Centre for Autonomous and Cyber-Physical Systems
School of Aerospace, Transport and Manufacturing

Sébastien LAMBERT
Sebastien.Lambert.349@cranfield.ac.uk

2023-2024 AVDC MSc Individual Research Project:

Aircraft Communications Availability based Flight Dynamics Restriction

1st Interim Project Review

10 June 2024

THALES

Supervisors: Prof Saba Alrubaye,Dr Dmitry Ignatyev and Dr Christantus Obinna Nnamani

Sébastien LAMBERT
Sebastien.Lambert.349@cranfield.ac.uk

Introduction

A320 Denver CO USA 2009

A319, Nantes, 2006

TBM8, Birmingham UK, 2011

https://skybrary.aero/articles/loss-communication

Sébastien LAMBERT
Sebastien.Lambert.349@cranfield.ac.uk

Aim and objectives

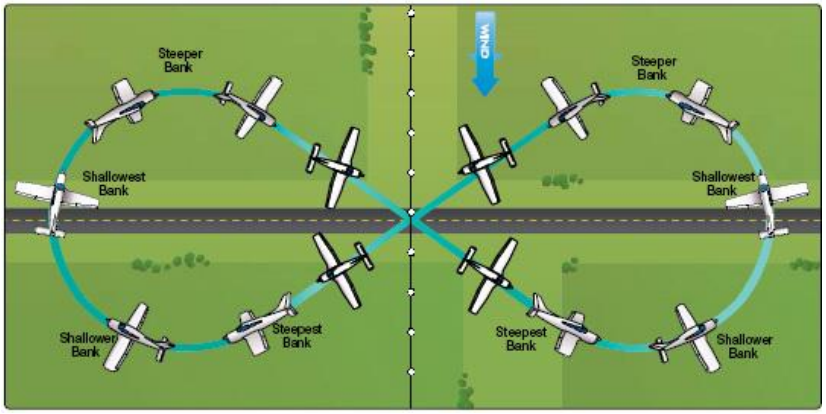
Aim: Develop a system integrating real-time flight data and dynamic parameters able to intelligently manage and optimize communication resources, ensuring efficient and secure aircraft communication during different phases of flight.

Objectives:

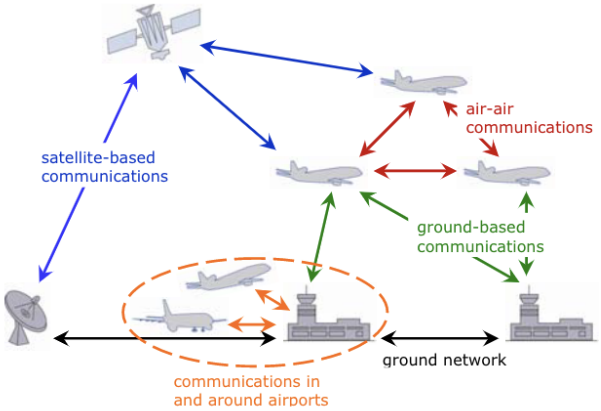
- Develop a model in Unity able to simulate air to ground communications
- Integrate an algorithm to compute the quality of the signals
- Develop an algorithm to swap between antennas to always get the best signal
- Predict no communication zones and avoid them

Sébastien LAMBERT
Sebastien.Lambert.349@cranfield.ac.uk

Literature Review



Control system



Communication system

Impact of the control system on the communication system

https://www.aviationsafetymagazine.com/features/commercial-maneuvers/
https://www.researchgate.net/figure/Integration-of-different-aeronautical-communication-systems-into-a-global-airborne_fig2_224989091

