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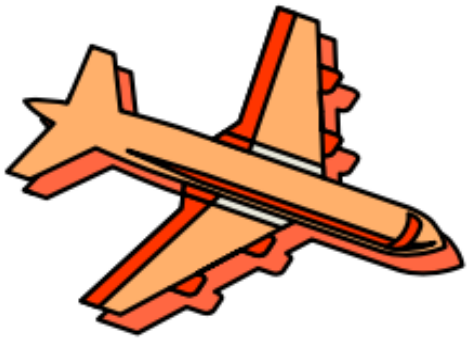

All Wheels Up Roadmap: Final Report

Mission Reach

All Wheels Up

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Executive Summary

In 2019, the U.S. Access Board published a study which established the feasibility of a Wheelchair Tiedown and Occupant Restraint System on airplanes. This study called for the design of a high-level roadmap that lays out the series of tasks and descriptions required to

implement such a system. Mission Reach was tasked by non-profit organization, All Wheels Up, to develop this roadmap which is an essential next step in efforts to allow passengers to remain in their personal wheelchair throughout the travel experience.

By reviewing literature and interviewing stakeholders in the airline industry, a bank of information was established. Outlining a general framework for the roadmap (design, certification, implementation) allowed for the organization and categorization of information. Building out the framework included defining steps and substeps as well as identifying the following for each: description, participant, action, deliverable, and notes/requirements. Regular iterations of the roadmap and constant consultation with industry experts refined the results.

The roadmap was deemed successful in fulfilling the goal of laying out a clear path from ideation to implementation by surveying industry experts before presenting our project deliverables and after. 60% of those surveyed indicated an increase in clarity of steps to implementation; however, 20% indicated full clarity in steps to implementation (with no room for improvement) both times surveyed.

Introduction

Created in 2011 by Michele Erwin, All Wheels Up (AWU) is currently the only organization in the world crash testing wheelchair tie downs and wheelchairs for commercial flight. According to a 2018 DOT study, airlines reported “32,445 disability-related complaints, which was a 7.5% increase from previous year” (DOT, 1). As a result, All Wheels up has pushed for implementing a Wheelchair Tiedown and Occupant Restraint System (WTORS) that allows wheelchair users to secure their personal wheelchair to the aircraft floor. For many years the disabled community has fought for the opportunity to travel on airplanes from the comfort of

their own wheelchair. We believe in making air travel more accessible and providing everyone the opportunity to travel safely. The main goal of our project is to develop a roadmap, for All Wheels Up, that helps outline the necessary steps to implement a wheelchair securement system on aircrafts.

Problem Definition

The goal of this project was to create a roadmap which outlines the steps and tasks necessary to design and certify a WTORS. There are currently people and companies who wish to create or help create such a product, but the lack of clarity on how to do so has stopped them from actively attempting it. A clear roadmap which provides the needed clarity of what needs to be done, when it needs to be done by, and who needs to do it will help potential designers and investors understand the process and increase their willingness to commit to the creation of a WTORS. There are several steps to laying out the problem: defining the problem variables, identifying the customers' needs, and acquiring the necessary data.

There were a number of variables that needed to be assessed in order to successfully create a roadmap for designing a WTORS. The first variable involved understanding all of the possible components of a design of a WTORS to ensure that all of them are accounted for. The second category of variables were the stakeholders who might have been involved in the project, along with their potential roles, responsibilities, and relationships with one another. The third category of variables were the steps to the design, certification, and implementation processes. Once all of these steps were identified and analyzed, it became possible to combine and organize them into the roadmap for a WTORS.

Another factor of the problem was the identification of customers and stakeholders. There are two types of customers and stakeholders which are relevant for this project. The first type of stakeholder are the roadmap customers, or those who will be actively using and implementing the roadmap. This included the aviation industry, wheelchair industry, and organizations dedicated to accessibility such as AWU. These stakeholders are directly impacted by the contents and quality of the roadmap, and its success may directly impact their decision on whether they participate or support in creating a WTORS. The other type of customer or stakeholder are those impacted by the implementation of a WTORS. This not only includes wheelchair users, but also anyone they come in contact with during their travel, and everyone involved in physically manufacturing and installing a WTORS. As the second type of customer does not interact with the roadmap, the roadmap had to include a place to address their needs, requirements, and preferences.

In addition to identifying the customers, the constraints of what was possible for this project must also be discussed. In the initial evaluation of the project it was highlighted that no one knew where to start with creating a WTORS, they needed information or cooperation from another stakeholder, and they were unclear how to certify such an unconventional and innovative product. Due to this lack of clarity, no one wanted to invest the time or the money into such a risky venture without a clear path to success. These four factors (process clarity, information, time, and money) have been identified as the key variables to the successful development of a WTORS. However, this team was only allotted six months to create a roadmap, which also had to be versatile enough for it to be used by any number of different stakeholders within the aviation industry. Thus, it has been determined that the focus of this project would be to provide process clarity and a pathway for gathering the necessary information in order to develop a

WTORS. There are many factors which may greatly impact the time required for each step, especially due to the innovative nature of a WTORS, and there is no historical data to create any kind of accuracy in time estimates. The financial constraints are also not being considered. There are several ways and opportunities to assure the financial backing for this project, but spending time determining how to secure the finances needed for this project was outside of the scope laid out by our project sponsor Michele Erwin. Due to these constraints, the roadmap only focuses on laying out the steps for developing and implementing a WTORS with a focus on process clarity.

There were two main ways that our team gathered the necessary data to create a comprehensive roadmap. The first and main way was by interviewing stakeholders who would likely be involved in the design and certification of a WTORS. This approach was critical to understanding the role and requirements of each stakeholder, and identifying where they fit into the roadmap. The second source of data came from reviewing relevant literature about product design and certification for airplanes. This helped us understand both the details of creating a WTORS and the challenges which will need to be addressed in order to be successful in its implementation. Our combination of interviews and literature has allowed our team to understand all of the variables, customers, and constraints surrounding our project.

Analysis

Assumptions

There are four major assumptions that we have determined to be relevant to our project. They include: implementing a wheelchair spot is feasible, there is sufficient funding for the project, stakeholders are willing to implement, and the roadmap can be easily adapted to future changes.

The first assumption, implementing a wheelchair spot is feasible, is vital for determining the scope of our project. It was determined in the Transportation Research Board (TRB) report ordered by congress that a wheelchair spot is feasible. This specifically applies to being able to navigate a wheelchair through an airplane, which includes a possible reconfiguration of the interior of an airplane and determining a floor structure that supports the load of a power wheelchair and the occupant. The feasibility assessment from the TRB report does not guarantee that individual wheelchairs can withstand the necessary pressures. The TRB report suggests a need for crash testing to ensure the safety of the wheelchairs and tie downs. They did however, acknowledge that AWU has performed successful tests, but there needs to be official tests that the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) and the Federal Aviation Administration (FAA) can accept. Thus, the safety of wheelchairs on aircrafts is not included in the assumption of feasibility and crash testing efforts will need to be a step in the roadmap. The feasibility assumption indicates that it is possible to get wheelchairs on an aircraft, but the safety and specific requirements of how that will work will need to be determined in the future to avoid applying for special conditions and exemptions.

The next assumption is that there is sufficient funding to implement this project. This essentially means that securing the necessary funding is outside the scope of this roadmap and the first step will start after that is assured. The roadmap will also be used to help ensure the commitment of stakeholders and government funding. Our project sponsor, Michele Erwin, has also ensured us that AWU has begun pushing for federal funding. Therefore, including steps for the securement of funding would not be beneficial to the roadmap, as well as it being outside our area of expertise.

Another assumption is that stakeholders are willing to participate and are responsible for carrying out their actions stated in the roadmap. This assumption is essential in being able to create this roadmap, as without their involvement there is no one to implement a wheelchair securement system. We understand that there may be risks and challenges in ensuring participation and this will be addressed in our risks section. However, in order to build a functional roadmap we must assume all stakeholders are willing to participate.

The last major assumption we have made is that the roadmap can be adapted to future changes regarding wheelchair standards on aircrafts and/ or new design developments. We understand that as the project gets implemented, there will be changes in design plans, stakeholders, and regulations. Thus we are assuming the roadmap can be changed without rendering the rest of it obsolete. After the end of Mission Reach's participation in the roadmap, we will be creating a dynamic solution in order to account for future changes.

These are the four assumptions guiding the creation of the roadmap, and will be used throughout the project to help us stay within the scope of our work.

Stakeholder Meetings

To obtain necessary data for our roadmap, we met with individuals who have helped us better understand the process of implementing a securement system for personal wheelchairs on airplanes. Our information gathering process consisted of meetings with over ten stakeholders, many of which are involved in either the design phase, certification phase, implementation phase, or all of the phases. While gathering new information from stakeholders, we were able to develop a roadmap that can be adapted to future changes in the aviation and federal industry.

The first major stakeholder we met with was Michele Erwin, our project sponsor and the president of AWU. We set up recurring weekly meetings with Michele to ensure we were on the right path of schedule meetings with stakeholders involved in the process. Our meetings with Michele provided valuable insight on the construction of our roadmap. Michele provided us with a list of stakeholders involved and their contact information. She also provided us with insight to our roadmaps risks, assumptions, and requirements stated earlier. We continued to meet with Michele weekly to update her on our project, as well as utilize her as a resource to connect us with necessary stakeholders.

