Space Traffic Management Conference | 2019 Progress through Collaboration

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Human-in-the-Loop Landing Flare Flight Test Simulation of the SpaceLiner Orbiter

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DLR

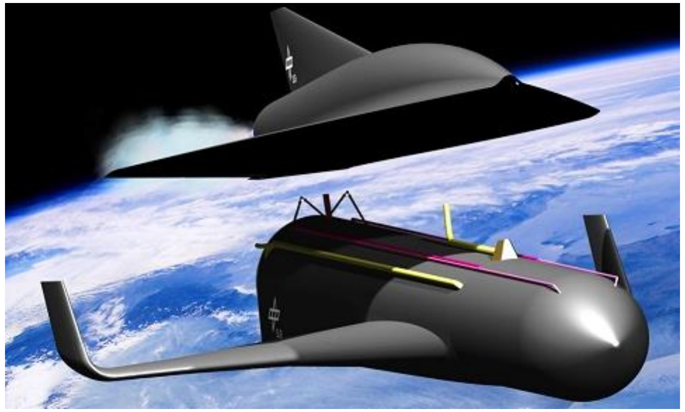
Overview

- Motivation
- Methodology
- Results
- Discussion & Outlook

Motivation

- **Now**

- **Future (Who knows when ?)**



Methodology

Human-in-the-Loop Simulation for Space Traffic integration test purposes !

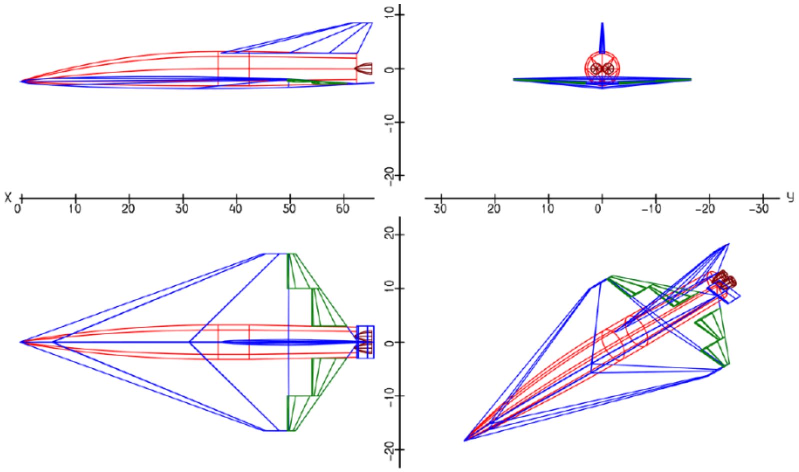
→Use Case: DLR SpaceLiner concept

Methodology

Design drawings + CFD results

→X-Plane flight simulation model

Methodology



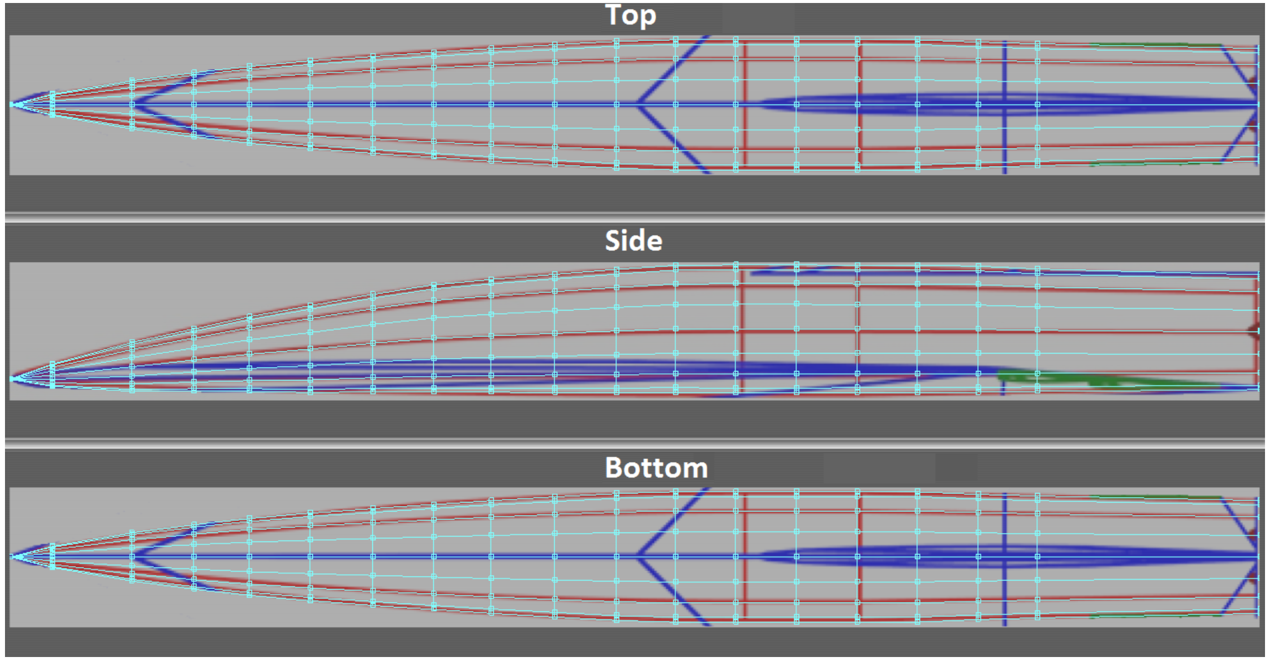
+ (CAC)[1] & PAN AIR[2] model experiments' results