Sébastien LAMBERT
Sebastien.Lambert.349@cranfield.ac.uk

Literature Review – Manoeuvres

Manoeuvre	Rudder Position	Ailerons Position	Elevators/Horizontal Stabilizer Position	Flaps/Slats Position
Level Flight	Neutral	Neutral	Neutral	Neutral
Climb	Neutral or Slight Deflection towards turn direction	Neutral	Upward	Neutral
Descent	Neutral or Slight Deflection opposite turn direction	Neutral	Downward	Neutral
Turn (Banking)	Deflected towards turn direction	Up in the direction of the bank	Neutral	Neutral
Roll (Aileron Roll)	Neutral	Full deflection in the direction of roll	Neutral	Neutral
Pitch Up	Neutral	Neutral	Upward	Neutral
Pitch Down	Neutral	Neutral	Downward	Neutral
Takeoff	Neutral	Neutral	Upward	Extended
Landing	Neutral	Neutral	Downward	Fully extended
Stall Recovery	Neutral or opposite to stall direction	Neutral	Neutral	Neutral

D. Ignatyev , “Basic aerodynamics,” [Online]. Available: https://canvas.cranfield.ac.uk/courses/27249/files/1921602?wrap=1.

Sébastien LAMBERT
Sebastien.Lambert.349@cranfield.ac.uk

Literature Review – Antennas

Antenna Type	Antenna Description	Main function of the antenna	Wavelength
VHF Antenna	Whip-like, often located on top or bottom of fuselage	Communicates with ground stations for voice and data	118–137 MHz (30 MHz-300 MHz)
GPS Antenna	Small, dome-shaped or blade-like	Receives GPS signals for navigation and precise positioning	L5 1176.45 MHz
ATC/UHF/DME Antenna	Blade or cone-shaped, on the bottom of the aircraft	radar-based aircraft identification and tracking	960 MHz - 1,215 MHz
TCAS Antenna	Blade or circular disk	Transmits and receives signals for Traffic Collision Avoidance System (TCAS)	2.0 GHz - 3.0 GHz
ELT Antenna	Whip or blade-like	Transmits Emergency Locator Transmitter signals in distress	121.5 MHz, 243 MHz and 406 MHz
Weather Radar Antenna	Large, dish-shaped	Sends and receives radar signals for weather detection	3.0 GHz - 30.0 GHz
5G	Blade or cone-shaped, on the bottom of the aircraft	Communicates with ground stations for everything	410-7125 MHz or 24.25-52.6 GHz

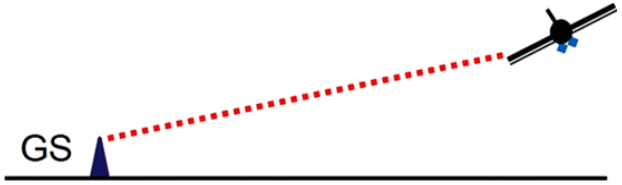
S. I. A. M. L. W. Douglas W.Burgess, «TCAS: Maneuvering Aircraft in the Horizontal PLane,» THE LINCOLN LABORATORY JOURNAL, vol. 7, n° %12, pp. 295-312, 1994.
W. contributors, «Very high frequency,» Wikipedia, The Free Encyclopedia., 4 May 2024. [En ligne]. Available: https://en.wikipedia.org/w/index.php?title=Very_high_frequency&oldid=1227114617.
W. contributors, «GPS signals,» Wikipedia, The Free Encyclopedia, 3 May 2024. [En ligne]. Available: https://en.wikipedia.org/w/index.php?title=GPS_signals&oldid=1224166622.
W. contributors, «Distance measuring equipment,» Wikipedia, The Free Encyclopedia, 22 February 2024. [En ligne]. Available: https://en.wikipedia.org/w/index.php?title=Distance_measuring_equipment&oldid=1209645947.

Sébastien LAMBERT
Sebastien.Lambert.349@cranfield.ac.uk

Literature Review – Cross Impact

In What respect the control system affects the communication:

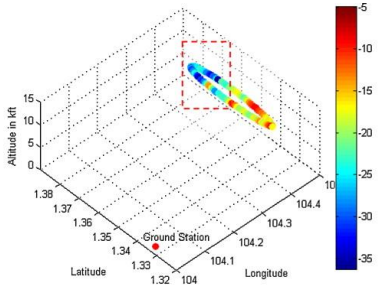
- Shadowing effect
- Antenna beam deflection
- Link Budget (position)



Airframe shadowing illustration

Other impacts on the communication:

- Antenna position
- Weather



(a) Variation of the received power in 3-D geometry for Channel 1

Yu Song Meng, Yee Hui Lee,Study of shadowing effect by aircraft maneuvering for air-to-ground communication,AEU - International Journal of Electronics and Communications,Volume 66, Issue 1,2012,Pages 7-11,ISSN 1434-8411.
R. Sun, D. W. Matolak and W. Rayess, "Air-Ground Channel Characterization for Unmanned Aircraft Systems—Part IV: Airframe Shadowing," in IEEE Transactions on Vehicular Technology, vol. 66, no. 9, pp. 7643-7652, Sept. 2017, doi: 10.1109/TVT.2017.2677884.

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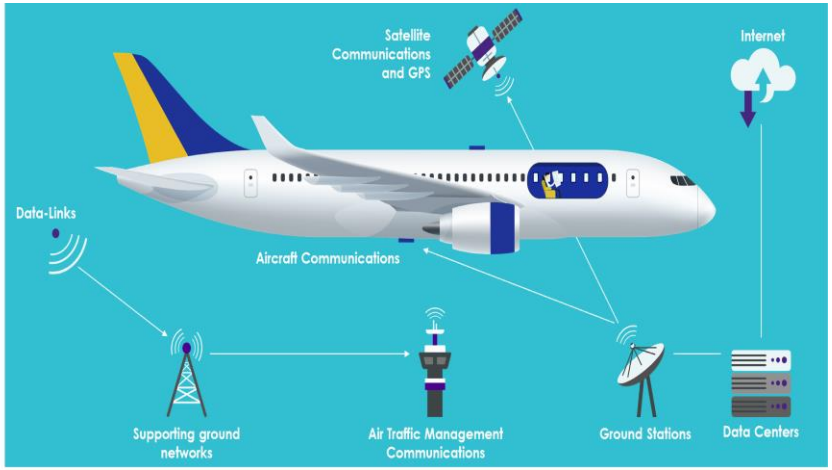
Problem statement

Model:
- Unity
- Ansys
- Boeing 727
- VHF



Antennas:
- Antennas of the Boeing 727
- VHF
- Multiple ground antennas
- Possibility to move the Aircraft antenna

