

# Software Engineering

Paper Plane Rotations

**Ivo Prahm (IU14089444)**

Computer Science (M.Sc.)

DLMCSPSE

24th January 2025

## Contents

<b>1</b>	<b>List of Acronyms</b>	<b>III</b>
<b>2</b>	<b>Conception Phase</b>	<b>1</b>
2.1	Problem Statement . . . . .	1
2.2	Assumptions . . . . .	1
2.3	Risks and Measures for Risk Minimization . . . . .	1
2.4	Requirements . . . . .	2
2.4.1	Requirements - Non-Functional . . . . .	2
2.4.2	Requirements - Functional . . . . .	2
2.5	Software Development Methodology . . . . .	3
2.6	Timeline . . . . .	4
2.7	Milestones and Deadlines . . . . .	4
2.8	User Interaction and Design . . . . .	5
2.9	System Design . . . . .	5
<b>3</b>	<b>Implementation Phase</b>	<b>6</b>
3.1	Objective . . . . .	6
3.2	Requirements Refinement . . . . .	7
3.2.1	Functional . . . . .	7
3.2.2	Functional - Technical . . . . .	15
3.2.3	Non-Functional . . . . .	15
3.3	Out of Scope . . . . .	16
3.4	Requirements that were moved to the next release. . . . .	16
3.5	Documentation of Software & System Architecture . . . . .	17
3.6	explanation of your design and implementation procedure ?!?!?! . . . . .	17
<b>4</b>	<b>Test Document</b>	<b>18</b>
4.1	Test Plan . . . . .	18

4.2	Manual Tests . . . . .	18
4.3	Mathematical Functions . . . . .	22
4.4	Automated Tests . . . . .	25
<b>5</b>	<b>Finalisation Phase</b>	<b>26</b>
5.1	Sprint Retrospective - Main Take-Aways . . . . .	26
5.2	Methodologies and Tool . . . . .	26
<b>6</b>	<b>Glossary</b>	<b>27</b>
	<b>References</b>	<b>28</b>
<b>1</b>	<b>List of Acronyms</b>	

**M2FR** Moved to a Future Release

## 2 Conception Phase

### 2.1 Problem Statement

Visual-spatial intelligence is challenging for the human brain and often times sheer impossible the more complex the layout becomes. Writers of test cases for software involved with more complex transformations and their interplay between objects frequently run into this issue. As well as students trying to gain an understanding of the math behind these transformations and what their calculated transformation matrix actually does.

Since all these transformations are immensely abstract, a visual representation of the problem at hand would help to write better test cases, gain a better understanding of specific szenarios and therefore to facilitate the identification of possible edge cases. Hence, improving the test-suite even further. Which in turn will improve the reliability, robustness and maintainance of the delivered product.

It is for that reason, that I am proposing a tailor made tool to assist the design process of aforementioned test cases.

### 2.2 Assumptions

Considering the target audience, a basic understanding of trigonometry is to be expected. Also it is presumed that this application is likely not going to be used on mobile devices, as its intention lies more in a univerity milieu.

Since the content of this web-app is aimed towards a more tech-savvy audience, backwards compatibility with older browsers is not considred as of now.

### 2.3 Risks and Measures for Risk Minimization

The goal could be too lofty and not possible to be built in the designated time frame by only one part-time developer. → Cut down on **NICE TO HAVE** -Requirements and Requirements that are not essential for the functionality of the project.

Implementing a full frontend test-suite is out of scope for this project and may lead to problems due to insufficient testing. → Design a comprehensive checklist that is to be passed before every release.

## 2.4 Requirements

A very rough sketch of future requirements. Reminiscent of the first meeting with stakeholders in which a broad idea is sketched out and refined in later sprints.

### 2.4.1 Requirements - Non-Functional

Requirement	Scope
An instance of the project shall be directly accessible via the internet.	MUST HAVE
The Application shall run in modern browsers.	MUST HAVE
The application shall run as a dockerized container.	NICE TO HAVE

### 2.4.2 Requirements - Functional

User Story	Scope
As a user I want to be able to rotate the plane by providing euler angles.	MUST HAVE
As a user I want to be able to see the current angle and distance between a selected threat and the plane.	MUST HAVE
As a user I want to be abler to freely translate the plane in space by providing a translation vector in cartesian coordinates.	MUST HAVE
As a user I want to freely add and remove individual threats to the scene.	MUST HAVE
As a user I want to see a 3D representation of the plane and threats.	MUST HAVE
As a user I would like to see a 2D projection next to the 3D scene. Akin to the stereo-typical image of a submarine radar.	MUST HAVE
Continued on next page	