Next we met with Ryan Nelson, whose expertise centers around the logistics of the certification processes done by the FAA and RESNA. Ryan provided us with a technical CPI guide for certifying a product between industry partners and the FAA; as well as the logistics behind a Supplemental Type Certificate (STC); and a special conditions and Equivalent Level Of Safety (ELOS) request. Ryan's main concern with implementation was in regards to the interior of the airplane, specifically the physical space needed for the wheelchair to maneuver between aisles and the bathroom. Ryan also stated that we needed to identify the process of crash testing power wheelchairs to ensure the safety of fliers. He provided us with all necessary data to solidify our certification process, including a list of standards we should be aware of from other regulatory bodies and standards making organizations (EASA, IATA, etc), as well as documents we were able to reference for our certification phase (i.e the IATA Best Practices Guide for Cabin Interior Retrofitting, the FAA and Industry Guide to Product Certification, etc). Our biggest takeaway from Ryan was the logistical process of the certification phase, specifically the necessary forms needed to certify a unique product, the required standards that need to be met to

achieve certification, and how certification can be easily achieved regardless of there not being any current wheelchair standards on aircrafts.

After meeting with Ryan we met with Robin Wearly, an expert on evacuation procedures in airplanes and the creator of the ADAPTS sling. We chose to meet with Robin because we wanted to better understand the current evacuation process and to make sure we were considering the safety of disabled fliers in cases of emergency. Robin and Michele both indicated there is a safety sling wheelchair users currently carry that can be used to safely lift the flier to be evacuated. Robin states that the wheelchair evacuation plans need to be updated after implementation and the airlines should be required to keep these safety slings on board in the emergency kits. Meeting with Robin allowed us to better understand the feasibility of implementation and the processes already in place to ensure in-flight staff are prepared to assist wheelchair users on board.

Our next stakeholder meeting was with Glenn Johnson, a Fellow of Industrial Design at Collins Aerospace, who provided us with concrete information on the certification process for our roadmap. The most valuable information Glenn provided us with was a general flow of information for implementing a securement system. First, Glenn stated the money for implementation would come from FAA reauthorization acts. Next, in order for the design criteria to be met the FAA and RESNA would perform a set of studies with airline companies to determine the feasibility and safety of the product. Once studies are conducted, the FAA must certify the securement system, the aircraft space, and the safety sling used for evacuation. After certification, the manufacturers will begin to build enough securement systems to be distributed to all suppliers. Finally, airline companies must begin the implementation process by conducting

field testing and training their in-flight employees. In conclusion, Glenn's knowledge allowed us to construct a general outline for our roadmap and decide on stakeholders we should prioritize.

We also met with Victoria Bamford, a former New Zealand Air employee who helped design a roadmap for sleeper beds on planes. Our meeting with Victoria provided valuable insight on the structure of our roadmap and what exactly we should include in our report. More specifically, Victoria mentioned some key components her team had included in the New Zealand Air: Sleeper Beds Roadmap, including safety standards, ratio of passenger to bathrooms, flight attendant ratio, and certifications. She also recommended we emphasize the wait that is going to be placed on decision criteria; and establish who is making a decision and who they need to confer with to make that decision. The main takeaway from our meeting with Victoria was the general structure of our roadmap that should include key milestones, key decisions, stakeholders involved, the people who are responsible for decision making, and stakeholders they need to engage with.

Next, we met with Miriam Manary, a lead research engineer involved in the wheelchair crash testing efforts at the University of Michigan. Miriam provided us with knowledge on current motor crash testing standards, how the RESNA certification process operates, how the post certification process is approached, and how WC-19 standards were created. Although the University of Michigan is still working towards creating crash testing standards for wheelchairs on aircrafts, Miriam was able to provide us with valuable insight on the federal regulations and standards needed for our roadmap in relation to the current state of the aviation industry.

The next stakeholder we met with was Michelle Albert, an engineer at Boeing who specializes in certification and cabin safety. Michelle explained to us that the main operational challenge of the solution will be to figure out if the wheelchair tie down and occupant restraint

system will need to replace seats; and if it will need to be adjusted between flights. The motivating factor for Boeing would be to see if there is any airline desire for a wheelchair spot, which could come from legislation or a perceived financial gain. Our meeting with Michelle provided us with insight to the design and certification processes. Within the design process, we noted that there will have to be early on collaboration between all participants involved to develop a design. The main takeaways from the information we received about the certification process were the forms necessary to certify this newly developed design idea, since there are no current standards for personal power wheelchairs on aircrafts. These forms include an STC, Special Condition, Exemptions, and a Technical Standard Order.

In order to make sure we were prioritizing the safety and needs of wheelchair users, we met with Mike OKray, an AWU Board member and Senior Data Analyst with Southwest Airlines; Dave Stevens, a wheelchair user and motivational speaker; and Ryan Russell, an individual with Muscular Dystrophy and a life coach. From this meeting we were able to identify two significant components to our project; the experience wheelchair users face during the current boarding process and their own requirements for making air travel more accessible. When talking with Ryan, we were able to understand the importance of boarding with a personal wheelchair. Ryan, like many other wheelchair users, has to be in his own personal wheelchair as a medical necessity. This is because many wheelchair users have medical devices attached to their personal chair (i.e oxygen, specific angle of recline, etc). When speaking with Dave, we were able to identify the severity of damages many wheelchair users face when their personal chair is put into cargo. Dave stated that his wheelchair has been shipped to an entirely different location, forcing him to find alternative, and uncomfortable, methods to get around the airport. Our main takeaway from meeting with wheelchair users was the importance and impact of our

project. We were able to better understand the impact of creating a more accessible environment for wheelchair users to travel safely and comfortably on aircrafts.

Next we met with QStraint, a manufacturing company for wheelchair securement and safety products in transportation. We specifically met with Oli Davalos, a project manager with QStraint, and Bill Ott, the Vice President of Global Engineering. Both Oli and Bill explained to us that QStraint (or any wheelchair tie down manufacturer) would need to be heavily involved in the design phase because a tie down system will need to be integrated into the design of an aircraft. QStraint specifically provided us with insight on which step of the process needs the most clarification; the certification process. With this in mind we made sure to add as much detail and information necessary to ensure that stakeholders were aware of necessary federal regulation forms and standards. QStraint pushed us to focus on the regulations and federal standards necessary to implement and develop a unique system.

The next stakeholder we met with was Teague, a design firm. In this meeting we were able to connect with Gaia Borgias, a strategic engagement manager; Ant Harcup, a senior director of airline experience; Carrie McEwan, a senior human factors specialist; and Eric Klein, a design visualization manager. When meeting with Teague, we realized our starting phase can begin after a specific design has been chosen to test. Teague walked us through the design process, indicating that after a design is chosen the prototype must be continually iterated until it meets all necessary regulations and requirements. Teague also explained the current environment of the aviation industry. The Teague team, along with many other stakeholders, stated that the main drive for implementing a wheelchair tie-down and occupant restraint system would be airline support and interest. Our meeting with Teague allowed us to fully develop our certification phase and confirm that airline support is a must to move forward in the process.

Lastly we met with Bryan Parker, an interim engineering manager for Southwest Airlines; and Joanna Reimer, an engineer at Southwest Airlines specialized in accessibility. Our main reason for meeting with Bryan and Joanna was to better understand the roles of airline companies during all phases of our roadmap. The two members notified us that Southwest Airlines was interested in being a driving force of implementation in efforts to improve inflight experience. Bryan and Joanna were valuable in providing context around regulatory requirements, operational requirements, technical designs, and their challenges and constraints. Southwest notified us that before airline companies can get involved there has to be a certified configuration of the interior of an airplane that accommodates for implementation. They also walked us through the retrofitting process, the post certification phase, and the training process for inflight staff. Finally, Bryan and Joanna emphasized that Southwest Airlines, as well as many other airline companies, know their roles after implementation, but need more input and involvement in prior stages. Our meeting with Southwest allowed us to solidify our implementation phase, specifically post certification; and training and manufacturing.

After we completed our information gathering we were able to determine that all the data we received correlated with our assumptions. From here, we were able to better understand the stakeholders involved in each step, the necessary actions needed before moving on to the next step, and the deliverable required in each step. At the end of the quarter our roadmap was presented to many of the stakeholders we met with; and we received positive reviews on the order of steps and the information included. Therefore, we can conclude that our methodology for information gathering and analysis of the problem was successful.

Considerations

Health & Safety

With the end stakeholder of the WTORS being wheelchair users, it was essential that our group take into consideration the impact of the system on their health and safety. Wheelchair users rely on their chairs for support and supplies to mitigate the effects and symptoms of their medical conditions. Often, they are unable to go without essential functions like oxygen and adjustable backrests. The current state of the airline industry does not support the traveling needs of these individuals as there is no way to efficiently guarantee these functions on regular flights and users cannot board with their personal chairs. The boarding process for wheelchair users who are able to fly without their personal chair involves multiple transfers between chairs and seats, resulting in many opportunities for injury. There is not currently adequate training for staff members lifting wheelchair users into their seats, which is clearly a danger to many wheelchair users. The people being lifted into their seats are at risk of being dropped or bumped against a surface in the process of being lifted, and the people doing the lifting can be injured if they do not know how to properly support another person. Having the ability to board with a personal chair would allow persons with medical conditions the chance to travel in a system already equipped to support their needs, and would significantly reduce the chances of injury during the boarding process.