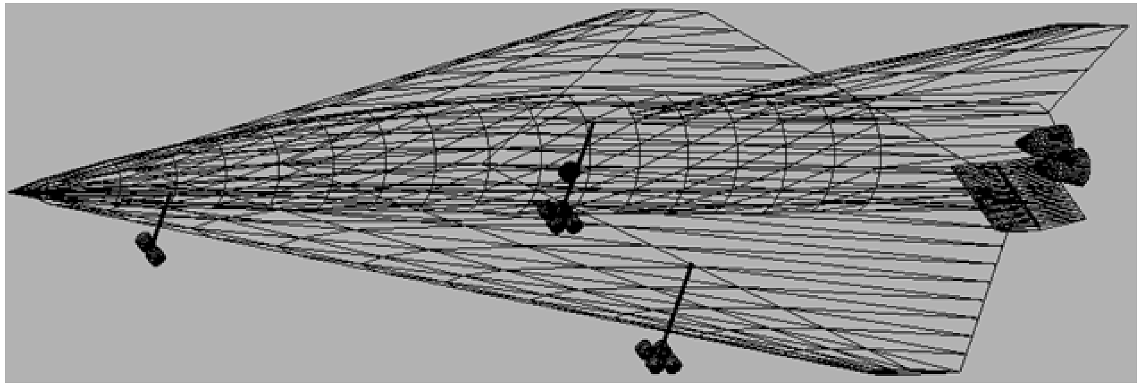
→X-Plane flight simulation model

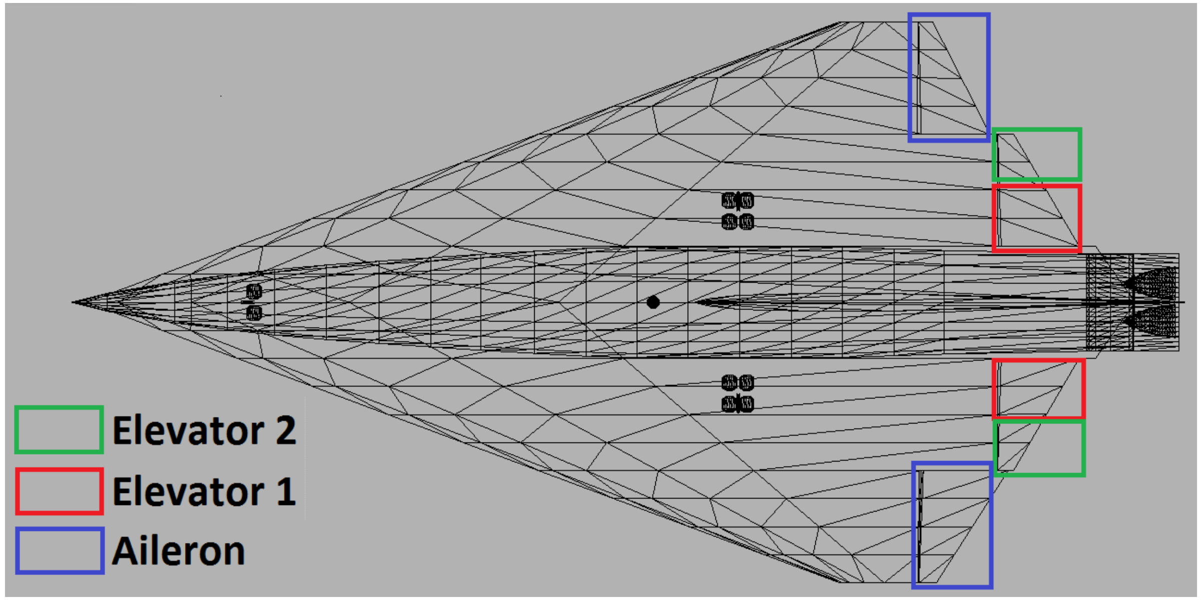
[1]Software developed by DLR Institute of Space Systems, Dep. Space Launcher System Analysis