Table 2 – continued from previous page

User Story	Scope
As a user I want to move threats in space by providing a translation vector.	NICE TO HAVE
As a user I would like to enter a full transformation matrix by hand and see its effect on the plane and/or bird.	NICE TO HAVE
As a user I would like to move the calculation center arbitrarily.	NICE TO HAVE
As a user I would like to visually differentiate my added threats.	NICE TO HAVE
As a user I would like to see an animation of the entered movement.	NOT IN SCOPE
As a user I would like to use this tool on all my devices.	NOT IN SCOPE

## 2.5 Software Development Methodology

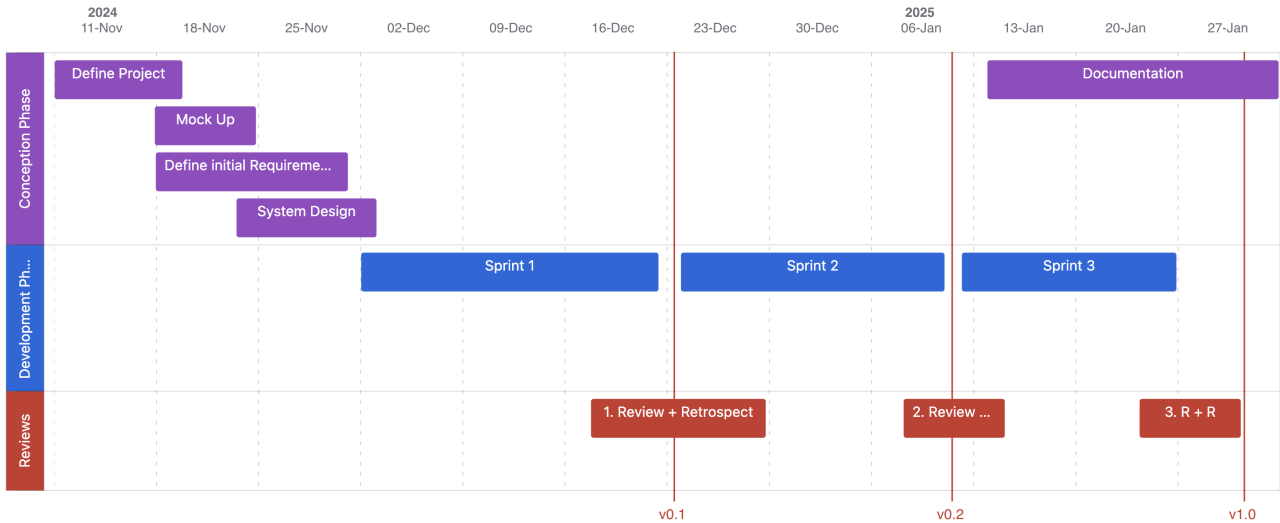
Since Scrum excels at projects with high levels of uncertainty that require an adaptive approach, and the idea for this app was only a rough sketch at the beginning of the project, Scrum is the perfect pick.

Because this is not my fulltime occupation, I decided on three sprint intervals of roughly three weeks each to have enough implementation time for each sprint. After each of the following review phases the requirements get updated according to newly discovered requirements and ideas from the customer/me.

As this project is developed only by me, the obligatory Scrum meetings are replaced with a relaxing run outside to contemplate ideas or do my sprint retrospective.

## 2.6 Timeline

The Timeline of the project plan is built according to the standard scrum sprint procedure.



