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Writing Assessment Training for Capstone Design Instructors

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Introduction

Technical writing is vital for professional engineers, but engineering students often struggle to master written communication [1]. To help students develop the necessary writing skills for their careers, many engineering programs implement writing intensive courses (W courses). The goal of these courses is to integrate writing instruction into students' engineering instruction, emphasizing to students the inextricability of writing from the work of engineering. In the J. Mike Walker '66 Department of Mechanical Engineering at Texas A&M University, the capstone design course serves as one of these W courses. Capstone design courses are an especially attractive setting for this kind of writing instruction. As students are exposed to the types of real-world engineering problems they design solutions for as professionals, they can also practice the kind of writing they will have to produce as professionals.

Although developing writing skills is important to capstone design students' professionalization, instructors face several challenges in both implementation and assessment of student writing assignments. This paper will focus specifically on two problems associated with assessing student writing. First, providing feedback on student writing is time-consuming. Second, despite their instructors' spending significant time commenting on students' writing, students often disregard much of the feedback. While instructors may identify many issues, including organizational and logical problems, within their students' writing, students tend to focus their attention on the problems that are quickest and easiest to fix, such as grammar and usage errors. This results in design reports that are disorganized and incoherent, therefore failing to communicate the design process effectively to the reader.

To make providing feedback more efficient for instructors and to improve the quality of student writing through formative assessment, the senior design coordinator collaborated with the department's writing lecturer to develop grading guidelines and an updated grading rubric for the report. In addition to the guidelines and rubric, two thirty-minute writing assessment workshops were conducted. The first focused on setting goals for grading, spending grading time wisely, and leaving useful feedback while the second was a grade norming session to help instructors practice the concepts presented in the first workshop and to discuss their expectations for the design reports as a group. Finally, the technical writing coordinator offered one-on-one grading consultations to provide feedback and support to instructors during the grading period. To evaluate the effectiveness of the materials and resources, instructors were asked for feedback about how they implemented the materials and training provided and what, if any, effect the materials and training had on their grading. This paper will discuss the findings gleaned from instructors' feedback.

Literature Review

As most university educators would agree, writing is indispensable to students' development into professionals in their respective fields. Engineering faculty are particularly aware of the importance of writing, in terms of both students' advancement through their careers and as part of program evaluation by the Accreditation Board for Engineering and Technology [2]. Capstone design courses have become attractive contexts for writing instruction embedded in a discipline specific context because they require students not only to devise solutions but also to explain how they arrived at those solutions through the design process [3]. Nevertheless, teaching writing alongside technical course content presents significant challenges. For example, faculty at the institution referenced in this report generally do not receive writing assessment training. They are therefore unsure of how to grade written reports and uncomfortable with grading them.

Among the challenges of integrating writing instruction into a technical course such as capstone design is creating effective rubrics for design reports. These rubrics must assess both the students' design process and their written communication of that process, and they are subject to the pitfalls of rubrics in any setting. For example, rubrics aid but do not ensure translation from a qualitative piece of work (the report itself) to a quantitative measure of success (the grade). Additionally, common rubrics deployed at a programmatic level require instructors to agree about what constitutes successful writing. These rubrics also force students to write for a universal audience, which diminishes the natural differences in needs and preferences that students will encounter among readers in the workplace [4]. Nevertheless, rubrics are useful tools for guiding student revisions. Paired with appropriate support for instructors, including grade norming sessions, rubrics simulate consensus on what constitutes successful completion of a written assignment [5]. In addition to written and oral communication [6], rubrics have been deployed in capstone design courses to assess design quality and sustainability [7] and teamwork [8]. Instructors using these rubrics report improved confidence in their assessments of student performance, improved student understanding of instructor expectations, and improved learning effectiveness [7], [8], [9].

While rubrics are often used to set expectations for successful writing prior to students' attempting to complete the assignment, written feedback in the form of instructor comments are essential responding to students' work and guiding their revisions. Across disciplines, university instructors often approach providing writing feedback by commenting on or marking every issue or error they encounter in their students' writing. While intuitive, this approach is often counterproductive because students tend to become overwhelmed when receiving a great deal of detailed feedback on their writing [10]. This feeling of overwhelm leads students to either ignore feedback entirely or to focus only on surface-level editing, rather than revising their papers for clarity [11]. When making these surface-level corrections, students cede control of their writing to their instructors. Rather than taking ownership of their writing and thinking about how revision can better communicate their own ideas, they understand their instructors' comments to be directing them toward "correct" writing and expression of ideas. In other words, they imagine that the instructor is leading them through feedback to an "ideal" text, which forces them to attempt to figure out the instructor's idea of "good writing" [12]. These problems are compounded when writing assessment is tied to numerical grades. Students see themselves as correcting errors to earn a higher grade rather than revising their work to improve their communication [11]. The overall effect is that when students are overwhelmed with feedback, they have a limited sense of how to prioritize their instructors' comments and how to apply those comments to make meaningful revisions.