[2]Software developed by BOEING

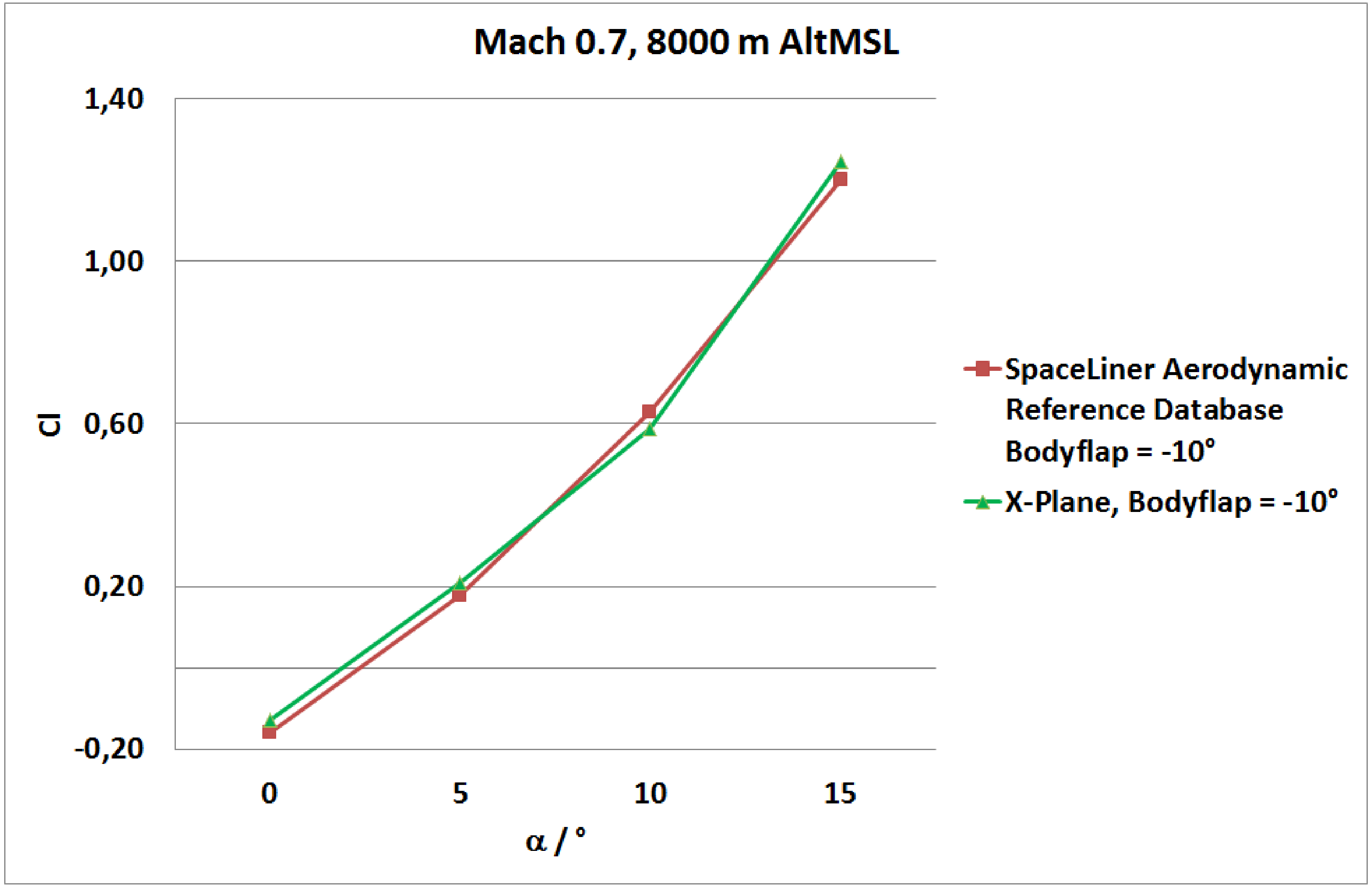
Methodology







Results (flight model)



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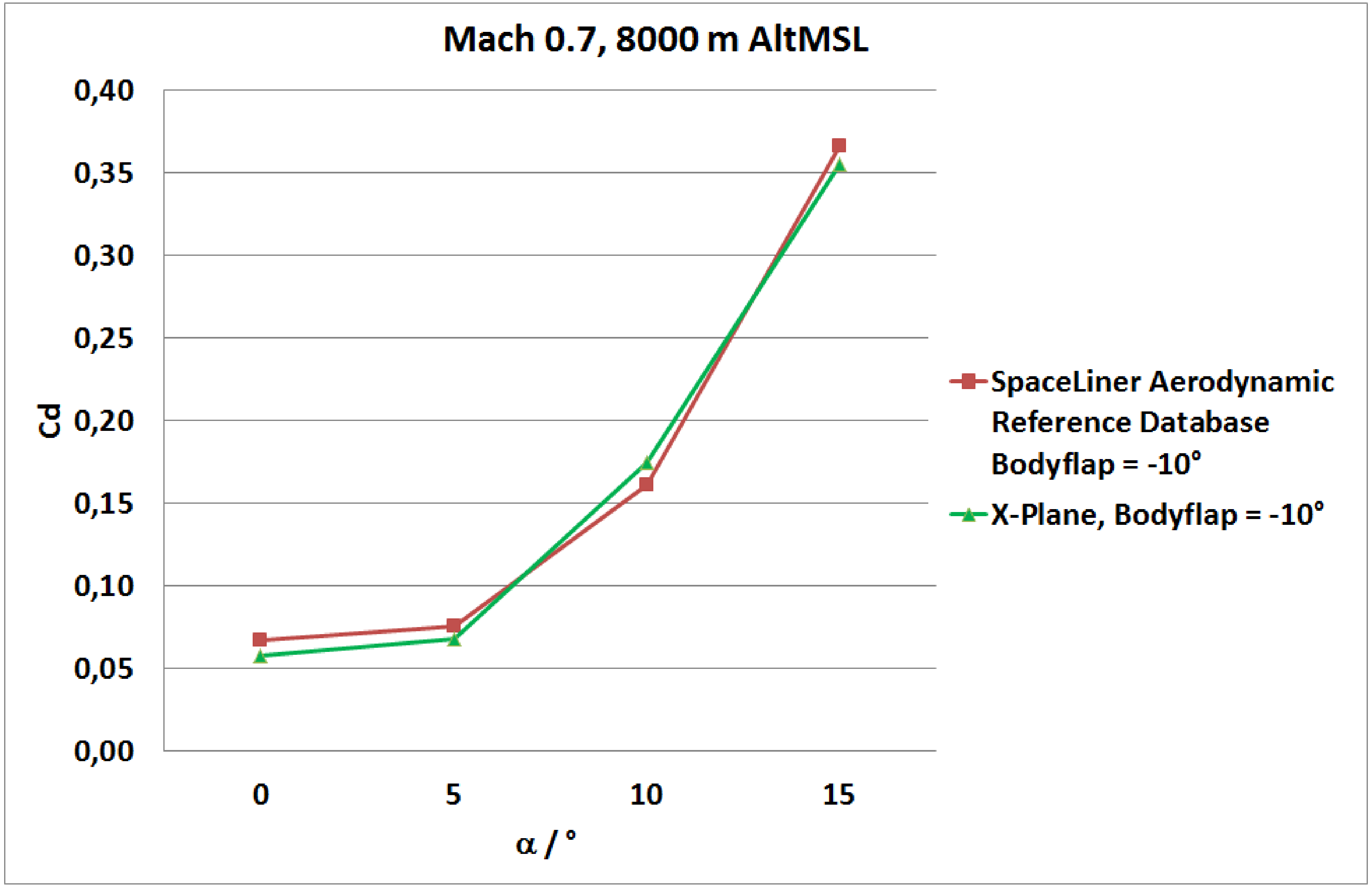