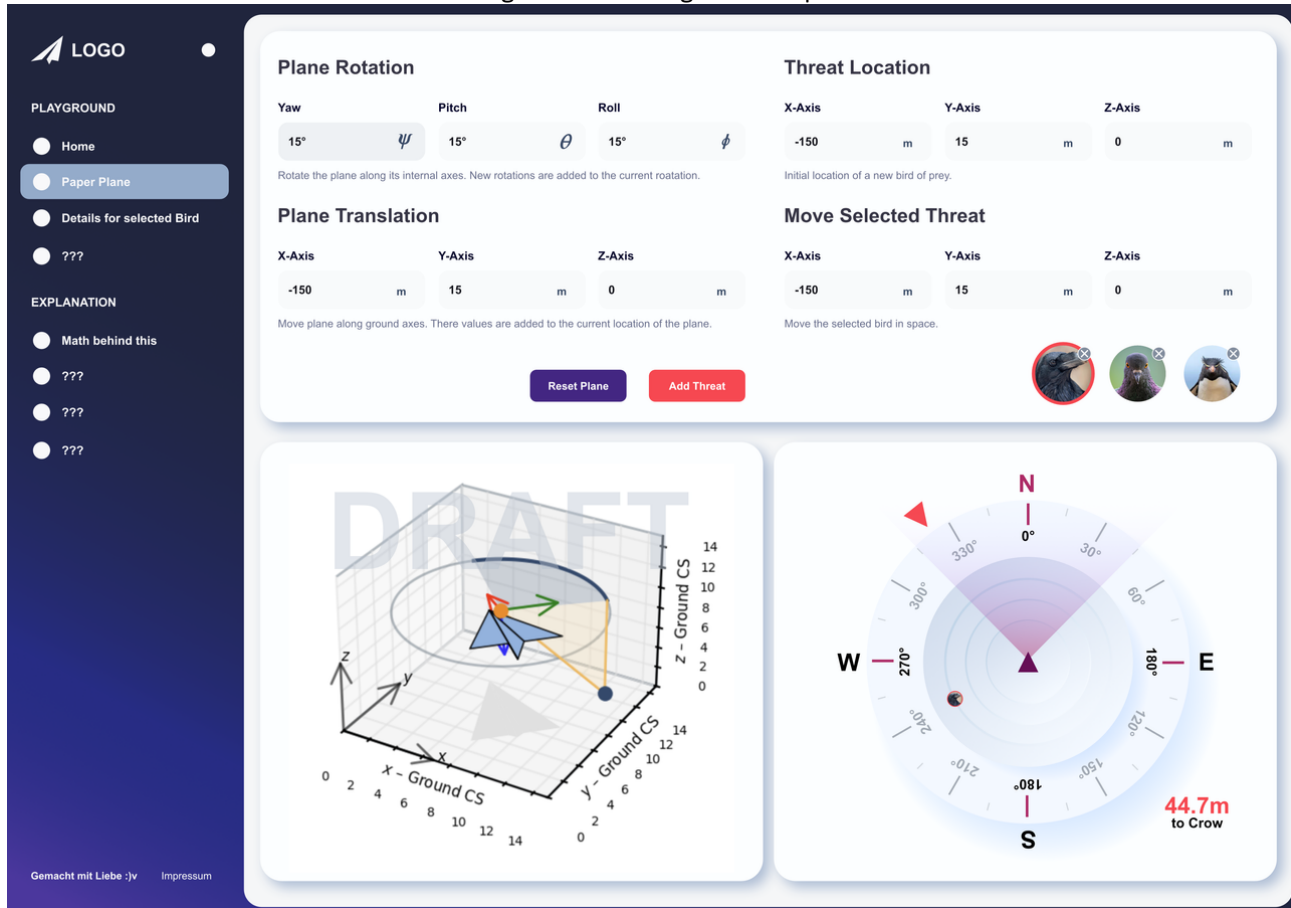
## 2.7 Milestones and Deadlines

Milestones and Deadlines	Version	Deadline	Status
Basic Layout + Diagram-Skeleton	v0.1	29 Dec 2024	DELIVERED
Functionality	v0.2	19 Jan. 2025	DELIVERED
Finalisation/Polish + (inevitable) Bug Fixes	v1.0	2 Feb. 2025	IN PROGRESS

## 2.8 User Interaction and Design

Mock-up of the main intention and vital component of this project. All other minor aspects were designed on the fly according to the respective user stories.

Figure 1: Main Page Mock-Up



## 2.9 System Design

Since the app is a self-contained single-page application and does not require a backend, isn't part of any larger system that would justify a container diagram (yet), and has no need for any form of authorization at this point, the system design is omitted.

As for 3rd-party tools:

- The App shall be developed in TypeScript using the vite framework (V. Inc., 2019a).
- For 3D Graphics the open source library plotlyjs shall be used (Plotly, 2025).
- Testing is done using the vitest framework (V. Inc., 2019b).
- The App shall be deployed as a dockerized container on my personal server (D. Inc., 2025).



### **3 Implementation Phase**

#### **3.1 Objective**

The purpose of this application is to provide an intuitive as well as interactive tool to visualise transformations and their respective effect on the relation to fixed points in three-dimensional space.

This tool is supposed to support the development of better test cases as well as aid students in the understanding of trigonometry. This tool is mainly aimed at software testers, as it helps them to get a more tangible vision of possible szenarios and now imaginable edge-cases. A secondary target group are (engineering-)students struggling to get their head around trigonometry.

Since rotations in space become far more difficult to envision if we are concerned about an arbitrary point on the plane, and its relation to fixed points in space, instead of its center, this issue is being addressed by this application.