Link Budget:
- Free space loss
- Antenna loss
- Temperature loss

https://www.thalesgroup.com/en/markets/aerospace/thales-connected-aircraft

Sébastien LAMBERT
Sebastien.Lambert.349@cranfield.ac.uk

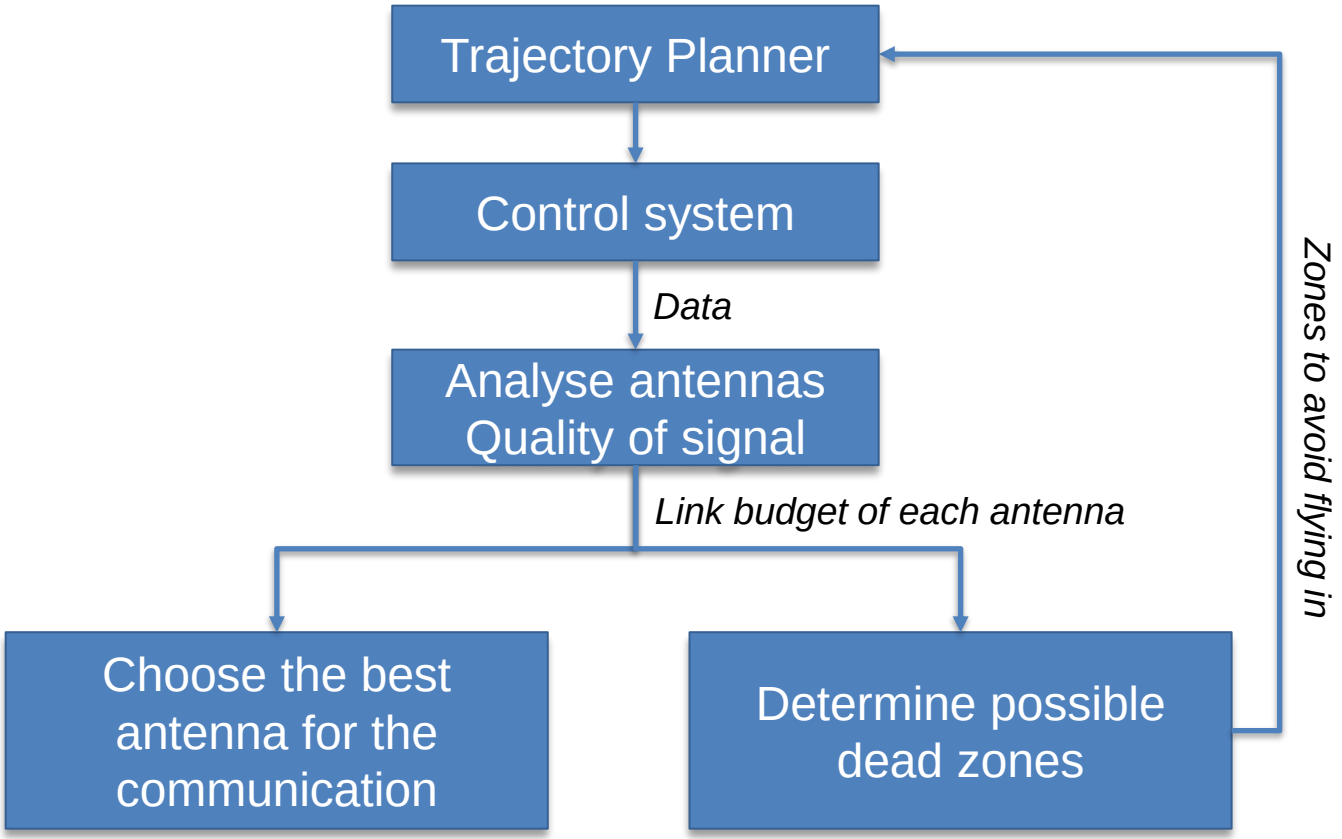
Simulation Software

- 3D simulation easy to get and modify
- Faster implementation
- Flexibility

- Allow 3D simulation with CAD designs

Sébastien LAMBERT
Sebastien.Lambert.349@cranfield.ac.uk

Methodology



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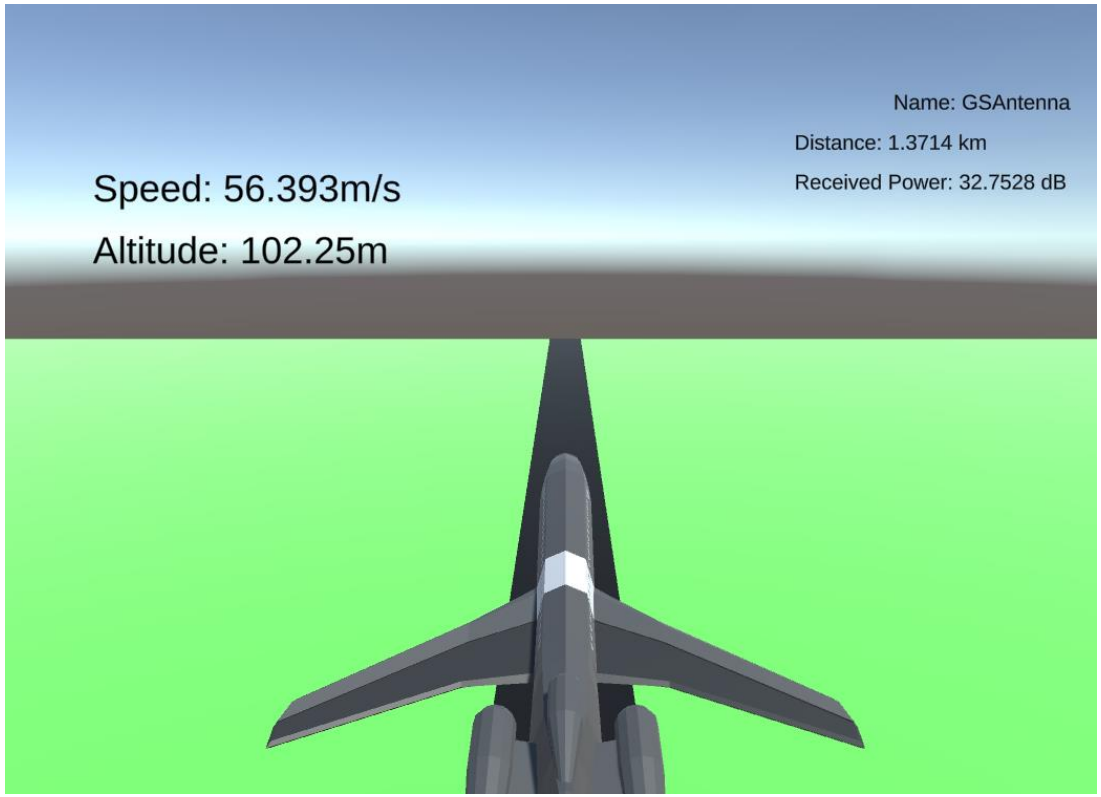
Result to date



