his superiors at Morton Thiokol and NASA. According to Michael Davis' theory of justification for whistle-blowing, Boisjoly had a duty to prevent harm and disclose information about potential risks to others, even if it meant violating loyalty to his employer.

- **C1.** Boisjoly's testimony was mostly based on the information derived from his work on Booster rockets at Thiokol.
- **C2.** Boisjoly was a voluntary member of Thiokol.
- **C3.** He believed Thiokol, a legitimate organisation, was attempting to mislead its client, the government, about the causes of a deadly accident. Attempting to do that certainly seems a serious moral wrong.
- **C4.** The night before the Challenger disaster, Boisjoly stopped objecting to the launch when his bosses refused to listen to him anymore. He also thought that Thiokol would use his silence and the information he had given them to deceive their client.

C5. David found the evidence justifying beliefs C3 and C4 sufficient to justify the belief both that Boisjoly's organisation was engaged in wrong-doing and that his work was implicated.

C6. The evidence now available justifies Boisjoly's belief both about what Thiokol was attempting and about what would have been his part in the attempt. Therefore, his testimony seems to satisfy C6 just as it satisfied the complicity theory's other five conditions.

Do you consider Roger Boisjoly morally responsible for the Challenger disaster?
Overall, the question of Boisjoly's moral responsibility for the Challenger disaster is a difficult one, with both positive and negative reasons to consider. It is likely that different people will have different opinions on the matter, depending on their perspective and values.

Reasons for considering Boisjoly morally responsible for the Challenger disaster might include:

- Boisjoly was a member of the team that designed the O-rings and was aware of their potential safety risks. Thus, he had a professional duty to ensure that the shuttle was safe for launch and to raise any concerns with his superiors.
- Boisjoly did raise concerns about the safety of the O-rings with his superiors, but he did not take a more forceful stance for the launch to be delayed until the O-ring issue was undertaken. Therefore, for some people, Boisjoly could be thought to be complicit in the disaster.

Reasons for considering Boisjoly not morally responsible for the Challenger disaster might include:

- Boisjoly did raise concerns about the safety of the O-rings, but his superiors did not take his warnings seriously and overruled him. In this sense, Boisjoly was not solely responsible for the decision to launch the shuttle, and others who were in positions of greater authority should be held more accountable than Boisjoly.
- Boisjoly could expect to suffer significant personal and professional consequences as a result of his whistle-blowing, including being ignored by his colleagues and losing his job. It could be argued that he acted in a morally responsible way by speaking out, but was not morally obligated to act further because that responsibility now laid on his superiors.

What could NASA and Morton Thiokol management, and Boisjoly have done differently in the Challenger situation?
NASA and Morton Thiokol Management:

- They could have taken Boisjoly's concerns more seriously and conducted a more thorough investigation into the safety of the O-rings before making the go-ahead decision to launch.
- They could have delayed the launch until the O-ring issue was resolved.
- They could have communicated more openly and honestly about the risks involved in the launch.

Boisjoly:

- He could have been more forceful in his objections and pushed harder for the launch to be delayed.
- He could have taken his concerns to higher levels of management or to outside authorities if he felt his concerns were not being adequately addressed.

· CHAPTER II.2 ·

Codes of Conduct

Codes of conduct are a set of rules that members of an organisation or people with a particular job or position must follow.

As stated in the previous chapter, responsibilities as employee and as an engineer can lead to some discords. In order to prevent some of these situations, every organisation should have an official code of conduct. This code has value as both an internal guideline and an external statement of corporate values and commitments [34]. Such guidelines must express the values and norms that should guide behaviour and decision-making inside the organisation. Also, they are often intended as an addition to the requirements of the law.

This chapter will discuss the role of codes of conduct through:

- Importance of codes of conduct.
- Types of codes of conduct for engineers.
  - Conflict of interest and loyalty.
- Limitations of codes of conduct.

References

All the information presented in this chapter is based on the following references unless otherwise specified:

- Poel (2011) *Ethics, Technology and Engineering: an Introduction*, Wiley-Blackwell [14]
- Harris (2018) *Engineering Ethics: Concepts and Cases*, Cengage [9]

II.2.1 The Importance of Codes of Conduct

As said before, a code is a main reference for employees to support day-to-day decision-making plus it encourages discussions of ethics and compliance empowering employees to handle ethical dilemmas.

As well, codes of conduct also serve several external purposes [34]:

- **Compliance**: Some organisations are required to implement codes or clearly explain why they have not. Moreover, from another compliance point of view, if an employee performs illegal activity while at work, a code of conduct provides documentation showing they broke organisation policy.
- **Marketing**: A code presents a public statement of what the organisation stands for and its commitment to high standards and the right conduct.
- **Risk mitigation**: Organisations which have codes of ethics can reduce the financial risks associated with government fines for ethical misconduct by demonstrating they have a guideline to prevent illegal acts.

On the other hand, a Harvard Business Review analysis of 2020 [8] shows that for consumers, shared values with a brand are one of the most significant aspects for choosing or not a corporation. These levels of awareness become more meaningful for younger people as Fig.II.2.1 shows. Even though, generally these preferences are manifested by at least half of people over 55 consulted in the study. Thus, having an accurate and honest code of conduct that reflects the organisation's beliefs can also improve the outcomes of a company as it let customers know who they are supporting.

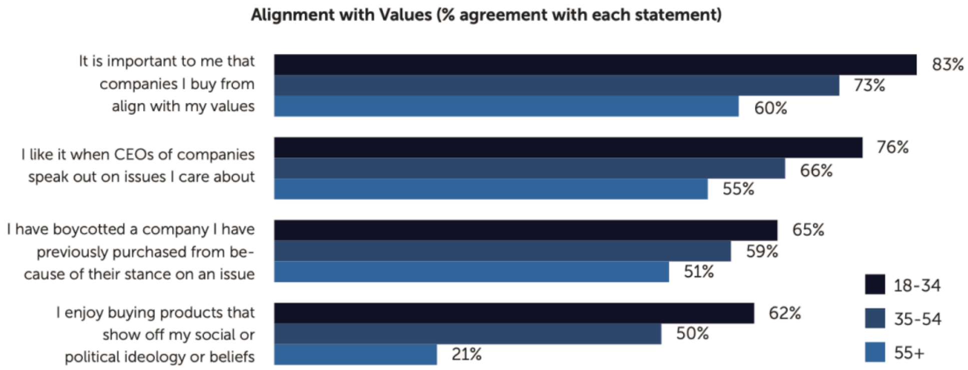

Figure II.2.1: Results of the Harvard Business Review analysis of 2020 which shows the percentage of people, broken down by age, who prefer to have an alignment with a corporation's values. Source: [8]

II.2.2 Codes of Conduct for Engineers

Codes of conduct have a variety of reasons to be implemented in an organisation and depending on their exact objectives, there is a distinction between three types of them:

- An **aspirational code** expresses the moral values of a profession or organisation. Its objective is to express the kind of values the organisation is committed to.
- An **advisory code** has the objective to help individual professionals or employees to apply moral judgements in particular situations on the basis of the more general values and norms of the profession or organisation.
- A **disciplinary code** aims to encourage that the behaviour of all professionals meets certain values and norms.

For engineers, two types of codes of conduct are especially relevant: first, professional codes which are formulated by professional associations of engineers and, second, corporate codes of conduct that are defined by companies in which engineers are employed.

II.2.2.1 Professional and Corporate Codes

Professional codes of conduct are ethical codes that guide the conduct of professionals within their line of work, outlining their ethical obligations, responsibilities, and behaviours while performing their job duties. That is to say, these codes are designed to promote ethical behaviour, ensure the safety of clients and the public, and maintain the integrity of the profession. Professional codes of conduct commonly cover a wide range of topics, including confidentiality, conflict of interest, professional competence, and respect for diversity.

Engineers are expected to follow the codes of conduct established by their respective professional organisations since adherence to these codes is fundamental in order to maintain standards of professionalism and to ensure the well-being of all those impacted by engineering decisions and actions.

There are several professional codes of conduct for engineers, some of the most prominent ones for aerospace engineers are:

- The **National Society of Professional Engineers** (NSPE) in the United States of America: This code outlines six fundamental principles of ethical behaviour for engineers [35]. These standards are the following:
  1. Hold paramount the safety, health, and welfare of the public.
  2. Perform services only in areas of their competence.

3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

- The **Code of Ethics and Conduct of the Royal Aeronautical Society** (RAeS) in the United Kingdom: This society is a professional engineering institution licensed by the Engineering Council. It aims to comply a generic framework of ethics based on integrity, objectivity, accountability, openness, honesty, and leadership [36].
- The **American Institute of Aeronautics and Astronautics Code of Ethics** (AIAA) in the United States of America: This guideline upholds ten high standards of ethical conduct which are also quite similar to those of the previous ones [37].
- The **European Council of Engineers Chambers Code of Conduct** (ECEC): This code sets out seven fundamental principles that engineers should adhere to in their practice, including guides for behaviour towards clients and colleagues, responsibility towards the general public and the environment, and professionalism [38].
- The ***Colegio Oficial de Ingenieros Técnicos Aeronáuticos y Aeroespaciales*** **Deontological Code** (COIAE) in Spain: This document is divided into six parts, which also include general principles and guidelines for behavior towards college, clients, and colleagues [39].

Different professional codes of conduct for aerospace engineers exist to provide specialised guidance and ensure ethical actions. These codes are necessary because aerospace engineers work on projects that involve human safety and security and national defense, which have significant ethical implications. Additionally, different aerospace engineering disciplines may have different ethical considerations and require different approaches to proper decision-making.

On the other hand, corporate codes of conduct outline the principles, values, and standards of behaviour that an organisation expects its employees to follow. These codes are designed to control the business practices and conduct of the organisation, ensuring that employees uphold ethical standards when carrying out their duties. Besides, these in aerospace engineering may cover a range of topics, such as conflicts of interest, confidentiality, compliance with laws and regulations, health and safety, and respect for human rights and the environment.

Therefore, the main difference between professional and corporate codes of conduct is that the former applies to individuals within a specific profession, while the latter is applicable to an entire organisation.

II.2.2.2 Conflicts of Interest and Loyalty

All professional codes require professionals to work with honesty, competence, and integrity. This means that practitioners must be well-educated and skilled in their profession. They should also keep up to date with the latest developments in their field and only take on work within their area of expertise. Honesty, faithfulness, and truthfulness are also important in professional practice. This means that facts should not be manipulated, and agreements must be kept. Engineers should avoid conflicts of interest, which occur when their interests differ with their obligations to their employer or clients. Conflicts of interest can affect professional judgement and trustworthiness, so it is better to avoid them. If they are unavoidable, they should be disclosed to the relevant parties. An example of a conflict of interest in the aerospace engineering field could be an engineer who works for an organisation that produces aircraft. If that engineer is tasked with designing a new aircraft model and is told that they will receive a bonus or promotion only if the new design is profitable for the company or completed within a certain amount of time, they may have a conflict of interest. In this case, the engineer may prioritize designing a model that will be more profitable for the company, even if it compromises the safety or effectiveness of the aircraft. This conflict of interest could compromise the engineer's professional judgment and lead to unethical behaviour.

On the other hand, the notion of loyalty in codes of conduct for engineers requires clarification and interpretation. The NSPE code of conduct expects engineers to be loyal to their employer or client. However, there is a difference between critical and uncritical loyalty. Uncritical loyalty means prioritizing the interests of the employer above all else, which can be misguided. Critical loyalty involves considering the employer's interests while balancing personal and professional ethics. This is especially important in cases where public safety is at risk.

II.2.3 Limitations of Codes of Conduct

When evaluating objections to codes of conduct, it is important to consider that different codes may have different intentions. This is particularly relevant for aspirational, advisory, and disciplinary codes. For instance, criticisms of disciplinary codes may not apply to advisory codes, and vice versa. The objections mentioned below reveal some limitations of codes of conduct. However, these objections are not powerful enough to suggest that codes of conduct are undesirable. The effectiveness of a code largely depends on how it is written and executed.

II.2.3.1 Self-interest

Codes of conduct are a type of self-regulation that sometimes can be created for self-interest, like to improve one's image or avoid government regulation. This is not a problem as long as the code is ethical and followed. To ensure this, it is important to involve different stakeholders in creating and implementing the code.

If a code only serves the interests of an organisation or profession, it can be considered window-dressing, which means that the code creates a good impression for the public but does not reflect the behaviour of the organisation or its employees. Aspirational codes are more likely to be window-dressing because they tend to be too general and vague.

II.2.3.2 Potential Contradictions

Another issue with codes of conduct is their vagueness. The language used in these codes can be open to interpretation, making it difficult to know exactly what is expected of engineers. For example, codes of conduct often require engineers to act with ”integrity” or ”professionalism,” but these terms are not always clearly defined. As a result, it can be challenging for engineers to know whether they are acting ethically or not.

Some other potential problem with codes of conduct is that they can sometimes contain contradictory statements. For example, a code of conduct may require engineers to prioritise the safety of the public, but it may also require them to prioritise the interests of their employer. In cases where these two objectives conflict, it can be challenging for engineers to know which one to prioritise. Also, discrepancies between different codes (e.g. NSPE, RAeS, AIAA, and so on) can exist.

Organisations can deal with potential contradictions in codes of conduct by clearly defining terms and providing detailed examples, acknowledging and addressing potential conflicts, plus regularly reviewing and updating the code to ensure it is effective.

II.2.3.3 The Challenge of Codification

Some authors argue that ethics cannot be written down in a code of conduct because it requires individual moral judgement, then blindly following a code conflicts with moral behaviour which requires autonomous decisions. As said before, this does not mean that codes of conduct are objectionable but blindly following them without any critical thinking is undesirable. However, an advisory code can still be useful without taking away people's moral autonomy.

A second argument is that codes of conduct are not morally binding. Even if one rejects the view that codes of conduct entail a contract, one can still argue that they express existing moral responsibilities and obligations. This means that a code of conduct cannot create new moral obligations beyond what was already morally required. Nonetheless, a code can still be useful in reminding people of their moral obligations and responsibilities.

The third argument against codes of conduct is that they assume that morality can be expressed through universal moral rules. This argument is questionable because engineering is too diverse in terms of disciplines and activities for one code to apply. However, having a variety of codes of conduct and taking into account moral judgement always requires taking into account the particularities of a situation that can address this objection. Therefore, codes of conduct always require interpretation in particular situations.

II.2.3.4 Implementation of Codes of Conduct

The challenge with codes of conduct is that they may include provisions that are difficult or even impossible to follow in real-life situations. Professional codes, for example, can require actions that go against the interests of an employer. Similarly, professional codes may ask engineers to inform the public about the safety, health, or welfare concerns of a project. However, this can conflict with the confidentiality duties imposed on engineers by law. If engineers reveal this information outside their organisation, they may be blowing the whistle and their employer may take legal action against them.

Employees who blow the whistle are often in a legally vulnerable position. Most countries have laws that impose confidentiality obligations on employees or allow employers to order employees to keep certain information confidential. These laws are intended to protect companies' competitive positions and prevent employees from causing disproportionate harm by making certain information public. Breaching confidentiality obligations can lead to dismissal in some countries. In the US and the EU, however, employees can be dismissed at any time, but they can sue the organisation if they believe they were unfairly dismissed.

II.2.3.4.1 How to Protect Whistle-blowers

In some countries such as the US and the UK, legal protections for whistle-blowers have been established. In the US, the Sarbanes-Oxley Act of 2002 requires companies to have internal whistle-blowing policies for accounting and auditing, and can extend to other areas covered by the organisation's code of conduct. In the UK, the Public Interest Disclosure Act of 1998 protects both internal and external whistle-blowers from retaliation, and also the Combined Code on Corporate Governance of 2003 encourages companies to have whistle blowing policies [14, page 51].

On the other hand, nowadays the European Commission is taking legal action against several countries for not following a law that protects whistle-blowers who report wrong-doing, Directive (EU) 2019/1937 of the European Parliament and of the Council of 23 October 2019 [40]. The law requires countries to create safe and confidential channels for whistle-blowers to report illegal activity and protects them from retaliation. Moreover, this law applies to both public and private sectors [41].

In the case of Spain, Law 2/2023 of 20th February 2023 [42] aims to protect citizens who report regulatory violations and corruption in the workplace, incorporating into Spanish law Directive (EU) 2019/1937. This legislation requires that private enterprises with 50 or more employees must implement an internal reporting system before 1st December 2023. According to the law, companies are obligated to offer clear and accessible information of the internal reporting channel, safeguard the confidentiality of reports, and maintain a private record of both the reports received and internal investigations. In addition, the presumption of innocence and protection of the identity of affected persons are guaranteed. The sanctioning regime establishes fines of up to 300,000€ for individuals and up to 1,000,000€ for legal entities in cases of reported corruption.

II.2.3.5 Enforcement

Professional codes are often not enforced due to their advisory nature, with enforcement not being a key objective. Besides, professional codes lack legal status. Thus, enforcement of codes is limited due to the inability of professional associations to exercise sanctions, with the most severe being loss of membership. This is ineffective in most countries as membership of professional associations is voluntary and not a requirement to practise as an engineer.

The enforcement of corporate codes is more common than in the case of professional codes, even though they lack legal status. Companies usually have more influence on the daily practices of individual engineers which offer better possibilities for enforcement. They can fire engineers if in infringement of the code of conduct. External auditing is also becoming increasingly popular and is done by external organisations as it increases the credibility and image of the organisation. Even if corporate codes are not enforced, they offer better possibilities for stimulating responsible behaviour than many professional codes because external parties can criticise an organisation for not living by its own code of conduct, and companies are often more sensitive to external criticism than professional associations are.

II.2.4 Development of the Class Activity

Proposal of Morton Thiokol's code of conduct which could have prevented the Challenger disaster and study of its limitations and how to deal with them.

The code of conduct should address the following issues:

1. Safety should be the top priority in all decision-making processes.
2. Employees should be encouraged to speak up if they have any concerns about safety.
3. All decisions should be based on scientific evidence and data.
4. There should be a clear communication process between different departments and stakeholders.
5. Ethical principles such as honesty, integrity, and responsibility should be integrated into the organisation culture.

The limitations could include:

1. The difficulty of balancing safety concerns with cost and time constraints.
2. The potential for conflicts of interest among different departments and stakeholders.
3. The possibility of employees feeling pressured to prioritize organisation goals over safety concerns.

How to deal with the limitations:

1. Implementing regular safety training and education programs to emphasise the importance of safety and provide employees with the knowledge and skills to identify potential safety issues.
2. Establishing an independent safety committee to review and evaluate all decisions related to safety.
3. Encouraging open communication and feedback from all stakeholders to promote transparency and accountability and creating a culture of ethical awareness and responsibility.

· CHAPTER II.3 ·

Normative Ethics

Different ethical theories developed by various philosophers are a mechanism to organise human thinking and to develop a coherent and admissible basis for dealing with moral issues. That is to say, ethical theories provide arguments and reasons for moral judgements.

In this chapter, the main concepts of normative ethics will be reviewed:

- The importance of ethical methods.
- Different fundamental concepts about ethics.
  - Ethics and morality.
  - Descriptive and normative ethics.
  - Values, norms and virtues.
- Primary ethical theories: utilitarianism, kantianism, virtue ethics, and care ethics.

References

All the information presented in this chapter is based on the following references unless otherwise specified:

- Poel (2011) *Ethics, Technology and Engineering: an Introduction*, Wiley-Blackwell [14]
- Hoppe (2011) *Ethical Issues in Aviation*, Routledge [27]
- Harris (2018) *Engineering Ethics: Concepts and Cases*, Cengage [9]

II.3.1 The Importance of Ethical Methods

Ethical approaches are necessary since they are needed to supplement codes of conduct in order to address many issues in engineering ethics. These methods can be thought of as analogous to tools in a toolbox. For some tasks a given method is appropriate, for others, a different method must be applied.

For example, a conflict between the safety and well-being of the public was illustrated when in 1993, it was publicly revealed that Germany's Heidelberg University had used more than 200 cadavers, including those of children, in automobile crash tests in the past. This discovery drew immediate protests in the country. In reply, the university stated that relatives granted permission in every case, as required by German law and that this practice had been stopped in 1989. Besides, the statement claimed that such tests had been used to save many lives. Moreover, similar testing has also been conducted in the US.

Therefore, as said before, this case exemplifies how technology raises important moral and social matters. The conflict in this case can be enhanced by the use of cadavers and concerns about the dignity of the cadaver and cannot be resolved through professional codes of conduct. For example, NSPE's first Fundamental Canon states that engineers must hold paramount the safety, health and welfare of the public but it does not imply that cadavers should not be used for testing or that the consideration of human dignity - rarely mentioned in engineering codes - overrides considerations of health, welfare, and safety. Thus, to address this case, ethical resources are required.

II.3.2 Fundamental Concepts about Ethics

II.3.2.1 Ethics and Morality

In contemporary literature, the term *ethics* is commonly used to refer to reflective and theoretical perspectives of right and wrong, which is also known as *moral philosophy* according to dictionaries. Additionally, it is often used to refer to the system or code of morals practiced by a particular person, group, or profession. In contrast, the term *morality* is generally used to refer to the actual principles of conduct practiced by individuals or groups of individuals [7, page 3]. This is consistent with the definition of morality as the set of norms and values that exist in society. Ethics is not a guidebook with definite answers, but rather a process of examining questions and arguments related to moral choices that individuals can make. Ethics is a process of searching for the right kind of morality.

II.3.2.2 Descriptive and Normative Ethics

The study of ethics can take two forms: descriptive or prescriptive. Descriptive ethics is concerned with describing the existing morality, including customs, habits, opinions, and acceptable behavior within certain subcultures or historical periods. Prescriptive or normative ethics goes further by judging morality, evaluating whether the norms and values used align with the ideas of proper behavior. This type of ethics is not value-free, and it considers the question of whether actual norms and values conform to people's expectations. That is to say, the main question in normative ethics is "what is a right opinion, decision, or action?". It does not provide a definitive answer, but instead offers arguments based on various ethical theories. These theories serve as a basis for critical discussion of moral issues.

II.3.2.3 Values, Norms and Virtues

Values, norms, and virtues are the points of departure, respectively, for three of the primary normative theories, utilitarianism, kantianism and virtue ethics.

Values are used to determine what goals or states of affairs are considered valuable. Moral values are specifically connected to the idea of leading a good life and creating a just society. They are separate from individual preferences or interests. These values are considered long-lasting convictions that are worth pursuing not only for oneself but for society as a whole. There are two types of values: intrinsic and instrumental. Intrinsic values are an end in themselves, while instrumental values are a means to achieving intrinsic values. For example, money may be an intrinsic value for some people while for others it is an instrumental value used to achieve a higher end such as helping the poor. Moreover, it is possible for a person to consider something, such as their work, to have both intrinsic and instrumental value.

Norms are rules that prescribe what actions are required, permitted or forbidden. These rules and agreements dictate how people should treat each other and are often based on values. Moral norms provide indications for responsible action, and there are also other types of norms such as legal norms, precepts of decorum, and rules of play. Certain moral norms have been turned into laws, such as "thou shalt not kill" and "thou shalt not steal". Therefore, the difference between values and norms can be described as follows. Values refer to abstract or general objectives that people aim to achieve through their actions, while norms are concrete rules that limit actions and are used as a means to realize those values.

Virtues are human characteristics or qualities that have the following five features according to the philosopher Alasdair MacIntyre:

1. They are desired characteristics and they express a value that is worth striving for.
2. They are expressed in action.

3. They are lasting and permanent – they form a lasting structural foundation for action.
4. They are always present, but are only used when necessary.
5. They can be influenced by the individual.

According to the last statement, individuals have the ability to acquire virtues through the formation of their character or personality, which takes place during their upbringing or training in an institution. Some examples of virtues include loyalty, honesty, courage, creativity, humor, and justice. Furthermore, moral virtues, also known as character virtues, can be distinguished from intellectual virtues. The latter prioritize knowledge and abilities while moral virtues refer to the positive traits that individuals possess, which make them good people.

II.3.3 Primary Ethical Theories

There are numerous ethical theories, each with their own set of principles and values. In this chapter, a brief overview of some of the most prominent ethical theories is provided, including utilitarianism, deontology, virtue ethics, and care ethics. However, it is worth noting that ethical theories are diverse, and people may adopt a combination of principles from different theories or develop their own personal ethical framework. Moreover, the importance of particular ethical theories can vary depending on the field, culture, and context in which they are applied.

On the other hand, the importance of knowing different ethical theories lies in the fact that if the same problem is analysed and the same conclusion is reached through all methodologies, it can be said that an ethical solution to this problem exists.

II.3.3.1 Utilitarianism

Consequentialism is a moral theory in which the consequences of actions determine whether an action is morally right or wrong. Utilitarianism is a type of consequentialism that focuses on the measurement of consequences against the value of human pleasure, happiness or welfare.

This model aims to maximize overall well-being, where the population over which well-being is maximized is referred to as the *audience*. The audience could ideally include all humans or even animals that can experience pain or pleasure. However, calculating which actions produce the most good for such a large audience can be challenging. Then, to implement utilitarianism, it is essential to determine the audience and choose the action that produces the most good in both the short and long term.

Hence, utilitarianism is a moral philosophy that states that the best action is the one that maximizes overall happiness for the largest number of audience. This principle provides the only and sufficient reason for any moral action, both for individuals and groups. Jeremy Bentham, the founder of utilitarianism, believed that the expected pleasure or pain resulting from an action can be calculated quantitatively. So, utilitarianism requires weighing the costs and benefits of each possible action to determine the one that provides the best results - the most pleasure and, therefore, the most utility. According to Bentham, money can even be used to express the quantities of pleasure or pain, as these experiences can be bought and sold.