Although there are many other rotation visualisation tools out there, none of them visualize the relation to fixed points in space, let you move said points or the plane in space and don't address afroementioned issues.

## 3.2 Requirements Refinement

Previous rough user stories now get a clear testable statement assigned to them.

Requirements that are tagged with **M2FR**, could not be implemented in time for the planned release and had to be moved to a future release.

Since these requirements are not essential for the core functionality and a timely release is ranked higher than the fulfillment of optional requirements, this was considered justified.

### 3.2.1 Functional

Requirement	User Story	Importance	Jira Issue	Status
<p>1. A maximum of 5 bird Avatar-elements shall be displayed in the main page. The most recent bird shall be at the front of the list.</p> <p>2. An Indicator shall signal if more than 5 birds were added.</p>	As a user I want to see an overview of my added birds in the main page	<b>HIGH</b>	DLMCSPSE-224	<b>DONE</b>
Continued on next page				

Table 4 – continued from previous page

Requirement	User Story	Importance	Jira Issue	Status
<p><b>1.</b> Birds shall be addable by providing the initial XYZ-coordinates. If no coordinate or a NaN-Value is provided, it shall be interpreted as 0.</p> <p><b>2.</b> A bird shall not be addable if its distance is greater than 100m from the plane. If such values are provided, the user shall be informed via a Toast-Message.</p> <p><b>3.</b> A bird shall be removable via a simple click on an X-icon, coloured in the birds highlight colour, on/adjacent to the bird's avatar.</p>	As a user I want to easily add and remove nearby threats without leaving the main page	<b>HIGH</b>	DLMCSPSE-225	<b>DONE</b>
<p><b>1.</b> A click on the birds avatar shall select the corresponding bird.</p> <p><b>2.</b> The fact that a bird is selected shall be visible in the UI.</p> <p><b>3.</b> Only one bird shall be selectable at a time.</p> <p><b>4.</b> A second click on a selected bird shall deselect said bird.</p>	As a user I want to be able to highlight a specific bird to make this specific bird stand out in the UI.	<b>HIGH</b>	DLMCSPSE-226	<b>DONE</b>
Continued on next page				

Table 4 – continued from previous page

Requirement	User Story	Importance	Jira Issue	Status
<p><b>1.</b> The user shall be able to translate the plane in space by adding values to the current position of the planes XYZ-axis.</p> <p><b>2.</b> If no coordinate or a NaN-Value is provided, it shall be interpreted as 0.</p> <p><b>3.</b> The plane shall not be able to be translated below ground.</p> <p><b>a.</b> If this would be the case, the plane shall not be moved and an error shall be displayed.</p>	As a user I want to move the plane in space.	<b>HIGH</b>	DLMCSPSE-228	<b>DONE</b>
<p><b>1.</b> The plane shall not be distorted → the viewport shall remain a cube.</p> <p><b>2.</b> The view shall always be centred around the plane.</p> <p><b>3.</b> The side length of aforementioned cube shall be the distance to the furthest threat and at least 10.</p>	As a user I always want to see the plane centred and as close as possible.	<b>HIGH</b>	DLMCSPSE-229	<b>DONE</b>
All birds shall be displayed as a point in space in the colour of the corresponding bird.	As a user I want to see my added birds in the 3D-Diagram in the main page	<b>HIGH</b>	DLMCSPSE-231	<b>DONE</b>
Continued on next page				

Table 4 – continued from previous page

Requirement	User Story	Importance	Jira Issue	Status
<p>1. The user shall be able to translate a bird in space.</p> <p>2. A Bird cannot be below ground.</p>	As a user I want to be able to move a threat in space	HIGH	DLMCSPSE-232	DONE
<p>The user shall be able to rotate the plane by providing Euler Angles in ZYX order.</p> <p>It shall be possible to enter angles greater than 360°</p> <p>If no angle or a NaN-Value is provided, it shall be interpreted as 0.</p>	As a user I want to be able to rotate the plane.	HIGH	DLMCSPSE-233	DONE
Continued on next page				

Table 4 – continued from previous page

Requirement	User Story	Importance	Jira Issue	Status
<p><b>1.</b> The user shall be able to navigate a page displaying every bird as a card component detailing its relation to the plane. Listed shall be the following information</p> <p><b>a)</b> name</p> <p><b>b)</b> distance to plane</p> <p><b>c)</b> Horizontal Distance to plane</p> <p><b>d)</b> angle from plane 2 bird (azimuth and elevation)</p> <p><b>e)</b> altitude</p> <p><b>f)</b> an indication of the direction and horizontal distance as an icon from the viewpoint of the user.</p> <p><b>2.</b> The information on the main page shall not be lost when navigation to and back from this page.</p>	<p>As a user I want to see a detailed view of all the birds and their relation to the plane.</p>	<b>HIGH</b>	DLMCSPSE-240	<b>DONE</b>
<p>The planes X-Axis shall represent the head of the plane and the ground X-Axis shall be treated as North (positive) and South (negative) in the compass component.</p>	<p>As a user I want to see a 2D "Compass-like" Representation of the planes rotation.</p>	<b>HIGH</b>	DLMCSPSE-244	<b>DONE</b>
Continued on next page				