While the scope of our project did not directly outline emergency landing procedures, it is also an essential consideration. Current emergency procedures have no plan of action on how to evacuate someone who is not able bodied. In the case someone needs to be assisted in

evacuation, flight staff and other passengers who may not have training or the ability themselves are relied on for the safety of this person. One solution to this problem is ADAPTS, a portable transfer sling that can be used in emergency situations to transfer a person comfortably and safely. Unfortunately, wheelchair users are currently responsible for bringing equipment like this onto the aircraft themselves as they are not currently provided by airlines. Having safety equipment like the ADAPTS sling on every airplane would better support the health and safety of passengers targeted by this project as well as other demographics who may need extra assistance such as elderly persons.

Social and Ethical

Mission Reach believes that every individual deserves the right to travel in an aircraft with dignity. Technology has made it possible to travel far distances in a fraction of the time it takes to do so via land and water. The current inability for some individuals to participate in dignified air travel is a reflection of the inaccessible nature of the airline industry. The responsibility to navigate a complex wheelchair travel experience or find other means of transportation to accomplish trips should not fall on these individuals. We see a future that supports the travel of an individual regardless of their need for support from a wheelchair. By implementing a wheelchair spot on an airplane, our project will allow wheelchair users to travel to places they may have never considered going to due to the travel limitations. We want to give people the chance to broaden their career opportunities, visit loved ones on the other side of the world, and have control of their travel options.

The Air Carrier Access Act (ACAA) of 1986 was enacted to prohibit the discrimination of people with disabilities in air travel. It is a necessary component of accessibility in the airline industry, but it is not comprehensive as airlines are able to exclude individuals for the safety of the flight. In the case that an individual requires more medical support than the airline determines it can provide, they can be turned away. The WTORS system could potentially fill this gap in discrimination by allowing these individuals to travel with a chair that supports their medical needs.

Legal

Our roadmap will only be effective if its users take into account the numerous legal considerations, federal regulations, and standards that apply. We expect our roadmap to be flexible to these considerations as the project evolves over time. Currently, there are several major gaps in federal regulations that relate to the implementation of a WTORS:

- FAA and RESNA collaborate on selecting WC19-compliant wheelchairs for testing on FAA crashworthiness and safety performance criteria like survivable crash, emergency landing, and severe turbulence
- FAA vertical load crash testing
- Flammability standards for each component

The current rendition of the roadmap allows for the certification and compliance with federal regulations and standards through other routes-- for example an Equivalent Level of Safety approval. However, as further testing is initiated and gaps in regulation are filled in the legal considerations of the process from ideation to implementation must be updated to ensure continued compliance.

Another legal consideration that must be taken into account is the continued airworthiness of the system in airplanes through post certification. It is an important step in the process as it helps determine the maintainability of the system over an extended period of time. The impact of this is mainly preparing for the future by making sure the applicant follows through with the post certification stage which ensures the safety of passengers and the longevity of the product.

Industrial Engineering Skills

This project has relied heavily on industrial engineering principles which have been applied throughout the project to come to a successful solution. The process of creating our roadmap was mainly a manufacturing systems problem with elements of human factors and quality engineering.

Our project was mainly a manufacturing systems problem due to its focus on gathering information and organizing it into a complete system. Though our system is information based instead of physical, we were able to use a lean approach in both our own process and in the roadmap we designed. We organized our project systematically and followed the DMAIC (Define, Measure, Analyze, Improve, Control) process in our design. The first step was to fully understand and establish the scope of the problem. This was accomplished by first meeting with our project sponsor, Michele Erwin, to establish what requirements she and AWU had for the roadmap. We then met with several industry stakeholders to understand the technical background of the project. Next, we gathered data for the roadmap through meetings with stakeholders who had expertise in the creation or certification of each component of a WTORS. The process was then analyzed by organizing all the information into a process flow diagram that would make up

the core of the roadmap. We continued to improve the process flow diagram by doing several iterations, integrating new information from stakeholders, and ensuring that each step included any necessary context from the previous step or necessary information for the next step. Once the new information we collected was integrated into our process flow diagram, we finalized our roadmap with descriptions for each step in order to create a standard procedure for the implementation process. We understand that our roadmap is only the first iteration of roadmaps that will be created in the pursuit of implementing a WTORS on airplanes, so we strove to make a clear and replicable process that future teams can use to easily improve on our roadmap.

To continue our manufacturing systems approach to this problem, we strove to create our roadmap like a manufacturing process by using DMAIC principles. We structured the roadmap in a proactive manner, ensuring that any possible requirements and challenges were addressed early on. Additionally, to allow the process to stay organized we tried to maximize value added tasks and minimize waste, particularly in terms of time and rework. Time waste is minimized by highlighting which steps can be either temporarily skipped over and which ones must be completed before moving on. This allows the users of the roadmap to keep working while waiting for certain steps to be completed, or plan for having to complete a step in its entirety. We ensured the minimization of waste by highlighting the assessment of requirements in the first steps and recommending that the user initiates contact with the FAA or another regulatory body early in the project. This reduces the amount of rework that will be necessary by ensuring that all potential certification challenges are agreed upon by all stakeholders at the very beginning of the project. Throughout both our own processes and in the deliverable roadmap, our team applied a manufacturing systems approach to ensure logical steps are taken in order to create a clear process that is easy to follow and replicate as needed.

Human factors is another area that is essential to the success of both this project and the implementation of the roadmap. Human factors were a large component of our project process, as they emphasize the need to consult the user frequently and early in the design process. This principle is one that our team utilized throughout the entirety of the creation of our roadmap. The success of this project is largely dependent on the clarity of the roadmap, so if we could not present the roadmap in a clear and logical fashion then the information contained within it would be irrelevant. This was one of the main factors when determining the format of the roadmap. It was determined that a process flow diagram would be useful to visually show the process, as it is a quick way to show the scale and complexity of the implementation of the WTORS. It is also helpful as a guide to measure where in the process of creating and implementing a WTORS one is. Thus we determined the need for a diagram, and applied further components of human factors when selecting the size, font, and coloring of the roadmap to maximize readability and comprehension. We also included steps for the team lead on the project to consult with wheelchair users several times, as their feedback will ultimately ensure that the final WTORS product is actually usable by the people it was created to help.

Human factors principles were also considered when determining the straightforward language and minimal jargon of the roadmap and accompanying documents. While the roadmap would primarily be used by experts in the airline industry, there is also a possibility of it being shown to executives, investors, or government bodies in order to request support or funding. Thus, it is essential that anyone may comprehend it without having any technological or engineering background. Our consideration of human factors principles is also prevalent in the creation of step descriptions which provide details of what each step entailed in an organized manner. The step descriptions were given several components: Description, Participants, Action,

Deliverables, and Notes or requirements for the next step. These would be organized to provide clarity on what needs to be done, who needs to do it, as well as any additional information or resources that are required. The decision was made to organize the step descriptions in this manner in order to provide the user clear directions, without limiting their choices or interfering with their processes or approach.

Human factors were also considered when making the decision to create a website which integrated both the process flow diagram and the step descriptions that made up the roadmap. As this team had full control over its creation, we chose to create a simple design that would highlight the essential steps without overwhelming the user.

Through the use of both manufacturing system and human factors principles, this team was able to create a product using a cohesive and thorough process designed to use our resources effectively while prioritizing the usability and quality of the roadmap to help ensure our product is effective and supports the needs of AWU.

Decision Making

Consider Alternatives

Given the open-ended nature of the project, our team considered a number of options for how to present our final roadmap. We knew from talking with our project sponsor Michele that a visual roadmap was the ideal method for delivering our roadmap, but we also wanted to provide some supplementary deliverables to further flesh out the project. After we brainstormed alternatives, we settled on four possible options: a visual roadmap, a detailed report of the steps in the roadmap, a PowerPoint presentation, or a roadmap in website form. While each option had

its merits, we ultimately chose to go with the visual roadmap and then integrate the detailed step descriptions into a roadmap website.

The visual roadmap was an obvious choice given the problem that we were asked to solve by AWU. The path to the implementation of a wheelchair spot on an airplane was being blocked by a lack of clarity surrounding the actual process of developing a WTORS. Seeing this, we knew that we needed a way to present our roadmap so that anyone who might be involved with the development or implementation of a WTORS could easily understand the steps that needed to be taken to create one. While this could be accomplished with a report alone, we quickly realized that the easiest way of presenting a step-by-step process is with a flow chart that a user could visually take themselves through. Once we found a suitable program to create our visual roadmap in (Lucidchart), we knew that we could confidently move forward with this option.

While we were happy with our plan for a visual roadmap, we knew that this project would ultimately need a more detailed description of each step than what the visual roadmap would allow. Adding too much detail to the steps would make our roadmap unnecessarily difficult to read, so we chose to create a separate document with detailed information about each step. This allowed us to fully describe each step and what it entailed, as well as identify which stakeholders would need to be involved and what deliverable would need to come out of the step. We knew that one of our biggest problems was stakeholders not knowing where they fit into the roadmap, so assigning stakeholders to steps was a major benefit of creating this detailed report.