Implemented Systems

- Ray Tracing
- Real time Link Budget
- Trajectory Simulation

Model used

- Boeing 727
- VHF antenna C50-17

Sébastien LAMBERT
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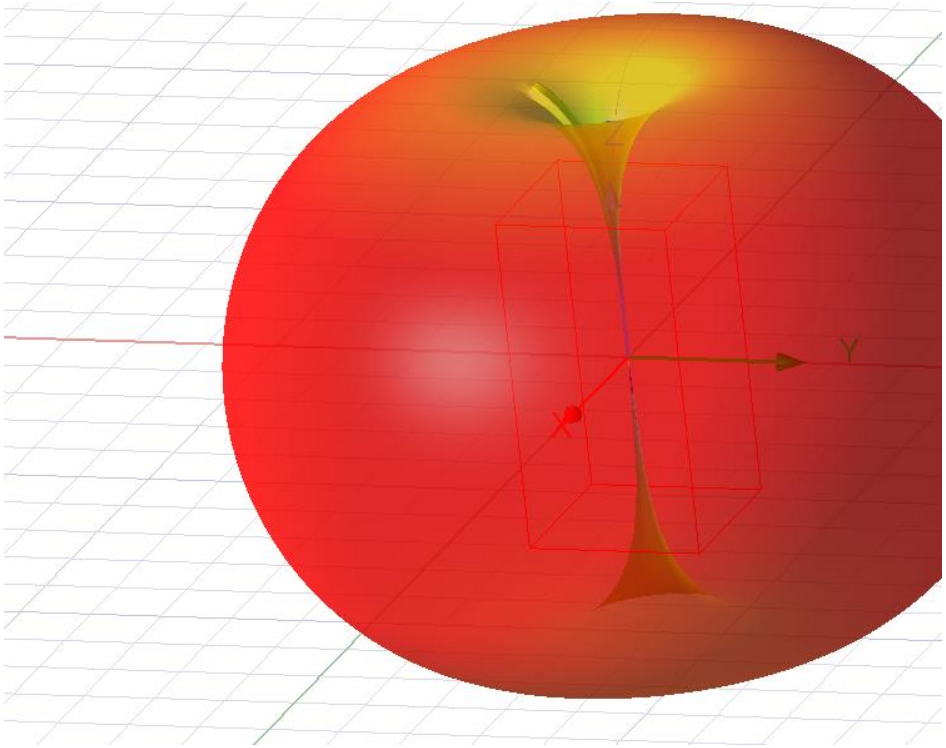
Result to date

Model of the antenna radiation pattern:

- Dipole
- Horn



Ansys

Sébastien LAMBERT
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Risk register

Category	Risk event	Probability	Impact	Priority	Risk Response
Project management	Delay	Medium	High	High	Use of GitHub as a productivity and management tool
Design	Ineffective research and literature review	Medium	High	High	Seek for some experts by asking to the supervisors
Design	Unable to properly design the antenna radiation pattern	Low	Medium	Medium	Slight change of the antenna or change software
Design	Unable to perform the best antenna switch	Medium	High	Low	Change algorithm and performances analysis