Table 4 – continued from previous page

Requirement	User Story	Importance	Jira Issue	Status
<p>The compass component shall indicate the birds' current, relative to the plane, position.</p> <p><b>Horizontal Distance &lt;= 14:</b></p> <p>A Bird Icon shall indicate the position.</p> <p><b>Horizontal Distance &gt;14:</b></p> <p>A Triangle shall indicate the direction of the bird</p>	As a user I want to see the birds displayed in their relative distance to the plane in the compass component.	HIGH	DLMCSPSE-245	DONE
The home page shall contain an article explaining the idea and concept behind this app	As a user I want to read an explanation on what I am seeing here	HIGH	DLMCSPSE-249	DONE
The birds name shall be displayed in a Tooltip with the birds color as the background color over the birds avatar.	As a user I want to see the birds name when I hover over it, to later identify it easier in the Card View	LOW	DLMCSPSE-227	DONE
<p>The footer shall include a link to a page displaying the legal information.</p> <p>All transformations that have been made, up to the point of navigating away, shall not be lost when navigating back to the main page.</p>	An Impressum is mandated by law to be included on every published medium in German speaking countries.	LOW	DLMCSPSE-236	DONE
Continued on next page				

Table 4 – continued from previous page

Requirement	User Story	Importance	Jira Issue	Status
-	As a user I would like to see the selected birds name in the “Move Bird”-Component. So it is absolutely clear which bird I’m translating.	LOW	DLMCSPSE-242	DONE
-	As a user I would like to set the center of my angle and distance calculation to the center of the plane	LOW	DLMCSPSE-247	DONE
Show two Arrows at ground Level indicating N and E	As a user I would like to easier see North and East in the Diagram	LOW	DLMCSPSE-248	DONE
<p>1. The name shall be displayed in the birds colour.</p> <p>1. The layout shall be ‘&lt;Name&gt;\n(X, Y, Z)’</p>	As a user I would like to see the name of the bird as I’m hovering over it in the diagram.	MEDIUM	DLMCSPSE-230	DONE
A page displaying the math behind these transformations shall be accessible via the main nav bar.	As a user I want to understand the math behind these transformations	MEDIUM	DLMCSPSE-234	DONE
The initial values of the plane shall be restoreable with the click of a button.	As a user I want to reset the plane to its default position without having to reload the page.	MEDIUM	DLMCSPSE-235	DONE

Continued on next page



Table 4 – continued from previous page

Requirement	User Story	Importance	Jira Issue	Status
<p>The rendering of the coordinate system shall be conditional.</p> <p>But the marble shall stay and not be rendered conditionally.</p> <p>The user shall toggle this condition via an switch component in the main page.</p>	As a user I want to be able to hide and show the “Pilot” and plane coordinate system at will.	<b>MEDIUM</b>	DLMCSPSE-239	<b>DONE</b>
<p>Display a shadow of the plane on the ground.</p> <p>The sun shall be assumed to be perpendicular to the ground.</p>	As a user I would like to a shadow of the plane to get a better sense of perspective.	<b>MEDIUM</b>	DLMCSPSE-241	<b>DONE</b>
These values shall only be rendered, iff a bird is selected.	As a user it would be nice to see the angle and distance to the selected bird in the compass component.	<b>MEDIUM</b>	DLMCSPSE-246	<b>DONE</b>
The NavBar shall contain a link to a page showing a bigger view of the plane scene.	As a user I would like to be able to see a bigger image of the plane scene.	<b>MEDIUM</b>	DLMCSPSE-250	<b>DONE</b>
-	As a user I would like to see visual pleasing 404 Page if i entered the wrong url.	<b>LOW</b>	DLMCSPSE-243	<b>M2FR</b>
The math explanation page shall contain at least one diagram explaining the azimuth and elevation angles along with important sides aiding in calculation	As a user I want to see an explanation of the mentioned azimuth and elevation angles	<b>MEDIUM</b>	DLMCSPSE-237	<b>M2FR</b>
Continued on next page				