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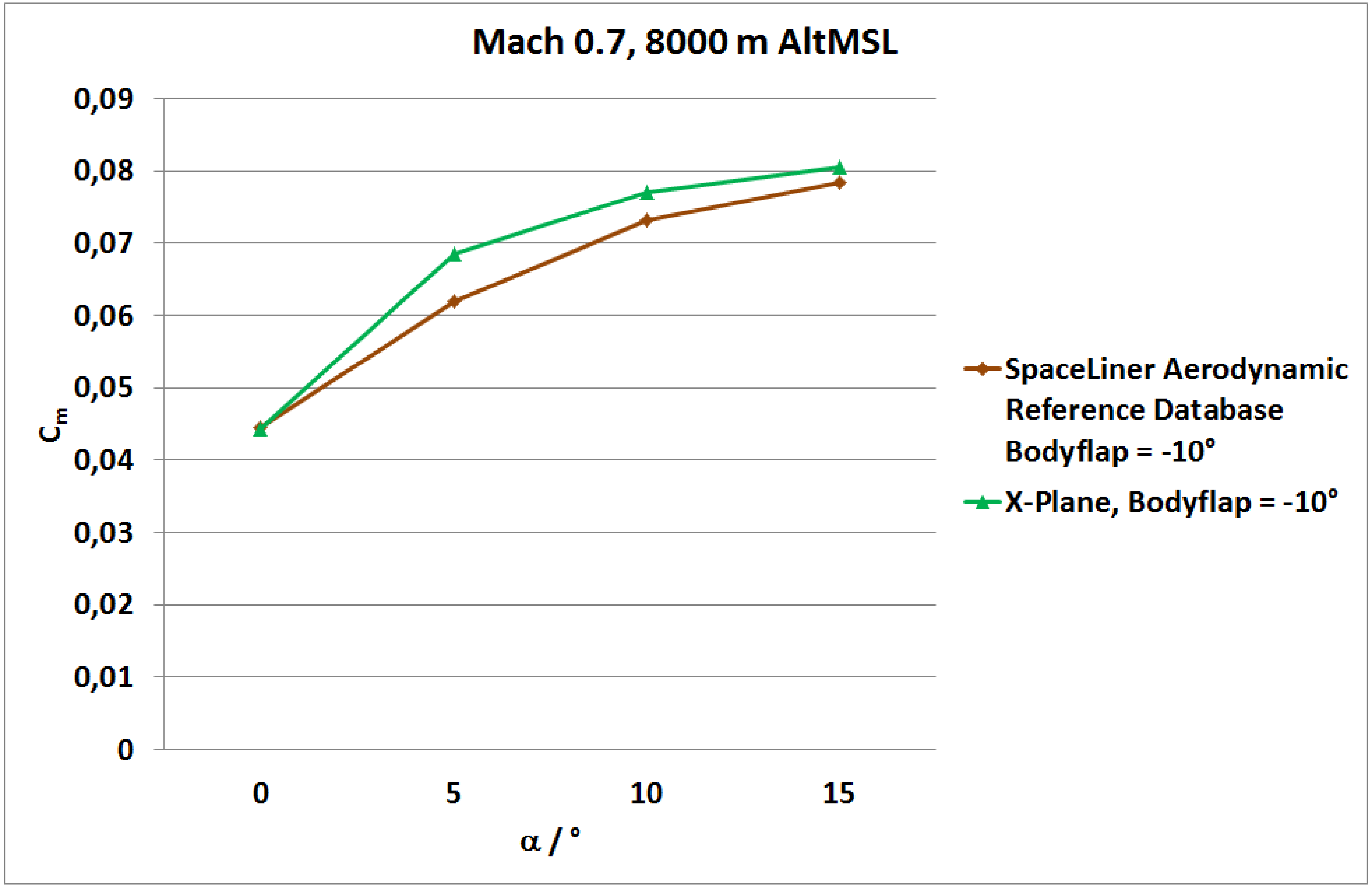
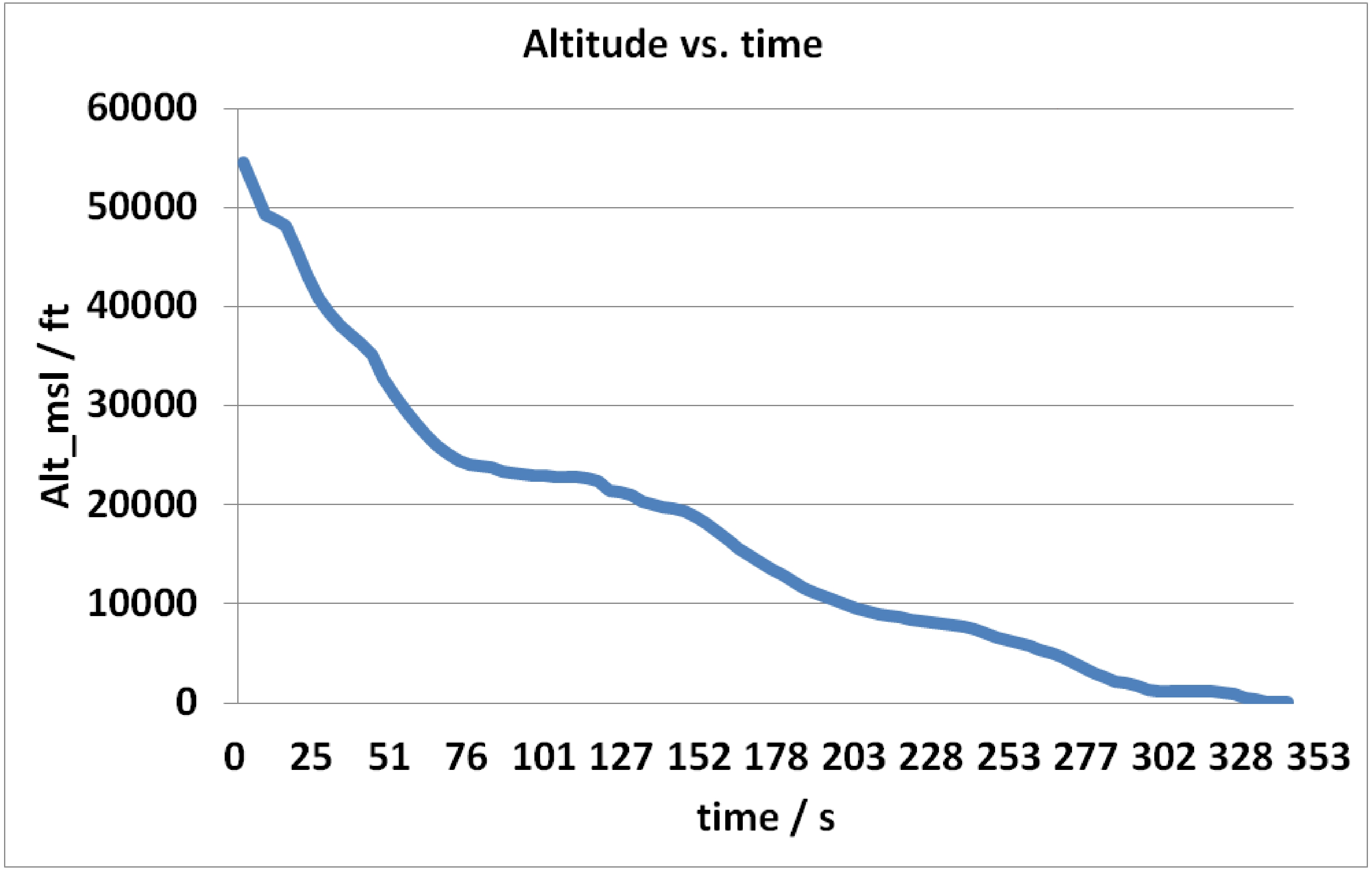