In conclusion, the main idea behind utilitarianism is: an action is morally right if it results in pleasure, and it is morally wrong if it gives rise to pain.

II.3.3.1.1 Criticism of Utilitarianism

The utilitarianism approach has been criticised because it may lead to the exploitation of minorities when the happiness of the majority is prioritised over the happiness of a few individuals. To solve this problem, John Stuart Mill formulated the freedom principle, also known as the no-harm principle, which allows individuals to strive for their own pleasure as long as they do not harm others. However, this principle is difficult to apply in practice, as any moral issue may involve harm or at least the risk of harm to others.

Furthermore, there is the issue of distributive justice, which refers to the importance of having a fair distribution of certain important goods such as income, happiness, and career opportunities. Utilitarianism can result in an unfair distribution of costs and benefits, even when following Mill's freedom principle. This is a complex matter because many technological issues are affected by this problem, such as how to justly distribute the risks and benefits of technology.

Another criticism of this method is that consequences are often unpredictable or unknown. An approach to deal with this is to work with expected consequences, which has been mathematically formalized using statistics.

Finally, certain actions are morally acceptable even though they do not create pleasure and some actions that maximise pleasure are morally unacceptable. Utilitarianism holds the view that the most basic rules, such as human rights, can be violated if it leads to greater benefits than harms, which means the "ends justify the means". Therefore, an engineer may be requested to break a fundamental professional conduct rule if the result leads to a positive consequence from a utilitarian perspective. A solution to this problem is proposed by one variant of utilitarianism: rule utilitarianism. It recognizes the importance of moral rules and aims to increase overall happiness by looking at the consequences of rules rather than individual actions. Therefore, for each situation, moral rules must be judged to decide whether they are morally correct or not since each situation is slightly different from another.

II.3.3.2 Kantianism / Deontology

Kant's moral philosophy - kantian deontology or duty ethics - is most concentrated in his work from 1785 known as the *Groundwork of the Metaphysic of Morals*. Kant believed that moral laws should not be based on happiness, which is difficult to measure and changes for each person. He argued that duty should guide ethics instead. Kant believed that individuals should be able to determine what is morally correct through reasoning, independent of external norms like religion. He believed that good will is when our actions are led by moral norms, which are unconditionally applicable to everyone in all circumstances. Kant's ethics is a monistic duty ethics, based on the universal principle called categorical imperative, from which all moral norms can be derived. The first formulation of the categorical imperative, the universality principle, is as follows [14, page 90]:

"Act only on that maxim which you can at the same time will that it should become a universal law."

In essence, Kant suggests that one must act as they think everyone else should act. He states that the maxim [2] should be unconditionally good, and should be able to serve as a general law for everyone without this giving rise to contradiction. He uses an example on how to reach such a contradictions. In the example, someone borrows money knowing they cannot pay it back, but promises to do so anyway to get the loan. Kant says this kind of behavior cannot be made into a general rule because it would make promises pointless. If everyone made promises they could not keep, promises would become meaningless. This illustrates that ethical actions cannot only be about personal gain, they must be guided by duty and rules that can apply to everyone.

The second formulation of the categorical imperative, the reciprocity principle, is as follows [14, page 91]:

"Act as to treat humanity, whether in your own person or in that of any other, in every case as an end, never as means only."

Kant's imperative commands that every person should acknowledge the rationality of others and refrain from manipulating or exploiting it. This emphasizes the concept of humans as rational beings with the freedom to direct

[2] A maxim is a practical principle or proposition that prescribes some action.

themselves. Kant also asserts that humans should never be treated solely as a means to someone else's ends, as this is disrespectful to their humanity and reduces them to objects or instruments.

Kant applies the reciprocity principle to the example of false promises and argues that lying to someone is using them merely as a means to an end, without considering their own ends. The person being used in this way cannot possibly agree to the action, and therefore cannot be considered as an end in themselves.

II.3.3.2.1 Criticism of Kantianism

Kantian moral philosophy has been criticized for its lack of flexibility since the categorical imperative does not permit exceptions. For example, according to this principle, lying is always immoral, even in situations where it could save an innocent person's life. This has been identified as a weakness in Kant's ethical framework. Some scholars propose that people should take into account relevant particulars of specific situations when creating a universal maxim. By including enough specific details, anyone may be able to accept that everyone should lie in those particular circumstances.

A second difficulty of the kantian moral philosophy is its lack of guidance on resolving moral conflicts when multiple duties come into play. The kantian framework does not account for the possibility of a legitimate moral dilemma.

Some philosophers, such as W.D. Ross, acknowledge the existence of conflicting moral duties but maintain that deontological moral reasoning is appropriate for ethical decision-making. They argue that Kant was mistaken in assuming that such reasoning can be reduced to a single value or moral law. Instead, they argue that there are multiple fundamental moral obligations and duties. That is to say, according to Ross the reason why a norm is a self-evident norm depends on the situation in which one finds oneself.

II.3.3.3 Virtue Ethics

Utilitarianism and kantian theory are both about what makes actions good or bad. On the contrary, virtue ethics focuses on what kind of person someone should strive to be. Virtue ethics states that people should try to develop good character traits and behave like a virtuous person would. That is to say, it holds that one should act as a virtuous person would act in the same circumstances.

This theory emphasises that people can become morally good through proper education and by following good examples. The goal is to develop individuals into responsible and morally upright people who can live good lives and these traits are called virtues.

Several lists of virtues have been suggested, but they have significant similarities. For instance, Aristotle, the primary virtue ethicist, offered a brief list of virtues, which includes courage, truthfulness, self-respect, wittiness, friendliness, modesty, and generosity or magnificence. On the other hand, since a more universal list is required, Christopher Peterson and Martin Seligman, modern psychologists, have conducted a worldwide survey to create a comprehensive list of core virtues and associated character strengths [9, page 42]:

1. Wisdom (creativity, open-mindedness, perspective).
2. Courage (bravery, persistence, vigor or energy).
3. Humanity (love, kindness).
4. Justice (citizenship, fairness, leadership).
5. Temperance (modesty, self-control).
6. Transcendence (appreciation of beauty and excellence, gratitude, spirituality).

Apart from the common virtues, there exist some virtues that are specifically related to a profession and are known as professional virtues. These virtues help professionals to fulfill the unique goals of their profession. For example, for engineers suggested virtues are professional care and respect for nature.

Besides, virtue ethics possesses a unique advantage in domains where a person has a significant degree of discretion in executing a moral imperative. For instance, engineering codes stipulate that engineers must prioritize public safety, but they provide minimal specifications on how to fulfill this obligation. While certain activities such as conflicts of interest or practicing without proper qualifications are prohibited, the more positive aspects of this duty require an alternative approach. In such cases, rules are inadequate, and the character of the engineer becomes the primary focus, particularly on the two professional virtues of care and respect for nature.

This necessity to rely on character instead of rules is particularly relevant in that part of aspirational ethics. Aspirational ethics involves going beyond what is morally required, such as attempts to improve the well-being of the poor or marginalised members of society. Whether or not an engineer engages in such projects and how they do so is contingent on personal values and character rather than a set of rules.

II.3.3.3.1 Criticism of Virtue Ethics

One of the main criticisms of virtue ethics is that it lacks a clear set of rules for determining right and wrong actions. Unlike consequentialist and deontological ethical theories, which rely on a set of universal principles or rules to guide ethical decision-making, virtue ethics emphasizes the importance of cultivating good character traits in individuals. This approach can lead to uncertainty and subjectivity in ethical decision-making, as it depends heavily on the judgement and character of the individual.

Additionally, some critics argue that the focus on virtues can lead to neglecting the consequences of one's actions and the rights of others, as the emphasis is placed on the inner qualities of the actor rather than the impact of their actions on society or individuals.

Another criticism is that the notion of virtues can vary across different cultures and historical periods, making it difficult to establish a universal framework for virtue ethics.

II.3.3.4 Care Ethics

Care ethics emphasizes the importance of relationships and caring in ethical decision-making. It is based on the idea that care is a fundamental human need, and that moral obligations arise from caring relationships.

Care ethics is a valuable perspective for engineers to consider since engineering projects often have significant impact on people's lives and the environment, and therefore, engineers have a moral responsibility to consider the impact of their work on those who will be affected by it.

From a care ethics perspective, engineers are not just technical problem-solvers but also caregivers who are responsible for the well-being of those affected by their work. This requires a shift in the traditional engineering mindset that values technical expertise over ethical considerations. Engineers must consider the needs and perspectives of all stakeholders, not just the immediate beneficiaries of their projects.

Furthermore, care ethics emphasizes the importance of empathy and emotional intelligence in ethical decision-making. Engineers must be able to understand and empathise with the concerns and values of those affected by their work. They must also be able to communicate effectively and build relationships with stakeholders to establish trust and ensure that their concerns are addressed.

In conclusion, by adopting a care ethics perspective, engineers can broaden their ethical considerations beyond technical expertise and prioritize the well-being of those affected by their work. This approach can help engineers build better relationships and ensure that their projects align with ethical principles and values.

II.3.3.4.1 Criticism of Care Ethics

Care ethics is often criticized for being philosophically unclear, as the term *care* is used in various contexts and can indicate more than one attitude or action, making it difficult to define precisely. It is also argued that care ethics is not very normative because it assumes that caring is good in itself, without providing specific guidelines for what constitutes the right way to pursue it. The philosophy judges a situation by *good care*, but what turns care into good care is not clear. Additionally, like virtue ethics, care ethics does not provide concrete instructions for how to act in a specific situation, unlike utilitarianism or kantian ethics. Rather, it focuses on the attitude of the person who can provide care, making it less practical for solving concrete moral problems.

II.3.4 Case Study: Ford Pinto

In the late 1970s, a Ford Pinto car carrying three teenagers was rear-ended by a truck, causing the car's gas tank to rupture and explode, killing all three occupants. This incident led to the first ever criminal homicide charge against an American company, Ford. During the trial, the judge stated that Ford should be convicted of reckless homicide if it was proven that the company had engaged in "*plain, conscious and unjustifiable disregard of harm that might result - from its actions - and the disregard involved a substantial deviation from acceptable standards of conduct*". The key phrase around which the trial hinged was "*acceptable standards*". Ford had rushed the development of the Pinto in response to market pressures, with a focus on producing a small, cheap car, and prioritizing styling over engineering design. Safety aspects of the design were not given sufficient attention, leading to the positioning of the petrol tank behind the rear axle and the puncturing of the tank in the event of a collision. Although Ford was aware of the risk of the petrol tank rupturing, they proceeded with production without making any changes. Ford justified its actions with a cost-benefit analysis that claimed the extra costs of making changes to the design did not outweigh the benefits of having fewer fatalities and injuries. The memorandum attached to the report described the costs and benefits is shown in Fig.II.3.1.

The calculation of fatalities, injuries, and vehicular damages was derived from statistical research. The valuation of $200,000 for the loss of human life was determined by the NHTSA (National Highway Traffic Safety Administration) study, which estimated social costs of a death as follows in Fig.II.3.1.

The statement was made that spending an extra $11 to improve the safety of the Pinto was not worth it, as the societal benefits of the riskier design were estimated to be nearly $50 million. This was calculated as 180 lives lost multiplied by $200,000, plus 180 seriously wounded multiplied by $67,000, plus 2100 burnt out cars multiplied by $700. These benefits were considered to outweigh the cost of improving the cars, which would have required calling back and retrofitting 11 million cars and 1.5 million trucks, at an estimated cost of $11 per unit, or a total cost of $137 million.

Benefits	
Savings	180 burn deaths, 180 serious burn injuries, 2,100 burned vehicles
Unit cost	$200,000 per death, $67,000 per injury, $700 per vehicle
Total benefits	180 × $200,000 plus 180 × $67,000 plus 2100 × $700 = $49.15 million
Costs	
Sales	11 million cars, 1.5 million light trucks
Unit cost	$11 per car, $11 per truck
Total costs	11,000,000 × $11 plus 1,500,000 × $11 = $137 million

Component	**1971 Costs**
Future productivity losses	
Direct	$132,000
Indirect	41,300
Medical costs	
Hospital	700
Other	425
Property damage	1,500
Insurance administration	4,700
Legal and court	3,000
Employer losses	1,000
Victim's pain and suffering	10,000
Funeral	900
Assets (lost consumption)	5,000
Miscellaneous accident cost	200
Total per fatality	$200,725

Figure II.3.1: Left: Memorandum attached to the Ford's report where the costs and benefits were described. Right: Estimated social costs of a death study by NHTSA in 1971. Source: [9, page 228]

II.3.4.1 Development of Study Questions

Analyse the cost-benefit analysis Ford used in their decision making process concerning the safety of the Pinto. Discuss your argument in favor or against Ford's decision.

Arguments in favor:

1. Cost-benefit analysis is a common practice used by businesses to make decisions that have financial implications.
2. The cost of recalling the cars was estimated to be very high, which would have led to significant financial losses for the company. It is argued that by not recalling the cars, Ford was acting in the best interest of its shareholders and employees.
3. It can be argued that Ford's choice to use cost-benefit analysis was not necessarily immoral. The problem lay in how the analysis was performed and the guesses made about the cost of accidents, which caused disapproval.

Arguments against:

1. The use of cost-benefit analysis in this case meant that the value of human life was reduced to a monetary figure. Critics argue that this approach is unethical and immoral, as it prioritizes financial gain over human life.
2. It was argued that the cost of accidents was significantly underestimated, and the number of deaths and injuries was also not accurately predicted.
3. It is also argued that Ford was aware of the design flaw in the gas tank and chose to ignore it, putting profits ahead of customer safety. This is seen as a clear violation of ethical standards.

What responsibilities do you think engineers have in situations like these?

1. **Safety**: The primary responsibility of engineers is to ensure the safety of their products. This means designing products that do not pose a threat to the users or the public. In the case of the Pinto, the engineers should

have designed a car that met the safety standards and did not have any known design flaws that could put people's lives at risk.

2. **Ethics**: Engineers have an ethical responsibility to prioritize the safety of people and the environment in their work. They need to adhere to the values and principles of their profession, including raising concerns about safety and taking action if necessary, even if it goes against a company's cost-benefit analysis. In the case of the Ford Pinto, engineers should have spoken up about safety concerns and advocated for a recall if needed, rather than prioritizing the company's financial interests.
3. **Transparency**: Engineers have a responsibility to be transparent about their work and any potential risks associated with their products. They need to communicate clearly and openly with the public, regulators, and other stakeholders. In the case of the Pinto, the engineers should have been transparent about any design flaws and the potential risks associated with the car, rather than keeping the information confidential to avoid negative publicity and financial losses.

How would utilitarianism evaluate the decision made by Ford to not modify the design of their Pinto model?

The Ford Pinto case highlights objections to utilitarianism in its application to ethical decision-making. Utilitarianism suggests that actions should be judged based on their consequences and how they promote the greatest happiness for the greatest number of people. However, in this case, the decision not to recall the unsafe cars was based on a cost-benefit analysis that weighed the potential costs of accidents against the costs of recalling and fixing the cars, and not on the value of human life. This approach raises questions about how Ford valued human life and how reliable their estimates of the number of deaths and injuries were.

One objection to utilitarianism that arises from the Ford Pinto case is that it seems to allow for the sacrifice of the few for the greater good of the many. This goes against the principle that human life is priceless and cannot be weighed against financial costs. Additionally, utilitarianism does not account for individual rights and liberties, and in the case of the Ford Pinto, it could be argued that Ford violated the freedom principle of Mill by failing to prioritize the safety of its customers.

Another objection to utilitarianism in the Ford Pinto case is that it may lead to short-term thinking that prioritizes immediate gains over long-term benefits. By following rules that prioritize safety, such as "companies must recall unsafe cars" or "companies should produce safe cars", the overall happiness of society is maximized in the long run. Therefore, Ford would have had an ethical obligation to recall the cars under utilitarianism, even if the act of not recalling it may have maximized utility in the short term since in utilitarianism, an action is not considered ethical just because it maximizes utility on a specific occasion.

How could the case of Ford Pinto be analysed by applying Kant's theory?

Applying Kant's first categorical imperative to the Ford Pinto case involves examining whether Ford's maxim of marketing an unsafe car without informing consumers can be universalised without contradiction. If this maxim were universalised, marketing any car would become impossible because no rational person would buy a car anymore if they could not trust its safety. Therefore, the maxim cannot be universalised and should not be followed by Ford.

The second categorical imperative, the reciprocity principle, states that people should not be treated as mere means, which is precisely what Ford did by prioritizing cost over safety. The engineers who designed the Pinto also had a moral obligation to ensure that they were treating individuals as ends in themselves by creating a safe and reliable vehicle.

In conclusion, when analysing the case from a kantian perspective, Ford would need to take responsibility for its actions and prioritise the safety of its customers. This could involve recalling the cars and implementing safety measures to prevent similar situations from occurring in the future.

How could the case of Ford Pinto be analysed by applying virtue ethics?
In the framework of virtue ethics theory, the emphasis is placed on the moral character and virtues of the individual or organization involved in decision-making, rather than on the specific actions or outcomes. In the Ford Pinto case, a virtue ethicist would examine the character traits that contributed to Ford's decision to prioritize cost savings over the safety of its customers.

One possible strategy for applying virtue ethics to this case is to identify the virtues that the company ought to have developed in order to prevent such unethical conduct. These virtues may include honesty, integrity, transparency, accountability, and concern for human life.

For instance, Ford could have developed a culture that prioritised transparency and honesty by informing consumers about the potential risks of driving the Pinto. They could have taken responsibility for the design flaws and implemented a recall of the cars. Ford could have also demonstrated care for human life by placing greater value on the safety of its customers rather than prioritising profits.

How could the case of Ford Pinto be analysed by applying care ethics?
Care ethics theory emphasises the importance of relationships and caring for others in ethical decision making. In this case, care ethics would focus on the responsibility of Ford to care for the safety and well-being of its customers, as well as the impact of their actions on the wider community.

To analyse the Ford Pinto case through the lens of care ethics, one approach would be to consider the impact of Ford's decision on the individuals affected by the faulty design of this car. This includes not only the customers who were injured or killed in accidents but also their families and innocent by-standers affected by the accident who never even purchased the car. Care ethics would prioritise the needs and well-being of these individuals over the company's profits.

One possible solution based on care ethics would be for Ford to take responsibility for their actions and compensate the victims and their families for the harm caused by the faulty design. They could also implement changes in their corporate culture to prioritise the safety and well-being of its customers and society over profits. This may involve establishing closer relationships with customers, listening to their concerns, and making sure that their needs are met. In addition, they could invest in research and development to improve the safety of their products, demonstrating a long-term commitment to care for the well-being of its customers and society as a whole.

· CHAPTER II.4 ·

Normative Argumentation

The main purpose of argumentation is to justify or refute a statement. Argumentation involves either defending an opinion as a means of justification or attacking an opinion as an attempted refutation, both of which contribute to the critical function of argumentation in their own unique ways.

This chapter will develop the main concepts of normative argumentation through the following topics:

- Distinction between deductive and non-deductive arguments.
- Valid, invalid, sound and unsound arguments.
- Argumentation schemes and their associated critical questions.
  - Argumentation by analogy, means-end argumentation, causality argumentation, proof from the absurd, and characteristic-judgement argumentation.
- Identification of fallacies.

References

All the information presented in this chapter is based on the following references unless otherwise specified:

- Poel (2011) *Ethics, Technology and Engineering: an Introduction*, Wiley-Blackwell [14]
- Porat (2021) *A Brief Introduction to Philosophy*, Southern Alberta Institute of Technology [43]
- Matthews (2020) *Philosophical Ethics: A Guidebook for Beginners* [44]

Definitions of Key Concepts

There are some terms that need to be understood beforehand for the proper comprehension of this chapter.

- **Statement**: It is a type of sentence that can be true or false and corresponds to the grammatical category of a declarative sentence.
- **Premises**: It is a statement that provides evidence or a reason to believe in a conclusion. It is offered as justification or support for the conclusion.
- **Argument**: It is a set of statements, of which one - the conclusion - is claimed to follow from the others - the premises -. It can also be defined as reasons for thinking that a statement, claim or idea is true.
- **Conclusion**: The conclusion of an argument is the statement that is validated based on the other statements presented in the argument.
- **Critical questions**: Questions belonging to a certain type of non-deductive argumentation to check the degree of plausibility of a conclusion.

So, to reiterate: all arguments are composed of premises and conclusions, which are both statements. The premises of the argument provide a reason for thinking that the conclusion is true. And arguments typically involve more than one premise.

Generally, an argument can formally be expressed as "P_1, P_2, ..., P_n, so C", where P_i are the premises and C is the conclusion.

II.4.1 Deductive and Non-Deductive Arguments

Arguments can be classified as either deductive or non-deductive. In both deductive and non-deductive arguments, it is important to carefully evaluate the premises and the reasoning used to support the conclusion. Depending on the type of argument, there are subcategories to classify them according to their strength. This classification can be seen in the Fig.II.4.1.

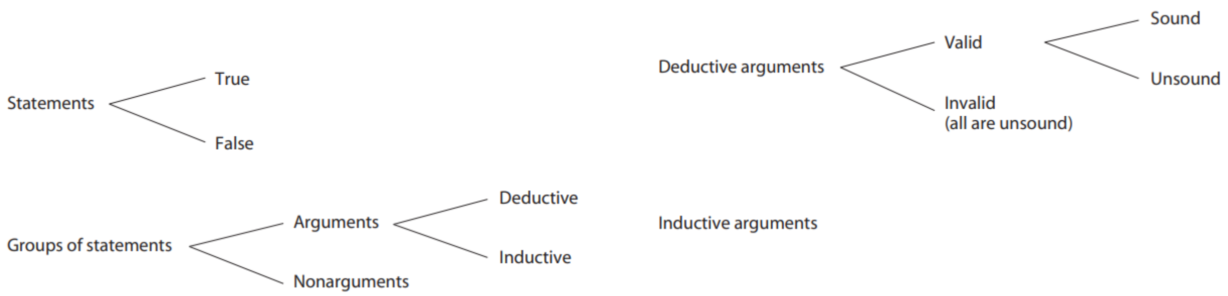

Figure II.4.1: Argument terminology. Source: [10, page 53]

Deductive arguments are those in which the conclusion necessarily follows from the premises. In other words, if the premises are true, the conclusion must also be true. Deductive arguments are often used in mathematics and logic, and are considered to be strong arguments if the premises are true. For example, a deductive argument in ethics might be:

P_1 Killing innocent people is morally wrong.
P_2 Dropping a bomb on a civilian area would kill innocent people.
C Therefore, dropping a bomb on a civilian area is morally wrong.

On the other hand, non-deductive arguments are those in which the conclusion does not necessarily follow from the premises. These arguments are often used in everyday life, and rely on probability or likelihood rather than certainty. Non-deductive arguments can be strong or weak depending on the strength of the evidence and the reasoning used. In other words, the premises – if true – give a limited amount of support to the conclusion and adding new premises can strengthen or weaken the conclusion. In the realm of non-deductive argumentation, accepting a conclusion is grounded on the plausibility principle, which states that enumeration and supplementary argumentation in a non-deductive argumentation can make the conclusion acceptable. For instance, the disappearance of important documents in a particular room could be attributed to a specific person. The plausibility of them being the culprit would be based on factors such as their presence in the room, the absence of other people, and the lack of alternative explanations. The strength of this argument lies in its enumeration and supplementary reasoning that ultimately lead to a plausible assumption. However, such non-deductive argumentation entails a small degree of uncertainty due to its indirect nature, as in the case where no one actually witnessed them stealing the documents.

Another example of a non-deductive argument in ethics might be:

P_1 Our company produces and sells unmanned aerial vehicles (UAVs) to both military and civilian customers.
P_2 We have received reports from multiple sources that our UAVs have caused civilian casualties in conflict zones.
P_3 The use of UAVs in warfare is controversial and raises ethical concerns.
C We should conduct a thorough review of our production and sales practices to ensure that our UAVs are not being misused or causing harm to civilians.

This argument is non-deductive because the conclusion is not guaranteed by the premises; rather, it is based on the plausibility that our company's UAVs could be causing harm and the ethical concerns associated with their use. The argument relies on the strength of the premises and the additional considerations that make the conclusion plausible.

II.4.2 Valid and Invalid Arguments

A deductive argument can be classified as either valid or invalid. A valid argument is one where the conclusion necessarily follows from the premises, meaning that if all the premises are true, then the conclusion must also be true. It is impossible for all the premises to be true and the conclusion to be false in a valid argument. On the other hand, an invalid argument is one where the conclusion does not follow necessarily from the premises. To test for invalidity, one can assume that all the premises are true and check whether it is still possible for the conclusion to be false. If it is, then the argument is invalid. In other words, if the premises do not provide sufficient evidence to support the conclusion, the argument is invalid. It is important to be able to identify invalid arguments to avoid being deceived by invalid reasoning [45].

In evaluating an argument, its effectiveness is a crucial factor to consider as it pertains to the degree to which it is useful in achieving its intended purpose. To assess an argument's effectiveness, two opposing approaches can be distinguished: the rhetorical analysis, which concerns the argument's persuasiveness to the audience, and the logical analysis, which considers the argument's validity. The rhetorical analysis places greater importance on being proved right over being right, while the logical analysis emphasizes the argument's validity, focusing on its ability to withstand critical examination.

When examining arguments through a viewpoint of rational thinking, their primary purpose is to provide evidence for a conclusion, which is why the rhetorical analysis is often excluded. The discipline of logic is dedicated to argumentation, with the goal of distinguishing between good and bad arguments. The objective is to investigate, develop, and systematise principles and methods that can be used to differentiate valid and invalid arguments. In principle this distinction is not difficult, as valid arguments have a conclusion that necessarily follows from their premises, while invalid arguments do not entail their conclusion. An example of invalid argument is:

P_1 Developing advanced aerospace technologies benefits society.
P_2 SpaceX is a company that develops advanced aerospace technologies.
C Therefore, SpaceX's actions are always morally justified.