Table 4 – continued from previous page

Requirement	User Story	Importance	Jira Issue	Status
The math explanation page shall contain at least one diagram visualising the planes axes.	As a user I want to see an explanation of the planes coordinate system	<b>MEDIUM</b>	DLMCSPSE-238	<b>M2FR</b>

### 3.2.2 Functional - Technical

**TODO:!!!** Requirements for more technical aspects of the application that are not facing the user directly.

Requirement	Jira Issue	Status
azimuthAngle	TECH-001	<b>DONE</b>

### 3.2.3 Non-Functional

Requirement	Importance	Status
The Application shall run smoothly in the following browsers: Chrome $\geq$ 109  FireFox $\geq$ 98  Opera $\geq$ 100	<b>HIGH</b>	<b>DONE</b>
Images shall either have the format .svg or .webp.	<b>MEDIUM</b>	<b>DONE</b>
The application shall run as a dockersied container.	<b>HIGH</b>	<b>PENDING</b>
Continued on next page		

Table 6 – continued from previous page

Requirement	Importance	Status
An instance of the project shall be directly accessible via the internet.	HIGH	PENDING

### 3.3 Out of Scope

- **Possibility for the user to enter a full transformation matrix by hand.**
- **Adding a Trajectories** - via speed vectors in x,y and z direction. And calculating possible intersections/collisions.
- **Mobile responsiveness** - mobile users aren't the target audience. Therefore the extra time can not be justified.
- **A complete automated Frontend Test Suite** - currently I confined myself to manual tests after every major update to ensure correct functionality. This is feasible since the scope/functionality of this project is comparably small and the extra time can not be justified.
- **Backwards compatibility with older browser**
- **Assure correct rendering in more niche browsers**
- **Undo/Redo functionality**
- **Add a 2D ('Ship')-Mode** - Still render everything in 3D but give the option to be limited to the ground and render the plane as a ship. In this case threats could come from above and below.
- **Move and rotate Marble arbitrarily** - The point on the plane from which all measurements are calculated shall be freely positionable in relation to the plane.

### 3.4 Requirements that were moved to the next release.

These requirements were not fulfillable in the set time frame and had to be moved to the next release since they are not vital for the intended functionality of the app.

- **DLMCSPSE-238** (Math Explanation Page)
- **DLMCSPSE-237** (Math Explanation Page)
- **DLMCSPSE-243** (404 Page)

### **3.5 Documentation of Software & System Architecture**

TODO: !!!!

a documentation of the software and system architecture

Version and release control of the software and the corresponding architecture documentation must be established.

### **3.6 explanation of your design and implementation procedure ?!?!?**

TODO: ????

## 4 Test Document

### 4.1 Test Plan

Test Coverage for all functions that are involved in mathematical calculation shall have 100% code coverage and shall cover edge cases. Functions and methods involved in mathematical calculations are listed under 'Mathematical Functions'.

The user interface shall be tested according to the checklist listed under 'Manual Tests'.

### 4.2 Manual Tests

A page reload shall be performed before each test case.

Test Case	Expected Outcome	Satisfies	Status
On the 'Paper Plane'-Page, click on 'Add Threat' 6 times.	Only 5 bird avatars shall be displayed and a grey circle showing '+1'. Pay attention that the first bird is the one that disappears after the 5th bird. All birds shall be displayed at (0,0,0).	DLMCSPSE-224 DLMCSPSE-225-1	PASSED
Click 'Add bird' without providing any number. Click on the 'X'-Icon next to the birds Avatar. Add a bird at (101,0,0).	A bird shall be added at (0,0,0). Now no bird shall be displayed. No bird shall be added. A toast shall be displayed.	DLMCSPSE-225	PASSED
Enter the coordinates (1,2,3) and click 'Add Threat'.	A new bird shall be displayed at the specified coordinates.	DLMCSPSE-225-1	PASSED
Enter the coordinates (101,2,3) and click 'Add Threat'.	No new bird is added and a warning pop-up is displayed.	DLMCSPSE-225-2	PASSED
Continued on next page			