Providing extensive feedback impedes both students' ability to revise and the clarity of instructors' comments. As instructors sink more time into marking every error in their students' work, their energy wanes, which leads to comments that seem clear to the instructor but are inscrutable to the student. Check marks, underlining, and one- or two-word comments confuse and frustrate students, and they rarely meet with their instructors to clarify the feedback. Moreover, such feedback is difficult for students to apply in future writing situations [13]. This is especially true when students encounter an instructor who has a different system of marking papers than teachers in their previous experience. For example, some instructors underline sentences as positive feedback while others use underlining to indicate a problem. For students, the lack of clarity results in feedback being of limited use. Similarly, students need a clear understanding of how exactly to revise problematic writing. Many instructors use "facilitative feedback," which attempts to guide students toward revision using questions or reflections [14]. Such feedback is written with the goal of maintaining student ownership over the work, but students who are unsure of their reader's expectations for revision struggle to respond to facilitative feedback. Finally, feedback that is too broad or observational leaves students unsure of how to apply the feedback [14]. When students cannot apply feedback, either because of its volume or lack of clarity, their revisions suffer despite their instructors' significant efforts to guide them toward better technical communication.

To address these challenges, many engineering departments have adopted Writing Across the Curricula (WAC) and Writing in the Disciplines (WID) curricula, which are aimed at training students to write in their respective fields [15], [16]. The primary goal of WAC and WID curricula is to foster students' abilities to identify as members of their chosen profession by teaching them to communicate effectively with other members of their profession. WAC and WID arise from the field of composition pedagogy, which understands writing as an enactment of identity [17], [18]. For example, writing technical reports in engineering is a way of not only communicating engineering content but also *being* an engineer. WAC and WID curricula allow students the opportunity to practice writing under the instruction of a senior member of their field, something they miss when writing instruction is siloed in English departments. WAC and WID programming can take many different forms depending on the site where it is implemented [19]. In addition to supporting students' writing processes, WID programming is also useful for helping instructors develop their ability to teach writing within their fields. When well-integrated into a program's writing instruction, WAC and WID practices can help subject matter experts offer specific writing instruction appropriate to their field.

Methods

Although the Senior Capstone Design course spans two semesters, only the first semester is designated as a W course. On-cycle students take the first senior design course in the fall semester of their senior year. These courses average about three hundred students across sixteen studio sections, each of which is divided into four teams. During spring semesters, the studio classes contain a total of about one hundred students.

W courses, which are governed at the university level, require students to be assigned at least 2,000 words of writing, to be completed and assessed individually. Additionally, W courses must include writing instruction and formative feedback. To meet these requirements, students in the capstone course are assigned a 2,000-word design review report (DR1) in the second week of class. The DR1 must include four sections: an introduction, a background research section, a problem section, and a conclusion. Students complete and submit an initial submission of the DR1 during the fourth week of class. Once instructors receive the initial DR1 submissions, they provide feedback on the reports within two weeks. Students are then given the opportunity to revise their DR1 reports based on their instructor's feedback and submit it again during the sixth week of class. Instructors reported that prior to the Fall 2023 semester, an individual paper would take them anywhere from one to three hours to grade. For the three hundred students enrolled in the capstone course during the fall semesters, one to three hours of grading per report results in about three hundred to nine hundred hours spent providing feedback.

To improve the quality of feedback and instructors' efficiency in providing it, the capstone design coordinator and technical writing coordinator introduced several resources to instructors, including updated grading materials, a two-part writing assessment training, and opportunities for instructors to meet with the technical writing coordinator to discuss any concerns with grading the DR1 reports.