This argument is invalid because the conclusion does not logically follow from the premises. While it is true that developing advanced aerospace technologies can have societal benefits (P_1) and SpaceX is involved in such development (P_2), it does not automatically imply that all of SpaceX's actions are morally justified and the argument oversimplifies the ethical evaluation.

Rules of inference are fundamental principles used in deductive reasoning to draw conclusions from premises. Among these rules, *Modus Ponens* and *Modus Tollens* are two of the most important. These rules are valid not because of their content, but because of their form. Hence, any argument with the same structure as those will be automatically considered valid. This feature is valuable because it allows to establish the validity of an argument without analysing its content in detail. By recognising the valid forms of inference, arguments can be evaluated and fallacious reasoning identified efficiently.

II.4.2.1 Modus Ponens

Modus Ponens allows to draw a conclusion from a conditional statement and its antecedent [46]. That is to say,

If p, then q;	$p \longrightarrow q$
p;	p
So, q;	$\therefore q$

For example,

P_1	If an engineer is aware of a safety issue with an aircraft, they have a duty to report it.
P_2	An engineer is aware of a safety issue with an aircraft.
C	Therefore, the engineer has a duty to report the safety issue.

Here, the first premise establishes a normative principle regarding an engineer's responsibility in case they detect a safety issue. The second premise presents a factual situation where an engineer has detected a safety issue. Applying Modus Ponens, the conclusion can be inferred that logically follows from the premises, and therefore, the engineer has a duty to report the safety issue.

II.4.2.2 Modus Tollens

Modus Tollens is another valid rule of inference that can be useful in evaluating arguments in ethical discussions. This rule states that if a conditional statement is accepted, and the consequent of that statement is denied, then the antecedent must also be denied [46]. That is to say,

If p, then q;	$p \longrightarrow q$
not p;	$\neg p$
So, not q;	$\therefore \neg q$

For example,

P_1	If a particular launch vehicle is safe, then it can be launched.
P_2	It is discovered that the launch vehicle has a design flaw that makes it unsafe.
C	Therefore, it cannot be launched.

In the realm of argumentation, there are two common methods of challenging a conclusion. The first is to demonstrate the falsehood of a premise, while the second is to demonstrate that the argument is invalid, resulting in a premature conclusion. Therefore, if the argument is valid but the conclusion is not accurate and can be challenged, it means that some premises are false.

In the field of science, inductive argumentation is a common form of non-deductive argumentation where empirical laws are supported through the use of measurement results. This form of argumentation involves moving from particular instances to more general conclusions, aiming to demonstrate the truth of an empirical law. In these cases, the degree of plausibility of the conclusion can be checked using the following critical questions:

1. Were the experiments carried out relevant for the conclusion?
2. Were sufficient experiments carried out to support the conclusion?
3. Are there no counterexamples?

When all questions can be answered affirmatively, the argumentation can be considered sound, rather than just valid. An argument is valid when there is a clear and solid connection between every step of the reasoning that leads inevitably from premises to conclusion and it is sound when it is both valid and all of its premises are true. If any of the premises are false, the argument is considered unsound.

In conclusion, a sound argument is both valid and true, making it a powerful tool for convincing others and reaching conclusions. On the other hand, an invalid argument is one where the premises do not necessarily lead to the conclusion, while an unsound argument is an invalid argument with false premises. Understanding these concepts is crucial for avoiding fallacies and ensuring that reasoning is based on reliable and accurate information. In essence, the validity and soundness of arguments are key to constructing logical and persuasive arguments.

II.4.3 Types of Normative Argumentation Schemes

II.4.3.1 Argumentation by Analogy

Analogical reasoning involves making a comparison between two things or situations that are not identical, but have similar features. This type of argument has the following form:

S and T are similar in respect to certain - known - properties.
S has been observed to have further property Q.
Therefore, T also has the feature Q, or some feature Q* similar to Q.

For example,

	Earth (S)		**Mars** (T)
		Known similarities:	
↑vertical↓	orbits the sun		orbits the sun
	has a moon	←**horizontal**→	has moons
	revolves on axis		revolves on axis
	subject to gravity		subject to gravity
		Inferred similarity:	
	supports life	⇒	*may* support life

Figure II.4.2: Tabular representation of an argumentation by analogy. The horizontal relations in an analogy are the relations of similarity - and difference - in the mapping between domains, while the vertical relations are those between the objects, relations and properties within each domain. The correspondence - similarity - between Earth having a moon and Mars having moons is a horizontal relation; the causal relation between having a moon and supporting life is a vertical relation within the source domain - with the possibility of a distinct such relation existing in the target as well -. Source: [11]

The use of critical questions, listed as follows, aids in evaluating the soundness of an argument and the plausibility of its assumptions. If the argumentation by analogy is to be sound, all critical questions have to be answered positively. On the contrary, when these critical questions cannot have affirmative responses, the analogy fails.

1. Are the two situations comparable?
   - Are there important relevant similarities?
   - Are there no important relevant differences?
2. Is what is asserted about the example situation true? In other words, is it true that if situation S occurs then Q applies?

In the example illustrated in the Fig.II.4.2, it is clear that Q applies in S - the Earth supports life - and it can also be argued that the similarities exposed suggest that conditions on Mars may be conductive to the development and sustenance of life, just as they are on Earth. However, it is essential to conduct further scientific investigation to verify if any significant differences exist between both planets. For example, a crucial dependence on water broadly governs all life forms on Earth. Is water critical to support life? Is there or has there been water on Mars? Finally, if all critical questions can be satisfactory answered, the analogy could be deemed acceptable.

II.4.3.2 Means-End Argumentation

Means-end argumentation involves deriving the means necessary to achieve a particular goal. This type of argumentation is non-deductive and relies on making a persuasive case for the selected means. It is important to recognise that there may be alternative means to achieve the same goal, and the chosen means must be justified based on reason and evidence, rather than personal biases or preferences. Since the conclusion of the argument is not explicitly stated in the premises, the argument's plausibility and strength of reasoning must be assessed through evaluation.

x (the end)
carrying out action y realises x
So, do y

Its critical questions are as follows:

1. Does action y indeed realise end x?
2. Can action y be carried out?
3. Does execution of action y lead to unacceptable side effects?
4. Are there no other - better - actions to achieve x?
5. Is the end acceptable?

II.4.3.3 Causality Argumentation

In this argumentation, use is made of the fact that a certain expected consequence can be derived from a certain situation or action. There are two formal descriptions of the causality argumentation: non-deductive and deductive. The non-deductive variant does not embed the conclusion within the premise, while the deductive variant follows the pattern of "If p is true and if it is true that p has q as a consequence, then q is true too". However, both types encounter the problem of plausibility. The plausibility principle in the first type arises from the uncertainty that q is the expected consequence of action p, while it is hidden within the causality premise in the second type. Despite the possibility of converting non-deductive argumentation into deductive, plausibility remains a crucial issue in both types.

p (action or situation)
"p causes q" or "p has q as a consequence" - the causality premise -
So, q (the expected consequence)

Its critical questions are as follows:

1. Will the given situation or action indeed lead to the expected consequence?
2. Have no issues been forgotten, for example, with respect to the expected consequence?
3. How do you determine the expected consequence and can it be justified?

II.4.3.4 Proof from the Absurd

It is a type of argumentation where the conclusion is established by showing that its negation leads to a contradiction. In other words, the argument assumes the opposite of what is to be proved and then demonstrates that this assumption leads to a logical absurdity or contradiction. This proves that the opposite of the assumption - which is the original conclusion - must be true. This type of argumentation is commonly used in mathematics, logic, and philosophy.

Assuming A - logically - leads to an inconsistent set of statements
So, not A

Its critical questions are as follows:

1. Does assuming A indeed lead to an inconsistent set of statements?
2. Is not-A indeed the negation of A? In other words, can A be concluded from "not not A"?

II.4.3.5 Characteristic-Judgement Argumentation

Characteristic-judgment argumentation is a type of argumentation that relies on non-deductive argumentation because the conclusion does not necessarily follow from the premises. It is based on the premise that a particular judgement about a person or thing can be made based on certain characteristics or qualities that they possess. In other words, this type of argumentation involves making an inference about something or someone based on the traits or characteristics they exhibit. The effectiveness of this type of argumentation depends on the strength of the connection between the characteristics and the judgment being made, as well as the reliability of the information used to support the argument.

X has the characteristics s_1, s_2, ..., s_n
Characteristics s_1, s_2, ..., s_n are typical of A
So, A applies to X

Its critical questions are as follows:

1. Do the characteristics mentioned justify judgement A?
2. Are the characteristics mentioned all typical of A?
3. Are there any other characteristics necessary for A?
4. Does X possess characteristics that justify the judgement not A?
5. Does X possess the characteristics mentioned?

II.4.4 Fallacies

A fallacy refers to an error or weakness in an argument that appears to be valid at first glance, but upon closer examination is proven to be invalid. Therefore, critical questions are essential for identifying fallacies. It is crucial to identify fallacies as they have the potential to deceive. An individual who can identify fallacies is more likely to make persuasive arguments, while those who cannot may fall victim to the misleading tactics of those who use verbal tricks.

While there is no agreed-upon system for categorising fallacies, one commonly used classification is the differentiation between formal and informal fallacies.

II.4.4.1 Formal Fallacies

Formal fallacies are identified by examining the structure or form of an argument, rather than its content. Any argument that is not logically valid is considered a formal fallacy.

First, the **fallacy of affirming the consequent** is often confused with an instance of the Modus Ponens. For example,

P_1 If an aerospace company has a strong safety culture, then it will have a low accident rate.
P_2 The company has a low accident rate.
C Therefore, the company must have a strong safety culture.

This is an example of the fallacy of affirming the consequent, because there could be other reasons why the company has a low accident rate besides having a strong safety culture. For example, the company might have a small fleet of aircraft or operate in a less risky area. Therefore, the conclusion is not necessarily true based on the given premises.

Another fallacy related to Modus Tollens is the **fallacy of denying the antecedent**. It occurs when - in the formulation of Modus Tollens - the conclusion is $\neg$ p from the premises p $\longrightarrow$ q and $\neg$ q. For example,

P_1	If we do not rigorously test our aerospace products, they may fail in flight.
P_2	We did rigorously test our aerospace products.
C	Therefore, it is impossible for our aerospace products to fail in flight.

This is a fallacy since the conclusion denies the antecedent of the first premise - the absence of rigorous testing - as the only possible cause for product failure. The fact that the product was tested rigorously does not guarantee that it cannot fail in flight for other reasons.

As indicated before, when an analogy fails because its critical questions cannot be answered affirmatively, there is a fallacy: the **false analogy**. For example,

P_1	The safety protocols used in the automotive industry are successful in preventing accidents.
P_2	The aerospace industry should adopt the same safety protocols as the automotive industry.
C	Therefore, the aerospace industry can prevent accidents by adopting the same safety protocols as the automotive industry.

This is an example of a false analogy because the safety concerns and risks involved in the aerospace industry are vastly different from those in the automotive industry. The nature of accidents and their consequences are different in both industries, and what works for one industry may not necessarily work for the other. Thus, it is not logically valid to assume that the safety protocols used in the automotive industry will work in the aerospace industry.

II.4.4.2 Informal Fallacies

Informal fallacies are errors in reasoning that occur in arguments due to flawed logic or irrelevant information. Unlike formal fallacies, which are errors in the structure of an argument, informal fallacies involve errors in the content or context of the argument.

It is important to recognise and avoid informal fallacies in arguments as they can weaken the argument's effectiveness and credibility. To identify informal fallacies, one should critically examine the premises and assumptions of an argument and evaluate the relevance and reliability of the evidence presented. By avoiding informal fallacies, one can construct stronger and more persuasive arguments that are based on sound logic and evidence.

There are numerous types of informal fallacies that are often used in ethical discussions. Some of them are:

- **Ad Hominem**: Ad hominem attacks occur when an argument attacks a person's character or motives rather than addressing the argument itself.
- **Confusion of law and ethics**: It occurs when someone assumes that just because something is legal, it is also morally right. This fallacy is based on the mistaken belief that laws and ethics are always aligned.
- **Straw person**: It occurs when an argument misrepresents an opponent's argument to make it easier to refute. For example, in a debate about the benefits of electric cars versus gas-powered cars, one person argues that electric cars are more environmentally friendly and cost-efficient in the long run, while the other person argues that gas-powered cars are still more practical and convenient for most people's needs. However, during the debate, the second person misrepresents the first person's argument by claiming that they said electric cars are the only viable option and gas-powered cars should be banned altogether. By doing so, the second person creates a straw person argument that is easier to refute and dismiss, rather than addressing the actual argument presented by the first person.
- **Wishful thinking**: It occurs when an individual believes or argues for something to be true, not because there is sufficient evidence or reason to support it, but because they wish or hope for it to be true.

- **Ambiguity**: It occurs when a statement or argument contains ambiguous language or unclear meanings that can be interpreted in multiple ways. The vagueness of the language makes it difficult to determine the intended meaning and can lead to misunderstandings or false conclusions.

II.4.4.3 Development of the Class Activity

A debate can promote the learning of normative argumentation and fallacies by requiring students to develop and defend their positions based on reasoned arguments and evidence, while also challenging the arguments and evidence of their opponents. Through this process, students can learn to identify and avoid common fallacies. Additionally, by engaging with opposing viewpoints, students can develop their critical thinking skills and learn to consider multiple perspectives.

Background
Historically, the aerospace engineering industry has been male-dominated, with women being underrepresented and facing barriers to advancement. However, in recent years, there has been a push for greater gender diversity and inclusion in the industry and various measures have been implemented in the aerospace field. Some of these measures include:

- Promoting STEM education for girls.
- Implementing diversity and inclusion programs.
- Providing scholarships and mentorship programs.
- Establishing gender hiring ratios.

Some argue that promoting gender diversity and inclusion is not only the right thing to do but can also lead to better business outcomes, such as increased innovation and profitability. Others argue that the industry should prioritize merit over gender and that promoting diversity and inclusion could lead to reverse discrimination.

Topic
Should the aerospace engineering industry actively promote gender diversity and inclusion?

Possible arguments in favor of promoting gender diversity and inclusion [9, pages 240-243]:

- The aerospace engineering industry is currently not representative of society as a whole, and actively promoting gender diversity and inclusion would help address this inequality.
- There are talented women in the industry who have been overlooked or discriminated against in the past, and promoting gender diversity and inclusion would help create a more level playing field.
- A more diverse workforce would also bring diverse perspectives and experiences, leading to better problem-solving and decision-making.
- By promoting diversity and inclusion, the industry can attract and retain talented employees who may be discouraged by the lack of diversity in the field.

Arguments against promoting gender diversity and inclusion in the aerospace engineering industry:

- The industry should prioritize merit over gender, and hiring decisions should be made solely based on qualifications and skills.
- Promoting diversity and inclusion could lead to reverse discrimination, with less qualified candidates being hired over more qualified candidates based on their gender.
- It is not the industry's responsibility to promote gender diversity and inclusion, and companies should be free to make hiring decisions based on their own criteria.
- Promoting diversity and inclusion may be expensive and time-consuming for companies, which may not see a significant return on investment.

· CHAPTER II.5 ·

The Ethical Cycle

Formulating a moral judgment is a complex and intricate process that transcends the simple application of ethical theories to specific cases. It involves a dynamic interplay between the identification of the moral dilemma, the formulation of potential solutions, and the ethical evaluation of these solutions. Despite the inherent complexity of moral problems, it is still possible to adopt a systematic approach that acknowledges their intricate nature. The ethical cycle offers a structured framework for problem-solving that encompasses the multifaceted aspects of moral dilemmas and ethical judgment.

This chapter will develop the main concepts of the ethical cycle through the following topics:

- Properties of moral problems.
- Steps of the ethical cycle.
- Role of the ethical cycle in moral decision-making.
- Application of the ethical cycle to concrete moral problems in engineering.

References

All the information presented in this chapter is based on the following references unless otherwise specified:

- Poel (2011) *Ethics, Technology and Engineering: an Introduction*, Wiley-Blackwell [14]
- Poel (2007) *The Ethical Cycle*, Journal of Business Ethics [12]

II.5.1 Moral Problems

Similar to many other practical problems, moral problems fall under the category of ill-structured problems. Moral problems cannot be fully described in advance; they gradually unfold themselves during the problem-solving process. In the case of other ill-structured problems, such as design problems, thinking about potential solutions aids in clarifying the problem and may even need a reformulation of the initial problem statement. Moral problems typically lack a singular optimal solution, but rather offer a range of solutions that vary in their degree of acceptability. This is because, in the realm of ill-structured problems, no universally applicable criterion exists to definitively rank potential solutions from best to worst. Another shared characteristic of moral problems with other ill-structured problems is the inherent difficulty in generating an exhaustive list of all possible alternative courses of action. Consequently, solutions are provisional and subjected to improvement and revision.

Moral problem-solving is a complex process, but it can still benefit from a systematic approach. Without such an approach, moral judgment risks being reduced to mere intuition, lacking understanding or justification. To enhance moral decision-making and avoid shortcuts, Poel and Royakkers propose the ethical cycle, which aims to comprehensively analyse and justify actions, taking into account all pertinent aspects of the problem.

II.5.2 The Ethical Cycle

The ethical cycle, displayed in Fig.II.5.1, is a tool that assists in structuring and enhancing moral decisions by providing a systematic and comprehensive analysis of moral problems. It guides individuals through a step-by-step process that enables to reach a moral judgement and justify the final decision from an ethical standpoint. By using the ethical cycle, individuals can thoroughly evaluate the various aspects of a moral dilemma, consider different perspectives, and weigh the potential consequences of their actions.

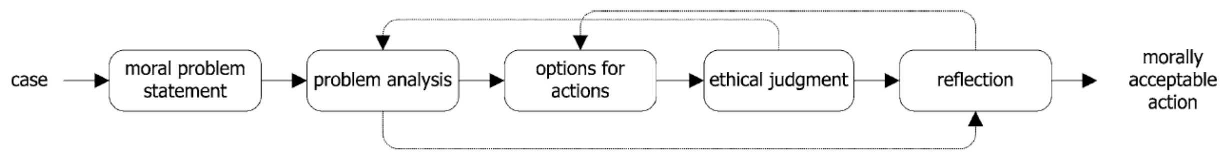

Figure II.5.1: Ethical cycle scheme. Source: [12]

The ethical cycle is typically undertaken by an individual, yet in reality, the actions chosen by that individual often impact others as well. This raises the question of whether it is morally acceptable for one person's choices to significantly affect the lives of others. One possible solution to address this issue is to engage in moral deliberation with the individuals affected. By engaging in discussions about the ethical cycle with those involved, a more informed decision can be made.

It is important to recognise that the ethical cycle functions as an ongoing and iterative process rather than a linear sequence, and revising and adjusting previous steps, if necessary, are essential procedures.

It consists of five basic steps:

1. Moral Problem Statement
The initial stage of the ethical cycle involves formulating a moral problem. A key feature of a moral problem is the presence of conflicting moral values or norms that cannot be fully achieved simultaneously. To implement the ethical cycle effectively, it is crucial to express the moral problem with precision and clarity. A good moral question meets three conditions:

1. It must clearly state what the problem is.
2. It must state for whom it is a problem.
3. The moral nature of the problem needs to be articulated.

In many cases, the moral problem may not be clearly defined at the beginning of the ethical cycle. It is acceptable to start with a somewhat ambiguous understanding of the moral problem and work towards refining and clarifying its formulation as other phases of the cycle are carried out.

2. Problem Analysis
In this stage, the key components of the moral problem are outlined. Three significant elements are considered: the interests of the stakeholders, the relevant moral values and the relevant facts.

Since the final option chosen at the end of the ethical cycle can depend on the suppositions made with respect to facts, it is recommended to occasionally express the moral standpoint in a hypothetical form: "If x is the case, then choose action A. If y is the case, choose B".

3. Generation of Possible Options for Actions
Following the analytical phase of formulating the moral problem, there is a subsequent phase where potential courses of action are generated based on the analysis of the problem.

In this step, creativity plays a crucial role, and a cooperative approach can be valuable in exploring alternative solutions. Consulting stakeholders for their input can often lead to mutually beneficial outcomes.

4. Ethical Evaluation
During this phase, an assessment is made regarding the moral acceptability of the different possible courses of action. This can be done on the basis of formal frameworks and informal frameworks. Formal frameworks include codes of conduct and ethical theories. Examples of informal frameworks are intuition and common sense.

Moral judgments are made regarding the available options for action. It is important to note that these judgments can vary as different frameworks may lead to different preferred choices in a given situation.

5. Reflection
Since the different ethical frameworks do not necessarily lead to the same conclusion, a further reflection on the outcomes of the previous step is usually required. The result of this step should be a choice for one of the possible actions and its goal is to select a well-argued choice among the different options for actions, taking into account the results of the earlier steps.

II.5.3 Case Study: SpaceX's Starlink and Astronomers

The problem between SpaceX's Starlink and astronomers derives from the interference caused by the Starlink satellite constellation on astronomical observations. Ground-based observatories, such as the Zwicky Transient Facility (ZTF), have been particularly affected. These observatories scan the sky for various celestial events, including exploding stars and near-Earth asteroids.

The issue stems from the streaks of light that appear in telescope images when Starlink satellites pass overhead. These streaks disrupt the observations made by astronomers and can hinder their ability to detect and study astronomical phenomena accurately. The impact is most significant during twilight hours, particularly around sunrise and sunset, which are crucial for identifying potentially dangerous asteroids coming from the direction of the Sun.

The problem has broadened with the rapid growth of the Starlink mega constellation. Analysing observations from 2019 onwards, it was found that the percentage of affected twilight images increased from 0.5% to 20% as the number of Starlink satellites in orbit grew. SpaceX currently has more than 1,400 active Starlink satellites, but they plan to launch many more, potentially reaching 42,000 satellites in the future. Other companies, like OneWeb, Amazon, and China's SatNet, also have similar satellite constellation plans [47, 48].

SpaceX has taken some measures to address the issue. The installation of visors on Starlink satellites has reduced their brightness, subsequently decreasing the severity of the streaks. However, despite this improvement, a small chance remains that an asteroid or other important celestial event could be obscured by a satellite streak, potentially impacting scientific discoveries.

The interference caused by Starlink satellites has raised concerns among astronomers and the wider scientific community. The International Astronomical Union has called for the protection of the night sky as a valuable human heritage, urging the United Nations to address the issue. Workshops organised by the American Astronomical Society have compared the impact of mega constellations like Starlink to light pollution, highlighting the potential harm they can cause to astronomical research.

Additionally, space safety experts have voiced worries about the collision risks posed by the increasing number of satellites in orbit. Starlink satellites are reportedly responsible for over 50% of collision risk situations between satellites. Moreover, scientists studying Earth's atmosphere have expressed concerns about the potential environmental effects of mega constellations. The regular replacement of satellites and the burning up of retired satellites in Earth's atmosphere may produce particles that could have unforeseen consequences for the planet's climate.

In summary, the issue between SpaceX's Starlink and astronomers arises from the disruption caused by streaks of Starlink satellites in astronomical observations. This problem has raised concerns regarding its impact on scientific discoveries, risks of collisions in space, and potential consequences for the Earth's climate.

II.5.3.1 Development of the Analysis of the Problem Using the Ethical Cycle

Application of the ethical cycle to analyse the problem between SpaceX's Starlink and astronomers, and discussion of possible actions and solutions.
Several factors need to be considered:

- Impact on astronomical research: The potential loss of scientific data, the limitations imposed on observations, and the impact on the advancement of astronomical knowledge.
- Collaboration and communication: The level of collaboration and communication between SpaceX and astronomers. Considerations of whether both parties have engaged in open dialogue, shared information, and worked towards finding mutually beneficial solutions.
- Long-term consequences: The potential benefits and risks associated with different courses of action. Analysis of whether the proposed solutions are sustainable, and whether they contribute to the overall well-being of the aerospace industry, scientific progress, and society as a whole.

Then, the development of the ethical cycle should follow the steps below:

1. **Problem statement**: The problem is the conflict between SpaceX's Starlink satellite constellation and astronomers. The large number of Starlink satellites in orbit poses challenges for astronomical observations and interferes with ground-based telescopes.
2. **Problem analysis**: The interests of stakeholders, relevant moral values, and relevant facts should be examined. Stakeholders include SpaceX, astronomers, and the general public. The moral values involved may include scientific research, technological development, and the equitable use of space.
3. **Possible options for actions**: Brainstorming possible actions and solutions is essential. These may include modifying the design of Starlink satellites to reduce their impact on observations, establishing communication channels between SpaceX and astronomers to coordinate satellite deployments, exploring alternative satellite deployment methods, or regulating space and low Earth orbits laws.
4. **Ethical evaluation**: Each solution should be evaluated based on its feasibility, effectiveness, and ethical considerations. Factors such as the technical feasibility of implementing changes, the extent to which the solution addresses astronomers' concerns, and the potential trade-offs and benefits should be taken into account.
5. **Reflection**: A decision is made regarding the best course of action. This decision should be guided by a thorough analysis of the problem, an understanding of the ethical implications, and a consideration of the interests and perspectives of all stakeholders involved.

· CHAPTER II.6 ·

Ethical Questions in the Design of Technology

The design phase is crucial for ensuring the proper functioning of a technology and identifying its potential risks and side effects. Additionally, activities closely associated with design, such as testing, certification, and inspection, play a significant role in ensuring quality and safety. The fact that the majority of designs involve trade-offs [3] should also be taken into account. The last problem of this phase is that while innovative design has the potential to address significant design issues, it can also introduce new risks.