Our team also briefly considered creating a PowerPoint presentation as part of our final deliverable for the project. We knew that our roadmap would be presented by AWU to a working group after our graduation, so creating a presentation to go along with the roadmap was a logical

option to consider. However, given the time constraints of the project and the scope of what we wanted to accomplish, we decided that creating a presentation for AWU to use was unnecessary. We wanted to spend as much of our time as possible fleshing out the physical roadmap and making it as accessible as possible, so we ultimately left the details of the presentation to Michele and AWU.

Finally, while we were happy with the direction of our visual roadmap and step descriptions, we decided that we wanted to try to tie them together into one deliverable. To accomplish this, we came up with the idea of creating a website where a user could click through the steps of the roadmap and see the detailed descriptions pop up alongside them. This would eliminate the need for users to reference multiple documents to fully understand our roadmap, improving the flow of the process as a whole. While our team was nervous about the time it would take to build this website, we decided that the benefits of integrating our roadmap and step descriptions were worth the extra time and effort.

Solution and Recommendations

As stated above, our final deliverables for the project are a visual roadmap in the form of a step-by-step flowchart, detailed step descriptions to go along with this roadmap, and a website that integrates the two together. While our website is our most comprehensive resource, we believe that all of our deliverables will be useful to users in different contexts. The visual roadmap is an ideal format for presentations, as it provides a full picture of the process of the development and implementation of a WTORS without going into too much detail. A large problem at the start of the project was a lack of clarity about the process among the stakeholders involved, so providing too much detail upfront might make the process seem even more confusing. Beginning a presentation by walking the stakeholders through the visual roadmap

alone would provide a solid overview of the process and give the stakeholders enough context to understand the detailed step descriptions.

Outside of presentations, the website would likely be the easiest way for most users to interact with the roadmap. It integrates both parts of the roadmap into one deliverable, allowing users to click on a step and see its detailed description alongside it. This makes it so that any user can get as much information as they need out of the roadmap without having to switch to another document. Additionally, we are including a resources section to the website that includes any documents that were referenced during the creation of the roadmap. Our vision is that users that need even more detailed information about a specific step will be able to find a relevant document that meets their needs in the resources section of the website. Linking this website to AWU's website once it is made public can help educate anyone who might want to get involved with the creation of a WTORS on what the process will entail.

Looking Forwards

While we have made our roadmap as detailed as possible given the amount of time that we had to work on it, we acknowledge that it will be a living document and will need to change over time as new information is presented. For instance, we have labeled the standards section of our roadmap as "non-comprehensive" because we know that we were not able to go in-depth on every relevant standard that might apply to the project. The WC standards are briefly mentioned in our document of relevant standards, but they could become much more relevant in the future. Miriam Manary at the University of Michigan indicated that she is working on adapting the WC standards to include airplane testing requirements; which is a development that could make establishing an ELOS easier by providing examples of the types of new tests that will need to be conducted.

Another aspect of the roadmap that could be explored in the future is the inclusion of a timeline. We chose not to include a timeline into our roadmap due to a lack of reliable time estimates from the stakeholders we interviewed, but one could conceivably be added further down the line. This addition would require all stakeholders involved to produce a time estimate that they are fairly confident in, meaning that it will likely not be possible until fairly late into the project. We also acknowledge that AWU may not want to include a timeline for the roadmap at all due to the risk of unreliability, so this addition is up to their discretion.

Financial constraints were considered outside of the scope of this roadmap, but it is likely that AWU will want to include them in future iterations. Many of the stakeholders that we met with expressed concerns for how funding would be secured for this project, so including some information about money may help alleviate some of their concerns. Another capstone study conducted by the University of Washington addressed the profitability of putting a wheelchair spot on an airplane, so including their findings may be a helpful next step for the roadmap.

Finally, since this is the first draft of the implementation roadmap, further iterations will be necessary to add depth to each section and adapt to any changes in the status of the project. We added as much detail to the roadmap as our knowledge and time limit allowed, but there is still much that could be done to clarify the exact procedures of each step. For example, step 4.3 is “Assess potential new standards”, which has lots of room to be fleshed out. More information on how to gather all of the relevant stakeholders or a more thorough look at the issue paper process could be areas to address in future iterations.

Conclusion

There is a clear need to improve accessibility in air travel throughout the world, and the development of a certified WTORS on aircrafts can be a major step forwards in this regard. Our team has developed the first ever roadmap outlining the process of implementing a WTORS, based on extensive interviews with relevant stakeholders and a thorough literature review. This roadmap includes steps to design, certify, and implement any and all possible designs for a WTORS regardless of its configuration. We have also included descriptions of each step in our roadmap and a non-comprehensive list of applicable standards in order to flesh out as much of the process as possible. While future iterations will be needed to account for inevitable changes to the project, our initial roadmap will serve as proof that putting a dedicated wheelchair spot on an airplane is an achievable reality that will make air travel more accessible throughout the world.

Appendix

Steps with Descriptions

Roadmap

Poster

Standards and Regulations

Working Group Slides

Abbreviations

ACAA: Air Carrier Access Act

AFM: Aircraft Flight Manual

AFS: Automated Flight Systems

AML: Approved Model List

ANSI: American National Standards Institute

AWU: All Wheels Up

CFR: Code of Federal Regulations

COS: Continued Operational Safety

DMAIC: Define, Measure, Analyze, Improve, Control

DOT: Department of Transportation

EASA: European Union Aviation Safety Agency

ELOS: Equivalent Level Of Safety

IATA: International Air Transport Association

ICA: Instructions for Continued Airworthiness

ISO: International Organization for Standardization

FAA: Federal Aviation Administration

FDA: Food and Drug Administration

MRO: Maintenance Repair and Overhauler

OEM: Original Equipment Manufacturer

PACO: Project Aircraft Certification Office

PSCP: Product Specific Certification Plan

PSP: Partnership for Safety Plan

RESNA: Rehabilitation Engineering and Assistive Technology Society of North America

STC: Supplemental Type Certificate

TCCA: Transport Canada Civil Aviation Directorate

TIR: Type Inspection Report

TRB: Transportation Research Board

WC-19: Voluntary Industry safety standards for wheelchairs in motor vehicles

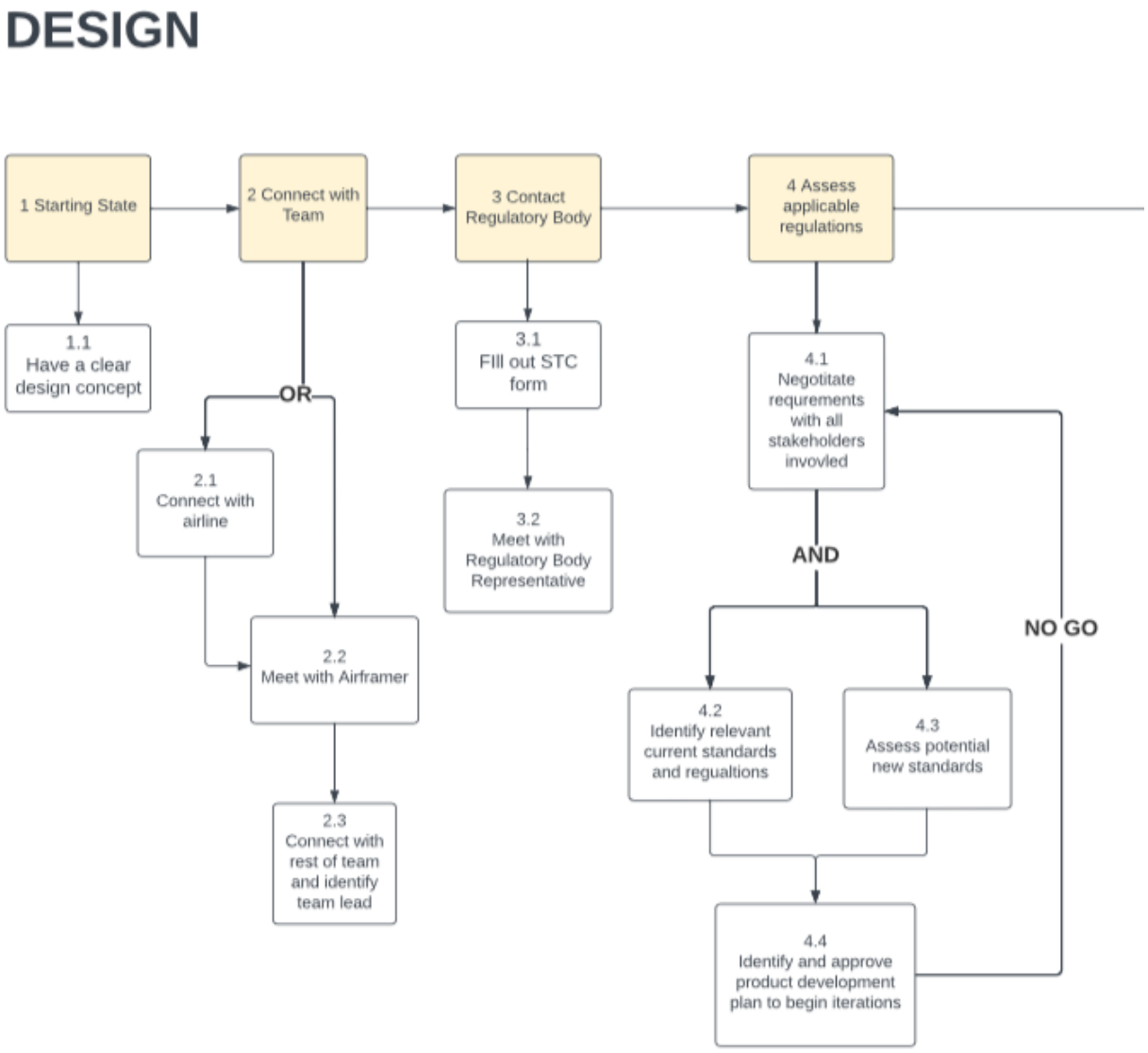
WTORS: Wheelchair Tiedown and Occupant Restraint System