Table 7 – continued from previous page

Test Case	Expected Outcome	Satisfies	Status
Click 'Add Threat'. Enter the coordinates (1,2,3) and click 'Add Threat' again. Click on the little x of the first bird.	Only one bird avatar is displayed at (1,2,3) on each page and in the 3D-Scene.	DLMCSPSE-225-3	PASSED
Add two birds. Click on a bird. Click on another bird. Click on the same bird again.	First no bird shall be selected. This bird shall now have a ring around it. And the compass component shall display 0m to <BirdName> and <BirdName> at 0°. Now the other bird shall have a ring around it and the ring of the first bird shall disappear. Now no bird shall have a ring. The extra values in the compass component shall now dissappear.	DLMCSPSE-226 DLMCSPSE-246	PASSED
Move the plane –3 on the <i>x</i> -axis.	The plane shall not move and a toast shall be displayed.	DLMCSPSE-228-3	PASSED
Add a bird at (50,2,2) Move the plane –10 on the <i>x</i> -Axis.	Before doing anything. The scale of the scene shall be (-6,6) for <i>x/y</i> and (0,12) for the <i>z</i> -Axis. After the addition of the bird. The scale shall be: (-50,50) for <i>x/y</i> and (0,100) for the <i>z</i> -Axis. After the translation the scale shall be (-60,60) for <i>x/y</i> and (0,120) for the <i>z</i> -Axis.	DLMCSPSE-229 DLMCSPSE-228-1/2	PASSED
Continued on next page			

Table 7 – continued from previous page

Test Case	Expected Outcome	Satisfies	Status
<p>Add a bird at (2, 2, -3).</p> <p>Add a bird at (2, 2, 2). And then try to move the bird z -3.</p> <p>And then move the bird x 2.</p>	<p>No bird shall be added and a toast is expected.</p> <p>A new dot in the colour of the bird is expected.</p> <p>The bird shall not move and a toast shall pop up.</p> <p>After the second translation the bird shall be at (4, 2, 2).</p>	<p>DLMCSPSE-232</p> <p>DLMCSPSE-231</p>	<b>PASSED</b>
<p>Rotate the plane yaw 405°.</p>	<p>The plane shall point NE 45°.</p>	<p>DLMCSPSE-233-2</p>	<b>PASSED</b>
<p>Randomly rotate the plane and click on 'reset plane'</p>	<p>the plane shall now be at 0, 0, 2.</p>	<p>DLMCSPSE-235</p>	<b>PASSED</b>
<p>Click 'Hide Coordinate System' twice.</p>	<p>After the first click the coordinate system in the scene shall disappear and reappear after the second click.</p>	<p>DLMCSPSE-239</p>	<b>PASSED</b>
<p>Add a bird at (2, 2, 2). And navigate to the 'Bird' Page.</p> <p>Navigate back.</p>	<p>A bird card shall be visible displaying the following information:</p> <p>2.83 Meter</p> <p>2.83 Meter</p> <p>-0.73 Degree</p> <p>3.13 Meter</p> <p>After navigating back the information shall not be lost.</p>	<p>DLMCSPSE-240</p>	<b>PASSED</b>
Continued on next page			

Table 7 – continued from previous page

Test Case	Expected Outcome	Satisfies	Status
Rotate the plane yaw 90°.           Add another rotation yaw 225°.	Before doing anything, the plane in the compass component shall point north. After the rotation the plane shall point East. After the second rotation the plane shall point NW (−45°)	DLMCSPSE- 244	<b>PASSED</b>
Add a Threat at (2,2,2).	A Bird Icon shall be displayed at roughly 315°/−45° in the compass component.	DLMCSPSE- 245-1	<b>PASSED</b>
Add a Threat at (14,0,0) and a Threat at (13,0,0).	The first one shall be indicated by an arrow and the second one shall be indicated by an icon at 0°	DLMCSPSE- 245-2	<b>PASSED</b>



### 4.3 Mathematical Functions

List of functions and methods that are involved in mathematical calculations and are therefore essential to test properly. Coverage is calculated by the vitest testing framework.

ID	Function/Method	Description	Coverage
F1	<code>azimuthAngle(A: Point, center?: Point): number</code>	Calculates the angle measure (in radians, with $-\pi < \theta \leq \pi$ between the positive x-axis and the ray from the origin to the point (x,y) in the Cartesian plane.  If a center point is provided, the angle is calculated from the new center position.	100%
F02	<code>yawPitchRoll2Matrix(yaw: number, pitch: number, roll: number): number[][]</code>	Returns a $3 \times 3$ rotations matrix that represents a rotation in ZYX order in degree.  Yaw, Pitch and Roll are in degrees.	100%
F03	<code>cosineDegrees(degrees: number): number</code>	Calculates the cosine of a number in degrees.	100%
F04	<code>sineDegrees(degrees: number): number</code>	Calculates the sine of a number in degrees.	100%
F05	<code>rad2Degrees(rad: number): number</code>	Converts rad to degrees.	100%
F06	<code>crossProduct(pointA: Point, pointB: Point): Point</code>	Calculates the cross product between two vectors	100%
F07	<code>vectorLength(p: Point): number</code>	Calculates the length of a vector	100%
Continued on next page			