This chapter will analyse the main issues of the design phase through the following topics:

- Identification of ethical issues at the different stages of the design process.
- Conflicts between design requirements and values.
- Methods for dealing with value trade-offs in design and their pros and cons.
- Application of these methods to engineering design problems.
- Discussion about the extent to which engineers can rely on existing regulatory frameworks when making ethical decisions in engineering design.
- Explanation of how technology influences human behaviours and its ethical considerations.

References

All the information presented in this chapter is based on the following references unless otherwise specified:

- Poel (2011) *Ethics, Technology and Engineering: an Introduction*, Wiley-Blackwell [14]
- Van Gorp (2005) *Ethical Issues in Engineering Design: Safety and Sustainability*, Simon Stevin Series [49]
- Van Gorp (2001) *Ethical Considerations in Engineering Design Processes*, Technology and Society [13]

II.6.1 Ethical Issues During the Design Process

Engineering design involves transposing specific functions into a blueprint for an artefact, system, or service capable of fulfilling the required functions. It is typically a systematic process that uses technical and scientific knowledge. The design process is iterative and can be divided into various stages:

1. **Problem analysis and formulation**, including the formulation of design requirements.
2. **Conceptual design**, including alternative conceptual solutions and reformulations of the problem.
3. **Simulation**, in order to test how well concept designs meet the requirements.
4. **Decision**, selecting one conceptual solution from the set of possibilities.
5. **Detailed design**.
6. **Prototype development and testing**, this testing process can result in modifications to the design.
7. **Manufacture and construction**.

Ethical aspects can be of significance in design processes. Mainly, ethical issues may appear in engineering design processes in two different ways: the formulation of design requirements and criteria, and the acceptance of trade-offs between different design criteria. In order to decide if an aspect of the design process is ethical, the following conditions should be considered:

[3] A trade-off is a balancing of two opposing situations or qualities, both of which are desired. It is also a situation in which the achieving of something you want involves the loss of something else which is also desirable, but less so.

- The aspect of the design process is connected to possible negative consequences for people other than the designers involved.
- Values or norms that are widely recognized, such as safety or privacy, are involved in the design process.
- The norms and values of the different engineers were in contrast with each other in the resulting technology or product.

Design choices significantly impact the social consequences of a product, although later choices by users also hold importance. However, it is during the design process that decisions have the greatest influence on the overall societal impact of a product.

Formulating design requirements is commonly regarded as an initial step in the design process. Various parties, not just engineers, often contribute to the formulation of design requirements or criteria. This can involve stakeholders providing specific design requirements or the establishment of generic requirements through legislation. Some authors argue that engineers should not be directly involved in the formulation of design requirements and instead, their role should be to determine the best technological solution based on given goals and criteria. This idea presupposes a division of labour as illustrated in Fig.II.6.1 in which politicians, managers, principals, and customers formulate the goals and criteria a technology has to meet. The described model has several limitations. Firstly, the design of products can influence their usage and resulting effects, as certain designs may encourage or discourage specific forms of use. Secondly, engineers may have valid moral reasons to question the adequacy of legal requirements, particularly in areas like safety. Furthermore, the division of labour proposed in the model is unsatisfactory due to the nature of design problems. Design problems are often ill-structured or ill-defined, making it challenging to formulate design requirements before exploring potential solutions. Instead, the formulation of design requirements is an ongoing process during design. Additionally, the ill-defined nature of design problems means that there is typically no definitive or optimal solution. Design involves decision-making that extends beyond the initial requirements and goals.

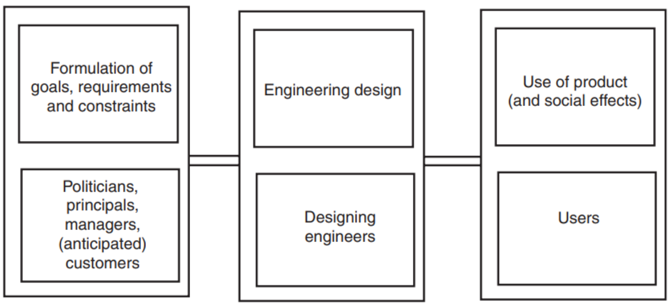

Figure II.6.1: Division of labour with respect to engineering design in which engineers should not have direct involvement in formulating design requirements; rather, their focus should be on identifying the best technological solution based on predefined goals and criteria. Source: [13]

In many cases, not all design requirements or criteria can be met simultaneously, requiring compromises or trade-offs. The determination of which trade-offs are acceptable or desirable is a normative decision, especially when ethical criteria like safety or sustainability are involved. Designers can approach trade-offs by seeking new technical options that minimise or satisfy all design criteria. However, there are instances where trade-offs must be accepted, and a decision needs to be made.

The main ethical issues typically encountered in each stage of the design process are discussed below.

II.6.1.1 Problem Analysis and Formulation

The formulation of the design problem and design requirements occurs in this stage, defining the criteria for an optimal or acceptable solution although subsequent findings may lead to the revision of the problem formulation or design requirements. The formulation of the design problem plays a crucial role as it sets the framework for addressing the problem throughout the design process.

Design requirements are formulated alongside the design problem, taking into account ethical considerations related to safety, health, environment, sustainability, and social consequences. These considerations, guided by professional and corporate codes, may also be reflected in legislation. In certain engineering fields, designs must undergo certification before they can be produced and used.

II.6.1.2 Conceptual Design

During the conceptual design stage, the primary objective is to generate new concept sketches or models. This phase heavily relies on the creativity of designers, while also emphasizing the significance of virtues such as competence, precision, honesty, accuracy, and reliability. Although creativity is considered a professional virtue rather than a moral one, it can still hold moral significance for designers since it has the potential to bridge conflicting moral values that are relevant to the design process.

II.6.1.3 Simulation

During the simulation stage, the concept designs undergo a thorough evaluation to determine their compliance with the design requirements. This evaluation is carried out through various methods, such as calculations, computer simulations, and prototype testing. Moreover, the simulation stage plays a crucial role in assessing the feasibility and effectiveness of the concept designs although the reliability of predictions is mainly a methodological matter.

Computer models are frequently employed in simulations, although it should be noted that these models may rely on knowledge that is not entirely reliable. Moreover, computer simulations can be deemed unreliable for several reasons, as suggested by Petrosky [14, page 170]:

- Computer models can contain errors that the users of the model are unaware of.
- The assumptions used in creating a computer model can be incorrect, even if no obvious errors are made. This issue is often worsened by the fact that users of the models are unaware of the assumptions made by the creators and the potential lack of reliability in these assumptions.
- Sometimes, people who use computer models do not realise that these models have specific limitations and can only be applied in certain situations. Therefore, there is a risk that these models are used in areas where their predictions are not very trustworthy.

These problems become worse because computer models give the impression of being precise and certain. Consequently, engineers tend to have excessive confidence in the accuracy of predictions derived from computer models. This misunderstanding aligns with the fallacy of wishful thinking.

II.6.1.4 Decision

In the decision stage, different concept designs are compared using the findings from the previous simulation stage, and a selection is made for a design that will be further developed. Also, the evaluation of the various potential designs typically considers the design requirements identified in the analysis stage. Then, the designs can be evaluated for their potential positive and negative effects on society.

In design processes, it is rare for any of the potential designs to excel in all design criteria. For example, the safest aircraft design may not be the cheapest. Therefore, compromises must be made regarding the different design criteria, which is known as a trade-off. The key issue is how to determine the most acceptable trade-offs between the different design criteria. This question often has ethical implications as different criteria, such as safety, sustainability, and ease of use are morally motivated. The key principle is that decision-making in design should be inclusive, considering the perspectives of relevant stakeholders and moral considerations. Effectively managing decision-making throughout the design process is crucial for achieving good design outcomes. David Collingridge has proposed four criteria that can guide this decision-making process [14, page 173]:

- Modifiability of decisions.
- Choose systems that are easy to control.
- Flexibility of the decision.
- Insensitivity of the decision to error.

It is important to note that a good solution will exhibit as many of these traits as possible.

II.6.1.5 Detailed Design

During the detailed design stage, moral considerations may also arise as the chosen design is elaborated and refined. One area of ethical concern in this stage involves decisions regarding, for example, the selection of materials since different materials have different risks, health effects, and environmental impacts.

II.6.1.6 Prototype Development and Testing

The lack of proper testing is often seen to play a significant role in causing a disaster during the service life of the product or technology. However, tests themselves are not infallible. One challenge is that tests may not accurately reflect the real-life conditions in which the product will be used. Thus, it is important to identify the relevant circumstances for conducting effective tests and distinguish them from irrelevant ones.

II.6.1.7 Manufacture and Construction

Manufacturing and construction processes can give rise to ethical concerns that can be identified and addressed during the design stage. One such concern is the labour conditions during these processes. In competitive markets, there is often an ambition to minimise production costs, which can lead to poorer labour conditions and this raises ethical questions about what conditions are acceptable. A related issue is the outsourcing of production to low-wage countries. Here, labour conditions also relate to matters of safety and health protection of workers. Furthermore, the production and construction phase can present ethical concerns regarding environmental impact and sustainability.

II.6.2 Trade-offs and Value Conflicts

Choosing between different designs can indeed be challenging because each design usually performs well in different aspects. Therefore, making trade-off decisions becomes difficult, especially when conflicting design criteria align with different moral values. This situation creates a value conflict in the design process. A value conflict arises when all the following conditions are met:

- A decision needs to be made among a minimum of two options, and at least two values are considered relevant as criteria for making that choice.
- At least two different values to identify different options as the most favorable one. The reason for this condition is that if all values select the same option as the best one, a value conflict is not really faced.
- Values do not override each other, that is, no value holds more significance than another. In other cases, a hierarchy of options based on the most important value can be established. Thus, when values do not trump each other, there is no real value conflict.

Value conflicts present moral challenges as they can lead to situations where designers are unable to uphold all relevant moral values simultaneously. In these cases, a value conflict becomes a moral problem.

For example, in the aerospace engineering field a trade-off may be the decision between weight and fuel efficiency. In aircraft design, reducing the weight of the aircraft can lead to improved fuel efficiency. However, reducing weight often involves using expensive lightweight materials, which can increase manufacturing costs. Designers must make a trade-off between achieving the desired fuel efficiency and managing the cost of materials. On the other hand, an example of a value conflict may be environmental impact versus performance when designing an aircraft. Increasing the performance of an aircraft, such as its speed or payload capacity, often leads to higher fuel consumption and emissions, thus negatively impacting the environment. Designers face the challenge of finding a balance between maximising performance and minimising environmental harm.

There are different ways to evaluate these conflicts. Some of these methods are: cost-benefit analysis, multiple criteria analysis, the determination of thresholds for design criteria, reasoning about values, and the search for new technical solutions.

II.6.2.1 Cost-benefit Analysis

Cost-benefit analysis is a commonly used method in engineering where all relevant considerations for selecting between different options are converted into a single unit, typically a monetary value. This approach is suitable for optimising the expected economic value of a design. Questions arise regarding how to account for future benefits compared to present costs. In addition, when non-economic values are also important, the use of cost-benefit analysis becomes more controversial.

Approaches such as *contingent valuation* have been created to assign monetary values to non-economic factors. It is carried out asking people how much they are willing to pay for a certain matters such as level of safety or sustainability. However, these approaches have significant limitations and are frequently criticised for their reliance on the fallacy of assigning prices to such values.

II.6.2.2 Multiple Criteria Analysis

A second method to weigh different design criteria is multiple criteria analysis. It is an approach and a set of techniques used to prioritise and rank different options based on multiple criteria. The main objective is to determine the preferred option among the available choices. Each option is evaluated based on its ability to achieve different objectives, and it is common for no single option to excel in all objectives. Conflicts or trade-offs often arise between the objectives, such as between costs and benefits. There may also be conflicts between short-term and long-term benefits, and certain options may carry higher risks despite their overall benefits. This approach helps navigate these complexities and provides a systematic method for decision-making by considering multiple criteria simultaneously [50].

In multiple criteria analysis, comparing options is less precise than in cost-benefit analysis since there is no explicit effort to convert all criteria into a single unit. As a result, decision-making can be flawed because the outcome depends on the chosen scale or measurement used for each criterion. Therefore, the recommended approach is to create a decision tree, outlining the consequences at the end, and use this method to assign an overall preference score to each consequence. These scores are then integrated back into the decision tree using the expected utility rule [4], taking into account probabilities. This process generates probability-weighted scores for each option, enabling a clear and comprehensive ranking of the options based on preference.

[4] In the expected utility method individuals should evaluate each possible outcome of a decision, assign subjective utilities to these outcomes, and weigh them by their probabilities. The utility represents the individual's subjective satisfaction or preference for a particular outcome.

II.6.2.3 Thresholds

A third way to handle the conflict in design criteria is to set a threshold for each criterion. Threshold refers to the minimum requirement or level that an alternative must meet in order to be considered acceptable in terms of a specific criterion or value. That is to say, it represents the lowest point that must be achieved for the alternative to be deemed satisfactory in relation to that criterion. One example of applying thresholds is in the design of aircraft wings. A criterion for wing design could be structural integrity, ensuring that the wings can withstand the forces and loads experienced during flight. Therefore, engineers may set a threshold for the maximum stress or deformation that the wings can tolerate without compromising safety. If a design option exceeds this threshold, it would be considered unacceptable and would require further modifications or improvements to meet the required criteria.

Setting thresholds has the advantage of individually considering the acceptable level for each criterion without directly trading off between different design requirements. This approach can ensure a minimum level of different issues during the design process. However, it raises the question of whether it is feasible to determine thresholds in complete isolation from other considerations.

II.6.2.4 Reasoning

The discussed approaches for handling trade-offs primarily rely on calculations and analysis. However, reasoning is another approach that takes a different perspective. It focuses on judgement and thoughtful consideration of values. This approach aims to uncover the underlying values associated with conflicting design requirements and involves two steps:

1. Identifying and specifying relevant values.
2. Seeking common ground among them.

By engaging in reasoning about values, designers can gain a deeper understanding of the ethical dimensions involved and work towards finding solutions that balance conflicting design requirements.

II.6.2.5 Value Sensitive Design

Value conflicts in engineering design can be addressed not only through analysis and argumentation but also through technical solutions. Engineering has the potential to develop new options that can resolve or mitigate value trade-offs. Value sensitive design is an approach that recognises this potential of engineering to address and mitigate value conflicts and it seeks to systematically integrate ethical values of importance into the design process.

That is to say, by considering these values from the outset, this method aims to ensure that ethical considerations are incorporated into the design decisions and outcomes. The approach aims at integrating three kinds of investigations: conceptual, empirical, and technical.

II.6.3 Regulatory Frameworks

Engineering design often involves the redesign of existing products or systems. Over time, experience with these products has led to the development of codes, standards, and legislation to regulate their design and operation. While some rules apply universally to all engineers and technical products, many are specific to particular industries or technologies.

These product-specific rules, collectively known as the regulatory framework, can be seen as a form of morality as they provide guidance on how to act rightly in the context of a specific technology. The rules are often based on past experiences, such as accidents or social impacts associated with the technology and they may also be influenced by public concerns or democratic decision-making processes.

Therefore, the regulatory framework serves as a helpful tool for engineers in making ethically relevant decisions during the design process since it provides a set of established guidelines and helps prevent the drawbacks of technocracy. However, it is important for engineers to critically evaluate the regulatory framework and not blindly follow it. Just because something is part of the regulatory framework does not automatically make it ethically acceptable.

To assess the feasibility of adhering to a regulatory framework during the design process, engineers may consider the following set of criteria:

- It is accurate because it includes all the important decisions and does not overlook any relevant issues.
- It is free of contradictions and inconsistencies.
- It is unambiguous.
- It is morally acceptable.
- It is accepted in practice.

In this situation, when the existing framework is morally unacceptable or open to debate, engineers have several strategies to consider:

- Engineers can work towards changing the framework by actively participating in the formulation of technical codes and standards, as well as setting up test procedures.
- They can inform other parties responsible for formulating different parts of the framework, such as the government or professional associations, about their concerns regarding the existing framework.
- They have the option to deviate from certain elements of the regulatory framework during the design process. While some elements of the framework may be mandatory due to legislation, there is often room for flexibility in other aspects. However, it is important to carefully consider the implications and potential consequences of deviating from the established framework, as it may involve additional risks and responsibilities.

II.6.4 Do Artefacts Have Politics?

The influence of everyday artefacts on human behaviour and decision-making raises the question of whether these objects possess inherent moral characteristics. Thus, can people attribute moral qualities to technology based on its impact on their actions? Additionally, another ethical dimension to consider is whether is it acceptable to intentionally shape human behaviour by designing objects that manipulate their actions or not.

In essence, the issue revolves around whether the influence employed by technology implies an inherent moral dimension. Furthermore, it motivates to reflect on the ethical implications of deliberately designing objects that steer human behaviour.

In 1980, Langdon Winner, a political theorist, published one of the most renowned articles addressing this topic: "Do Artefacts Have Politics?" [51]. This publication has become a highly recognised work in the field, inducing critical discussions about the role of technology in shaping social dynamics and power structures. The key points of the article are as follows:

- Winner argues that technologies reflect and influence social relations and power dynamics. They shape social relationships and can have political implications.
- Winner describes two ways in which objects can have politics.

- The first way is when the design and organisation of objects influence how society functions. It goes beyond the expected and unexpected results, as the process of creating technology can favour specific social groups.
- The second way in which objects can have politics is through the values embedded in their design and organisation. Objects can embody certain social and political ideologies, shaping and influencing the power dynamics within society.

Winner emphasises, therefore, that the process of technological development is crucial in determining the politics of an artefact since the biases and values embedded in the design process can have significant social and political implications. He also highlights the importance of involving all stakeholders in the development process. Determining who the stakeholders are and how to incorporate their perspectives becomes essential in addressing the political dimensions of artefacts.

In this article, an example of how artefacts can have politics is discussed through the case of Robert Moses' racist overpasses. Robert Moses, a urban planner in New York City, designed a series of low overpasses on parkways leading to Long Island. These low overpasses were built at a height that prohibited public buses from passing underneath. By implementing these low overpasses, Moses effectively restricted the access of marginalised communities – in Moses' days these were generally Afro-American people – to public spaces. This example illustrates how the design and arrangement of physical structures can be used as a tool to perpetuate existing power dynamics and social hierarchies.

On the other hand, critical responses to Winner's article, such as "Do Politics Have Artefacts?" by Joerges [52], have raised several important points. One critique revolves around the extent to which artefacts themselves possess inherent politics or if it is the intentions and actions of individuals that shape their political impact. Besides, attributing politics to artefacts can overlook the agency and responsibility of human actors in designing and using technology. Additionally, he questions the generalisation of Winner's analysis, arguing that the case studies he presents may not be representative of all technological artefacts. Furthermore, the notion of artefacts having politics is seen by some as an oversimplification, as it fails to consider the complex and multifaceted factors that contribute to social and political dynamics. Despite these critiques, Winner's article has sparked valuable discussions about the relationship between technology, power, and social order, inviting further exploration into the ethical implications of technological design and implementation.

It should be noted that, in both cases, although the ethics of engineering design tends to mainly focus on the importance of taking individual responsibility to prevent technological disasters, it is in this process that people can start analysing the moral dimension of technological products and actively take responsibility for the moral considerations associated with them. To examine these effects of technologies and the different facets of how technological artefacts operate within their usage contexts, the notion of technological mediation proves to be a useful tool. Technological mediation refers to the idea that technological artefacts are not just passive tools, but active agents that shape human interactions. Thus, it recognises that technologies have an influence on how people perceive, understand, and interact with the world.

II.6.5 Case Study: Autopilot Mode and the Ethics of Autonomous Vehicles

Autonomous vehicles are quickly becoming a part of our tangible future as numerous industries are investing in research and development to make this technology a reality. Companies ranging from traditional automobile manufacturers to social media platforms are heavily involved in developing autonomous vehicles to replace human-operated vehicles. The expectation is that the cost-effectiveness and convenience of autonomous vehicles will eventually surpass those of traditional vehicles and proponents of this technology also argue that it has the potential to significantly enhance highway safety by reducing the frequency and severity of automobile accidents [9, pages 258-259].

The introduction of self-driving vehicles raises numerous ethical issues that extend beyond the commonly discussed hypothetical scenarios. These issues cover a wide range of topics, including social and political conflicts stemming from strong opinions for and against driver-less cars, for example [53]:

- Trade-offs between safety and other requirements in the road traffic system are likely to arise.
- There is concern that relying too heavily on the collision-avoidance capabilities of self-driving cars may lead individuals to engage in risky behaviour, such as assuming a vehicle will always brake in time.
- Safety instructions, such as seat belt usage for children travelling alone, may be disregarded.
- The digital information transmitted to car users about routes and destinations can be used for commercial or political purposes.
- There are apprehensions about hackers accessing and manipulating autonomous vehicles, either causing them to crash or using them for criminal purposes like transporting explosives or disrupting a country's road system.

These ethical concerns are shown in present-day news in articles such as "Tesla Autopilot and Other Driver Assist Systems Linked to Hundreds of Crashes" [54] and "Public Streets Are the Lab for Self Driving Experiments" [55] both published by the New York Times.

II.6.5.1 Development of Study Questions

Make a list of the ethical issues that arise in the design process and development of autonomous vehicles.

- **Safety**: Ensuring the safety of the vehicle occupants and other road users is of uttermost importance. Ethical questions arise regarding the level of reliability required for autonomous systems to minimise accidents and prevent harm.
- **Liability**: Determining the distribution of liability in the case of accidents or malfunctions is a complex ethical issue. Who should be held responsible: the vehicle manufacturer, the software developer, or the human occupant?
- **Decision-making in critical situations**: Autonomous vehicles may encounter situations where they must make split-second decisions that may impact human lives. Ethical considerations arise in determining how these decisions should be programmed, such as prioritising the safety of vehicle occupants versus pedestrians or choosing the lesser of two potential harms.
- **Privacy and data security**: Autonomous vehicles collect and store vast amounts of data about their occupants and surroundings. Protecting privacy and ensuring data security are significant ethical concerns that involve safeguarding personal information from unauthorised access.
- **Equity and accessibility**: Questions arise regarding the equitable distribution of autonomous vehicle benefits across different populations because ensuring accessibility, affordability, and inclusivity in autonomous transportation is fundamental.
- **Technological limitations**: Ethical issues also emerge when considering the limitations and dependencies of autonomous vehicle technologies. As engineers design and develop these technologies, it becomes crucial to effectively communicate the boundaries of the technology to the general public in order to prevent over-reliance on autonomous systems because failing to address these limitations can lead to potential risks. For instance, if users assume that autonomous vehicles are infallible and fail to remain aware and ready to take control when necessary, it can result in accidents. Therefore, considering the technological limitations and ensuring proper education and awareness are essential ethical considerations.
- **Environmental impact**: Ethical considerations involve promoting sustainability, reducing emissions, and designing systems that prioritise environmentally friendly transportation.
- **Public trust and acceptance**: Building public trust and acceptance in autonomous vehicles is an ethical challenge. Transparent communication, stakeholder engagement, and addressing concerns regarding safety, privacy, and ethical decision-making are basic to promote trust.

It is important to note that this is not an exhaustive list, as the field of autonomous vehicles is quickly evolving and new ethical issues may emerge.

The trolley problem is a thought experiment often used to discuss ethical dilemmas in autonomous vehicle design. It presents a scenario where a runaway trolley is heading towards a group of people, and the person controlling the trolley must decide whether to divert it to a different track, potentially sacrificing one person to save the others. In the context of autonomous vehicles, a similar ethical question can be formulated: In a situation where an unavoidable accident is imminent, should an autonomous vehicle prioritise the safety of its occupants or attempt to minimise harm to other road users, even if it means potentially sacrificing the occupants' safety?

There is a debate about whether autonomous vehicles should be programmed to follow a single moral theory or if different ethical frameworks should be considered. Deciding these complexities requires a balanced consideration of moral philosophy, societal values, legal frameworks, and public opinion.

- **Utilitarian approach**: Utilitarians argue that autonomous vehicles should prioritise the overall welfare of society, taking a utilitarian perspective. In this view, the vehicles should minimise overall harm, which may mean sacrificing the safety of the occupants if it saves a greater number of pedestrians or cyclists.

  Under this approach, the autonomous vehicle's algorithms would be designed to calculate the potential consequences of different actions and choose the course of action that results in the least amount of harm. For example, if the vehicle detects an imminent collision, it may prioritise turning aside or braking even if it poses a higher risk to the occupants.

  It suggests that prioritising the safety of others over the vehicle occupants would lead to a reduction in overall accidents and fatalities and they argue that this approach aligns with ethical principles of fairness and the greater good.

  However, there are criticisms and challenges associated with implementing the utilitarian approach. Some argue that it may lead to a decrease in consumer trust and acceptance of autonomous vehicles if people perceive them as prioritising others' safety over their own. It may also raise legal and liability issues, as manufacturers could face legal consequences if a vehicle's programming intentionally causes harm to occupants.

- **Kantianism**: According to a Kantian perspective, autonomous vehicles also should strive to prioritise the safety of all individuals on the road equally. They should follow consistent and universal moral principles that respect the inherent worth of all persons involved, rather than favoring one group's safety over another's.

- **Prioritising the safety of occupants**: Supporters of prioritising the safety of occupants argue that individuals have a natural instinct for self-preservation, and autonomous vehicles should prioritise protecting the lives of their occupants. From this perspective, the primary goal of the vehicle is to safeguard the people inside it, as the occupants are directly responsible for the vehicle's operations and well-being.

- **Prioritising the safety of pedestrians**: It presents an alternative perspective to the prioritisation of occupants.

  It argues that pedestrians are among the most vulnerable road users as they have no protection in case of a collision with a vehicle and prioritising their safety acknowledges their vulnerability and aims to reduce harm to those who are most at risk.