Citations

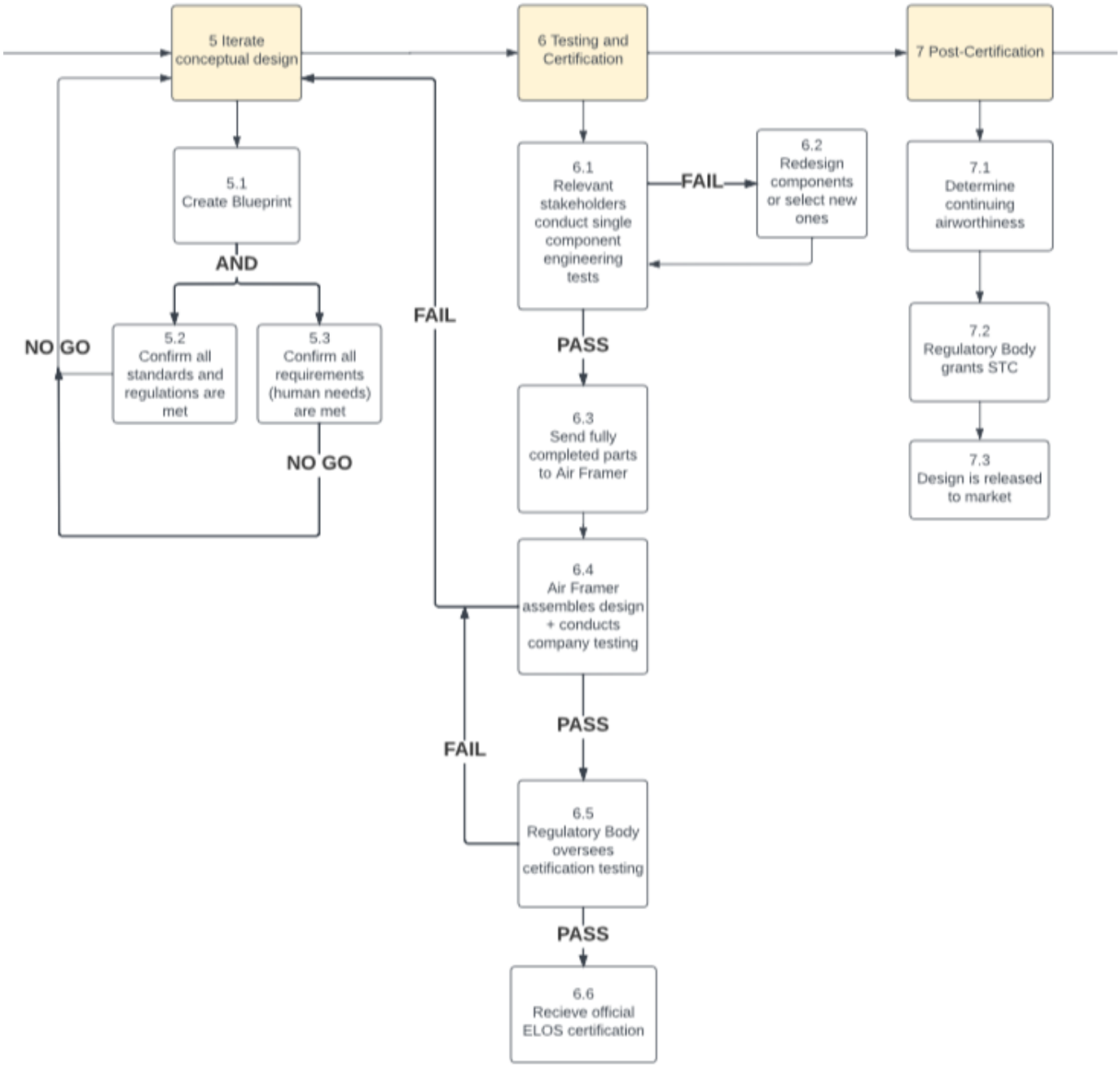
Dot Litigation News - Transportation.gov.

https://www7.transportation.gov/sites/dot.gov/files/docs/Litigation_News_March_2013.pdf.

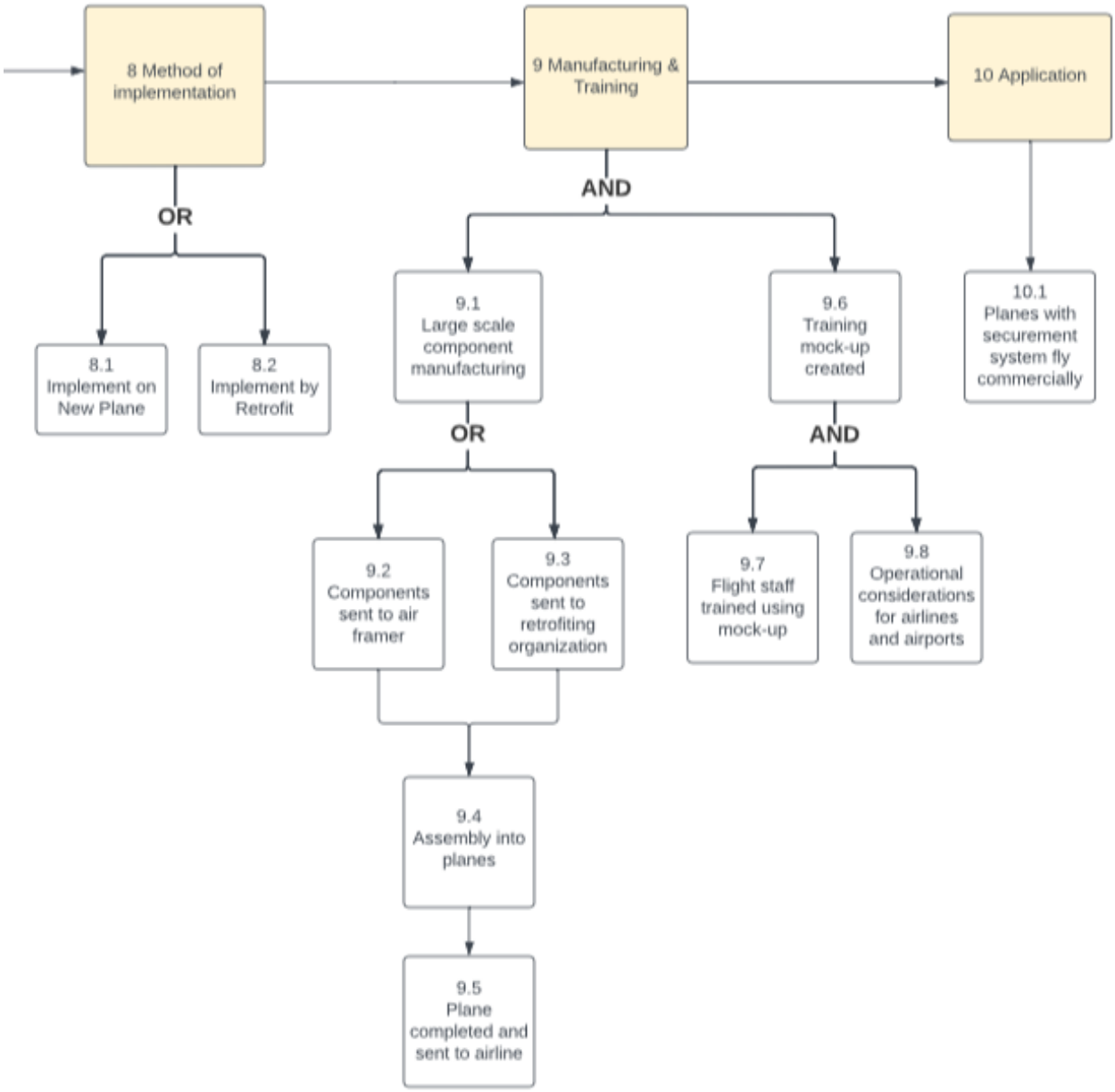
Roadmap


DESIGN
1 Starting State
2 Connect with Team
3 Contact Regulatory Body
4 Assess applicable regulations
1.1 Have a clear design concept
OR
2.1 Connect with airline
2.2 Meet with Airframer
2.3 Connect with rest of team and identify team lead
3.1 FIll out STC form
3.2 Meet with Regulatory Body Representative
4.1 Negotitate requrements with all stakeholders invovled
AND
4.2 Identify relevant current standards and regualtions
4.3 Assess potential new standards
4.4 Identify and approve product development plan to begin iterations
NO GO

CERTIFICATION



IMPLEMENTATION



Step Descriptions

*Requirements are participant driven

*Regulations are federally and legally in place

INFORMATION FOUND IN STEPS

1. **Description**
2. **Participant**
3. **Action**
4. **Deliverable**
5. **Notes or requirements for next step**

Scope:

- There are no time estimates listed as this project solely focuses on the order of the steps, as there are many factors that can drastically alter the length of each step..
- For the purpose of designing the roadmap, it is assumed that all parties will participate without convincing. However, in reality additional steps to convince other stakeholders/team members may need to be inserted.
- Financials are assumed to be secured by the necessary parties. This may need to be done during the implementation of the roadmap, however, the securement process is outside of the scope of this project, thus not included in the steps.
- Determining the profitability of the wheelchair securement system is outside the scope of this project. While this information may be necessary to convince stakeholders such as airlines to buy this product or help support certification, the profitability must be found independently. Please contact All Wheels Up for more information as they have funded research into the profitability.