Results (simulated whole descent)



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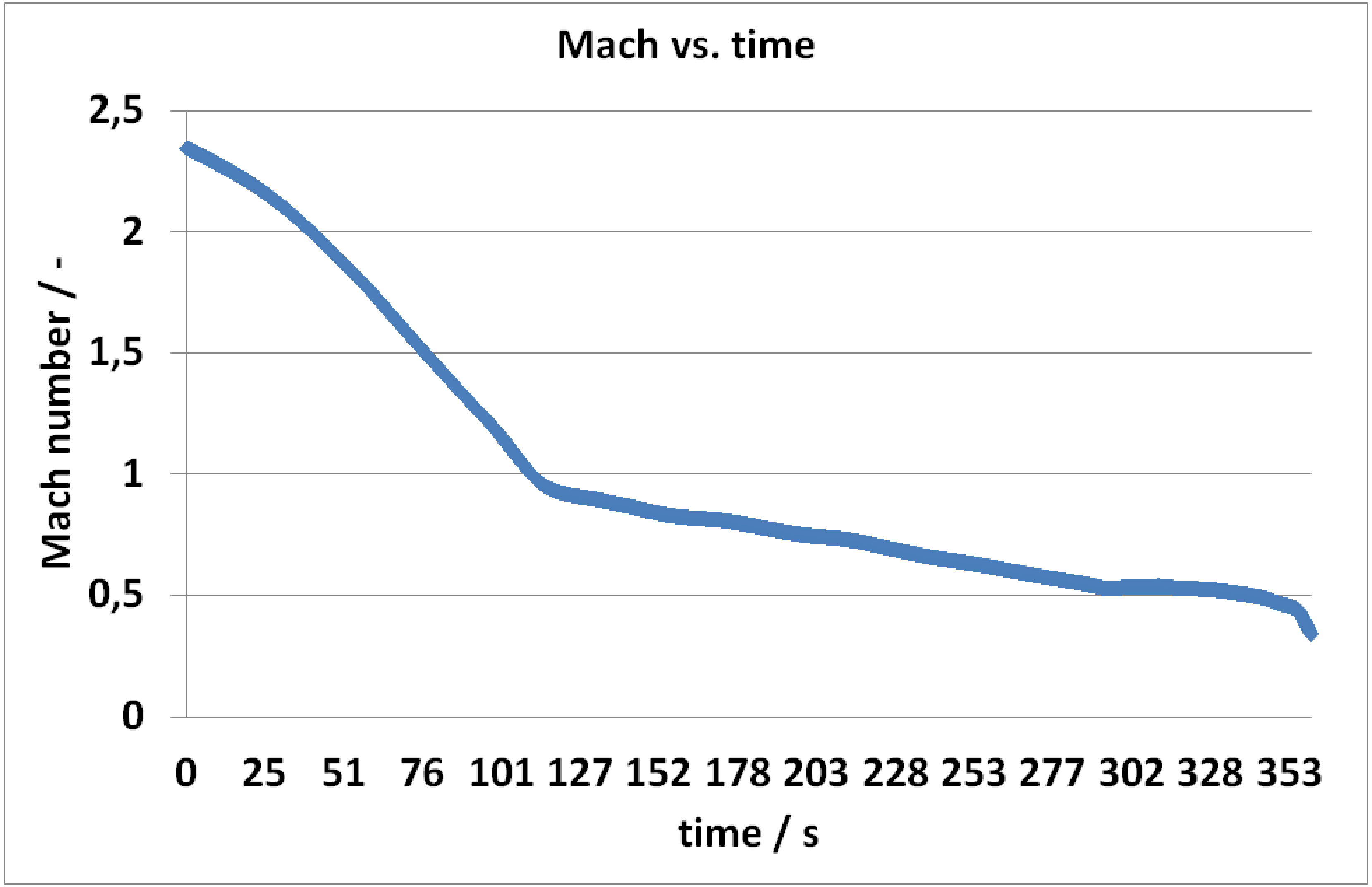