Updated Grading Materials

During Spring 2023 and previous semesters, the DR1 grade sheet demonstrated how points would be assigned for four criteria: Content and Technical Correctness, Rhetorical Appropriateness, Organization, and Writing Mechanics. For each section of the DR1, students could earn half of the points available from Content and Technical Correctness and half from Rhetorical Appropriateness, Organization, and Writing Mechanics. For example, in the Problem section, which was worth 20% of the final grade, students could earn ten points from presenting technically correct information and ten points writing. Students also earned 20% of their final grade from overall formatting and organization of the DR1. While the grade sheet was used to calculate students' individual scores, the rubric demonstrated how students' success in each criterion would be rated. Table 1 shows how Rhetorical Appropriateness was scored:

Table 1. Scoring for Rhetorical Appropriateness in the Spring 2023 DR1 Grade Sheet

Score	**Explanation**
1	The style and tone are unsuited to the report's requirements. The writer ignores or misses the concerns of the reader. Lacks a technical style, uses informal writing style, inappropriate terminology, and/or poorly defined terminology.
5	The style and tone are fairly well-suited to the report's requirements. A few word choices or other stylistic choices may be slightly off. May use informal or colloquial terminology.
10	The style and tone are exactly suited to the report's requirements. The writer addresses the reader and the concerns of the reader.

For each criterion, the rubric described a score of one point, five points, and ten points, marginal credit, half credit, and full credit. Similar explanations on this scale were provided for Content and Technical Correctness, Organization, and Writing Mechanics.

In their discussion of the grade sheet and rubric, the capstone course coordinator and technical writing coordinator identified several problems. Although the grade sheet allowed instructors to address students' writing *in situ*, breaking the writing grade down by section did not allow instructors to account for students' writing issues usually being consistent throughout the report. This resulted in students being over-penalized for the same problem in addition to complicating the grading process for the instructors. Moreover, while the grade sheet forced instructors to be too granular in their grading, the rubric provided limited guidance for how scores should be assigned. For example, a score of 5 for Rhetorical Appropriateness, as shown in Table 1, meant that the "style and tone are fairly well-suited" to the intended audience. Moreover, the rubric had been adapted from another course; therefore, it did not specifically address the DR1 content or how it should be presented. The complicated and unclear nature of the rubric and grade sheet led to confusion among students and instructors about how writing was assessed.

For the Fall 2023 semester, the capstone coordinator and technical writing coordinator simplified the grade sheet and clarified the rubric. Since then, minor updates have been made based on instructor comments and feedback. The rubric and grade sheet developed for the Spring 2025 semester have been reproduced in Appendix A and B, respectively. While points earned for technical correctness are still attached to the individual sections of the DR1, points for writing are awarded holistically based on three criteria: Rhetorical Appropriateness, Formatting and Organization, and Writing Mechanics. Each of these criteria is assessed on a 5-point scale, with the rubric explaining how points are applied for each criterion at each level. Table 2 demonstrates scoring for Rhetorical Appropriateness in the updated rubric.

Table 2. Scoring for Rhetorical Appropriateness in Updated Rubric

Exemplary (5)	**Good (4)**	**Acceptable (3)**	**Needs Improvement (2)**	**Unacceptable (1)**
The report clearly documents and communicates the design process in relation to the problem. The writer demonstrates a high degree of professionalism through their tone. Jargon is kept to a minimum and technical terms are explained when necessary. All sections communicate their respective content effectively to the audience.	Overall, the report documents the design process in relation to the problem. The sections communicate their respective content, but they are sometimes disjointed from one another.	For the most part, the report documents the design process in relation to the problem. The sections communicate their respective content, but the audience may need to ask clarifying questions about jargon or other technical content.	The report attempts to document the design process in relation to the problem but does not clearly communicate the steps or how the writer approached them. The audience would not have a clear understanding of the writer's design process or their reasoning behind it.	The report attempts to document the design process but does not take into account the problem. After reading this report, the audience would not understand the writer's design process nor their reasoning behind it.

These explanations were written with greater detail than presented in the previous rubric, thereby providing more guidance for the instructors. For example, a DR1 that demonstrates "exemplary" Rhetorical Appropriateness "clearly documents and communicates the design process in relation to the problem." An "acceptable" score in this category denotes that the report "documents the design process in relation to the problem" and that the "sections communicate their respective content, but the audience may need to ask clarifying questions about jargon or other technical content." This language provides clear distinctions between each level of achievement and allows for instructors to be precise in their grading. More broadly, the revised rubric and grade sheet allow instructors to assess DR1 reports more consistently and efficiently.