They state that there is a moral obligation to non-participants and autonomous vehicles operate in a shared environment, and their actions can impact individuals who are not directly involved with the vehicle. Prioritising the safety of pedestrians recognises the moral obligation to consider the well-being of those who are not inside the vehicle but are affected by its actions.

Prioritising the safety of pedestrians may also positively influence public perception and acceptance of autonomous vehicles. By demonstrating a commitment to public safety, autonomous vehicle manufacturers and operators can build trust, increase confidence, and foster a more favourable view of the technology.

However, it is important to carefully consider the implementation of such prioritisation to avoid unintended consequences, such as encouraging reckless behaviour among pedestrians or creating situations where autonomous vehicles become overly cautious, causing disruptions in traffic flow.

- **Occupant preference:** The occupant preference perspective suggests that individuals who use autonomous vehicles should have the ability to determine the vehicle's safety priorities based on their own values. In this approach, the responsibility of prioritising safety is shifted to the vehicle's occupants rather than relying on the programming of the system.

  Advocates of occupant preference argue that individuals should have the autonomy to make decisions about their own safety, especially in situations where there might be a trade-off between the safety of occupants and the safety of other road users. They believe that personal values, cultural norms, and individual risk tolerances should be taken into account.

  Under this perspective, the programming of autonomous vehicles could include customisable settings that allow occupants to define their preferred safety parameters.

  However, there are ethical and practical challenges with implementing occupant preference. Critics argue that allowing occupants to prioritise their own safety could lead to selfish or reckless behaviour, potentially endangering other road users. It may also create legal and liability issues if the programmed preferences conflict with established legal and ethical boundaries.

In case of accident, who should be held responsible: the vehicle manufacturer, the software developer, or the human occupant?
Determining responsibility in the event of an accident involving an autonomous vehicle is a complex and evolving topic that depends on various factors, including the specific circumstances of the accident, the applicable legal framework, and the level of autonomy of the vehicle. Although legal regulations may differ and they are subject to change, some general considerations are:

- **Vehicle manufacturer**: In cases where the accident is caused by a defect in the vehicle's hardware or mechanical components, the manufacturer could be held responsible. Manufacturers have a duty to ensure that their vehicles meet safety standards and are free from manufacturing defects.
- **Software developer**: If the accident is caused by a programming error, software bug, or inadequate system performance, the software developer may be held partially responsible. The software controlling the autonomous vehicle's functions plays a critical role in its safe operation, and any negligence could contribute to an accident.

- **Human occupant**: In certain circumstances, the human occupant may still bear some responsibility for the accident. This could occur if the occupant failed to intervene or take control of the vehicle when required, disregarded warnings or instructions, or engaged in reckless behaviour that contributed to the accident. The level of autonomy of the vehicle and the specific circumstances leading to the accident could influence the distribution of responsibility.

To what extent should autonomous vehicles balance the collection and use of personal data for improved functionality and safety with the privacy and data security concerns of vehicle occupants and other individuals sharing the road?
Some key points to address are:

- Privacy is a fundamental human right recognized by various international and regional frameworks. Engineers have an ethical obligation to respect and protect individuals' privacy rights. Autonomous vehicles should prioritise privacy considerations in the design and implementation of data collection and usage practices.
- Engineers should adhere to the principle of data minimisation, collecting and preserving only the necessary data for the proper functioning and safety of autonomous vehicles since unnecessary data collection increases privacy risks.
- Engineers should ensure that vehicle occupants and other road users have access to clear information about the types of data collected, how it is used, and with whom it is shared. Moreover, they should obtain informed consent from individuals.
- Engineers have an ethical responsibility to implement robust data security measures to protect personal data from unauthorised access, breaches, or misuse.

Therefore, engineers need to follow standards to protect people's privacy and personal information. This means they should make sure they are following the law and using best practices to keep data safe and prevent it from being misused.

To what extent should accessibility to autonomous vehicles for all members of society be prioritised over the costs of their design and manufacturing?
When considering the design of autonomous vehicles, prioritising accessibility to them for all members of society should be given significant importance over the overall costs of their design and manufacturing:

- Prioritising accessibility aligns with principles of social equity, fairness, and inclusivity. There is an ethical responsibility to ensure that the benefits of new technologies are accessible to everyone, especially marginalised communities.
- While the costs of design and manufacturing are important considerations, prioritising accessibility can allow long-term societal benefits. Accessible autonomous vehicles can enhance mobility, promote economic opportunities, and improve quality of life. These benefits outweigh the upfront costs and contribute to a more inclusive society.
- Prioritising accessibility does not mean disregarding cost considerations entirely. Instead, it encourages innovative approaches and collaborative efforts to develop cost-effective solutions without compromising accessibility.
- Prioritising accessibility in the design of new technologies can enhance public perception and trust. When the benefits of autonomous vehicles are accessible to all, communities are more likely to support their adoption.

· CHAPTER II.7 ·

Ethical Aspects of Technological Risks

When a risk becomes a reality, it is typical to inquire about the accountability for taking that risk. Hazards are inherent to technology, with some risks known in advance and accepted due to expected benefits. Negative effects can arise not only from known risks but also from unforeseen hazards. Instances like the Tacoma Narrows Bridge collapse [5] demonstrate how technology can fail in ways that had not been foreseen beforehand. There is also controversy with certain hazards, such as the intensified greenhouse effect and its consequences, which have been a topic of scientific debate for decades. Additionally, it is challenging to attribute specific hazards to one technology, as they often arise from the widespread use of various technologies.

This chapter will explore the concept of technological risks through the following topics:

- Discussion on why engineers are responsible for safety and how they can apply this responsibility.
- Main approaches to risk assessment.
- Main ethical considerations for judging the moral acceptability of risks and their applications.
- Ethical issues in risk communication and how to deal with them.
- Discussion on the conditions under which experiments are morally acceptable.

References

All the information presented in this chapter is based on the following references unless otherwise specified:

- Poel (2011) *Ethics, Technology and Engineering: an Introduction*, Wiley-Blackwell [14]
- Poel (2012) *Risk and Responsibility*, Springer Netherlands Dordrecht [57]

Definitions of Key Concepts

There are some terms that need to be understood beforehand for the proper comprehension of this chapter. These terms are as follows:

- **Hazard**: Possible damage or otherwise undesirable effect.
- **Risk**: It is a specification of a hazard. The most often used definition of risk is the product of the probability of an undesirable event and the effect of that event.
- **Safety**: The condition that refers to a state in which the risks have been minimised to the greatest extent that is reasonably possible and desirable.
- **Acceptable risk**: It refers to a risk that is considered morally acceptable. Several factors are relevant in determining whether a risk is morally acceptable:

  1. The level of informed consent regarding the risk.
  2. The balance between the benefits and drawbacks of engaging in a risky activity.
  3. The availability of alternatives with lower risks.
  4. The fairness in the distribution of risks and benefits.

- **Uncertainty**: It is a lack of knowledge, specifically in situations where the type of consequences is known, but probabilities cannot be meaningfully assigned to their occurrence.

[5] The Tacoma Narrows Bridge, built in 1940, collapsed only four months after its construction due to a phenomenon known as aeroelastic flutter. Since then, this event has gained popularity and has been widely studied in various case studies that focus on the failure phenomenon of suspension cable bridges [56].

- **Ignorance**: Lack of knowledge. It refers to the situation in which someone is unaware of certain information or body of facts.
- **Standardisation**: It refers to the process of establishing uniform guidelines, criteria, or specifications for the design, production, and implementation of technologies. It involves developing and implementing a set of standards that ensure consistency, reliability, and safety in engineering practices. These standards aim to promote efficiency, interoperability, and compatibility while minimising risks and uncertainties.

II.7.1 Conceptual Relations Between Risk and Responsibility

The connection between risk and responsibility changes depending on the chosen understanding of both concepts. The technical conception of risk primarily describes risks but also incorporates a judgement about undesirable consequences. Responsibility often relates to negative outcomes, particularly when blame is involved. However, the occurrence of undesirable consequences, as referred to by the technical concept of risk, does not necessarily assign blame to anyone. Several conditions must be satisfied for someone to be fairly held responsible for such consequences. In cases involving risks, the knowledge condition is typically fulfilled because the recognition of a risk implies an awareness of potential outcomes. However, determining if the wrong-doing condition is met can be less clear. Risks generally pertain to unintended but not necessarily unforeseen consequences of actions. Nonetheless, there are situations where introducing a risk becomes a wrong-doing. One instance is when someone consciously exposes others to an unacceptable risk. The other is negligence, where the party is unaware of the risk but should have been aware and exposing others to the risk is deemed unacceptable. By focusing on forward-looking responsibility rather than backward-looking responsibility, the technical understanding of risk may imply an obligation to avoid risks due to their association with undesirable outcomes. However, this relationship is not straightforward. Certain risks, such as natural risks, may be unavoidable, while others may be justifiable considering the benefits of certain risky activities. However, a sense of forward-looking responsibility seems to exist in appropriately managing risks.

II.7.2 The Responsibility of Engineers for Safety

Engineers are often held responsible for ensuring safety in their work, as reflected in various codes of conduct and legal obligations related to product safety. However, relying exclusively on the law and codes of conduct is not enough to establish engineers' moral responsibility for safety. Therefore, to this purpose, ethical frameworks must be taken into account. Consequentialism, duty ethics, and virtue ethics offer additional arguments for why engineers should prioritise safety in their work. Consequentialism emphasises the positive outcomes and consequences of engineering decisions, duty ethics emphasises the moral obligations and responsibilities of engineers, and virtue ethics focuses on the development of virtuous character traits in engineers. These ethical perspectives provide a deeper understanding of why engineers should actively strive for the design of secure technology and consider safety as an integral part of their professional practice.

Throughout the design process, engineers can employ different strategies to ensure the safety of products. These strategies include:

- **Inherently safe design**: A method for designing with safety which involves preventing hazards rather than managing them. This can be achieved by substituting hazardous substances, mechanisms, and reactions with less hazardous alternatives.
- **Safety factors**: A safety factor is a numerical value that represents the margin of safety incorporated into the design or analysis of a system, structure, or component. The use of safety factors is widespread in structural engineering.
- **Negative feedback**: A mechanism that ensures that if a device malfunctions or an operator loses control, the - potentially hazardous - device will automatically shut down.

- **Multiple independent safety barriers**: A series of safety barriers that function independently of each other, so if one barrier fails, the others may still remain functional, preventing a complete system failure. This can, for example, be achieved through redundancy in design.

II.7.3 Risk Assessment

Engineers have the responsibility of reducing risks, but they are not necessarily responsible for determining what risks are deemed acceptable. In the traditional approach, risk assessment is viewed as the duty of engineers, while risk management falls under the domain of governments and company managers. The challenge lies in the fact that risk assessment cannot be entirely objective, as it requires prioritising certain risks over others. Nevertheless, it may be argued that risk managers should make decisions regarding what is considered undesirable, while risk assessors, as researchers, investigate all potential risks. However, some risks may be more difficult to scientifically investigate or quantify, making their assessment more challenging or even statistically undetectable.

To evaluate the acceptability of hazards, the initial step is often to identify and quantify them as risks. This is achieved through the process of conducting risk assessments. This method is a systematic investigation in which the risks of a technology of an activity are mapped and expressed quantitatively in a certain risk measure. In the field of engineering, various types and methodologies of risk assessment are employed, although the specific methods can vary across different engineering domains.

A risk assessment usually consists of four steps:

1. **Release assessment**: Releases refer to any physical effects that can cause harm and come from a technical system or setup. Some examples include shock waves, radiation, and the spread of dangerous substances.
2. **Exposure assessment**: The goal of this step is to anticipate the exposure of vulnerable individuals to specific releases. It involves determining what substance or harmful effect subjects are exposed to, the mechanisms of exposure - e.g., inhalation of toxic substances -, and the intensity, frequency, and duration of the exposure.
3. **Consequence assessment**: Its emphasis is on establishing the connection between exposure and the negative outcomes or harmful consequences that may result.
4. **Risk estimation**: the risk is assessed and communicated based on the previously gathered data. This involves determining the extent to which the risk is expressed, which can be quantified by factors such as the number of expected fatalities per time period or the shortened lifespan of individuals residing or working near the facility.

II.7.4 Acceptance of Risks

Some engineers and scientists erroneously believe that if two different activities have the same risks according to risk assessments, they are equally acceptable. However, this argument is flawed for several reasons. The most important is that assessing the acceptability of risks is not the same as assessing the overall acceptability of a particular technology or activity.

Risk assessments serve as a valuable source of information when evaluating the acceptability of risks. Besides that, ethical considerations also play a role in this assessment process. Examples of ethical considerations which must be taken into account are:

1. **Informed consent**: It is the principle that states that activities are acceptable if people have freely consented to them after being fully informed about the potential risks and benefits of these activities.
2. **Advantages versus risks**: One significant justification for the ethical acceptability of risks is the potential advantages associated with risky activities. In a broader sense, it can be argued that activities carrying risks,

and consequently the risks themselves, are deemed acceptable when the benefits outweigh the potential costs involved.

3. **Availability of alternatives**: The acceptability of risks associated with a particular technology is also influenced by the availability of alternative options that carry lower risks. The concept of best available technology is important. It is an approach to determining acceptable risk or environmental emissions but it does not specify a particular technology, but rather sets the best available technological alternative as the standard for what is considered acceptable.
4. **Risks and benefits justly distributed**: One crucial ethical aspect of accepting risks is the equitable distribution of risks and benefits associated with risky activities. It is considered unfair if certain groups consistently carry the burdens of these activities while other groups enjoy the benefits without sharing in the risks.

A first potential issue in this task is the insufficient consideration given to the advantages and disadvantages of engaging in risky activities. This utilitarian objection is clarified by means of the Fig.II.7.1: Say that the cost-risk of technology 1 is examined through points A and B. Meeting the standards at point A incurs significant expenses but only provides a minimal reduction in risk compared to point B. Utilitarians may prefer point B over meeting the standard at point A due to its higher desirability in terms of cost and risk. Hence, standardisation in certain cases can result in increased risks compared to scenarios where cost considerations are taken into account. Consider technology 2, represented by a curve passing through points X and Y. While technology 2 meets the standard at point Y, a substantially safer product can be achieved at a minimal additional cost at point X. From a utilitarian perspective, point X is often considered a more preferable outcome than point Y.

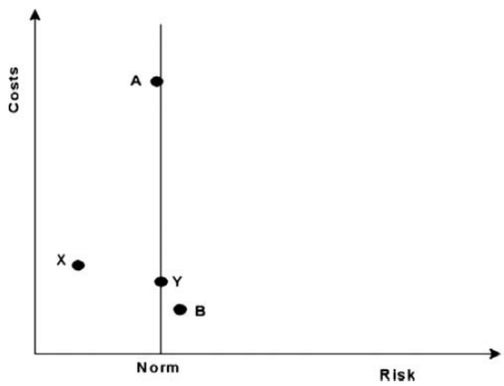

Figure II.7.1: Costs for risk reduction for different technologies. The points A and B represent technology 1. Points X and Y represent technology 2. Source: [14, page 235]

Another ethical objection to standardisation is its perceived paternalistic nature. Rather than allowing individuals to determine their own acceptable risks, the responsibility is placed on regulators, often the government, to make those decisions on their behalf. This objection is particularly relevant when it comes to personal risks, which only impact the buyer, user, salesperson, or producer. Market regulation may be a viable option for such products if certain conditions are met, such as providing complete information about risks and ensuring freedom of choice among different products, enabling informed consent. However, market regulation is ineffective for collective risks since it fails to address the risks that affect people beyond the user and producer. Collective decision-making becomes necessary in such cases to determine acceptable risks, which may or may not result in standardisation.

II.7.5 Risk Communication

The tasks of risk assessment, risk management and risk reduction involve different groups, such as engineers, scientists, the government, company managers, and the public, with different responsibilities. Since each group has its specific expertise and fulfilling one's specific responsibility often requires information from others, communication between the groups is of essential importance. Risk communication is therefore crucial for the entire system of dealing with risks to work.

Professional codes of conduct for engineers emphasise the responsibility to inform the public about risks and hazards, which raises ethical considerations. One question pertains to the purpose of risk communication: it is whether should it solely inform or also attempt to persuade. For example, when informing passengers about the risks of air turbulence, the focus can be on either providing factual information or also persuading them to remain calm and trust in the safety measures. Another question relates to the extent of informing people about risks, even if it may not be in their best interests or if there is a likelihood of misinterpretation. For example, in the case of a very low probability of a specific technical failure occurring during a flight, the question arises whether this information should be disclosed to passengers since sharing such information could potentially increase anxiety and lead to unnecessary concerns.

In the context of duty ethics, responsible risk communication is primarily focused on honesty, respecting individual freedom of choice, and avoiding paternalism. The principle of informed consent is crucial, meaning that the goal is to provide information rather than trying to persuade or convince people.

On the other hand, from a consequentialist perspective, the evaluation of risk communication differs. It is assessed based on the positive outcomes it produces. In some cases, attempting to convince or withhold certain information through risk communication can be morally justified if it leads to favourable consequences.

These contrasting ethical viewpoints highlight the different criteria used to determine responsible risk communication. Duty ethics emphasises honesty, autonomy, and informed consent, while consequentialism emphasises the overall goodness of the outcomes. Understanding these perspectives helps shape the approach to risk communication and ethical decision-making in different contexts.

II.7.6 Dealing with Uncertainty and Ignorance

In certain situations, risks are evaluated, but there remains uncertainty regarding the comprehensive assessment of all potential hazards. This leads to a fundamental ethical dilemma: Is it morally acceptable to introduce a new technology into society when there is scientific controversy or uncertainty surrounding its potential hazards? This question arises because, on one hand, there is a desire to safeguard society from risks, but on the other hand, completely forbidding a technology may also be undesirable. All in all, balancing the need for protection against hazards with the potential benefits of a technology becomes an ethical challenge that needs careful consideration.

II.7.6.1 The Precautionary Principle and The Burden of Proof

The precautionary principle is particularly applicable in situations where the full extent of hazards cannot be accurately quantified due to insufficient scientific knowledge. As a general guideline, the precautionary principle asserts that precautionary measures should be implemented when there are indications of potential hazards, even if they cannot be definitively proven through scientific means. This principle emphasises the importance of taking proactive steps to mitigate risks in the face of uncertainty and to prioritise the protection of human health and the environment.

On the other hand, the burden of proof pertains to the responsibility of demonstrating the safety and minimising risks associated with a particular technology or activity. Traditionally, the burden of proof lies with those raising concerns or questioning the safety of a technology. However, in the context of the precautionary principle, the burden of proof is shifted to those proposing or advocating for the adoption of a technology. It places the responsibility on engineers and stakeholders to provide evidence and justification that the proposed technology is safe and the potential risks are adequately addressed.

Therefore, while the precautionary principle emphasises the need for preventive action in the face of uncertainty, the burden of proof focuses on the responsibility of demonstrating and ensuring the safety of a technology and it is important to strike a balance between these two concepts [58, 59].

In summary, the precautionary principle and the burden of proof are different but complementary concepts and both approaches contribute to ethical decision-making by promoting caution, accountability, and protection of public welfare in engineering practices.

II.7.6.2 Engineering as a Societal Experiment

Before manufacturing a product or providing a project, several assumptions are made, and multiple trials, designs, and tests are conducted until the product is observed to function satisfactorily. Various materials and experiments must be tried and detailed design and retests must also be carried out based on the obtained test data. Consequently, both design and engineering are iterative processes and the development of a product or project as a whole may be considered as an experimental undertaking [60].

In many cases, it is not possible to fully predict the hazards of new technologies before they are introduced to society. This means that society itself becomes a testing ground for engineering experiments. Unlike controlled scientific experiments, societal experiments are usually difficult to stop if something goes wrong. Additionally, these experiments can have significant consequences, affecting not only the individuals involved but also third parties. Societal experiments with new technologies are typically large-scale and can cause irreversible harm. Therefore, it is essential to consider when it is acceptable to conduct these experiments and under what conditions.

Engineers are not entirely responsible for experiments; they share this responsibility with organisations, individuals, and the government. While engineers play a crucial role in monitoring projects, identifying risks, and providing factual information to the public, they also have the freedom to decide whether to participate, protest, or promote. As experimenters, engineers have several responsibilities towards society:

1. They must uphold moral values and act conscientiously.
2. They should maintain a comprehensive understanding of relevant information and continuously monitor the progress of the experiment, being alert to any potential side effects.
3. They should have the autonomy to be personally involved in all stages of project or product development.
4. They must be accountable for the outcomes of the project. Informed consent is an important principle used to assess these responsibilities.

The application of the principle of informed consent to societal experiments in engineering raises several concerns. Firstly, it becomes questionable to seek people's consent when the hazards or risks involved are uncertain or unknown to the experimenters. Giving consent to an experiment with unknown risks implies accepting any potential risk that may arise, which may not be a rational decision. Secondly, the principle of informed consent may be perceived as overly restrictive. Even if a societal experiment could bring significant benefits to society, it may be abandoned if any individual objects to it. This raises the question of balancing individual objections with potential societal benefits. Lastly, there is the challenge of dealing with individuals who are indirectly affected by the experiment but cannot give their informed consent, such as future generations.

One approach to addressing this issue is by considering the concept of hypothetical consent as a complement to actual consent. Hypothetical consent involves speculating about the conditions under which future generations would potentially give their consent to an experiment that poses hazards to them. By considering the long-term implications and potential benefits for future generations, it may be possible to establish criteria or principles that align with their best interests. However, determining the conditions for hypothetical consent requires careful consideration and input from different stakeholders, as it involves making assumptions about the preferences and values of future generations. Moreover, ensuring transparency and accountability in the decision-making process becomes crucial to safeguard the well-being and rights of those who cannot provide actual consent.

II.7.7 Case Study: Boeing 787 Dreamliner Battery Fires

The Boeing 787 Dreamliner, introduced in 2011, was acclaimed as a revolutionary aircraft that promised enhanced fuel efficiency, passenger comfort, and advanced technological features. However, the Dreamliner faced a significant setback in 2013 when a series of battery fires occurred, raising concerns about the safety and reliability of the aircraft.

The story of the Dreamliner battery fires can be traced back to the decision to use lithium-ion batteries, which offered higher energy density compared to traditional nickel-cadmium batteries. The lithium-ion batteries were chosen to power various critical systems, including the electrical system and auxiliary power unit.

In January 2013, a Dreamliner operated by Japan Airlines experienced a battery fire while parked at Boston's Logan International Airport. Shortly after, an All Nippon Airways Dreamliner also encountered a battery-related issue, leading to an emergency landing. On January 17th, 2013, the Federal Aviation Administration (FAA) ordered the entire 787 fleet across all airlines to be grounded, and the National Transportation Safety Board (NTSB) launched an investigation [61].

The subsequent investigation by the NTSB revealed that the battery had experienced an internal short circuit, which led to a quick increase in temperature and the release of flammable gases. The NTSB also discovered multiple design and manufacturing issues, including battery cell defects, inadequate insulation, and insufficient testing. These flaws, combined with the high energy density of the lithium-ion batteries, created a volatile environment that could potentially result in fire.

These incidents raised significant concerns about the safety and ethical aspects of the Dreamliner's design, the thoroughness of the testing, and certification procedures. Besides, Boeing faced intense scrutiny and pressure to address the issues promptly and the company worked closely with battery manufacturers and regulatory authorities to develop enhanced safety measures, including a redesigned battery containment system, improved thermal management, and stricter manufacturing standards.

Boeing implemented a series of modifications to enhance the safety of the 787's battery system. This included redesigning the battery enclosure, improving insulation, and implementing a better ventilation system to mitigate the risk of overheating. The revised battery system also included enhanced monitoring and containment measures to detect and contain any potential issues. After rigorous testing and scrutiny by the FAA and other regulatory bodies, the Dreamliner was eventually cleared to resume commercial service in April 2013, approximately three months after the initial grounding [62, 63].

These battery fires served as a warning for the aerospace industry, highlighting the need for rigorous risk assessment, testing, and ethical considerations in the development of new technologies. The incident prompted a reevaluation of safety protocols, regulatory practices, and the responsibilities of manufacturers and engineers in ensuring the safety and reliability of aircraft. While the incidents were undoubtedly a setback for Boeing and the Dreamliner program, the subsequent actions taken by the company and regulatory agencies have led to significant improvements in the safety and reliability of the aircraft. Nowadays, the Boeing 787 continues to operate as a popular aircraft in commercial aviation.

II.7.7.1 Development of Study Questions

Who do you believe was responsible for the case of the Boeing 787 Dreamliner Battery Fires?
Responsibility was attributed to multiple stakeholders:

- Boeing, as the aircraft manufacturer, was held responsible for the design and integration of the lithium-ion battery system.
- The battery supplier was also scrutinised for the quality and performance of the batteries since the investigation found that the batteries had internal short circuits, which generated the thermal runaway.
- Regulatory authorities, such as the FAA and NTSB, played a crucial role in overseeing the certification and safety of the Boeing 787. The battery fires prompted a reevaluation of the certification process and highlighted potential gaps in assessing the safety of emerging technologies. Therefore, these authorities faced criticism for not catching the issues earlier.

Did Boeing fulfill its ethical responsibilities in ensuring the safety of the Dreamliner aircraft? Why or why not?
The evaluation of whether Boeing fulfilled its ethical responsibilities in ensuring the safety of the Dreamliner aircraft is subjective and dependent on the perspective and the weight given to various factors. While there were weaknesses in the initial design and manufacturing of the battery system, Boeing took steps to rectify the issues and improve safety.