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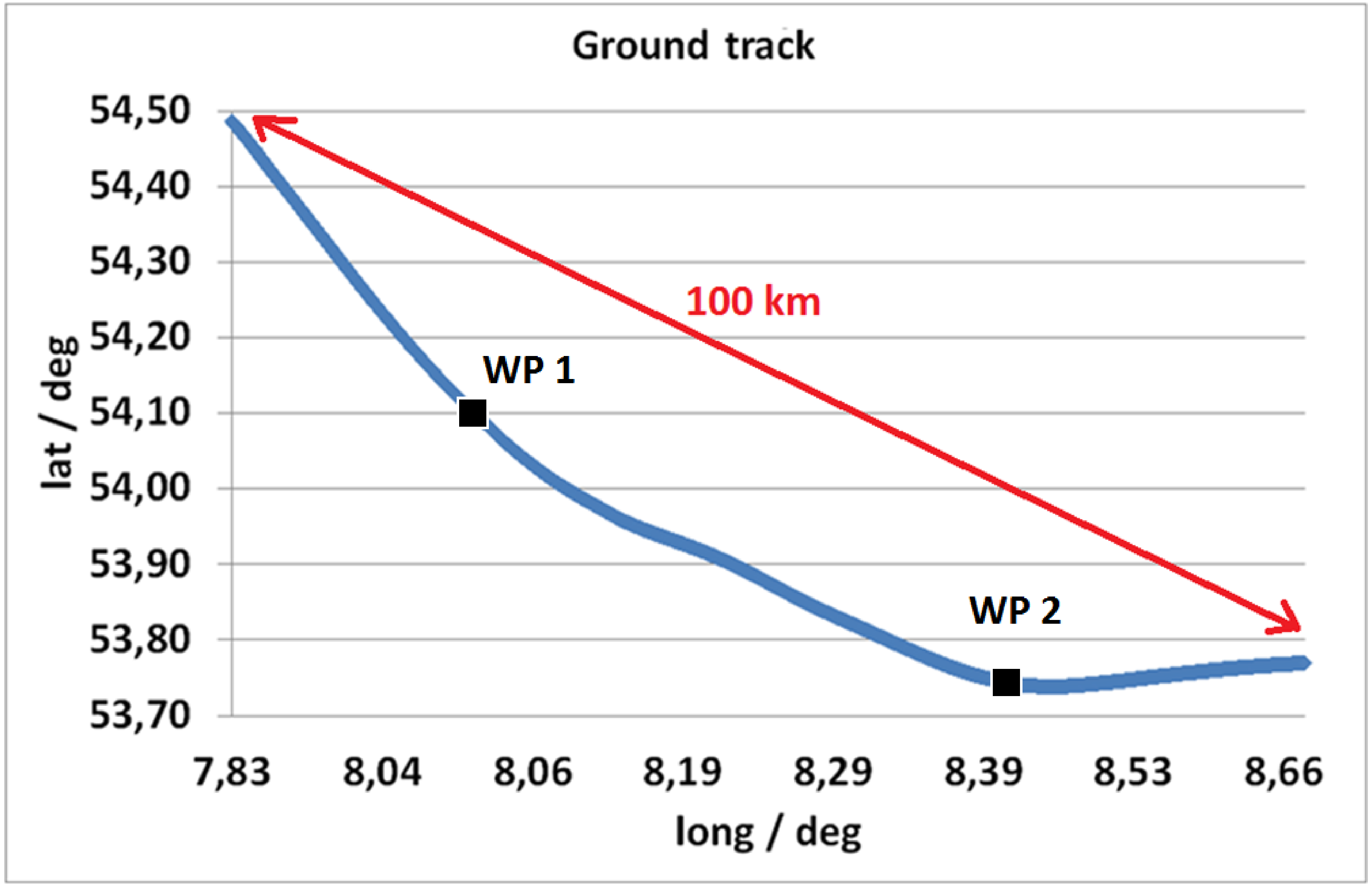