Writing Assessment Training

In addition to updated grading materials, the technical writing instructor provided writing assessment training for studio instructors beginning in Fall 2023. In its most recent iteration, the assessment training has been broken into two 30-minute workshops, offered during the weekly course coordination meetings. During the first workshop, the lecturer explained best practices for providing feedback on student writing. In particular, she introduced a novel approach to the department's senior design report grading, emphasizing the classification of issues into two categories: Higher Order Concerns (HOCs) and Lower Order Concerns (LOCs). "HOCs and LOCs" is a framework for understanding and prioritizing writing concerns during the revision process. HOCs encompass issues related to the students' ability to represent their thinking in writing, including the development of ideas, fulfillment of purpose, and attention to audience. In contrast, LOCs often pertain to sentence-level issues, such as word choice, sentence structure, and grammar and mechanics [20]. As a pedagogical tool, HOCs and LOCs originates from writing center pedagogy, where feedback is typically provided verbally; outside the writing center, the hierarchy is also useful for focusing instructor feedback and student response to that feedback [20], [21]. Therefore, senior design instructors were trained to prioritize the evaluation of HOCs and limit their LOC comments to streamline the grading process and provide more effective feedback.

In addition to the HOCs and LOCs framework, instructors were advised to adopt several feedback strategies aimed at managing their time and effort providing feedback for each report. There were two goals for encouraging instructors to adopt these strategies: to reduce time spent grading and to encourage students to take ownership of revising their work. For example, instructors were advised not to mark every instance of an error but to identify patterns of error. Identifying patterns allows students to locate instantiations of that pattern and correct it themselves, and they can apply this feedback within the given assignment and in their writing for other courses [22]. Instructors were also encouraged to use marginal comments rather than edit the students' papers using the "track changes" function in Microsoft Word. When instructors edit their students' papers, students tend to blindly accept the suggested changes with little or no reflection about why the changes were made [23]. Using marginal comments, however, places the responsibility of revising onto the students, giving them a chance to develop revision as a skill and saving the instructor time and energy. Finally, instructors were advised to limit the time spent grading each report to twenty to thirty minutes and to limit their comments to no more than three per page. Although difficult to maintain, these limits help instructors avoid providing overwhelming amounts of feedback to their students. It also forces instructors to prioritize the feedback they give, helping them adhere to the HOCs and LOCs framework and prompt meaningful revision.

While the first workshop in the assessment training is theoretical, focused on best practices, the second workshop offers instructors a chance to apply those best practices in a grade norming session. During the session, instructors were presented with a set of three sample Background sections responding to the following problem statement:

> The McDonnell Douglas DC-10's outward-opening cargo door has a faulty locking mechanism that, upon failure, causes the door to open and the plane to explosively decompress. The project sponsor, a representative of McDonnell Douglas, has asked the design team to redesign the aft cargo door to prevent accidental opening during flight.

Each background section was written with the aid of ChatGPT to simulate problems with rhetorical appropriateness and formatting and organization observed in students' background research sections in previous semesters. For example, the technical writing coordinator prompted ChatGPT to write a background research section focused on types of cargo doors and the aircraft in which they are used. This produced a background research section that included significant details about specific aircraft while only briefly explaining how each type of cargo door works. The overall effect is a background research section that does not adequately explain the problem with the current doors, how they work, why a new solution is needed, or which engineering principles will be useful to the team as they design a solution to the problem. All three sample background sections have been provided in Appendix C.

Instructors were asked to read each sample and discuss what feedback they would provide for the hypothetical student. Importantly, none of the sample background sections include significant issues with writing mechanics; this was done to encourage instructors to focus on the higher order concerns present in each sample. During their discussions, instructors compared feedback and discussed which issues with the "students'" writing took priority in providing feedback. As the instructors discussed their grading of the samples, the capstone coordinator and technical writing coordinator provided their grading and feedback for the same set of samples. The sample feedback demonstrated the best practice described in the previous writing workshop in that they were focused on HOCs, written in complete sentences, and limited to about three comments per page.

Post-workshop Support

Following the writing assessment training workshops, instructors were encouraged to contact the technical writing coordinator with any questions or concerns that might arise during their grading period. These consultation sessions, which generally lasted about thirty minutes, allowed instructors the opportunity to receive feedback about their comments and scoring of student papers. Additionally, the technical writing coordinator provided guidance for articulating comments specifically about writing issues.

Results and Discussion

To assess the effectiveness of the materials provided to instructors, namely the updated rubric and grade sheet, the assessment training workshop, and the post-workshop support, the capstone coordinator solicited feedback from studio instructors. The capstone coordinator and technical writing coordinator were particularly interested in feedback that allowed them to gauge the success of the writing assessment resources in two areas: making grading more efficient and improving the quality of feedback. The feedback was gathered via surveys and during the weekly capstone coordination meetings. For Fall 2024, there were 16 studio instructors present in the coordination meetings, and 8 of them provided feedback via the survey. While no formal pre-survey was provided to gather data from instructors' experiences teaching writing classes prior to the implementation of the new materials, many instructors had taught either the capstone course or another W course. They were asked as part of the survey to compare their previous experience teaching W courses with the experience of teaching the capstone course described in this paper.