While it is important to recognise that ethical judgements can vary, several factors can be considered in this context:

- **Design, manufacturing, and testing**: The investigation into the battery fires revealed design and manufacturing flaws in the aircraft's battery system. These included battery cell defects, inadequate insulation, and insufficient testing. These issues raised concerns about Boeing's adherence to rigorous safety standards during the design, manufacturing and testing processes.
- **Risk assessment and mitigation**: Boeing's ethical responsibilities include conducting thorough risk assessments and implementing appropriate mitigation measures. In the case of the Boeing 787 battery fires, questions were raised regarding the adequacy of the risk assessment and whether Boeing sufficiently anticipated and addressed the potential hazards associated with the lithium-ion batteries. The subsequent modifications made to the battery system could demonstrate Boeing's commitment to mitigating the risks, but the initial oversight raises some concerns.
- **Transparency and communication**: Ethical responsibilities also extend to transparently communicating safety-related information to stakeholders, including customers, regulatory authorities, and the public. In the aftermath of the incidents, Boeing faced criticism for the initial handling of the battery fire issues, with some accusing the company of not being anticipated enough about the problems. However, Boeing cooperated with investigations, implemented improvements, and worked with regulatory authorities to address the concerns.
- **Continuous improvement**: Ethical responsibilities include a commitment to continuous improvement and learning from mistakes. Following the battery fire incidents, Boeing implemented comprehensive modifications to enhance the safety of the Dreamliner's battery system. These changes, along with subsequent rigorous testing and scrutiny, could reflect Boeing's dedication to improving the safety and reliability of the aircraft.

What ethical considerations should be taken into account when testing and certifying new technologies in the aerospace industry?

When testing and certifying new technologies in the aerospace industry, several ethical considerations should be taken into account:

- **Safety**: Rigorous testing protocols should be in place to identify potential risks and hazards associated with the new technology.
- **Informed consent**: Participants should be fully informed about the nature of the testing, potential risks involved, and any necessary precautions. Their consent should be voluntary and based on a comprehensive understanding of the implications.
- **Transparency and accountability**: Regulatory authorities, manufacturers, and stakeholders should openly share information about the technology, testing protocols, and safety measures.
- **Environmental impact**: Considerations should include the potential for increased carbon emissions, noise pollution, resource consumption, and any other negative ecological consequences. Minimising these impacts and working towards sustainability should be prioritized.
- **Long-term effects**: Ethical considerations extend beyond the initial testing phase. The long-term effects of the technology on various aspects, including safety, efficiency, economy, and sustainability, should be assessed.
- **Compliance with regulations**: This includes following the guidelines set by regulatory authorities, industry organisations, and international aviation safety standards. Compliance ensures that the testing and certification processes align with established safety benchmarks.
- **Ethical use of data**: Testing may involve collecting and analysing data from different sources. Thus, it is crucial to ensure the ethical use and protection of this data, respecting privacy rights and maintaining confidentiality.

Were there any conflicts of interest between cost-saving measures and safety considerations in the design and testing of the Dreamliner's battery system?
There were notable conflicts of interest between cost-saving measures and safety considerations in the design and testing of the aircraft's battery system. The Dreamliner program aimed to revolutionise air travel by introducing advanced technologies that would enhance fuel efficiency and passenger comfort. However, in the pursuit of these goals, cost-saving measures and pressures may have compromised certain safety considerations.

One of the notable cost-saving measures involved the use of lithium-ion batteries, which offered higher energy density and weight savings compared to traditional nickel-cadmium batteries. However, lithium-ion batteries also come with their own safety challenges, particularly the risk of thermal runaway and fire. Moreover, the investigation findings suggested that adequate safety considerations may not have been prioritised during the design and testing processes. The emphasis on cost-saving measures could have potentially influenced decisions related to the selection of suppliers, testing protocols, and the extent of quality control measures implemented.

Furthermore, there were concerns raised about the FAA's reliance on Boeing's own self-certification process. This raised questions about potential conflicts of interest, as Boeing, as the manufacturer, had a vested interest in minimising costs and ensuring timely certification. This arrangement may have impacted the level of scrutiny and oversight of the battery system during the certification process.

How did the Boeing 787 Dreamliner Battery Fires case exemplify the application of the precautionary principle in the aerospace industry?
The precautionary principle is a guiding principle that suggests taking proactive measures to prevent harm, even in the absence of conclusive scientific evidence.

In this context, the precautionary principle could have prompted a more cautious approach to the introduction of lithium-ion batteries in the aircraft. While these batteries offered benefits such as higher energy density and weight savings, their potential safety risks were well-known. The precautionary principle would have encouraged a thorough assessment of these risks before implementing the technology.

The application of the precautionary principle would have needed a more comprehensive evaluation of the risks, including conducting extensive testing, anticipating potential failure modes, and implementing robust containment measures. By taking a more precautionary approach, potential safety issues may have been identified and addressed before the aircraft entered commercial service.

The subsequent grounding of the Dreamliner fleet and the implementation of significant modifications to the battery system can be seen as a response to the precautionary principle. The precautionary measures were taken to mitigate the risks and restore confidence in the safety of the aircraft.

Overall, the case of the Dreamliner battery fires serves as a reminder of the importance of applying the precautionary principle in the aerospace industry. It emphasises the need for comprehensive risk assessments, thorough testing, and proactive measures to prevent potential harm, even when conclusive scientific evidence may be lacking. By embracing the precautionary principle, the industry can prioritise safety and reduce the likelihood of incidents or accidents that could compromise the well-being of passengers, crew members, and the public.

· CHAPTER II.8 ·

Distribution of Responsibility

When multiple individuals are involved in an activity and various factors contribute to a disaster, determining responsibility and assigning blame becomes challenging. The problem of many hands in engineering highlights the need to address the distribution of responsibility. It is crucial to examine how responsibilities are allocated in engineering and evaluate this distribution in terms of moral fairness - whether the right individuals are held accountable - and effectiveness - whether it helps prevent harm and achieve positive outcomes -. By discussing responsibility distribution, engineers can strive for a fair and effective allocation of responsibilities that promotes safety and beneficial results.

This chapter will explore the concept of distribution of responsibility through the following topics:

- The problem of many hands and how it applies to engineering.
- Responsibility distributions by moral fairness and by the effectiveness requirement.
- Difference between moral responsibility and legal liability.
- Notions of legal liability.
- How engineering designs may affect the distribution of responsibility.

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II.8.1 The Problem of Many Hands

The social consequences of technology are not entirely determined by the actions of engineers. These consequences are influenced by a multitude of actors, including users, governments, companies, and managers. Ideally, if all these actors behave responsibly, the overall impact on society should be positive. However, decision-making in technology can be fragmented, with different individuals focusing only on their specific responsibilities and this can lead to a lack of overall responsibility for safety.

The problem of many hands arises when numerous individuals contribute to an undesired outcome, yet no single person directly caused or intended it. In such cases, it becomes challenging to determine the specific contributions of each actor or to assign moral responsibility for the collective actions that led to the outcome.

This highlights the complexity of responsibility distribution and the moral implications of joint causal responsibility. It raises questions about how to attribute accountability when multiple actors are involved in creating an undesired situation.

This presents a significant challenge when attempting to establish legal consequences for responsibility since the law needs evidence of irresponsible conduct that meets specific standards of proof.

Moreover, the problem of many hands extends beyond practical concerns and enters the realm of ethics. This is due to the possibility that it may be difficult to reasonably assign moral responsibility to any individual for an engineering disaster.

This poses moral dilemmas for two distinct reasons. Firstly, it can be morally unsatisfying for different individuals, including victims, the general public, and the engineering community, when no one can be held accountable in the event of an engineering disaster. While the search for blame may sometimes be misguided, there are situations where it seems reasonable to assign responsibility to someone. In fact, some philosophers have proposed the concept of collective responsibility to address the notion that responsibility in complex cases extends beyond the sum of individual responsibilities in isolation. This acknowledges the belief that the involvement of multiple individuals in a complex engineering project should not alter the ethical considerations for outsiders.

The second reason for attributing responsibility is the desire to learn from mistakes and improve in the future. If no one is held morally responsible for a disaster, valuable lessons may not be learned, hindering progress and preventing the avoidance of similar incidents in the future.

II.8.1.1 Distributing Responsibility

The concept of collective responsibility addresses the moral intuition that individuals should be held accountable for disasters in complex engineering projects, even if none of them individually meet all the conditions for blame. However, determining how responsibility is distributed among the members of a collective is not immediately clear. There are two main reasons for assigning responsibility: moral fairness and effectiveness. The moral fairness requirement entails holding people responsible for their actions and consequences if certain conditions - wrongdoing, causal connection, knowledge, and freedom of action - are met. This requirement for moral fairness can also be applied to active responsibility, meaning that individuals should only be attributed a certain level of responsibility if they have the means and authority to fulfil it. The effectiveness requirement aims to prevent harm and promote desirable outcomes. This requirement is particularly relevant for active responsibility, as it involves taking proactive measures to avoid errors, but it also applies to passive responsibility, as learning from mistakes and taking responsibility for them is crucial for improvement.

Moreover, philosopher Larry May [65] has presented a principle in addressing the responsibility of individuals when multiple people are involved in causing harm, whether through their actions or lack thereof. Specifically, when examining harm caused by collective inaction, May proposes that the level of individual responsibility among members of a group should be determined by the role each member could have hypothetically played in preventing the inaction. That is to say, in cases of harm resulting from collective inaction, the responsibility of each group member varies based on their reasonable efforts to prevent the action. However, it is important to recognise that there are limits to this expectation. If an individual would have had to employ extreme measures such as self-harm or causing harm to others in order to prevent the undesirable action, it would be unreasonable to expect them to do so. The degree of responsibility should be assessed within the bounds of what can reasonably be expected from each member.

II.8.2 Responsibility and the Law

Responsibility is a concept that encompasses both moral and legal dimensions. However, the way responsibility is understood and applied in law differs from its ethical counterpart. There are distinctions between legal responsibility and moral responsibility.

Legal liability is determined by specific conditions outlined in the law, which may vary depending on the type of action, consequences, and jurisdiction. Besides, it requires a verdict from a judge or jury and the formal proof of liability conditions.

Moral responsibility, on the other hand, can be established through less formal means. It is typically based on criteria of blameworthiness. This distinction means that a person can be morally responsible for an action without being legally liable, and vice versa.

Moreover, liability often entails the obligation to pay fines or compensate for damages, whereas moral responsibility does not necessarily imply such obligations.

While liability and moral responsibility are different concepts, there is an argument for aligning them to a certain extent. One approach is to base liability on the same conditions as passive moral responsibility. Advocates suggest that if morally irresponsible actions are not subject to legal consequences, there may be little incentive for individuals to behave morally. However, it can be questioned whether individuals only act morally when faced with punishment. On the other hand, aligning liability with moral responsibility avoids the creation of immoral laws. However, it is important to note that laws that deviate from morality in some aspects are not necessarily immoral, as not everything legally permitted aligns with moral principles. Thus, striking a balance between liability and moral responsibility requires careful consideration of the incentives for moral behaviour and the relationship between legal and moral norms.

II.8.2.1 Negligence and Strict Liability

The conditions for liability differ depending on the jurisdiction and can also differ from country to country. However, in many Western countries, negligence is the primary condition for liability. Negligence does not necessarily require the defendant to have anticipated the specific damage, but rather focuses on whether a reasonable person in the defendant's position could have foreseen the potential harm. To establish negligence, certain elements must be proven, including:

- A duty of care, which is the legal obligation for individuals to exercise a reasonable standard of care to prevent foreseeable harm to others, is an essential element in establishing negligence and liability. The duty of care between engineers and the public is determined by the expectations that the public can reasonably have from engineers, as well as the prevailing industry practices in engineering.
- A breach of that duty.
- An injury or damage.
- A causal connection between the breach and the injury or damage.

In contrast, strict liability does not necessitate negligence on the part of the defendant to establish liability. Instead, it is sufficient to show that the defendant engaged in a risky activity that directly caused the damage. Technological innovation inherently carries risks, including the potential for unforeseen hazards to society. As a result, innovation becomes a possible candidate for strict liability. Applying strict liability to technological products serves as a motivation for engineers and other individuals involved in innovation to exercise great caution. This can be achieved by thoroughly examining potential hazards and implementing necessary precautions. By adopting strict liability, there is a higher likelihood of achieving a higher level of safety.

II.8.2.2 Corporate Liability

Corporate liability refers to the legal accountability of corporations as separate legal entities. Unlike individuals, corporations are treated as legal persons and can be held responsible for their actions. One key advantage of corporate liability is that it simplifies the process of seeking compensation or legal recourse, as victims or authorities can sue the corporation as a whole instead of identifying individual employees or executives involved in wrongdoing. However, corporate liability also has limitations. Unlike individuals, corporations lack a conscience and cannot be put in prison, making certain legal measures less effective. Additionally, many modern corporations have limited liability, meaning that shareholders are only responsible for the corporation's debts up to the value of their shares.

II.8.3 Responsibility in Organisations

In contemporary organisations, there is a clear division of tasks and roles, which affects the allocation of responsibility within the organisation. Different models have been developed to determine who can be held accountable for undesirable outcomes, primarily focusing on passive responsibility. The suitability of each model depends on the formal and actual organisational structure in place.

Two key considerations come into play. First, the moral fairness of the model in assigning responsibility, and second, the effectiveness of the model in preventing undesirable behaviour.

There are three different models:

1. **Hierarchical responsibility**: The hierarchical responsibility model places accountability solely on the top-level personnel of an organisation, making it straightforward and clear. However, this model is not always effective in preventing negative outcomes because managers may feel disconnected from the organisation. They often struggle to obtain timely and relevant information and find it challenging to influence the behaviour of lower-level units. Despite this, knowing that they will be held responsible for any harm caused by the organisation may motivate managers to gather knowledge and steer it more effectively. The hierarchical responsibility model also raises moral concerns as it may be unfair to hold managers accountable for actions they are uninformed about and have limited control over. Consequently, strict hierarchical allocation of responsibility can face moral objections.
2. **Collective responsibility**: The collective responsibility model holds every member of a collective body accountable for the actions of all other members. However, this model is not favoured by large organisations because it lacks the ability to assign varying degrees of responsibility to individual members. Everyone is equally responsible for the collective's actions, disregarding individual fault or ability to prevent harm. This is viewed as morally unacceptable. Furthermore, in this model, no one feels a specific moral responsibility for the organisation's consequences, leading individuals to avoid taking responsibility, especially in large organisations. The collective responsibility model is more suitable for exceptional cases where members can effectively influence each other, requiring small-scale and equal collective members. Large organisations often fail to meet this condition, and a solution could involve creating smaller organisations with stronger solidarity.
3. **Individual responsibility**: The individual responsibility model holds each individual accountable based on their meeting the criteria for individual responsibility. It is morally fair and encourages responsible behavior. However, it can lead to the problem of many hands, where collective actions result in undesirable consequences without any individual being held accountable. Despite this drawback, the individual responsibility model can still be applied by implementing organizational measures such as improved information sharing and empowering employees to act responsibly. This can be achieved through policies like internal whistle-blowing, which allow employees to raise concerns without fear of reprisal or dismissal.

None of the discussed responsibility models are perfect in terms of moral fairness and effectiveness. There is no definitive answer regarding the best distribution of responsibility in organisations. The choice of model depends on the actual organisation and its legal status. For example, a strictly hierarchical organisation would find the collective responsibility model both morally unfair and ineffective. Contrariwise, if a particular responsibility model is deemed desirable, efforts can be made to adapt the organisation accordingly. The decision of which model to adopt and the organisational setup will depend on specific situations or tasks.

II.8.4 Responsibility Distributions and Technological Designs

The distribution of responsibility is not only influenced by laws and organisations but also by engineering design choices. The example of an automatic pilot in an airplane demonstrates this impact. Design decisions determine which tasks are assigned to the automatic pilot and which remain with human pilots, considering factors such as safety and costs. However, these design choices also affect passive responsibility for errors, such as in the event of an accident. If the automatic pilot is designed to be operational only during take-off and landing, human pilots lose the freedom to intervene during a crisis in-flight. Consequently, they cannot be held responsible if a calamity leads to a disaster since the ability to act is a crucial condition for responsibility. In such cases, the responsibility may shift to the designers or producers of the automatic pilot. However, they too may not meet the responsibility conditions, resulting in a problem of many hands where nobody can be held accountable.

Furthermore, it is essential to consider that if tasks are allocated to humans through design decisions, the necessary conditions for individuals to responsibly carry out those tasks must exist or be created. For example, human pilots require timely and accurate information to navigate the plane, which falls under the knowledge condition for responsibility. The system should provide pilots with reliable information, as they are dependent on it and the system designers. They cannot solely rely on visual estimation of flight altitude by looking out of the window.

In summary, engineering design choices impact the distribution of responsibility, and decisions made should consider both active and passive responsibility, as well as provide the necessary conditions for individuals to fulfil their tasks responsibly.

II.8.5 Case Study: Space Shuttle Columbia Disaster

The Columbia disaster occurred on 16th January, 2003, when the space shuttle Columbia lifted off from Kennedy Space Center for a 16-day mission. The crew, consisting of seven members, had planned to conduct various scientific experiments and return to Earth on 1st February. However, just 81.7 seconds after liftoff, a piece of foam broke off from the insulating foam covering the external tank and struck the leading edge of the left wing.

Unfortunately, neither the crew nor the ground support staff were aware of the damage caused by the foam and the impact created a 10-inch hole in the leading edge of the wing. Although cameras recorded the foam strike, the images were insufficient to determine the exact location and extent of the damage. Rodney Rocha and other engineers recognised the need for clearer images and even suggested that the crew inspect the wing for potential damage. However, NASA management held the belief that foam strikes were not a significant threat and dismissed the requests, considering them unnecessary for the safety of the mission. It was not until shortly before reentry that the crew was informed about the foam strike. They were assured that it was inconsequential but were advised to be aware of it in case they were questioned by the press upon their return [15].

During reentry into the Earth's atmosphere, a plume of super-heated air, exceeding temperatures of 2,760 degrees Celsius, entered the breach in the damaged wing. The destructive process began over the Pacific Ocean and intensified as the spacecraft entered U.S. airspace. The super-heated air gradually consumed the wing from the inside. As the damage worsened, the bottom surface of the left wing started to cave upward into its interior. This loss of control and structural integrity caused the Columbia to disintegrate [9, pages 50-51].

Tragically, the entire crew, along with the spacecraft, was lost in the disaster. The lack of awareness and underestimation of the foam strike's consequences played a significant role in the catastrophic chain of events. The Columbia disaster highlighted critical issues within NASA's decision-making processes and safety culture. This tragic event, which has many striking similarities with the Challenger disaster 17 years earlier, illustrates many of the issues surrounding notions of responsibility in the engineering profession.

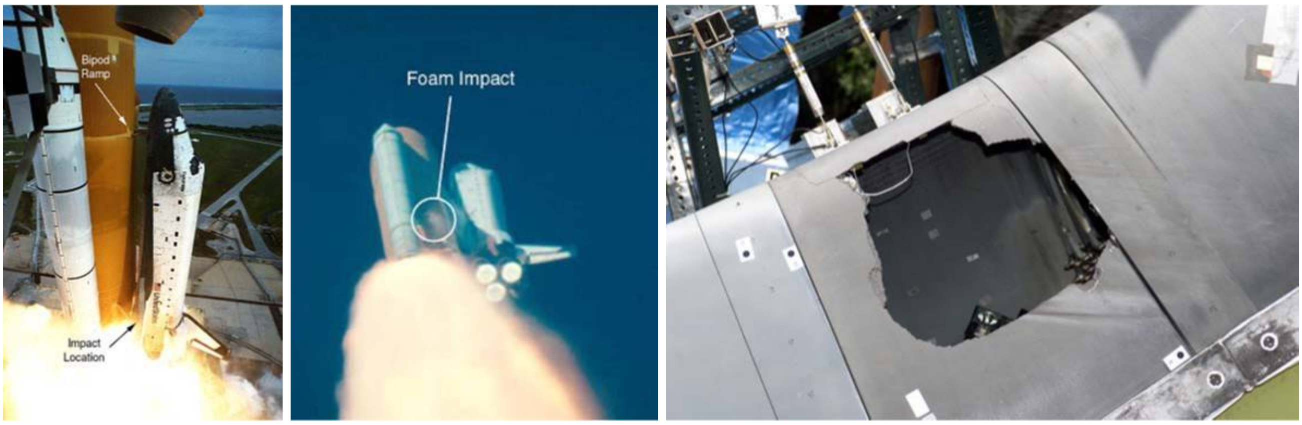

Figure II.8.1: Left: View of the launch of Columbia on the STS-107 mission, showing the location of the foam shedding and the point of impact on the orbiter's left wing. Middle: Still from a video of the STS-107 launch showing the moment of the foam impact on the wing leading edge. Right: Photograph of a sample of space shuttle wing leading edge following an experimental foam strike at the Southwest Research Institute. Source: [15]

II.8.5.1 Development of Study Questions

Who were the primary parties responsible for the Columbia disaster and how was responsibility distributed?
The primary parties responsible for the Columbia disaster were:

- **NASA**: As the governing body and operator of the Space Shuttle program, NASA held overall responsibility for the safe and successful execution of the Columbia mission. They were responsible for the design, maintenance, and operation of the Space Shuttle.
- **Space Shuttle Program**: The Space Shuttle program within NASA was responsible for the development, maintenance, and operational oversight of the Space Shuttle vehicles. This program managed the missions, including the Columbia mission, and made decisions related to the safety and operation of the Space Shuttle fleet.

Within these entities, there were specific individuals, engineers, managers, and decision-makers who played crucial roles in the events leading to the Columbia disaster. Responsibility is not solely attributed to the organisations themselves, but also to the individuals within them who made critical decisions and took actions or failed to take appropriate actions.

Did NASA adequately address and respond to the foam strike on Columbia's wing during launch?
NASA did not adequately address and respond to the foam strike on Columbia's wing during launch.

Despite concerns raised by engineers and imagery showing the foam strike, NASA did not view it as a critical safety issue at the time. NASA management believed that the foam strike posed minimal risk and did not take immediate action to investigate or mitigate the potential damage to the thermal protection system of the wing. NASA engineers and technicians made attempts to assess the foam strike after the launch through image analysis and limited ground inspections. However, the assessments were inconclusive, and the true extent of the damage to the wing was not fully understood.

In the consequences of the Columbia disaster, it became evident that NASA had not adequately addressed the foam strike issue, including conducting thorough inspections and taking appropriate measures to mitigate potential risks. The failure to respond effectively to the foam strike was a significant contributing factor to the tragic outcome.

What were the roles and responsibilities of the engineers and managers involved in the decision-making process? Did they fulfill their ethical obligations?
The roles and responsibilities of the engineers and managers involved in the decision-making process leading up to the Columbia disaster included:

- **Engineers**: They were responsible for analysing technical data, assessing risks, and raising concerns related to the foam strike and potential damage to the orbiter's thermal protection system. They had a duty to communicate their concerns to management and recommend appropriate actions to mitigate risks.
  Some engineers involved in the foam strike analysis and risk assessment raised concerns about the potential damage to the orbiter's thermal protection system. However, their concerns were not adequately communicated or emphasised, which limited the impact of their voices in the decision-making process.
- **Managers**: They were responsible for overseeing the decision-making process, considering inputs from engineers and other stakeholders, and making informed judgements. They had the authority to determine whether additional investigations were necessary, allocate resources for inspections, and make decisions regarding launch criteria and safety protocols.
  Certain managers within NASA and the Space Shuttle program were aware of the foam strike and the concerns raised by engineers but did not give adequate attention to the potential risks. They did not prioritize further investigation or implement measures to address the potential damage. This lack of action suggests a failure to fulfill their ethical obligations to ensure the safety of the crew and make decisions based on the best available information.

Not all engineers and managers involved may have been aware of the full extent of the risks or had the authority to take immediate action. Nevertheless, the general consensus is that there were failures in communication, decision-making, and risk assessment within the Columbia mission management structure.

What lessons were learned from the Columbia disaster regarding the distribution of responsibility in the aerospace industry?
The Columbia disaster provided several important lessons regarding the distribution of responsibility in the aerospace industry. Some of these lessons include:

- **Communication and transparency**: Effective communication and transparency are critical for the distribution of responsibility in the aerospace industry. The Columbia accident emphasised the need for open and honest communication between engineers, managers, and decision-makers. It highlighted the importance of creating an environment where concerns can be raised and addressed without fear of retribution.
- **Safety culture**: Organisations must prioritise safety at all levels, foster a culture of continuous improvement, and encourage the reporting of safety concerns.
- **Risk assessment and management**: The Columbia accident emphasised the importance of robust risk assessment and management processes. It highlighted the need for organisations to thoroughly evaluate potential risks, listen to and consider expert opinions, and take appropriate actions to mitigate risks before and during missions.
- **Learning from past incidents**: The Columbia disaster reinforced the importance of learning from past incidents and incorporating those lessons into future decision-making. It highlighted the need for organisations to review and analyse previous accidents to identify systemic issues and implement corrective actions.

Who should bear legal responsibility for the Columbia disaster?
Legal responsibility is typically determined through investigations, accident reports, and legal proceedings that assess the actions, decisions, and potential negligence of individuals and organisations involved. It is important to note that legal responsibility can vary depending on the jurisdiction, applicable laws, and the specific circumstances of the case.

Some potential parties who could be considered for legal responsibility in the Columbia disaster include:

- Specific individuals involved in the decision-making process, including engineers, managers, and executives, may face legal scrutiny to determine if their actions or omissions contributed to the accident.
- Entities such as NASA and the Space Shuttle program could face legal responsibility if their policies, procedures, or actions are found to have contributed to the accident. This could involve evaluating their safety protocols, oversight mechanisms, and overall responsibility for the mission's success and crew safety.
- Companies involved in the design, construction, or maintenance of the Space Shuttle or its components could potentially face legal scrutiny if their products or services are found to be defective, or if they failed to adhere to appropriate quality control standards or provide adequate warnings or instructions.