Table 8 – continued from previous page

ID	Function/Method	Description	Coverage
F08	<code>dotProduct(pointA: Point, pointB: Point): number</code>	Calculates the dot product of two vectors	100%
F10	<code>subtract2Point(pointA: Point, pointB: Point): Point</code>	Subtracts two vectors.	100%
F11	<code>multiply(a: number[][], b: number[][]): number[][]</code>	Multiplies two matrices.	100%
F12	<code>buildTransformationMatrix(rotationMatrix: number[][], translationVector: number[]): number[][]</code>	Builds a transformation matrix from the rotation and translation matrix.	100%
F13	<code>matrixTransformation(transformationMatrix: number[][], R: number[][]): number[][]</code>	Multiplies a point with a transformation matrix and thereby transforms it in space.	100%
M01	<code>matrixTransform: void</code>	Applies all subsequent transformations to the initial plane, marble and plane coordinate system.	100%
M03	<code>rotatePlane(yaw: number, pitch: number, roll: number): Plane</code>	Updates the rotation matrix via Euler Angles in ZYX order, rotates the plane and returns the freshly transformed plane.	100%
M04	<code>translatePlane(x: number, y: number, z: number): Plane</code>	Updates the plane's translation matrix, translates the plane and returns the freshly transformed plane.	100%
Continued on next page			

Table 8 – continued from previous page

ID	Function/Method	Description	Coverage
M05	getAngle2North(): number	Returns the angle $\alpha$ between the planes x-Axis and the earth referential x-Axis in degrees. $\alpha \in [0..359]$	100%
M06	getVerticalDistance2Plane(p: Point): number	Returns the vertical hight difference between the plane and a point in space.	100%
M07	getDistance2Plane(p: Point): number	Returns the length of the vector $\vec{MP}$ from the Marble $M$ to an arbitrary Point $P$ .	100%
M09	getAngle2Plane(location: Point): number	Returns the horizontal/azimuth angle $\alpha$ between a point in space and the marble $\alpha \in [0..359]$	100%
F09	angleBetween2Points(A: Point, B: Point): number	The final angle between is calculated according to the dihedral angle: The dot product of the two normal vectors divided by the product of their lengths. $\cos(\phi) = \frac{\text{Norm}(n_A) * n_B}{(\text{Norm}(n_A) * \text{Norm}(n_B))}$	0%
M02	resetPlane(): Plane	resets plane to its initial position.	0%
M08	getElevationAngle2Threat(p: Point): number	Returns the vertical angle $\alpha$ between the Marble and an arbitrary Point. $\alpha \in [-179..180]$	0%
M10	getDistanceFromGround(): number	Returns the altitude of the plane.	0%

4.4 Automated Tests

A list of test cases that cover all math functions and the requirements they are testing.

Test ID	ID	Test	Satisfies	Status
T1	F1	Calc angle from center (7,7) to the points: (7,3), (20,7), (7,10), (3,7), (6.9, 3) and (7.1, 3)	TECH-001	PASSED

## **5 Finalisation Phase**

### **5.1 Sprint Retrospective - Main Take-Aways**

Especially when working alone, complacency of procedure becomes a major issue and needs to get extra attention during future projects.

It is vital for future project plans and/or deadlines to be more realistic in terms of what is achievable in the given time/cost-frame.

### **5.2 Methodologies and Tool**

You should especially reflect on the applied tools, methodologies, and techniques and on your handling of the resources

## 6 Glossary

Term	Definition
Bird	A more friendly and on theme alias for <i>Threat</i> .
Marble	A coordinate system that is offset from the center of the plane and is rotated along with the plane. It represents a point on the plane that is affected by its transformation. This system is the heart of all calculations made in this Tool.
Pilot	A more friendly and on theme alias for <i>Marble</i> . Since the <i>Marble</i> is currently not moveable, it serves as a stand-in for the head of a pilot.
Plane	A visual pleasing and more tangible object to visualise the effects of transformations.
Threat	A point in space to which the Azimuth & Elevation as well as the distance from the <i>Marble</i> is calculated.

## References

Inc., D. (2025). *Docker*. Retrieved January 23, 2025, from <https://www.docker.com/>

Inc., V. (2019a). *Vite*. Retrieved January 23, 2025, from <https://vite.dev/>

Inc., V. (2019b). *Vitest*. Retrieved January 23, 2025, from <https://vitest.dev/>

Plotly. (2025). *PlotlyJS*. Retrieved January 23, 2025, from <https://plotly.com/javascript/>