As instructors entered the initial DR1 grading period, several of them reached out to the technical writing coordinator to discuss specific wording for writing-related comments. For example, one instructor asked help wording feedback to a student whose opinions and speculations (e.g., "We dedicated substantial effort to defining our assumptions" and "By applying our practical knowledge to community needs, this project can create exceptional social impacts.") detracted from their Rhetorical Appropriateness score. Another asked for help explaining to a student that the information gleaned from the team's technical questioning needed to be organized into paragraphs rather than reported in bullet points. These questions demonstrate instructors' willingness to engage more directly with the writing portion of the DR1 (rather than focusing solely on the technical content) and a need for training and expert support in grading.

Although the technical writing coordinator had encouraged instructors to limit their grading time per report to twenty to thirty minutes, this proved unfeasible in practice. However, across eight instructors from the Fall 2024 semester, it took an average of 39 minutes to grade each report, with each of them leaving an average of 4 comments per page. This is a significant reduction from the one to three hours per DR1 reported by instructors prior to Fall 2023. Some Fall 2024 instructors mentioned that the first few reports took over an hour to grade, but as they became acclimated to using the rubric and grade sheet, they were able to grade more quickly. Anecdotally, instructors commented that students seemed to more clearly understand assessment rationale. Whereas students from previous semesters had many concerns about how their DR1 reports were graded, students from more recent semesters were able to connect their numerical scores with their instructor's marginal comments and the completed grade sheet.

This study is limited by its small sample size. Other variables include the diverse levels of experience in assessing writing among instructors, the differing writing skills among undergraduate students across course sections and from semester to semester, and the inherent subjectivity of writing. Nevertheless, the improvements in the grading process reported by instructors are promising. The instructors were able to grade more efficiently than in previous semesters. Moreover, although instructors spent less time grading, focusing on HOCs in their formative comments and assessing writing holistically allowed instructors to provide high quality feedback to students.

Conclusion

This paper discusses the implementation of improved assessment tools and assessment training for instructors of a writing intensive course. The authors found that a rubric that allowed for holistic grading of writing and analytic grading for the technical content of students' design reports provided better guidance for assessing student writing and directing students' revisions. Additionally, providing assessment training, guided by best practices established in the field of composition pedagogy, helped instructors more efficiently and effectively provide feedback for students.

For future semesters, the assessment training will be improved based on instructor feedback. Namely, the writing samples will include LOCs for the instructors to discuss during the grade norming session. This will better simulate student writing, as HOCs rarely ever appear without at least a few LOCs, and will allow instructors the opportunity to practice focusing their feedback. Additionally, the technical writing coordinator is developing a comment repository that instructors can use as a guide for articulating feedback about writing. Other work in this area could take students' experiences into account. For example, students could be surveyed about how they interpret instructor comments, which comments they find most useful when writing technical reports, and how they apply comments as they revise their work. There are clearly many opportunities to support the development of students' technical writing skills, both through direct intervention in their writing practices and, perhaps less obviously, in helping instructors provide efficient, effective feedback.

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Appendix: Fall 2024 DR1 Rubric

	Report Criteria Notes	Exemplary (5)	Good (4)	Acceptable (3)	Needs Improvement (2)	Unacceptable (1)
Rhetorical Appropriateness	The target audience for this report is an individual who has basic engineering knowledge but knows little to nothing about the sponsor, industry, specific project, technology, class structure, or engineering design process.	The report clearly documents and communicates the design process in relation to the problem. The writer demonstrates a high degree of professionalism through their tone. Jargon is kept to a minimum and technical terms are explained when necessary. All sections communicate their respective content effectively to the audience.	Overall, the report documents the design process in relation to the problem. The sections communicate their respective content, but they are sometimes disjointed from one another.	For the most part, the report documents the design process in relation to the problem. The sections communicate their respective content, but the audience may need to ask clarifying questions about jargon or other technical content.	The report attempts to document the design process in relation to the problem but does not clearly communicate the steps or how the writer approached them. The audience would not have a clear understanding of the writer's design process or their reasoning behind it.	The report attempts to document the design process but does not take into account the problem. After reading this report, the audience would not understand the writer's design process nor their reasoning behind it.