· CHAPTER II.9 ·

Case Study I: Boeing 737 MAX

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All the information presented in this chapter is based on the following references unless otherwise specified:

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In December 2010, Boeing's primary competitor Airbus introduced the A320neo family of airplanes, which were an updated version of their successful A320 aircraft. These new planes had larger and more fuel-efficient engines. Meanwhile, Boeing had initially planned to develop a completely new aircraft to replace their ageing 737 series. However, in order to stay competitive with Airbus, Boeing made the decision in August 2011 to announce the 737 MAX family instead. The 737 MAX would feature engine upgrades similar to the A320neo, along with other improvements. It entered service in May 2017 and quickly became the best-selling airliner in Boeing's history, receiving over 5,000 orders from more than 100 airlines worldwide.

After being in operation for over a year, tragedy struck on October 29, 2018, when Lion Air flight JT610 crashed into the Java Sea shortly after takeoff from Jakarta, Indonesia. All 189 passengers and crew onboard lost their lives. Analysis of the flight data recorder indicated that the MAX's specific software, known as Manoeuvring Characteristics Augmentation System (MCAS), had forcefully pushed the nose of the aircraft downward 26 times within a span of 10 minutes. This system was designed to automatically adjust the aircraft's angle of attack to prevent stalling. However, it was discovered that faulty sensor readings triggered MCAS, pushing the nose of the aircraft down despite the pilots' attempts to regain control. In October 2019, the final report from Indonesia's Lion Air Accident Investigation placed some of the blame on the pilots and maintenance crews but primarily held Boeing and the FAA accountable for the crash.

The MCAS system had not been included in the original documentation or training materials for 737 MAX pilots. However, following the Lion Air crash, Boeing issued a bulletin on November 6, 2018, providing instructions for dealing with flight control issues that could arise from potential erroneous angle of attack (AOA) inputs. The next day, the FAA issued an Emergency Airworthiness Directive on the same matter. However, the FAA did not ground the 737 MAX at that time and these notices marked the first time that airline pilots were made aware of the existence of MCAS, according to reports.

Approximately four months after the Lion Air crash, on March 20, 2019, Ethiopian Airlines Flight ET302 crashed just six minutes after takeoff. The accident caused the deaths of all 157 passengers and crew. The preliminary report of the Ethiopian Airlines Accident Investigation, released in April 2019, indicated that the pilots had followed the checklist provided in Boeing's bulletin after the Lion Air crash but were unable to regain control of the aircraft. In March 2020, an interim report was published, absolving the pilots and the airline of blame and attributing the accident to design flaws in the MAX. Following this second crash, the 737 MAX was grounded worldwide, with the United States, through the FAA, being the final country to take action on March 13, 2019.

II.9.1 Development of Study Questions

II.9.1.1 The Responsibilities of Engineers

Could someone be blamed for the Boeing 737 MAX disaster according to the four conditions of blameworthiness?

1. **Wrong-doing**: There have been allegations of wrong-doing addressed against both Boeing and the FAA. Critics argue that Boeing failed to disclose critical information about the MCAS system to regulators, airlines, and pilots, potentially prioritising cost and time considerations over safety. On the other hand, the FAA has faced criticism for its oversight and certification process, with claims that it was too reliant on Boeing's self-certification and did not thoroughly assess the risks associated with the MCAS system.

2. **Causal contribution**: Both Boeing and the FAA had a causal contribution to the 737 MAX disaster. Boeing's design decisions, including the reliance on a single angle-of-attack sensor and the implementation of an aggressive MCAS system, played a substantial role in the accidents. The FAA's oversight and certification process, including its delegation of certain tasks to Boeing, also contributed causally to the disaster. Their respective actions and decisions had a direct impact on the safety of the aircraft.

3. **Foreseeability**: The foreseeability of the risks associated with the 737 MAX and its MCAS system is an important aspect to consider. Both Boeing and the FAA had access to information about the risks of high-angle-of-attack situations and the potential malfunctioning of the MCAS system. However, arguments have been made that the extent and severity of these risks were not adequately recognised or communicated. This raises questions about whether both Boeing and the FAA should have foreseen the potential dangers and taken appropriate actions to mitigate them.

4. **Freedom of action**: Boeing had a significant degree of freedom of action in designing and manufacturing the 737 MAX, as well as in communicating information to regulators, airlines, and pilots. The FAA, as the regulatory authority, had the power to oversee and certify the aircraft. Both entities had a considerable level of control and influence over the situation. Therefore, they had the freedom to take actions to address potential risks and ensure the safety of the aircraft.

Based on these four conditions, both Boeing and the FAA could be held accountable for the Boeing 737 MAX disaster. However, it is important to note that the determination of blameworthiness in a legal context would require formal investigations, legal proceedings, and the conclusions of aviation authorities.

Diffusion of responsibility refers to the psychological phenomenon where individuals feel less accountable for their actions or decisions when others are also involved. It occurs when responsibility is shared among multiple individuals or entities, leading to a decreased sense of personal obligation and potentially impacting decision-making, accountability, and ethical considerations [69].

To what extent did the diffusion of responsibility among different stakeholders, such as Boeing, regulatory agencies, and airline operators, contribute to the issues and ethical dilemmas surrounding the Boeing 737 MAX case?
The concept of diffusion of responsibility had significant implications in the disasters surrounding the Boeing 737 MAX case.

- With multiple stakeholders involved, it becomes challenging to assign clear accountability for decision-making and actions. Diffusion of responsibility can result in a lack of clarity about who bears ultimate responsibility for ensuring the safety of the aircraft.

- Diffusion of responsibility can lead to blurred lines of authority and decision-making. In the case of the 737 MAX, the relationship between Boeing and the regulatory agencies, such as the FAA, involved a level of cooperation and delegation of responsibilities.
- Diffusion of responsibility can lead to a lack of effective communication and information sharing among stakeholders. In the case of the 737 MAX, there were concerns about the transparency and adequacy of information provided by Boeing to regulators, airlines, and pilots. This lack of information sharing can hinder the identification and resolution of critical safety issues.
- When no single entity or individual feels solely responsible, there is a risk of complacency and a diminished focus on safety. In the case of the 737 MAX, the diffusion of responsibility may have played a role in undermining a strong safety culture within Boeing and the broader aviation industry.

Addressing the concept of diffusion of responsibility requires efforts to clarify accountability, promote transparency, and enhance communication among stakeholders. Strengthening regulatory oversight, fostering a robust safety culture, and ensuring effective information sharing are essential to mitigate the negative effects of diffusion of responsibility and prioritise safety.

If you were a Boeing engineer aware of the safety issues with the sensors, in what cases would you consider yourself morally responsible for whistle-blowing? Why would you feel responsible when there are many more colleagues who could do it?
As a Boeing engineer aware of safety issues with the sensors on the Boeing 737 MAX, several factors would influence the decision to consider yourself morally responsible for whistle-blowing. While there may be colleagues who could also blow the whistle, individual moral responsibility remains significant. Some factors to take into account for whistle-blowing are:

- **Imminent danger to public safety**: The engineer must have evidence that the safety issues pose a grave and relevant harm to public safety. In the case of the 737 MAX, if the faulty sensors could potentially lead to accidents or jeopardise the lives of passengers and crew, it would satisfy this condition.
- **Exhaustion of internal channels**: The engineer must have made reasonable efforts to address the safety issues internally through existing reporting mechanisms. If the engineer has exhausted all available internal channels to report the concerns but has not seen adequate action or resolution, this condition would be fulfilled.
- **Consequences and potential harm**: When weighing the potential harm caused by remaining silent against the potential risks of whistle-blowing (such as career implications or strained relationships), if the risks of not acting outweigh the personal consequences, the engineer must reasonably believe that whistle-blowing is necessary.

After all, personal moral responsibility is not diminished by the presence of others who could also blow the whistle. Each individual has a duty to act in accordance with their own moral compass, guided by the principles of integrity, public safety, and ethical responsibility.

II.9.1.2 Normative Ethics

How would utilitarianism assess the disasters related to the Boeing 737 MAX case?
Utilitarianism evaluates actions based on their overall consequences and seeks to maximize the greatest happiness or well-being for the greatest number of people. When applying utilitarianism to the disasters surrounding the Boeing 737 MAX case, the evaluation would consider the overall consequences in terms of the happiness and well-being of the stakeholders involved.

- **Evaluation of the safety issues**: Utilitarianism would assess the safety issues with the Boeing 737 MAX and their potential consequences. It would consider the number of lives at risk, the severity of potential accidents, and the overall impact on public safety.
- **Assessing the decision-making**: Utilitarianism would evaluate the decision-making processes and actions taken by Boeing, regulatory agencies, and airline operators. It would consider whether the decisions were driven by maximizing overall happiness and well-being or if other factors, such as financial considerations or competitive pressures, played a significant role.
- **Calculation of overall consequences**: Utilitarianism would analyse the overall consequences of the disasters. This would include considering the number of lives lost, injuries suffered, and the psychological impact on survivors and their families. It would also consider the economic impact on the aviation industry, public trust, and the potential ripple effects on related sectors.

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How would kantianism assess the disasters related to the Boeing 737 MAX case?
When assessing the disasters related to the Boeing 737 MAX case, kantianism would focus on the moral principles and ethical obligations involved and it would evaluate actions based on their adherence to them.

- **Universality**: Kantianism emphasises the principle of universality, which requires individuals to act according to principles that could be universally applied. In the context of the 737 MAX disasters, kantianism would evaluate whether the actions and decisions made by Boeing, regulatory agencies, and airline operators could be considered universal moral principles. For example, did they prioritise the safety of passengers and adhere to principles of honesty, transparency, and integrity?
- **Human dignity**: Kantianism values human dignity and treats individuals as ends in themselves, rather than as means to an end. In evaluating the case, kantianism would consider whether the actions taken respected the dignity and autonomy of all stakeholders involved, including passengers, employees, and the wider public. This would involve examining whether the decisions were made with their well-being and safety as a fundamental concern.
- **Moral duties**: Kantianism places great emphasis on moral duties and obligations. In the context of the 737 MAX disasters, kantianism would evaluate whether Boeing, regulatory agencies, and airline operators fulfilled their moral duties such as ensuring the safety of passengers, adhering to regulations, providing accurate information, and rectifying any known safety issues promptly and effectively.

How would virtue ethics assess the disasters related to the Boeing 737 MAX case?
When assessing the disasters related to the Boeing 737 MAX case, virtue ethics would emphasise the character traits and virtues exhibited by the key individuals and organisations involved and how they contribute to ethical decision-making.

- Virtue ethics would focus on the character traits displayed by Boeing employees, regulatory agencies, and airline operators. It would examine whether they demonstrated virtues such as honesty, integrity, responsibility, and prudence in their decision-making processes. Therefore, the assessment would look at whether the actions and decisions made align with virtuous behaviour, examining whether they prioritised safety, took responsibility for their actions, and demonstrated concern for the well-being of passengers and the wider public.
- Virtue ethics also emphasises the long-term consequences of actions. It would consider whether the individuals and organisations took into account the potential long-term consequences of their decisions, including the impact on public trust, the aviation industry, and the safety of future passengers.

How would care ethics assess the disasters related to the Boeing 737 MAX case?
Based on care ethics' evaluation, the Boeing 737 MAX case would be analysed based on the level of care, responsibility, empathy, and compassion demonstrated by the individuals and organisations involved. The evaluation would focus on the quality of interpersonal relationships, the understanding of specific contexts, and the consideration of the needs and vulnerabilities of those affected. Ultimately, care ethics seeks to promote the well-being and dignity of all individuals involved in the complex network of relationships.

- **Care and responsibility**: It would focus on whether the key individuals and organisations involved demonstrated a genuine care for the safety and welfare of passengers and other stakeholders. It would examine whether they fulfilled their responsibility to protect and prioritise the interests of those affected by their decisions.
- **Interpersonal relationships**: It would consider how the actions of Boeing, regulatory agencies, and airline operators affected the relationships between stakeholders. It would assess whether they fostered trust, open communication, and collaboration.
- **Empathy**: Care ethics places a strong emphasis on empathy and compassion. Therefore, it would consider whether the individuals and organisations involved demonstrated empathy towards those affected by their decisions, including the potential risks posed by the faulty sensors. It would evaluate whether they showed a genuine understanding of the potential harm and took appropriate actions to mitigate it.

II.9.1.3 The Ethical Cycle

Application of the ethical cycle to analyse the problem between Boeing and families of the victims, and discussion of possible actions and solutions.

1. **Problem statement**: The problem between Boeing and the families of the victims involves the loss of lives due to the crashes of the Boeing 737 MAX aircraft. The families of the victims have experienced immense grief and suffering as a result.
2. **Problem analysis**: The responsibilities of Boeing towards the families of the victims, including their duty to ensure the safety of their aircraft, provide accurate information, and support those affected by the tragedies have to be considered. It is also important to assess whether Boeing has met these ethical obligations and whether their actions have been consistent with principles of transparency, accountability, and empathy.
3. **Possible options for actions**: Based on the analysis and evaluation, propose possible actions and solutions. These could include compensation and financial support, emotional and psychological support, transparency and accountability, and safety enhancements and preventive measures.
4. **Ethical evaluation**: Each solution should be evaluated based on its feasibility, effectiveness, and ethical considerations.
5. **Reflection**: A decision must be made regarding the best course of action. Besides, the most ethical and appropriate steps for Boeing to take in order to address the concerns of the families of the victims, promote their well-being, and restore trust and confidence in the company must be determined.

II.9.1.4 Ethical Questions in the Design of Technology

What ethical considerations should be taken into account by the engineers during the design process of a new aircraft, such as the Boeing 737 MAX? How much importance would you give to each consideration?
Engineers play a crucial role in the design process of a new aircraft. Some ethical considerations that engineers should take into account during the design process are:

- **Safety**: Engineers should adhere to rigorous safety standards, conduct thorough risk assessments, and design technology that minimise the potential for accidents or failures.
- **Transparency and accountability**: Engineers should promote transparency in their work by providing accurate and comprehensive documentation of the design process. They should take responsibility for their designs, be transparent about potential risks, and communicate openly with stakeholders, including regulators, airlines, and passengers.
- **Stakeholder engagement**: Engineers should consider the needs and concerns of different stakeholders.
- **Environmental impact**: Engineers should consider the environmental impact of the aircraft's design and aim to minimise its carbon footprint.
- **Ethical use of technology**: Engineers should consider the ethical implications of the technologies and systems they incorporate into the aircraft's design. They should ensure that these technologies are used responsibly and do not compromise safety, privacy, or human rights.
- **Integrity and professionalism**: Engineers should act in an honest and trustworthy manner, avoiding conflicts of interest and putting the interests of safety and the public ahead of any other gain.
- **Continuous improvement**: Engineers should actively seek opportunities to learn from past incidents, engage in ongoing professional development, and stay updated with the latest advancements in aviation safety.

The importance of these considerations can shift depending on the specific circumstances, regulatory requirements, and the values and priorities of stakeholders involved.

Did the design choices made in the development of the Boeing 737 MAX prioritise safety or other factors, such as cost-effectiveness or market competitiveness?
Boeing's prioritisation of factors like cost-effectiveness and market competitiveness alongside safety in the design of the 737 MAX has raised concerns. The implementation of the MCAS, while aiming to improve stability, has faced criticism due to its reliance on a single sensor and potentially intrusive behaviour. Evidence suggests that design choices were influenced by the goal of making the aircraft more competitive. Questions have also been raised about potential conflicts of interest in the certification and regulatory process, highlighting the relationship between Boeing and the FAA.

Nevertheless, these observations are based on investigations, reports, and public discourse surrounding the Boeing 737 MAX case. The ultimate determination of whether safety was compromised in favour of other factors would require a thorough examination of internal documents, decision-making processes, and the motivations behind specific design choices.

To what extent should aerospace engineers prioritise ethical considerations over meeting regulatory requirements and industry standards in the design of a new aircraft?
While the balance depends on different factors, ethical considerations should hold significant importance in the decision-making process. Key points to consider include prioritising safety and well-being, maintaining public trust through ethical design practices, fulfilling moral obligations to society, considering long-term consequences, demonstrating ethical integrity, and engaging in collaboration and advocacy. While regulations provide a baseline for safety, they may not cover the full range of ethical considerations. Striking the right balance between ethics and regulations is necessary for fostering innovation, trust, and progress in the aerospace industry.

What lessons can be learned from the Boeing 737 MAX case regarding the ethical responsibilities of aerospace engineers, regulatory bodies, and industry stakeholders, and how can these lessons inform

future design practices and safety regulations?
The Boeing 737 MAX case provides several important lessons regarding the ethical responsibilities of aerospace engineers, regulatory bodies, and industry stakeholders. These lessons can inform future design practices and safety regulations in the following ways:

- Ethical responsibilities of aerospace engineers.
  - Safety as the top priority.
  - Transparency and accountability.
  - Ethical decision-making.
- Role of regulatory bodies.
  - Independence and rigour: Regulatory bodies should ensure their independence from industry influence and exercise rigorous oversight to verify compliance with safety regulations. They should prioritise public safety over industry interests and have the authority and resources to enforce robust safety standards.
- Responsibilities of industry stakeholders:
  - Ethical business practices: Industry stakeholders should also prioritise safety and public well-being over cost-effectiveness or market competitiveness.
  - Information sharing: Stakeholders should actively collaborate, share information, and address safety concerns collectively. Sharing best practices, lessons learned, and safety insights can contribute to the development of safer design practices and improved safety regulations.

II.9.1.5 Ethical Aspects of Technological Risks

Did Boeing fulfill its ethical responsibilities in ensuring the safety of the 737 MAX? Why or why not?
The question of whether Boeing fulfilled its ethical responsibilities in ensuring the safety of the 737 MAX is a complex issue and different perspectives exist. Some key arguments from both sides are the following.

Boeing's actions and ethical responsibilities:

- **Safety oversights**: The MCAS system, which was central to the accidents, is seen as a flawed design that lacked sufficient redundancy and was susceptible to erroneous inputs from a single sensor. Some believe that Boeing rushed the development process, compromising safety in favour of meeting tight production deadlines.
- **Transparency and disclosure**: Boeing has faced criticism for the lack of transparency and disclosure regarding the MCAS system. It has been argued that the company did not adequately inform regulators, airlines, and pilots about the existence and potential risks associated with MCAS.
- **Regulatory influence**: Critics suggest that Boeing exercised undue influence over the regulatory process. There have been allegations of regulatory capture, where industry interests may have influenced the certification and oversight of the 737 MAX.

Counterarguments:

- **Compliance with regulations**: Boeing followed the regulatory requirements and industry standards that were in place during the development of the 737 MAX. It obtained the necessary certifications from the FAA and other regulatory bodies, suggesting that it met the established safety criteria.

- **Industry norms and competitiveness**: Boeing faced intense competition from Airbus and the pressure to release a more fuel-efficient aircraft to compete with the A320neo. Some argue that Boeing's design choices, including the reliance on MCAS, were driven by the need to stay competitive in the market and balancing cost-effectiveness and market competitiveness with safety considerations is a complex challenge.

How should aerospace engineers approach the process of risk assessment in the design and development of aircraft like the Boeing 737 MAX, considering the potential consequences of system failures and the ethical implications involved?
Aerospace engineers should approach the process of risk assessment in the design and development of aircraft with careful consideration of the potential consequences of system failures and the ethical implications involved.

1. **Identify potential hazards**: Engineers should systematically identify potential hazards and risks associated with the aircraft's design, systems, and operations. This includes considering both internal factors - e.g., system failures, human error - and external factors - e.g., environmental conditions, external threats -.

2. **Assess probability**: Engineers should evaluate the probability of each identified hazard occurring and the severity of its potential consequences.

3. **Evaluate risk tolerance**: Engineers, in consultation with relevant stakeholders, should define the acceptable level of risk tolerance for different hazards. This involves weighing the potential harm to human life, environmental impact, property damage, and societal implications against other factors such as economic considerations and feasibility.

4. **Implement risk mitigation strategies**: Based on the risk assessment, engineers should develop and implement appropriate risk mitigation strategies to reduce the probability or impact of system failures.

How did the risk communication surrounding the Boeing 737 MAX contribute to the overall safety failures and public trust issues?
It was marked by inadequate transparency, insufficient information to operators and pilots, and a lack of collaboration with regulators. The lack of transparency resulted in a knowledge gap and hindered stakeholders from fully understanding and addressing risks while insufficient information and training materials contributed to mismanagement of the MCAS system and compromised flight safety.

Therefore, public trust in both Boeing and regulatory bodies was deteriorated due to perceptions of safety concerns being disregarded.

How could the application of the precautionary principle in the design and certification process of the Boeing 737 MAX contribute to the prevention of the disasters?
The application of the precautionary principle in the design and certification process of the Boeing 737 MAX could have contributed to the prevention of the disasters by emphasising a proactive and cautious approach to safety.

The precautionary principle encourages early identification of potential hazards, even in the absence of conclusive scientific evidence. In the case of the Boeing 737 MAX, it would have prompted a thorough examination of the risks associated with the new design features - the MCAS system - and the potential consequences of system failures.

Applying the precautionary principle would also have called for a rigorous risk assessment process that considers worst-case scenarios and worst-case assumptions. This would have required evaluating the potential risks associated with relying on a single AOA sensor for MCAS activation, possible sensor malfunctions, and the impact on flight safety.

In conclusion, by applying the precautionary principle, aerospace engineers and regulatory bodies could have taken a more cautious and proactive approach to safety, identifying and addressing potential risks early on. This would have helped prevent the disasters associated with the Boeing 737 MAX and emphasised the importance of prioritising safety in the design and certification process.

II.9.1.6 Distribution of Responsibility

Who were the primary parties responsible for the Boeing 737 MAX disasters and how was responsibility distributed?

- **Boeing**: As the manufacturer of the aircraft, Boeing bears significant responsibility for the disasters. Boeing designed and developed the 737 MAX, including the implementation of the MCAS, which played a central role in the accidents. The design choices, software implementation, and insufficient communication about MCAS contributed to the accidents.
- **Boeing engineers and designers**: The engineers and designers involved in the development of the 737 MAX have a responsibility to ensure the safety of the aircraft. Any design flaws, inadequate risk assessment, or failure to address potential hazards could be attributed to them.
- **Boeing managers**: Managers at various levels within Boeing's organisational structure have a responsibility to ensure proper oversight and supervision of the design and development process. They are responsible for creating a culture that emphasises safety, fosters open communication, and encourages proactive risk assessment and mitigation. Failure to provide adequate resources, support, and guidance can contribute to safety failures.
- **FAA**: As the regulatory body responsible for certifying aircraft safety in the United States, the FAA shares responsibility for the accidents. There were concerns raised regarding the FAA's oversight and certification process, particularly with regards to the delegation of certain safety assessments to Boeing employees. The FAA's reliance on manufacturer self-certification came under scrutiny.

Did Boeing and the FAA adequately address and respond to the first accident involving this aircraft?
Some key points to consider are the following.

Boeing's Response:

- After the Lion Air crash, Boeing issued a Flight Crew Operations Manual (FCOM) Bulletin on 6th November, 2018. This bulletin provided guidance to pilots on how to respond to flight control problems caused by potential erroneous AOA sensor inputs.
- Boeing developed a software update for the MCAS system, which was identified as a contributing factor in the Lion Air crash. The update aimed to address the issues with MCAS activation and improve the system's functionality.

FAA's Response:

- The FAA issued an Emergency Airworthiness Directive (AD) on 7th November, 2018, which required operators to revise the airplane flight manual to provide instructions to the flight crew on how to handle MCAS activation.
- The FAA also issued a Continued Airworthiness Notification to the International Community (CANIC) to inform other civil aviation authorities and operators worldwide about the actions required to address the MCAS-related issues [70].

While these actions were taken after the first accident, there have been other criticisms raised about the adequacy of Boeing and the FAA's response:

- Prior to the Lion Air crash, pilots were not explicitly informed about the existence and functionality of the MCAS system. There are concerns that the initial response by Boeing and the FAA did not adequately address this communication gap.
- Questions have been raised about the level of training provided to pilots regarding the MCAS system and the associated procedures. Additionally, there have been concerns about the clarity and completeness of the documentation provided by Boeing to operators and pilots.
- The investigation into the Lion Air crash could have inquired deeper into identifying the underlying issues with the MCAS system and the design choices made by Boeing.
- Furthermore, the initial response to the first crash being in Indonesia with Lion Air, rather than in the United States with an American airline, may have had an influence. This raises questions about potential biases and differential treatment based on geographic location and the nationality of the airlines involved.

Ongoing investigations and legal proceedings continue to examine the actions and responses of both Boeing and the FAA regarding the first accident. The ultimate judgement of the adequacy of their responses will depend on the outcomes of these investigations and the subsequent implementation of necessary changes to prevent similar incidents in the future.

· CHAPTER II.10 ·

Case Study II: Discovery of Microbial Life on Mars and the Ethics of Exploration

The exploration of Mars has captivated scientists and researchers since the time of ancient Babylonian astronomers. The potential discovery of microbial life on Mars raises a significant ethical question: How should we handle the revelation of these microorganisms? Should we let them develop without interference, or is it acceptable to proceed with our exploration and potential plans for colonisation?

In 1997, Lupisella and Logsdon presented an article [71] that raises the question of whether it is necessary to develop a cosmocentric ethic or not. They argue that as humanity expands its presence beyond Earth, it becomes increasingly important to consider the ethical responsibilities and obligations we have towards the cosmos.