1. Start

Description: Has a clear conceptual design, the designer has decided to pursue certification and implementation, has secured or plans to secure the necessary funding.

Deliverable: defined components of design, case study, research, etc.

- 1.1 Have design
    - **Description:** Determine whether the design idea is ready to be presented to other industry stakeholders. Requirements to consider:
        - Economic
            - Contact All Wheels Up for their research on profitability
        - Safety
            - Consult wheelchair users for their needs and preferences
    - **Participant:** *Designer, Wheelchair users*
    - **Action:** Ensure the design idea is flushed out enough to be able to discuss it with industry stakeholders that you want on your team, and a Regulatory Body.
    - **Deliverable:** defined components of design, case study, research, etc.
    - **Notes or requirements for next step:** Must complete this step before moving on to 2.

2. Connect with Team

Description: Assemble team of industry stakeholders that will work jointly to certify the design.

Deliverables: Statement of work, starting and end dates, high level design, level of quality, other customer requirements

- 2.1 Secure Airline Support
    - **Description:** Connect with an Airline company to gauge interest in funding or supporting the development of the design. The main goal of this interaction is to

gain the support of the airline. While convincing them to buy/fund the design is ideal, it is also unlikely as it carries great financial risk for the airline.

- **Participant:** *Designer, Airline*
- **Action:** Talk with airlines to convince them to consult on the design of the project.
- **Deliverable: NA**
- **Notes or requirements for next step**
  - Connect with the airline via the supply chain team.
  - While it is feasible to certify a design without an airline consulting/supporting the project, it is far more challenging and not recommended
  - This step or 2.2 must be complete before moving on to 2.3

- 2.2 Connecting with an Airframer
  - **Description:** Convince an airframer to assist with developing and certifying the design. If step 2.1 has been completed, especially if the airline is funding the project, they may want to select their preferred airframer.
  - **Participant:** *Designer. Airframer, Airline (if 2.1 completed)*
  - **Action:** Convince airframer to assist in developing and certifying design
  - **Deliverable: NA**
  - **Notes or requirements for next step**
    - This step or 2.1 must be complete before moving on to 2.3

- 2.3 Connect with rest of team and select team lead
  - **Description:** Gather all relevant stakeholders, assess the state of the design, and determine the team lead.
  - **Participant:** *Designer. Airframer, Airline, Tie-Down manufacturers, Wheelchair Manufacturers, Wheelchair users*
  - **Action:** Connect with relevant stakeholders, determine team lead (Applicant for Certification), assess the state of the project
  - **Deliverable**

        - **Statement of work, starting and end states, high level design, level of quality, client requirements**
    - **Notes or requirements for next step**
        - The team lead, also the applicant in terms of certification, will be the main party working with the FAA or other regulatory body to certify the design
        - Ensure that wheelchair users are consulted on the design concept. They are the final user, thus ensuring they are heard in the development of the design is crucial.
        - This step must be complete before moving on to 3

3. Contact Regulatory Body

Description: Initiate contact with the FAA by filling out the STC form and establish a working relationship.

Deliverable: STC form, Prelim cert basis, definitions and plan for resolution of critical issues, Partnership for Safety Plan (PSP), identify core team to ensure continuity, meeting minutes (and correspondence to document decisions, agreements, schedules, etc).

- 3.1 Fill out STC Form
    - **Description:** Initiate the certification process by filling out the STC form. STC : Supplementary Type Certificate.
    - **Participant:** Project lead/Applicant
    - **Action:** Fill out the STC form
        - https://www.faa.gov/aircraft/air_cert/design_approvals/stc/stc_app/
        - https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgSTC.nsf/MainFrame?OpenFrameSet
    - **Deliverable:** Submitted STC form
    - **Notes:** If STC Form MUST be filled out to move to 3.2. May move onto step 4 while waiting for STC to be inspected, however, the sooner the Regulatory Body is involved, the smoother the process will be as less work may have to be redone. STCs are applicable to a single type of aircraft, and a separate STC needs to be completed for each additional aircraft that the securement system will go into.

        - This step must be complete before moving on to 3.2

- 3.2 Meet with Regulatory Body Representative
    - **Description:** Connect with an Regulatory Body representative to begin a familiarization meeting. Create a PSP to clearly outline roles and responsibilities for the project.
    - **Participant:** *Regulatory Body, Designer, Wheelchair Manufacturers, Wheelchair users, OEMs, Tie Down System Manufacturers*
    - **Action:** Contact with Regulatory Body representative (can ask AWU for connections), Create PSP
    - **Deliverable:**
        - Prelim cert basis, definitions and plan for resolution of critical issues, partnership for safety plan (PSP), identify core team to ensure continuity, meeting minutes (and correspondence to document decisions, agreements, schedules, etc)
    - **Notes or requirements for next step:**
        - The team may move onto step 4 while this step is being completed. However, having step 3.2 completed will make future work faster and easier, while decreasing the probability of needing to rework the design.

<u>4. Assess Applicable Regulations</u>

Description: Work with all involved stakeholders to identify all requirements and regulations for the project.

Deliverables: A list of all stakeholder requirements, a list of all applicable regulations, an issue paper for the STC, and the product development plan.

- 4.1 Negotiating Requirements with All Stakeholders Involved
    - **Description:** Negotiate with each participant to determine what design requirements they have to be able to successfully complete their part of the securement system. Stakeholders will also be able to provide consultation about their areas of expertise at this stage. This is also a good place to consider the requirements that wheelchair users would have in order to fly using this system.

All Wheels Up has an advisory board of wheelchair users that may be able to assist with this. The creation of the Product Specific Certification Plan (PSCP) will begin here.

- **Participant:** *Airline, Airframer, Wheelchair Manufacturers, OEMs, Tie Down System Manufacturers, Wheelchair Users, Designer (if not already listed)*
- **Action:** Negotiate with the other participants until everyone can agree on the design requirements. Make sure to include wheelchair user requirements as they are the ultimate stakeholder. Begin creating PSCP
- **Deliverable:** List of requirements of all participants and stakeholder, especially wheelchair users
- **Notes:** This step must be complete before moving on to 4.2

- 4.2 Identify Relevant Current Standards and Regulations
  - **Description:** Identify all the current national and international government standards and regulations necessary to design an airworthy securement system for wheelchairs. Reference: **List of Current Applicable Standards (Non-Comprehensive)**
  - **Participant:** *Airline, Airframer, Wheelchair Manufacturers, Wheelchair Users, additional OEMs, Tie Down System Manufacturer, Designer (if not already listed)*
  - **Action:** Determine all relevant standards and regulations.
  - **Deliverable**
    - Completed checklist of all standards (national and international) being met.
  - **Notes or requirements for next step**
    - All current standards must be considered before moving on to 4.4
- 4.3 Assess Potential New Standards
    - **Description:** We know there are no existing standards for a wheelchair securement system. Once standards are created this step can be skipped. Because there are no current standards, participants must fill out an Issue Paper. Within the Issue Paper participants must also apply for a special condition and equivalent of safety (ELOS) approval.

- Applying for a special condition and ELOS
  - Special Conditions
    - **Description:** "A special condition is a regulation that applies to a particular aircraft design. The Regulatory Body issues special conditions when we find that the airworthiness regulations for an aircraft, aircraft engine, or propeller design do not contain adequate or appropriate safety standards, because of a novel or unusual design feature." https://www.ecfr.gov/current/title-14/chapter-I/subchapter-B/part-11/subpart-A/subject-group-ECFR8ebf6bddc82be9b/section-11.19
    - "Special conditions contain the additional safety standards that the administrator considers necessary to establish a level of safety equivalent to that established by the existing airworthiness standard"
      - From a description of a special condition granted to Boeing
  - ELOS
    - **Description:** "Applicants are responsible for making the request and submitting to the PACO the proposed ELOS with all necessary data required for the Regulatory Body to develop the IP and make the finding of equivalent safety"
      - PACO (Project Aircraft Certification Office)
    - https://www.faa.gov/documentLibrary/media/Order/Regulatory_Body_Order_8110.112A.pdf
      - Chapter 4: process for ELOS
  - **Participant:** *Airline, Airframer, Wheelchair Manufacturers, Wheelchair Users, OEMs, Tie Down System Manufacturers, Regulatory Body, Designer (if not already listed)*
  - **Action:** Identify areas where new standards are needed. Assess ways to determine an equivalent level of safety. Properly fill out and submit an Issue Paper.
  - **Deliverable:**