Formatting and Organization	Your report may be better formatted with major and minor subheadings and paragraphs and/or by reorganizing the order of the sections. The report should not be a set of bulleted lists or unrelated statements. Discuss what you did, why you did it, and the results of your efforts.	The report contains all necessary components and is formatted with care and attention. The writer effectively uses topic sentences, transitions, signposts and other structural elements to establish a clear internal logic for the report. Pages are numbered and all figures and appendices are appropriately labeled, cross-referenced, and discussed in the main text. Section headings follow a clear, consistent organizational logic. The references page and in-text citations are	Overall, the report contains all necessary components and is well formatted. The writer establishes clear, consistent organizational logic for the report, though there are some mistakes in formatting which detract attention from the content. Figures and appendices are appropriately labeled and cross-referenced with rare, minor mistakes. The references page is formatted. Section headings follow a consistent	For the most part, the report contains all necessary components and is generally well formatted. The writer generally keeps consistent internal logic for the report. Figures and appendices are labeled and cross-referenced, though there may be some mistakes. The references page is formatted. There are section headings, but they are either unnecessary or inconsistent in their logic.	The report contains all necessary components but does not follow a clear organizational logic. The individual sections feel separate from one another instead of establishing a consistent internal logic from introduction to conclusion. Figures are not appropriately labeled, cross-referenced, or discussed. The references page is not appropriately formatted.	The report is missing sections, is not formatted appropriately, or is otherwise so disorganized as to hinder the audience's understanding of the work. There was either no attempt to format the references page or it is nonexistent.

		formatted appropriately according to ASME guidelines.	organizational logic.			
Writing Mechanics		The entire report is written coherently and cohesively. The report is free of grammatical and usage errors.	Overall, the report is generally written coherently and cohesively. There are minor grammatical or usage errors, but they do not hinder the overall clarity of the work.	For the most part, the report is written coherently and cohesively, though with some exceptions. There are minor grammatical or usage errors that sometimes hinder clarity of the work at the sentence level.	The report is written coherently but lacks cohesion. There are significant grammatical and usage errors that hinder the audience's understanding of the report.	The report lacks coherence and cohesion. The writing is difficult to understand because of significant grammatical or usage errors.

Appendix B: Fall 2024 DR1 Grade Sheet

Student Name:				
	Points Available	**Score (0 to 5)**	**Points Received**	**Additional Feedback**
Technical Content				
Introduction	**10**		**0**	
Background Research	**20**		**0**	
Problem	**15**		**0**	
Conclusion	**5**		**0**	
Writing				
Rhetorical Appropriateness	**20**		**0**	
Formatting and Organization	**20**		**0**	
Writing Mechanics	**10**		**0**	
Final Grade			**0**	
Overall Notes:				

Appendix C: Sample ChatGPT-generated Background Sections

Sample 1

This sample is meant to be the best of the three, though it is not necessarily perfect. The "student" does the best job of providing relevant details that inform the team's decision making.

When flying at high altitudes, airplanes undergo cabin pressurization, a process in which air is pumped into the cabin of the aircraft after being conditioned by an on-board environmental control system. Unintended loss of cabin pressure can result in injury or death for the passengers and flight crew aboard the plane. To maintain safe cabin pressure, aircraft fuselages, including windows and doors, must be able to withstand the pressure differential between the plane's internal pressure and the external atmospheric pressure. To address the multifaceted problem of the DC-10 cargo door's potential to open during flight, the design team has elected to research several topics. Cabin pressure maintenance systems and uncontrolled decompression are discussed in the reports produced by other members of the team. This report focuses on airplane doors, including an overview of airplane door designs and how they are designed to maintain cabin pressure.

Airplane cargo doors have evolved significantly from the early days of aviation. Originally, cargo was loaded manually through relatively small doors, limiting the size and volume of cargo transportable. As aircraft design progressed, larger and more sophisticated doors were developed to accommodate increased cargo volumes and improve loading efficiency. The introduction of standardized cargo containers and pallets further influenced cargo door designs, leading to the development of larger, more robust doors equipped with automated loading systems (Smith, 2018). Modern airplane cargo doors are designed with a focus on maximizing space utilization, safety, and reliability. There are several types of cargo doors, including plug doors, upward-lifting doors, and outward-opening doors.

Plug doors are larger on the inside than the outside frame and are wedged to the door frame from the inside. When the cabin is pressurized, the higher internal pressure pushes the door outward against the frame, creating a tighter seal. This design ensures that the higher the internal pressure, the stronger the force holding the door closed, making accidental opening virtually impossible during flight (Johnson & Malone, 2020). However, they can represent a hazard in emergency situations because they cannot be opened until the pressure is equalized with the outside environment.