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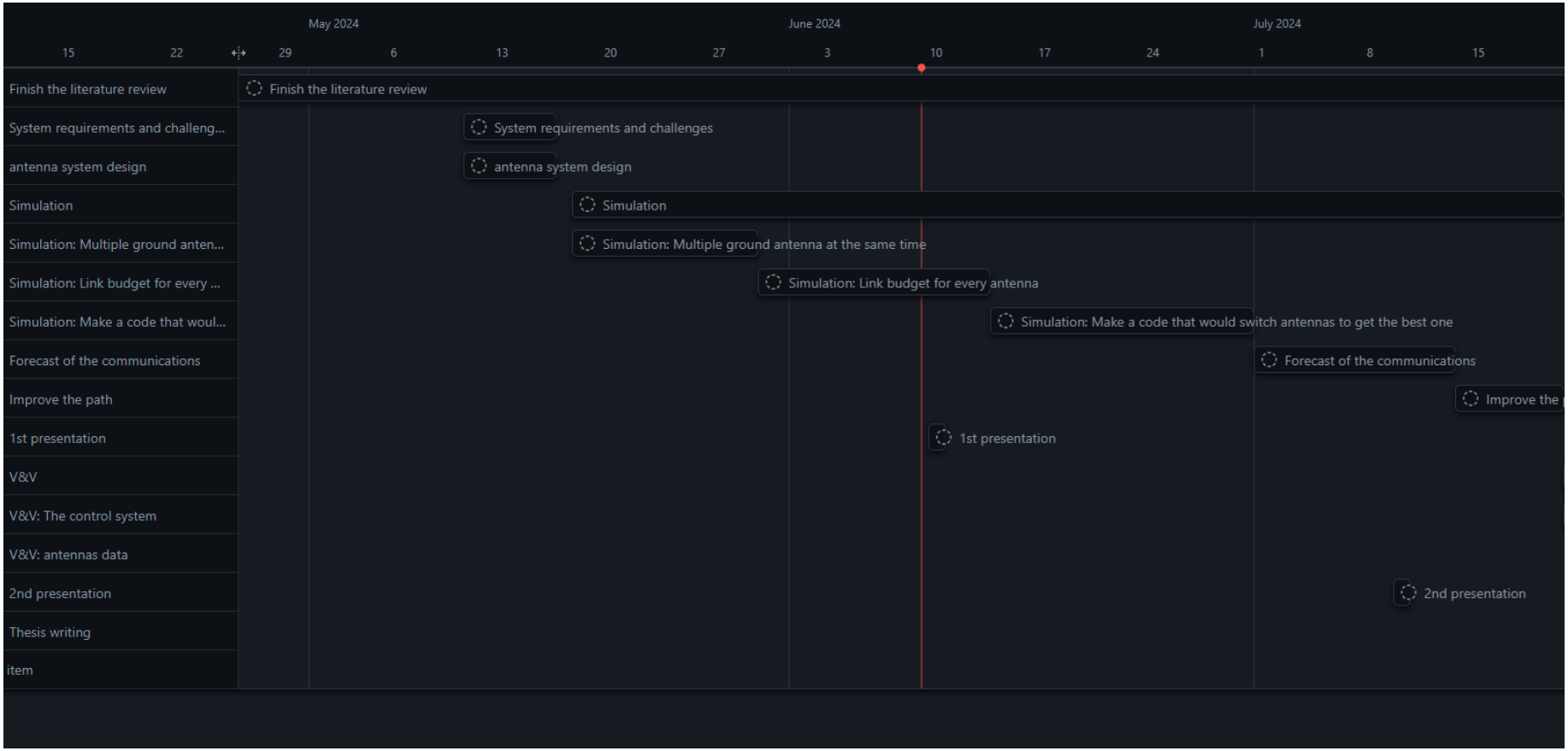
Gantt chart