            - Issue Paper (including special condition and ELOS section)
        - **Notes or requirements for next step**
            - Issue paper must be filled out to get an approval for the STC form. This step must be fulfilled or participants cannot continue to 4.4
- 4.4 Identify and Approve Product Development Plan to Begin Iterations
    - **Description:** Create a product development plan with the help of all participants, and get it approved by your Regulatory Body representative
    - **Participant:** *Airline, Airframer, Designer, Wheelchair Manufacturers, Wheelchair Users, OEMs, Tie Down System Manufacturers, Regulatory Body*
    - **Action:** Work together to create a product development plan and have it approved by the Regulatory Body
    - **Deliverables**
        - **Define work for Engineering, Manufacturing, on-aircraft production, inspection and test; Develop and maintain a single integrated master schedule with gates and milestones; Control work processes (e.g. enterprise resource planning ERP system); Provide for communication, document control and release and distribution; Provide for feedback and changes; Provide for reports to stakeholders; Conduct team and departmental training as required; Define key Applicant roles and responsibilities**
    - **Notes or requirements for next step:** The product development plan must be approved to move on to step 5. If the plan is rejected, evaluate steps by moving back to 4.1

<u>5. Iterate Conceptual Design</u>

Description: The conceptual design for the system must be iterated until the team is certain the system has the ability to meet standards

Deliverable: A conceptual design that meets all applicable stakeholder requirements and relevant regulations

- 5.1 Create Blueprint
    - **Description**

        - Create paper design consisting of all product components and overall product
    - **Participant**
        - Designer
    - **Action**
        - Construct conceptual design of product that outlines the components so that design meets relevant regulatory and stakeholder requirements as detailed in step 4
    - **Deliverable**
        - Conceptual/paper design
    - **Notes or requirements for next step**
        - This step must happen to move onto steps 5.2 and 5.3
- 5.2 Confirm All Standards and Regulations Are Met
    - **Description**
        - Ensure that all federally mandated regulations and any other safety considerations are addressed. If this step is failed, they must iterate the design to accommodate a pass.
    - **Participant**
        - Designer
    - **Action**
        - Reference 4.2 and 4.3
    - **Deliverable**
    - **Notes or requirements for next step**
        - Currently needs to be tested or excepted:
            - FAA and RESNA collab on selecting WC19-compliant wheelchairs for testing on FAA crashworthiness and safety performance criteria
                - Survivable crash, emergency landing, and severe turbulence
            - FAA vertical load crash testing
            - Flammability standards for each component

        - This step and 5.3 must be complete before moving on to 6. If not, go back to step 5 and iterate conceptual design before trying again.
- 5.3 Confirm All Stakeholder Requirements Are Met
    - **Description**
        - Ensure that considerations required by stakeholders are addressed and met. If this step is failed, they must iterate the design to accommodate a pass.
    - **Participant**
        - Designer
    - **Action**
        - Consult with the team to determine other requirements. Additional requirements are referenced below
    - **Deliverable**
    - **Notes or requirements for next step**
        - *Reference stage 4.1*
        - Additional requirements to be considered
            - Include Maintenance and training requirements for the airlines in the design
            - Implications of installation and use on airline operations and economics
            - Crashworthiness maintained with time and modification
            - There is a way to ensure safe and proper use by passengers and attendants
        - This step and 5.2 must be complete before moving on to 6. If not, go back to step 5 and iterate conceptual design before trying again.

<u>6. Testing and Certification</u>

Description: Tests are conducted to make sure that both the components of the WTORS and the WTORS itself are fully certified.

Deliverables: Single components fully certified, full WTORS fully certified by both the air framer and the regulatory body.

- 6.1 Relevant Stakeholders Conduct Single Component Engineering Tests

    - **Description:** All manufacturing stakeholders conduct relevant tests to certify that their individual products meet airplane regulations. If they fail, they must move back to step 5 and iterate the design of the securement system.
    - **Participant:** *Tie-Down Manufacturers, Wheelchair Manufacturers, OEMs (Seat Manufacturers)*
    - **Action:** Complete engineering tests for components of securement system
    - **Deliverable:** Fully certified components
    - **Notes or requirements for next step**
        - This must be complete before moving. If failed, move on to 6.2, otherwise move onto 6.3
- 6.2 Select New Components
    - **Description:** In the event that a component used in the design fails the relevant tests, the component will have to be redesigned to meet the certification standards. Alternatively, the company can replace the original component with a different component that can pass the required tests.
    - **Participant:** *Tie-Down Manufacturers, Wheelchair Manufacturers, OEMs (Seat Manufacturers)*
    - **Action:** Determine possible relevant replacement components or design new ones
    - **Deliverable:** New components for securement system ready to test
    - **Notes or requirements for next step**
        - After completion, move back to 6.1
- 6.3 Send Fully Completed Parts to Air Framer
    - **Description:** Send certified parts to air framer for assembly into full securement system
    - **Participant:** *Tie-Down Manufacturers, Wheelchair Manufacturers, OEMs (Seat Manufacturers), Air Framers*
    - **Deliverable:** Air framer receives all components of securement system
    - **Notes or requirements for next step**
        - This step must be complete before moving on to 6.4.
- 6.4 Airframer Assembles Design and Conducts Company Testing

    - **Description:** Air framer takes the assembled securement system and inserts it into a test plane. They then conduct all relevant testing to ensure that the securement system meets the company's standards and is ready for certification. This company testing is both for meeting internal requirements for safety and for making sure that the securement system will pass the regulatory body's certification. If they fail, move back to step 5 and iterate, if they pass they can move on.
    - **Participant:** *Air Framer*
    - **Action:** Company testing of full securement system
    - **Deliverable:** Securement system that is ready for Regulatory Body certification
    - **Notes or requirements for next step**
        - This step must be complete before moving on to 6.4. If failed, move back to step 5 and iterate the conceptual design.
- 6.5 Regulatory Body Oversees Certification Testing
    - **Description:** Air framer gets into contact with the Regulatory Body for certification testing. Regulatory Body representatives come and conduct final certification tests on the securement system. If they fail, move back to step 5 and iterate. If they pass, move on to the next step. Once the regulatory body completes their determination they will review the necessary proposed documents for acceptance; this includes, but is not limited to, the Aircraft Flight Manual (AFM).
    - **Participant:** *Air Framer, Regulatory Body*
    - **Action:** Get in contact with the Regulatory Body. Next, Regulatory Body conducts certification tests on the securement system using a test plane.
    - **Deliverable:** Securement system that fully passes certification testing
    - **Notes or requirements for next step**
        - This step must be complete before moving on to 6.6. If failed, move back to step 5 and iterate the conceptual design.
- 6.6 Receive Official Certification
    - **Description:** Regulatory Body awards the securement system the official certification. The team lead could also potentially get an AML (Approved Model

List) STC, which applies to different models of the same aircraft if they are similar enough.

- **Participant:** *Regulatory Body*
- **Action:** Regulatory Body reviews the test results and certifies the securement system
- **Deliverable:** Fully certified securement system
- **Notes or requirements for next step**
  - This step must be complete before moving on to 7.

7. Post Certification

Description: To reach this step, the applicant must have met all the final regulation requirements. This step is necessary as a way to ensure continued airworthiness. It is an important step in the process as it helps determine the maintainability of a product over an extended period of time. Making sure the applicant follows through with the post certification stage ensures the safety of passengers and the longevity of the product. This step must be completed to even begin the integration process.

- 7.1 Continued Airworthiness Determination
  - **Description:**
    - In this step, a regulatory body evaluates the product and its systems for operational suitability and maintainability. They will also conduct appropriate flight testing related to AFS (automated flight system) operational issues, and assist participants in understanding operations and maintenance issues for a timely transition into service. Once the regulatory body completes their determination they will review the necessary proposed documents for acceptance; this includes but is not limited to the Instructions for Continued Airworthiness (ICA) and Operating Instructions.
  - **Participant:**
    - *Regulatory Body, Designer, Wheelchair Manufacturers, Wheelchair users, OEMs, Tie Down System Manufacturers*

    - **Action:**
        - Connect with Regulatory Body to receive airworthiness determination
    - **Deliverable:**
        - Regulatory Body proposed documents: ICA, Operating Instructions, etc
    - **Notes or requirements for next step:**
        - Must complete this step before moving on to 7.2.
- 7.2 Regulatory Body Grants STC
    - **Description:**
        - In this step, the applicants must ensure the regulatory body that they have complied to all regulatory standards. Compliance inspections and pre-flight airworthiness activities will be conducted in coordination with the applicant. All of these regulations should have been met in previous standards. If the applicant succeeds in meeting all regulations, the regulatory body will grant an STC (supplemental type certificate) and approval to the applicant.
    - **Participant:**
        - *Regulatory Body, Applicant (Designer, Wheelchair Manufacturers, Wheelchair users, OEMs, Tie Down System Manufacturers)*
    - **Action:**
        - Applicants must show the regulatory body they have met all standards.
    - **Deliverable:**
        - Compliance Summary or Checklist Document, Type Inspection Report (TIR), Approved Instructions for Continued Airworthiness (ICA), Continued Operational Safety (COS) Report
    - **Notes or requirements for next step:**
        - Must complete this step before moving on to 7.3.
- 7.3 Release to Market
    - **Description:**
        - In this step, the designer has received all necessary approvals in documentation to begin to publicize their product. The designer now has the jurisdiction to publicize their product in any form they choose. The

most common methods of marketing we have found is printing the product in a catalog or online media that is then to be distributed to customers.