Common in the military and some commercial freighters, upward-lifting doors lift upwards to provide full access to the cargo bay. Some upward-lifting doors operate by moving straight up vertically along tracks. This is often facilitated by hydraulic or electric actuators that lift the door smoothly. In other designs, the door pivots at the top and opens upward, aligning with the aircraft's contour when fully open. This type is common in military transport aircraft, where rapid deployment of equipment and personnel is essential. Like other aircraft doors, upward-lifting doors are equipped with robust sealing and locking mechanisms to ensure airtight closure. These doors typically engage with multiple locking points around the perimeter to withstand the pressure differentials and dynamic stresses encountered during flight (Doe & Smith, 2021).

Finally, outward-opening doors swing outward and then upward, allowing for a larger opening and reducing the risk of cargo hitting the door during loading and unloading. With the door mechanism positioned outside the cargo area, there is no intrusion into the cargo space, allowing for optimal use of the available volume. These doors can have simpler hinge and sealing mechanisms compared to doors that must slide into the aircraft fuselage or fold upwards. This can reduce the complexity of the door's construction and potentially decrease maintenance requirements. The outward-opening mechanism can also provide better access for maintenance personnel and, in some designs, may facilitate easier access in emergency situations (Lee, 2019).

Based on the research conducted here, the team better understands how different door designs offer unique benefits and drawbacks. Because the McDonnell Douglas DC-10 is used as a passenger plane for long-range flights, it is important to maintain ample cargo space. Therefore, the team will develop concepts that capitalize on the outward-opening design’s ability to maximize cargo space while also consistently maintaining cabin pressure to prevent explosive decompression.

Sample 2

This sample focuses too much on which planes use each door type, which obscures the issue of cabin pressurization. It is also missing in-text citations.

When flying at high altitudes, airplanes undergo cabin pressurization, a process in which air is pumped into the cabin of the aircraft after being conditioned by an on-board environmental control system. Unintended loss of cabin pressure can result in injury or death for the passengers and flight crew aboard the plane. To maintain safe cabin pressure, aircraft fuselages, including windows and doors, must be able to withstand the pressure differential between the plane's internal pressure and the external atmospheric pressure. To address the multifaceted problem of the DC-10 cargo door's potential to open during flight, the design team has elected to research several topics. Cabin pressure maintenance systems and uncontrolled decompression are discussed in the reports produced by other members of the team. This report focuses on airplane doors, including an overview of airplane door designs and which planes employ them.

Airplane cargo doors have evolved significantly from the early days of aviation. Originally, cargo was loaded manually through relatively small doors, limiting the size and volume of cargo transportable. As aircraft design progressed, larger and more sophisticated doors were developed to accommodate increased cargo volumes and improve loading efficiency. The introduction of standardized cargo containers and pallets further influenced cargo door designs, leading to the development of larger, more robust doors equipped with automated loading systems (Smith, 2018). Modern airplane cargo doors are designed with a focus on maximizing space utilization, safety, and reliability. There are several types of cargo doors, including plug doors, upward-lifting doors, and outward-opening doors.

Plug doors, known for their safety-enhancing features, are a critical component in several specific aircraft models. The Boeing 737 series, a staple in short to medium-haul aviation, employs these doors for safe and secure passenger entry and emergency exits. Similarly, the Airbus A320 family, which competes directly with the 737 in commercial aviation, incorporates plug doors to maintain cabin pressurization and ensure passenger safety across its fleet. The larger Boeing 777, favored for long-haul flights, also utilizes plug doors, benefiting from their secure seal that prevents accidental openings. Additionally, the Airbus A380, unique for its double-deck configuration, relies on plug doors to safely manage the complex pressurization needs of its expansive cabin space. These aircraft models exemplify how plug doors are integral to modern aviation, combining enhanced safety with the rigorous demands of passenger and cargo transport.

Upward-opening doors are a specialized feature predominantly found on certain types of aircraft, particularly those designed for cargo and military purposes. Notably, military transport aircraft like the Lockheed C-130 Hercules extensively use upward-opening doors to facilitate rapid deployment of troops and equipment directly from the airfield. Similarly, the Boeing C-17

Globemaster, a strategic airlift aircraft, employs large upward-opening doors that enhance its capability to handle a wide range of cargo, including outsized military equipment. These doors lift vertically, maximizing accessibility and efficiency during loading and unloading operations. Commercial freighters, such as certain configurations of the Boeing 747, also feature upward-opening doors to optimize the cargo loading process. This design is essential for aircraft that need quick and easy access to their cargo holds, making them pivotal for logistical operations in both commercial and military aviation.