They emphasise the importance of addressing ethical considerations early on, as the decisions made today will have long-term consequences for the future of human activities in space. They argue that a cosmocentric ethic would promote sustainable and responsible practices, minimise harm to celestial bodies and potential extraterrestrial life, and foster a greater understanding and appreciation of the universe [72].

As well, Carl Sagan [6] offered his perspective on this ethical issue surrounding the discovery of microbial life on Mars. In his book Cosmos, Sagan expressed the belief that if life were to be found on Mars, people should avoid any interference with the planet. He affirmed that Mars would then belong to the Martians, even if they were only microorganisms. Sagan's posture reflects a deep respect for the autonomy and intrinsic value of any potential extraterrestrial life. By advocating for non-interference, he emphasized the importance of preserving the integrity and unique characteristics of other planetary ecosystems. Sagan's viewpoint also serves as a reminder to approach the exploration of Mars and the search for life with a deep sense of responsibility and an ethical framework that prioritises the preservation and understanding of other forms of life in the universe [74].

Even today, this ethical dilemma remains of interest, and a clear answer has not yet been agreed upon. Therefore, some questions regarding this topic should be studied in order to reach a consensus.

II.10.1 Development of Study Questions

How could we handle the revelation of these microorganisms? Should we let them develop without interference, or is it acceptable to proceed with our exploration and potential plans for colonisation?
Allowing uninterrupted development:

- Preservation of Martian ecosystem: Allowing the microorganisms to develop without interference respects the potential ecological balance on Mars and preserves its unique biosphere.
- Scientific significance: Studying the microorganisms in their natural environment could provide valuable insights into the possibility of extraterrestrial life and advance our understanding of biology.
- Ethical consideration: Taking a cautious approach and not interfering with another potentially living species demonstrates a sense of ethical responsibility.
- Precautionary principle: Proceeding with exploration and colonisation without fully understanding the potential risks to Martian life could have irreversible consequences and violate the precautionary principle.

[6] Sagan was an American astronomer and writer, a well-known and influential figure in the United States. He was controversial in scientific, political, and religious circles for his views on topics such as extraterrestrial life, nuclear weapons, and religion [73].

Proceeding with exploration and colonisation:

- Human advancement: Exploring and colonising Mars can open new frontiers for humanity, expanding our knowledge, resources, and potential for long-term survival.
- Missed opportunities: By avoiding further exploration or colonisation, we also may miss out on valuable scientific, technological, and potential human advancement opportunities on Mars.
- Human curiosity: Humans have an innate curiosity to uncover the mysteries of the universe. Restricting exploration and colonisation contradicts this fundamental aspect of human nature.

How should we approach encounters with extraterrestrial civilisations, if they exist, respecting their cultural values, beliefs, and rights? How can we ensure that our actions do not impose our own cultural perspectives on these civilisations?
If encounters with extraterrestrial civilisations occur, it is essential to approach them with utmost respect for their cultural values, beliefs, and rights. To avoid imposing our cultural perspectives, we must prioritise active listening, open dialogue, and cultural sensitivity. Striving to understand their perspectives and practices will foster mutual respect and prevent cultural imperialism. Establishing international guidelines and frameworks for ethical engagement can help ensure that our actions align with universal principles while respecting the autonomy of extraterrestrial civilisations.

Analysing the ethics of exploration of the universe also raises different interesting questions.

Who owns the universe and its celestial bodies? Do they belong to all humanity, or are they the property of individual nations or organisations?
Pros of universal ownership:

- Some argue that celestial bodies should be considered the common heritage of all humanity and the universe should be managed collectively for the benefit of all.
- Advocates of universal ownership also suggest that humanity should act as responsible of the universe, taking care to preserve its natural resources for future generations.
- By establishing universal ownership, the potential for conflicts and disputes over territorial claims and resource exploitation could be minimised.

Cons of universal ownership:

- Critics argue that individual nations or organisations that invest in space exploration should have the right to claim ownership of celestial bodies since ownership rights could serve as an incentive for innovation and progress in space exploration.
- Currently, there is a lack of an international legal framework. Therefore, until such regulations are established, individual nations may assert ownership claims based on their own interpretations of existing laws.

How can international collaboration and cooperation be fostered to promote shared benefits, avoid conflicts, and ensure responsible exploration and use of celestial bodies?
International collaboration and cooperation can be fostered in several ways to promote shared benefits, avoid conflicts, and ensure responsible exploration of celestial bodies. Firstly, establishing international agreements, such as space treaties and cooperative frameworks, can provide a foundation for collaboration and the equitable sharing of resources. Secondly, creating platforms for scientific and technological exchange, joint research projects, and data sharing can encourage collaboration among nations. Additionally, promoting transparency, open communication, and diplomacy in decision-making processes related to space exploration can help prevent conflicts and ensure responsible conduct.

Part III

Teaching Guide

In this final part of the project, a teaching guide for the Ethics course is presented. The guide is organised according to the course sessions. It also proposes the contents and structure of each session, activities for students, and learning objectives.

Every session in the course is aligned with a unit in the curriculum, except for the introductory session and the final three sessions. The purpose of these last sessions is to review and consolidate the knowledge and concepts covered throughout the course. As a result, they do not have specific learning objectives associated with them.

Structures and activities are developed taking into account all the theory explained in Part I, as well as the guidelines presented by Brent and Felder in chapters 3, 4 and 5 of the book *Teaching and Learning. STEM. A Practical Guide* [75] where chapter 3 focuses on planning courses, chapter 4 focuses on planning class sessions, and chapter 5 covers elements of effective instruction.

Besides, to properly develop the learning objectives for each topic, Bloom's taxonomy is taken into account, which is also explained in chapter 2 of the aforementioned book. It is a hierarchical ordering of cognitive skills that was developed to provide a common language for teachers to discuss and exchange learning and assessment methods.

· CHAPTER III.1 ·

First Session

III.1.1 Contents and Structure of Session 1

1. Presentation of the subject. The following items will be explained to students:
   (a) Overview of the course syllabus.
   (b) Teaching methodologies and what is expected from them.
   (c) Course structure and qualification system.
2. Debates on different examples of hypothetical situations in the aerospace industry.
   (a) Some examples that could occur in the aerospace field will be presented [7], and students will discuss possible solutions they consider appropriate.
3. At the end of the session, students will be asked to prepare the next topic before the next class.
   (a) Teaching material required for this task should be available in Atenea when the session ends.
   (b) The after-class activity will also be proposed.

III.1.2 After-Class Activities and Deliverables for Session 1

Students will be required to read and prepare the theory for the next session (Unit 1: The Responsibilities of Engineers). The teaching material needed for these activities has also been developed throughout this project.

Moreover, they will have to familiarise themselves with the case of the Challenger disaster. They can do so through articles, news, or documentaries.

[7] Some proposed examples of situations are included in Appendix B.

· CHAPTER III.2 ·

Second Session

III.2.1 Contents and Structure of Session 2

1. Instruction of the Unit 1: The Responsibilities of Engineers.
   (a) Explanation of the most relevant concepts for understanding the topic.
   (b) Resolution of potential doubts of the students.
2. Case study: The Challenger.
   (a) Story of the Challenger disaster presentation.
   (b) The students will be organised into groups and the questions will be presented to them. For each question, they will have a few minutes to discuss the answer. Afterwards, the answers of some groups will be presented out loud until a complete answer is developed.
3. At the end of the session, students will be asked to prepare the next topic before the next class.
   (a) Teaching material required for this task should be available in Atenea when the session ends.
   (b) The after-class activity will also be proposed.

III.2.2 After-Class Activities and Deliverables for Session 2

Students will be required to read and prepare the theory for the next class (Unit 2: Codes of Conduct). Then, they should suggest some possible points for a Morton Thiokol corporate code of conduct - focused on engineering matters - that they believe could have prevented the disaster of the Challenger. They should justify their ideas by taking into account the objectives of codes of conduct for engineers and their limitations, as well as ways of dealing with these limitations.

This activity will allow students to share their ideas in the next session to develop and discuss a proposal for a corporate code with as few limitations as possible.

III.2.3 Learning Objectives of Unit 1

At the end of this unit, students will be able to...

1.1. Define what is responsibility for engineers.
   (a) State motives of the importance of this value.

1.2. Describe the differences between moral and causal responsibility.

1.3. Differentiate between active and passive responsibility.
   (a) Describe what aspects require and involve the both types of responsibilities.

1.4. List the four conditions of blameworthiness.
   (a) Explain what each condition means.
   (b) Analyse if someone could be blamed when something has gone wrong according to these four conditions.

1.5. Discuss how someone who is actively responsible for something is expected to act.

1.6. Identify the five features of active responsibility according to Mark Bovens.

1.7. Describe situations where there is a conflict between responsibilities of different roles.

1.8. List and define the three models proposed for dealing with this potential discord (separatism, technocracy, and whistle-blowing).

(a) Explain the advantages and drawbacks of each model.

(b) Develop how each model could be applied to deal with a real case and list their possible pros and cons.

(c) Analyse all the inconveniences that whistle-blowing can lead to and list the possible negative consequences that a whistle-blower could suffer in a real case.

(d) State the instructions for the cases when whistle-blowing is morally required proposed by Richard De George and evaluate if whistle-blowing is morally required in a real situation according to this guideline.

(e) Formulate different and more desirable methods that can be applied instead of the three models proposed.

· CHAPTER III.3 ·

Third Session

III.3.1 Contents and Structure of Session 3

1. Brief review of Unit 1 and resolution of possible questions.
2. Instruction of Unit 2: Codes of Conduct.
   (a) Explanation of the most relevant concepts for understanding the topic.
   (b) Resolution of potential doubts of the students.
3. Activity: Development of a corporate code of conduct.
   (a) The class will be divided in groups of three or four people, which will work on the development of the main points of a code of conduct applied to the case of Morton Thiokol. All points must be justified and analysed by applying them to the case. Possible limitations should also be considered. Finally, each group will present their results, and a final code of conduct will be developed among all members of the class.
4. At the end of the session, students will be asked to prepare the next topic before the next class.
   (a) Teaching material required for this task should be available in Atenea when the session ends.
   (b) The after-class activity will also be proposed.

III.3.2 After-Class Activities and Deliverables for Session 3

Students will be required to read and prepare the theory for the next class (Unit 3: Normative Ethics). Moreover, each student will be assigned to a group. There will be four groups and each one should specialise in one of the four proposed ethical theories, expanding their knowledge with other sources. These sources should be formal and they should subsequently use them to justify their class work, since in the next session, each group will analyse the proposed case according to each ethical theory.

III.3.3 Learning Objectives of Unit 2

At the end of this unit, students will be able to...

1.1. Explain why codes of conduct are important.
   (a) List external purposes of codes of conduct and explain them.

1.2. List the three types of codes of conduct depending on their objectives (aspirational, advisory, disciplinary) and identify these objectives.

1.3. Differentiate between professional codes and corporate codes.
   (a) List and analyse different professional codes of conduct for aerospace engineers.
   (b) Explain why professional codes of conduct are necessary.

1.4. Identify conflicts of interest and how to avoid them.

1.5. Explain the notion of loyalty.
   (a) Differentiate between critical and uncritical loyalty.

1.6. List the limitations of codes of conduct presented in the unit (self-interest, contradictions, codification, implementation, and enforcement).

(a) Argue different methodologies to deal with these limitations.

(b) Identify different methods to protect whistle-blowers.

· CHAPTER III.4 ·

Fourth Session

III.4.1 Contents and Structure of Session 4

1. Brief review of Unit 2 and resolution of possible questions.
2. Instruction of Unit 3: Normative Ethics.
   (a) Explanation of the most relevant concepts for understanding the topic.
   (b) Resolution of potential doubts of the students.
3. Case study: The Ford Pinto.
   (a) The students, divided into four groups, will analyse the case from the perspective of their specific ethical theory. Then, new groups will be formed with one student from each of the previous groups, who will explain their findings to each other. After this, students will return to their original group and discuss which approach they believe is the most suitable and why. Finally, a representative from each group will present their arguments to the class. This exercise promotes the understanding of different ethical theories and encourages students to think critically and develop persuasive arguments.
4. At the end of the session, students will be asked to prepare the next topic before the next class.
   (a) Teaching material required for this task should be available in Atenea when the session ends.
   (b) The after-class activity will also be proposed.

III.4.2 After-Class Activities and Deliverables for Session 4

Students will be required to read and prepare the theory for the next class (Unit 4: Normative Argumentation). Moreover, they will be expected to complete a questionnaire on this topic that will be shared on Atenea. The questionnaire will contain questions related to the theory covered in the readings to ensure comprehension and retention of the material.

On the other hand, the class will be divided into three different groups, and a debate topic on an important issue in the aerospace field will be assigned - either the one proposed in this project or another topic of interest suggested by the students -. One group will prepare arguments against the topic, the second group will prepare arguments in favor to organise a debate in the following session, while the third group will be assigned the role of moderators and judges and their responsibility will be to identify invalid arguments and possible fallacies in the debate. To prepare for this debate, students should consider the theories of logical argumentation and fallacies, ensuring their arguments are based on sound reasoning and evidence.

III.4.3 Learning Objectives of Unit 3

At the end of this unit, students will be able to...

1.1. Explain the importance of the existence of different ethical theories.

1.2. Describe the fundamental concepts about ethics explained in the chapter (ethics and morality; descriptive and normative ethics; values, norms, and virtues).

1.3. Explain the main concepts of utilitarianism and describe its criticisms.

(a) Analyse different cases applying this theory.

1.4. Explain the main concepts of kantianism and describe its criticisms.

(a) Analyse different cases applying this theory.

1.5. Explain the main concepts of virtue ethics and describe its criticisms.

(a) Analyse different cases applying this theory.

1.6. Explain the main concepts of care ethics and describe its criticisms.

(a) Analyse different cases applying this theory.

1.7. Compare all these theories and evaluate the most suitable option in each case.

· CHAPTER III.5 ·

Fifth Session

III.5.1 Contents and Structure of Session 5

1. Brief review of Unit 3 and resolution of possible questions.
2. Instruction of Unit 4: Normative Argumentation.
   (a) Summary of the most important points of the topic to carry out the proposed activity.
   (b) Resolution of potential doubts of the students.
3. Development of the suggested debate.
   (a) The students in each group will have some time to share their ideas collectively.
   (b) One or two representatives from each group will have time to present their arguments. Meanwhile, the other group should pay attention and prepare counterarguments for the next round. The judges should identify invalid arguments or fallacies.
   (c) A second round of responses with similar characteristics will take place.
   (d) At the end of the debate, the group of judges will present their opinion regarding the arguments that have been presented.
   (e) Finally, a post-debate discussion where students can reflect on the strengths and weaknesses of their arguments and the overall debate will be carried out.
4. At the end of the session, students will be asked to prepare the next topic before the next class.
   (a) Teaching material required for this task should be available in Atenea when the session ends.
   (b) The after-class activity will also be proposed.

III.5.2 After-Class Activities and Deliverables for Session 5

Students will be required to read and prepare the theory for the next class (Unit 5: The Ethical Cycle). Furthermore, they will practice the application of the ethical cycle by developing group presentations on the proposed topic or another current topic suggested by the students. In the following session, each group will present their proposed solution and its justification.

III.5.3 Learning Objectives of Unit 4

At the end of this unit, students will be able to...

1.1. Explain what is a deductive and a non-deductive argument.
   (a) Differentiate when an argument is deductive or non-deductive.

1.2. Compare between valid and invalid arguments.
   (a) Distinguish between the validity and invalidity of an argument.
   (b) Distinguish between a sound and unsound argument.
   (c) Identify *Modus Ponens* and *Modus Tollens* statements.

1.3. Explain the different types of normative arguments presented (argumentation by analogy, means-end, causality, proof from the absurd, and characteristic-judgement argumentation).

(a) Analyse arguments taking into account their pertinent critical questions.

1.4. Differentiate between formal and informal fallacies .

(a) Identify different types of fallacies in an argumentation (affirming the consequent, false analogy, *Ad Hominem*, confusion of law and ethics, straw person, wishful thinking, and ambiguity).

1.5. Apply the principles of argumentation theory during a debate.

· CHAPTER III.6 ·

Sixth Session

III.6.1 Contents and Structure of Session 6

1. Brief review of Unit 4 and resolution of possible questions.
2. Instruction of Unit 5: The Ethical Cycle.
    (a) Explanation of the most relevant concepts for understanding the topic.
    (b) Resolution of potential doubts of the students.
3. Presentations from each group on how they have applied the ethical cycle to address a current issue.
    (a) In each presentation, they should explain what conclusions have been drawn from each step, the iterative cycle they have followed, and the possible solution they finally conclude.
4. Corrections and debate among the entire class, and a decision on the best possible proposed solution and its justification.
5. At the end of the session, students will be asked to prepare the next topic before the next class.
    (a) Teaching material required for this task should be available in Atenea when the session ends.
    (b) The after-class activity will also be proposed.

III.6.2 After-Class Activities and Deliverables for Session 6

Students will be required to read and prepare the theory for the next class (Unit 6: Ethical Questions in the Design of Technology). Moreover, they will be required to investigate about the topic of autonomous driving and read some articles proposed in order to be able to develop the study questions in groups in the next session.

III.6.3 Learning Objectives of Unit 5

At the end of this unit, students will be able to...

1.1. Explain the main characteristics of moral problems.

1.2. Discuss the importance of the ethical cycle.

(a) Identify the steps of the ethical cycle.
(b) Explain what each concept consists of.
(c) Apply the ethical cycle to decide the best solution for a moral problem.

· CHAPTER III.7 ·

Seventh Session

III.7.1 Contents and Structure of Session 7

1. Brief review of Unit 5 and resolution of possible questions.
2. Instruction of Unit 6: Ethical Questions in the Design of Technology.
   (a) Explanation of the most relevant concepts for understanding the topic.
   (b) Resolution of potential doubts of the students.
3. Case study: Autopilot Mode and the Ethics of Autonomous Vehicles.
   (a) Introduction to the topic and the most important information.
   (b) The students, divided intro groups of four or five, will develop answers for the different questions proposed. Afterward, the answers of some groups will be presented out loud until a general consensus is reached.
4. At the end of the session, students will be asked to prepare the next topic before the next class.
   (a) Teaching material required for this task should be available in Atenea when the session ends.
   (b) The after-class activity will also be proposed.

III.7.2 After-Class Activities and Deliverables for Session 7

Students will be required to read and prepare the theory for the next class (Unit 7: Ethical Aspects of Technological Risks). They will also have to do research on the Boeing 787 battery fires case to develop the case study in groups in the next session.

III.7.3 Learning Objectives of Unit 6

At the end of this unit, students will be able to...

1.1. Discuss the importance of assessing ethical issues during the design process.
   (a) List the conditions that should be considered in order to decide if a situation in the design process is ethical.
   (b) Identify and interpret the different stages of the design process.
   (c) Formulate design requirements and criteria for different technologies.
   (d) Discuss whether engineers should be taken into account in the formulation of design requirements or not.

1.2. Discuss the acceptability of trade-offs, including when and which trade-offs are deemed acceptable.
   (a) Recognise the conditions that real value conflicts meet.
   (b) Identify when a value conflict becomes a moral problem.
   (c) List and describe the different methods to deal with these conflicts.

1.3. Debate the importance of regulatory frameworks in the design process.
   (a) Analyse when it is acceptable to adhere to a regulatory framework.

1.4. Evaluate the influence of everyday artefacts on human behaviour.

· CHAPTER III.8 ·

Eighth Session

III.8.1 Contents and Structure of Session 8

1. Brief review of Unit 6 and resolution of possible questions.
2. Instruction of Unit 7: Ethical Aspects of Technological Risks.
   (a) Explanation of the most relevant concepts for understanding the topic.
   (b) Resolution of potential doubts of the students.
3. Case study: Boeing 787 Dreamliner Battery Fires.
   (a) Introduction to the topic and the most important information.
   (b) The students, divided intro groups of four or five, will develop answers for the different questions proposed. Afterward, the answers of some groups will be presented out loud until a general consensus is reached.
4. At the end of the session, students will be asked to prepare the next topic before the next class.
   (a) Teaching material required for this task should be available in Atenea when the session ends.
   (b) The after-class activity will also be proposed.

III.8.2 After-Class Activities and Deliverables for Session 8

Students will be required to read and prepare the theory for the next class (Unit 8: Distribution of Responsibility). Moreover, they will have to familiarise themselves with the case of the Space Shuttle Columbia. They can do so through articles, news, or documentaries.

III.8.3 Learning Objectives of Unit 7

At the end of this unit, students will be able to...

1.1. Describe in which cases risks and responsibilities are related.

1.2. Debate if engineers are responsible for ensuring safety.
   (a) List and describe different strategies that engineers can apply to ensure safety.

1.3. Evaluate the acceptability of different hazards.
   (a) List and explain the four common steps of risk assessment.

1.4. Justify how the acceptability of risks can be assessed.
   (a) List some ethical considerations that must be taken into account in the acceptability of risks process.
   (b) Analyse some potential criticisms to standardisation of the acceptability of risks.

1.5. Explain the importance of communication between different groups in the design and testing process.
   (a) Discuss the purpose of risk communication.
   (b) Debate to what extent it is desirable to inform people about risks.

1.6. Distinguish between the precautionary principle and the burden of proof.

1.7. List the responsibilities of engineers as experimenters.

· CHAPTER III.9 ·

Ninth Session

III.9.1 Contents and Structure of Session 9

1. Brief review of Unit 7 and resolution of possible questions.
2. Instruction of Unit 8: Distribution of Responsibility.
   (a) Explanation of the most relevant concepts for understanding the topic.
   (b) Resolution of potential doubts of the students.
3. Case study: Space Shuttle Columbia Disaster.
   (a) Introduction of the topic and the most important information.
   (b) The students, divided intro groups of four or five, will develop answers for the different questions proposed. Afterward, the answers of some groups will be presented out loud until a general consensus is reached.
4. At the end of the session, the after-class activity will be proposed.

III.9.2 After-Class Activities and Deliverables for Session 9

The students will have to study the case of the Boeing 737 MAX. They should learn what, how, and when happened, and the reasons behind. They should begin to assess the potential responsible parties and how it could have been avoided in order to carry out the activity in the next class. To conduct the research, they should search for articles, news, or documentaries on the topic.

III.9.3 Learning Objectives of Unit 8

At the end of this unit, students will be able to...

1.1. Explain what the problem of many hands is.
   (a) Analyse when the problem of many hands arises.

1.2. List and explain the main reasons for assigning responsibility.

1.3. Distinguish between legal responsibility and moral responsibility.
   (a) Justify when negligence can be determined.
   (b) Explain the advantages and limitations of corporate liability.

1.4. List three models to organise responsibility in organisations.

1.5. Explain how engineering design choices also influence the distribution of responsibility.

· CHAPTER III.10 ·

Tenth Session

III.10.1 Contents and Structure of Session 10

1. Brief review of Unit 8 and resolution of possible questions.
2. Case study: Boeing 737 MAX.
   (a) Introduction of the case and the most important facts.
   (b) Students will be divided into groups of four or five people, and each group will be assigned a different topic based on the units covered in this course. They should then develop a presentation that addresses different questions related to their assigned topic.
   (c) Afterwards, each group will expose their presentation with their proposed answers. After each presentation, all groups will engage in a discussion to share their thoughts on the resolution.
3. At the end of the session, the structure of the next session will be presented and the after-class activity will also be proposed.

III.10.2 After-Class Activities and Deliverables for Session 10

After this session, once all topics have been discussed, each group will be required to write a brief report containing their final answers with the justifications. The report should be submitted through Atenea.

CHAPTER III.11

Eleventh Session

III.11.1 Contents and Structure of Session 11

1. Brief review of the course and resolution of possible questions.
2. Review the examples from the first session and discuss them again.
   (a) Also, evaluate whether the answers have changed compared to the first session and explain the reasons behind any differences.
3. At the end of the session, the structure of the next session will be presented and the after-class activity will also be proposed.

III.11.2 After-Class Activities and Deliverables for Session 11

Students will be encouraged to review the course syllabus, prepare any questions or other topics and cases of interest for the next session.

· CHAPTER III.12 ·

Twelfth Session

III.12.1 Contents and Structure of Session 12

1. Resolution of possible questions presented by the students.
2. Review and study the topics and cases proposed by the students.
3. If applicable, introduction of a final case study: Discovery of Microbial Life on Mars and the Ethics of Exploration.
   (a) Introduction to the case and the most important issues.
   (b) The students will be organised into groups of four or five and the questions will be presented to them. For each question, they will have a few minutes to discuss the answer. Afterwards, the answers of some groups will be presented out loud.

Conclusions and Future Improvements

There is a clear need for incorporating ethics education into the syllabus of aerospace engineering studies. The absence of such a course at the national level highlights the importance of filling this gap and providing students with the knowledge and tools to make ethical decisions throughout their careers.

Therefore, the course developed covers different ethical aspects in aerospace engineering, such as safety, moral duties, ethical behaviour, and the importance of decision-making in design, testing and certification processes. By studying these topics, students can gain a thorough comprehension of the ethical factors they will encounter in their future careers.

Furthermore, the case study approach adopted in the course allows students to apply ethical principles and frameworks to real-world scenarios, enhancing their critical thinking and decision-making skills.

In summary, the design of this course on ethics in aerospace engineering is a crucial step towards for training upcoming engineers to effectively address the ethical challenges that arise in the field. The course aims to develop engineers who prioritise safety, act ethically, and make positive contributions to society.

Future work in the development of this course on ethics in aerospace engineering should aim to implement and evaluate the effectiveness of the course in real educational contexts. This can involve conducting pilot programs and gathering feedback from students and instructors to identify areas of improvement and refine the course content.

Additionally, it is important to stay updated with the evolving ethical challenges and technological advancements in the aerospace industry since the course should be regularly reviewed and updated to address emerging ethical issues and incorporate new case studies and examples.

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