- **Participant:**
  - *Designer*
- **Action:**
  - Print product in catalog/online media to be distributed to customer
- **Deliverable:**
  - Catalog with product design promoted
- **Notes or requirements for next step:**
  - Must complete this step before moving on to 8.

<u>8. Airline chooses securement system for a specific amount of planes</u>

Description: In this step, Airlines can decide if they would like to implement WTORS (wheelchair tiedown and occupant restraint system) onto existing planes or onto new planes. Airlines must choose one path as this is an or gateway. We have made this an or gate because depending on the complexity of the design chosen, 8.1 may be an easier route to encounter versus 8.2 for a complex design, and 8.2 may be an easier route versus 8.1 for a less complex design. Therefore, we recommend the airline to do a cost analysis before determining the route they want to pursue. Complexity, in this case, indicates how drastically the configuration of the interior of an aircraft will need to be changed.

- 8.1 Constructing the WTORS Onto a New Plane
  - **Description:**
    - If the Airline decides to implement the WTORS during the manufacturing process on a new plane, then they must first purchase the design from a catalog. After purchasing the design and finalizing sales, the WTORS can now be manufactured and sent to an airframer.
  - **Participant:**
    - *Airline (leading), Designer*
  - **Action:**
    - Purchase WTORS design from client.

    - **Deliverable:**
        - Final order of WTORS. Must include quantity of WTORS and types of aircraft the WTORS will be implemented on.
    - **Notes or requirements for next step:**
        - This step (or step 8.2) must be completed to move onto step 9.
- 8.2 Retrofitting the WTORS to Existing Planes
    - **Description:**
        - If the Airline decides to implement the WTORS after the manufacturing process onto an already existing plane, then they must first meet with a Retrofit company, integrator, and MRO (maintenance repair and overhauler). After meeting with and finalizing their team, the group must then plan and design the integration process. The Retrofitting team must then secure their deliverables and purchase the WTORS from the manufacturer.
    - **Participant:**
        - *Retrofit company, Airline (leading), integrator (to help plan, design and implement the integration process) and MRO (maintenance repair and overhauler) (to help conduct operations of repair, service, or inspection of aircraft systems to ensure the continued airworthiness)*
    - **Action:**
        - Connect with Retrofit company, MRO, and integrator. Finalize plans and purchases.
    - **Deliverable:**
        - Finalize plans for implementation; which must include, but is not limited to, the quantity of WTORS and types of aircraft the WTORS will be implemented on.
    - **Notes or requirements for next step**
        - This step (or step 8.1) must be completed to move onto step 9.

<u>9. Manufacturing & Training</u>

Description: Once an airline has placed an order for WTORS planes, all of the components of the WTORS are manufactured. The components are then sent to an air framer or retrofitting organization, who assembles the WTORS into the aircraft and delivers the finished plane to the airline. At the same time, the airline will create a mock-up WTORS for training and establish all necessary operational guidelines.
Deliverables: Finished planes with WTORS onboard, airline staff fully trained, operational guidelines created.

- 9.1 Large Scale Component Manufacturing
    - **Description:** All companies that are involved with the securement system manufacture their components on a scale large enough to fit the demand from the airline. Must have a large enough manufacturing operation to accommodate demand.
    - **Participant:** *Tie-Down manufacturers, OEMs (Seat Manufacturers)*
    - **Action:** Manufacture components
    - **Deliverable:** Enough of each component part to meet airline demand
    - **Notes or requirements for next step**
        - This step must be complete before moving on to 9.2 or 9.3. This step can be done in conjunction with 9.6.
- 9.2 Components Sent to Airframer
    - **Description:** If solution is going into a new plane, finished components are sent to the air framer
    - **Participant:** *Tie-Down manufacturers, OEMs (Seat Manufacturers), Air Framers*
    - **Action:** Components are sent to an airframer
    - **Deliverable:**
    - **Notes or requirements for next step**
        - This step or 9.3 must be completed before moving on to 9.4.
- 9.3 Components Sent to Retrofitting Organization
    - **Description:** If the solution is going into an existing plane, the finished components are sent to whichever organization is overseeing the retrofits. This can be a retrofit company, an air framer, or an airline.

    - **Participant:** *Tie-Down manufacturers, OEMs (Seat Manufacturers), Retrofitting organization*
    - **Action:** Parts sent over to retrofit company
    - **Deliverable:**
    - **Notes or requirements for next step**
        - This step or 9.2 must be completed before moving on to 9.4.
- 9.4 Assembly Into Plane
    - **Description:** Whoever receives the finished components assembles the securement system and inserts it into the airplane. If this is being done via retrofit, changes to the layout of the plane will need to be made. The complexity of these changes will vary based on the design of the WTORS and the layout of the plane in question.
    - **Participant:** *Air framer or Retrofitting organization*
    - **Action:** WTORS is inserted into the plane and any necessary adjustments to the plane are made.
    - **Deliverable:** Completed securement system onboard plane
    - **Notes or requirements for next step**
        - This step must be completed before moving on to 9.5.
- 9.5 Plane Completed and Sent to Airline
    - **Description:** Finished plane with the securement system is sent to the airline to be put to use.
    - **Participant:** *Air framer or Retrofitting organization, Airline*
    - **Action:** Completed plane sent to airline
    - **Deliverable:** Completed plane
    - **Notes or requirements for next step**
        - This step must be completed before moving on to 10.
- 9.6 Training Simulation is Created
    - **Description:** Airline receives an additional securement system from manufacturers for use as a training tool
    - **Participant:** *Airlines, Tie-Down manufacturers, OEMs (Seat Manufacturers)*
    - **Action**

    - **Deliverable:** Completed training simulation
    - **Notes or requirements for next step**
        - This step must be completed before moving on to 9.7 and 9.8. This step can be done in conjunction with 9.1.
- 9.7 Flight Staff is Trained Using Simulation
    - **Description:** Flight and/or airport staff are trained using the securement system simulation created in the previous step. This is done outside of an actual plane.
    - **Participant:** *Airlines, Wheelchair users*
    - **Action:** Staff training
    - **Deliverable:**
    - **Notes or requirements for next step**
        - This step and 9.8 must be completed before moving on to step 10
- 9.8 Operational Considerations
    - **Description:** There are a number of operational considerations that must be taken into account for successful implementation of the securement system. Keep in mind, many of these will need to be checked with a regulatory body.
    - **Participant:** *Airlines, Airport Staff, Wheelchair users*
    - **Action:**
    - **Deliverable:** Establish operational procedures including: flight reservations, sufficient availability, flight change mitigation, safe use, proper service and assistance, training appropriate staff
    - **Notes or requirements for next step**
        - This step and 9.7 must be completed before moving on to step 10

<u>10. Application/Implement/Use/Usage</u>

- 10.1 Planes With Securement System Fly Commercially
    - **Description**
        - Iterate the training step 9 as necessary to ensure the experience of loading, securing and unloading the wheelchair user is as comfortable and dignified as possible for both the wheelchair user and the staff.
    - **Participant**
        - Airline, Wheelchair users & families, Airline & Airport staff, Passengers

- **Action**
  - Air travel in personal wheelchairs
- **Deliverable:** N/A
- **Notes or requirements for next step**
  - It will be important to understand demand considerations

List of Current Applicable Standards (Non-Comprehensive)

- Regulatory Bodies
  - FAA
    - Adheres to the Code of Federal Regulations (CFR)
      - Title 14 of the CFR sometimes called the Federal Aviation Regulations (FARs)
    - 14 CFR Part 25 (Airworthiness Standards)
      - 25.561 (Emergency Landing Conditions - General)
      - 25.562 (Emergency Landing Dynamic Conditions)
      - 25.785 (Seats, Berths, Safety Belts, and Harnesses)
      - 25.789 (Retention of Items of Mass)
      - 25.853 (Compartment Interiors (Flammability))
    - 14 CFR Part 21 (Certification Procedures)
      - Governs STCs
        - STC: Special Type Certificate - allows for a special modification to an airplane
    - ACAA
      - Prohibits discrimination on the basis of disability in air travel
      - Implemented under 14 CFR Part 382
  - EASA
    - Europe's Regulatory Body
    - Use FAA equivalent regulations
  - DOT

        - Some relevant regulations are governed by the DOT instead of the FAA
    - TCCA
        - Canadian FAA equivalent

- <u>Standard Making Organizations</u>
    - RESNA
        - WC standards for wheelchairs - WC19 is most relevant for our project
            - WC-1 (Requirements and test methods for wheelchairs)
            - WC-10 (Wheelchair containment and occupant retention systems for use in large accessible transit vehicles)
            - WC-18 (Wheelchair Tiedown and Occupant Restraint Systems - WTORS)
            - **WC-19** (Wheelchairs used as seats in motor vehicles)
            - WC-20 (Wheelchair seating systems for use in motor vehicles)
            - WC-25 (Performance and crash testing for wheelchair batteries)
    - ISO
        - International/European standards making organization
    - ANSI
        - American standards organization

- <u>Other Organizations</u>
    - FDA
        - Governs wheelchair battery regulations
    - IATA
        - Based in Canada
        - Publishes a best practices guide for interior retrofits on airplanes
        - Uses ISO standards