Outward-opening doors are particularly advantageous for cargo aircraft, facilitating easier and more efficient loading and unloading processes. Models like the Boeing 747 Freighter incorporate these doors to maximize the usable cargo space within the aircraft by ensuring that the doors do not intrude into the cargo area. This feature allows for optimal utilization of the available volume, which is crucial for transporting large volumes of goods efficiently. Additionally, some variants of the Boeing 767 also use outward-opening doors, enhancing their functionality in cargo operations by allowing a wider opening and reducing the risk of cargo hitting the door during loading. These doors are designed with simplicity in mind, often featuring fewer moving parts and thus requiring less maintenance. The implementation of outward-opening doors across various models underscores their importance in the design of cargo aircraft, aiming to improve operational efficiency and reliability in the aviation industry.

Sample 3

This sample is meant to demonstrate a student's attempt to hit the word minimum by using flowery, repetitive language. Additionally, the section is over-formatted to make it appear more informative than it actually is.

In the context of aviation, especially when aircraft ascend to high altitudes, maintaining cabin pressure is absolutely crucial. This process, commonly referred to as cabin pressurization, involves pumping air that has been conditioned by an on-board environmental control system into the cabin of the aircraft. It's critical to understand that any unplanned loss of this cabin pressure can have extremely serious implications, potentially leading to injuries or even death for passengers and crew members alike. Ensuring the integrity of the aircraft's structure, including all windows and doors, is paramount as they must withstand the differential between the internal pressure of the plane and the external atmospheric pressure.

To tackle the complex issue of the DC-10's cargo door potentially opening during flight, our design team has opted to research several pertinent topics. These include but are not limited to cabin pressure maintenance systems and the phenomena associated with uncontrolled decompression. While other members of our team have produced reports discussing these topics, this particular report will focus exclusively on airplane doors, providing an extensive overview of the various designs of airplane doors.

Detailed Discussion on Airplane Cargo Doors:

A Brief History

Airplane cargo doors have undergone significant evolution from the early days of aviation to the present. Initially, cargo was loaded manually through relatively small doors, which significantly limited the size and volume of cargo that could be transported. As advancements in aircraft design were made, larger and more sophisticated doors were developed to not only accommodate increased cargo volumes but also to enhance loading efficiency. The advent of standardized cargo containers and pallets played a pivotal role in influencing the designs of cargo doors, leading to the creation of larger and more robust doors equipped with automated loading systems.

Types of Cargo Doors

In modern aviation, cargo doors are designed with a particular emphasis on maximizing space utilization, safety, and reliability. Among the types of cargo doors that exist today are plug doors, upward-lifting doors, and outward-opening doors:

Plug Doors: These doors are larger on the inside than the frame on the outside and fit snugly against the door frame from the inside. The mechanics of how they work are fascinating: when the cabin is pressurized, the higher internal pressure pushes the door outward against the frame, creating a tighter and more secure seal. This design principle ensures that the higher the internal pressure, the stronger the force that holds the door closed, thus making it virtually impossible for the door to open accidentally during flight. However, it's worth noting that in emergency situations, plug doors can represent a hazard because they cannot be opened until the pressure between the inside and the outside of the aircraft is equalized.

Upward-Lifting Doors: Commonly used in military applications and some commercial freighters, these doors lift upwards to grant full access to the cargo bay. Some of these doors operate by moving straight up vertically along tracks, a process often facilitated by hydraulic or electric actuators that ensure the door is lifted smoothly. In other designs, the door pivots at the top and opens upward, aligning with the aircraft's contour when fully opened. This type of door is particularly common in military transport aircraft, where the rapid deployment of equipment and personnel is essential. Like other aircraft doors, upward-lifting doors come equipped with robust sealing and locking mechanisms to ensure an airtight closure. These doors typically engage with multiple locking points around their perimeter to adequately withstand the pressure differentials and dynamic stresses that are encountered during flight.

Outward-Opening Doors: These doors swing outward and then upward, which allows for a larger opening and reduces the risk of cargo hitting the door during loading and unloading. With the door mechanism positioned outside the cargo area, there is no intrusion into the cargo space, allowing for optimal use of the available volume. These doors can have simpler hinge and sealing mechanisms compared to doors that must slide into the aircraft fuselage or fold upwards. This reduction in complexity can decrease the overall construction and potentially lower maintenance requirements. The outward-opening mechanism also provides better access for maintenance personnel and, in some designs, may facilitate easier access in emergency situations.

By delving into the intricacies of these various door types, our team aims to devise strategies to enhance the safety and reliability of aircraft cargo doors, thereby mitigating the risks associated with their potential failure during flight.