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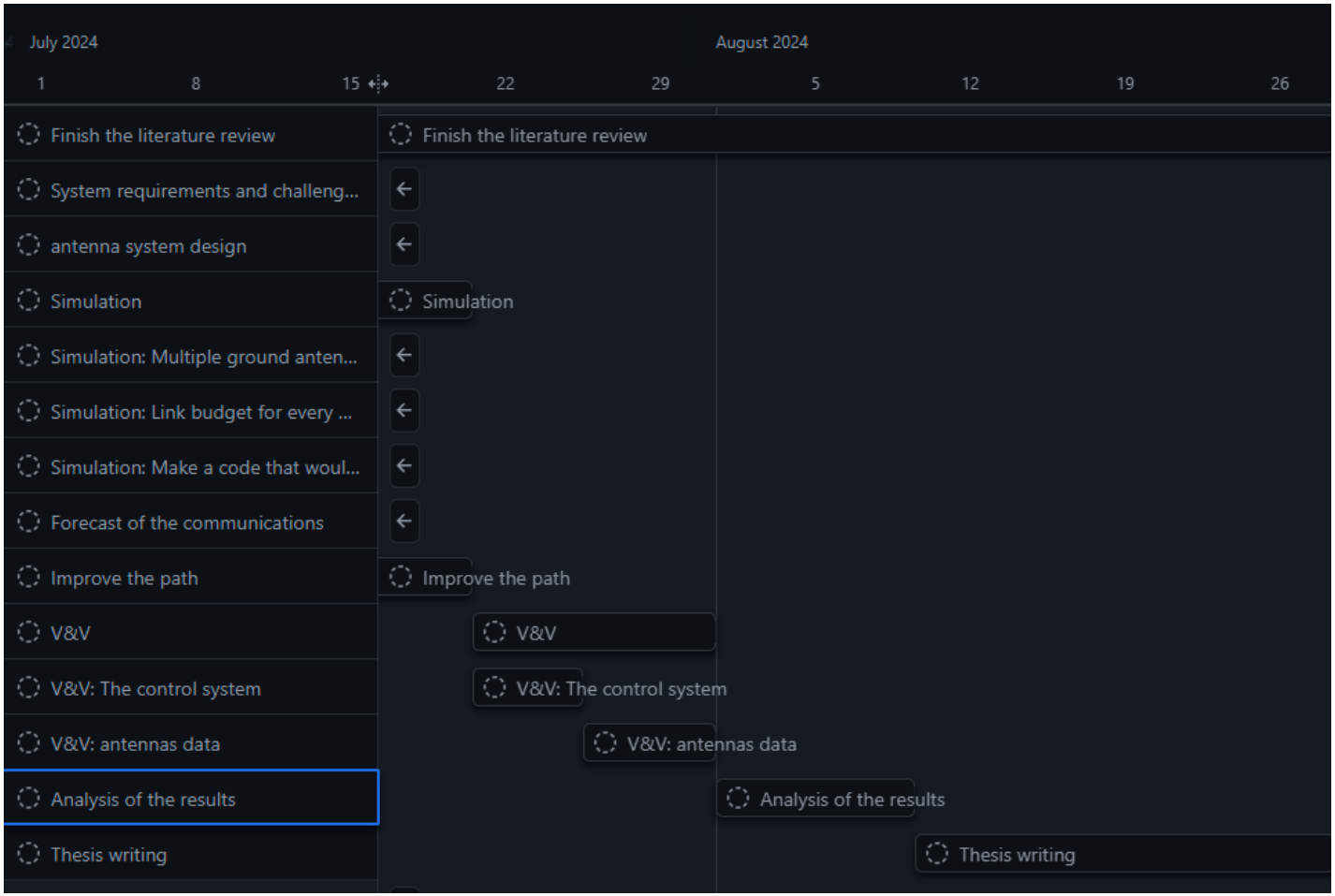
Gantt chart



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Conclusion

- Model in Unity
- Shadowing effect different from literature
- Not a lot of literature on air to ground communication
- Link budget could be improved

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Thank you!