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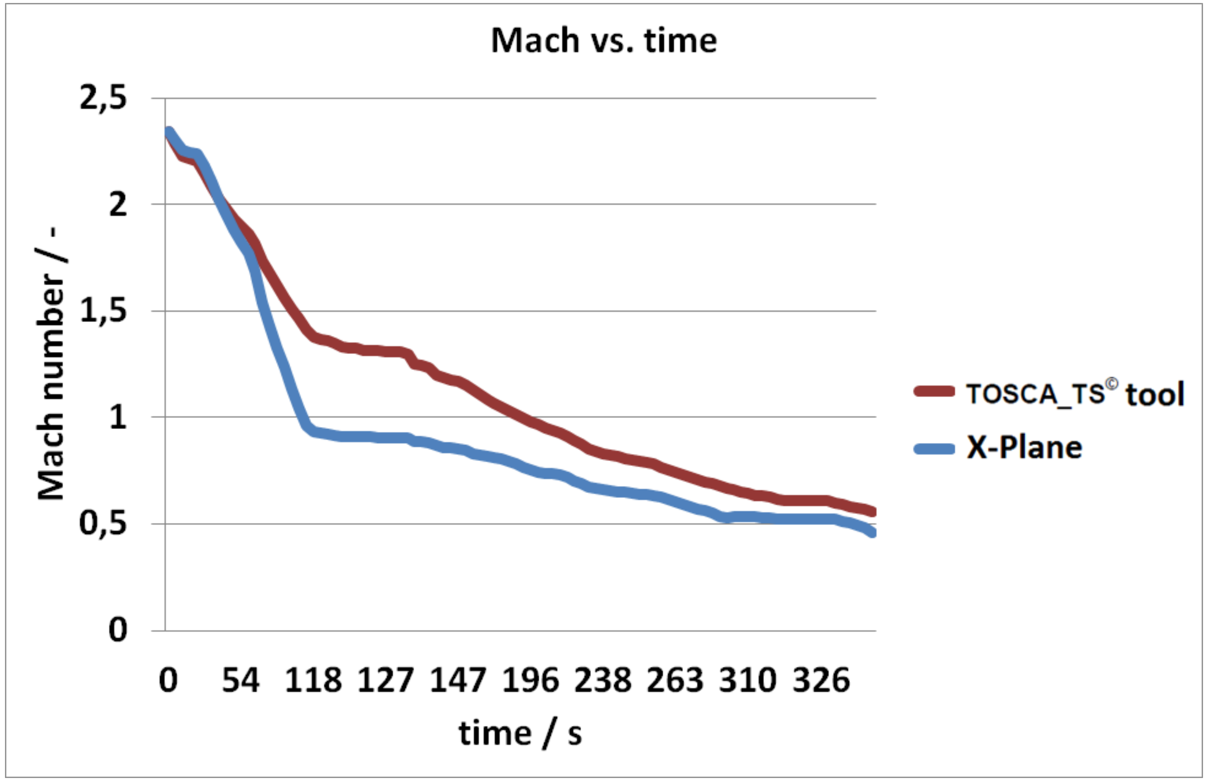
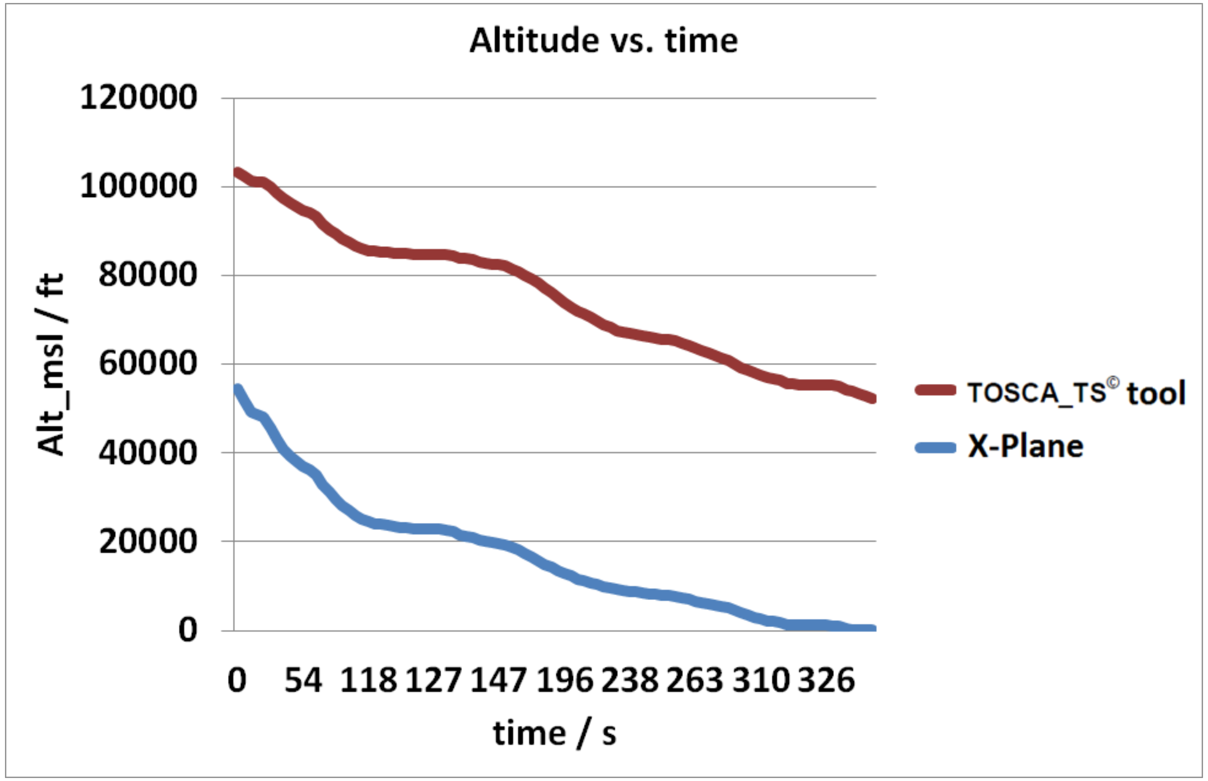
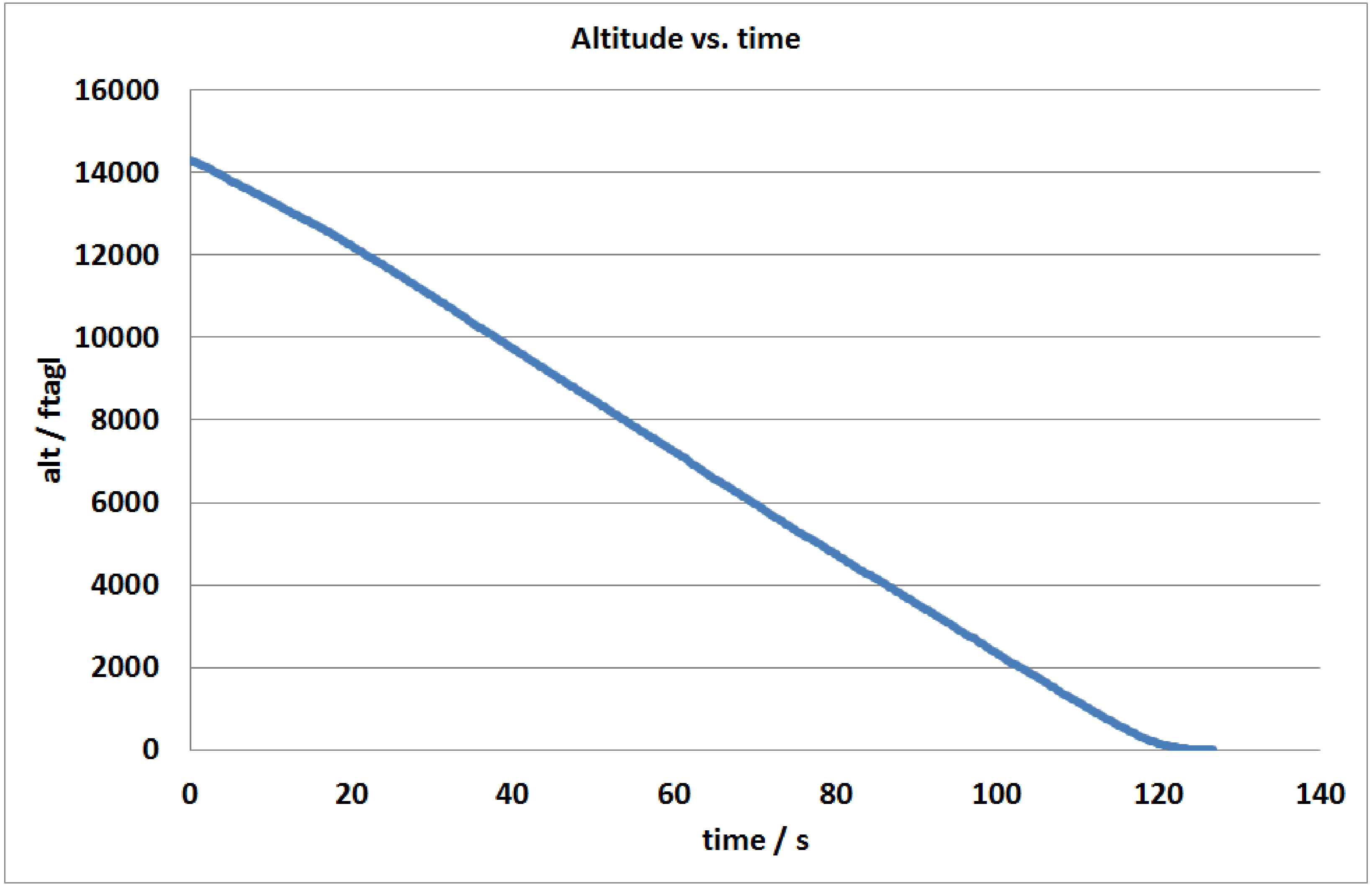




Results (simulated landing flare test)

- Initial altitude setting of 14000 ftagl
- Autopilot pitch mode speed with pitch setting of 250 kts
- Gear extraction at 10000 ftagl
- Flare out at 1200 ftagl with autopilot pitch mode vertical speed of 0 feet per minute

Results (simulated landing flare test)



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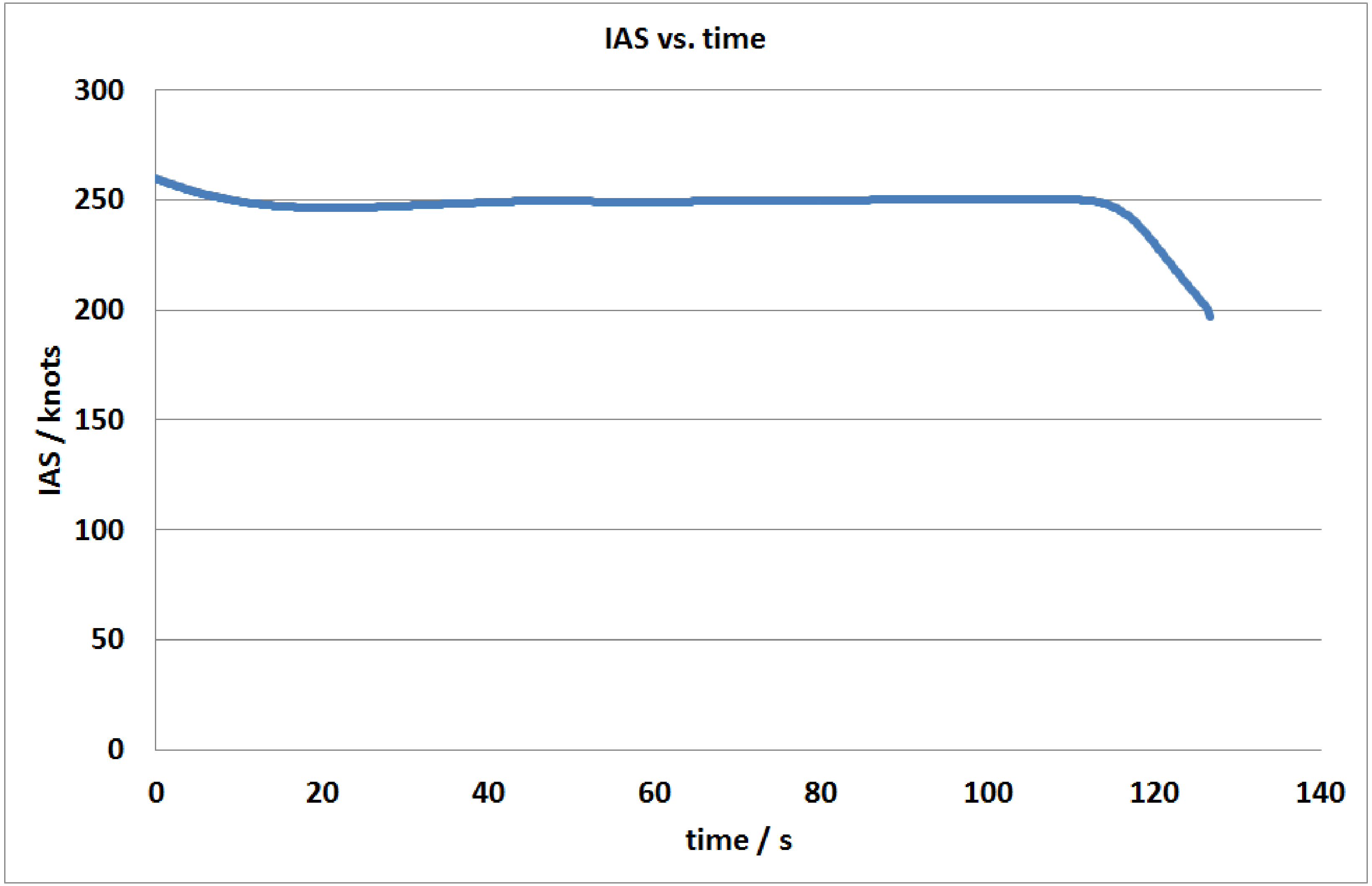

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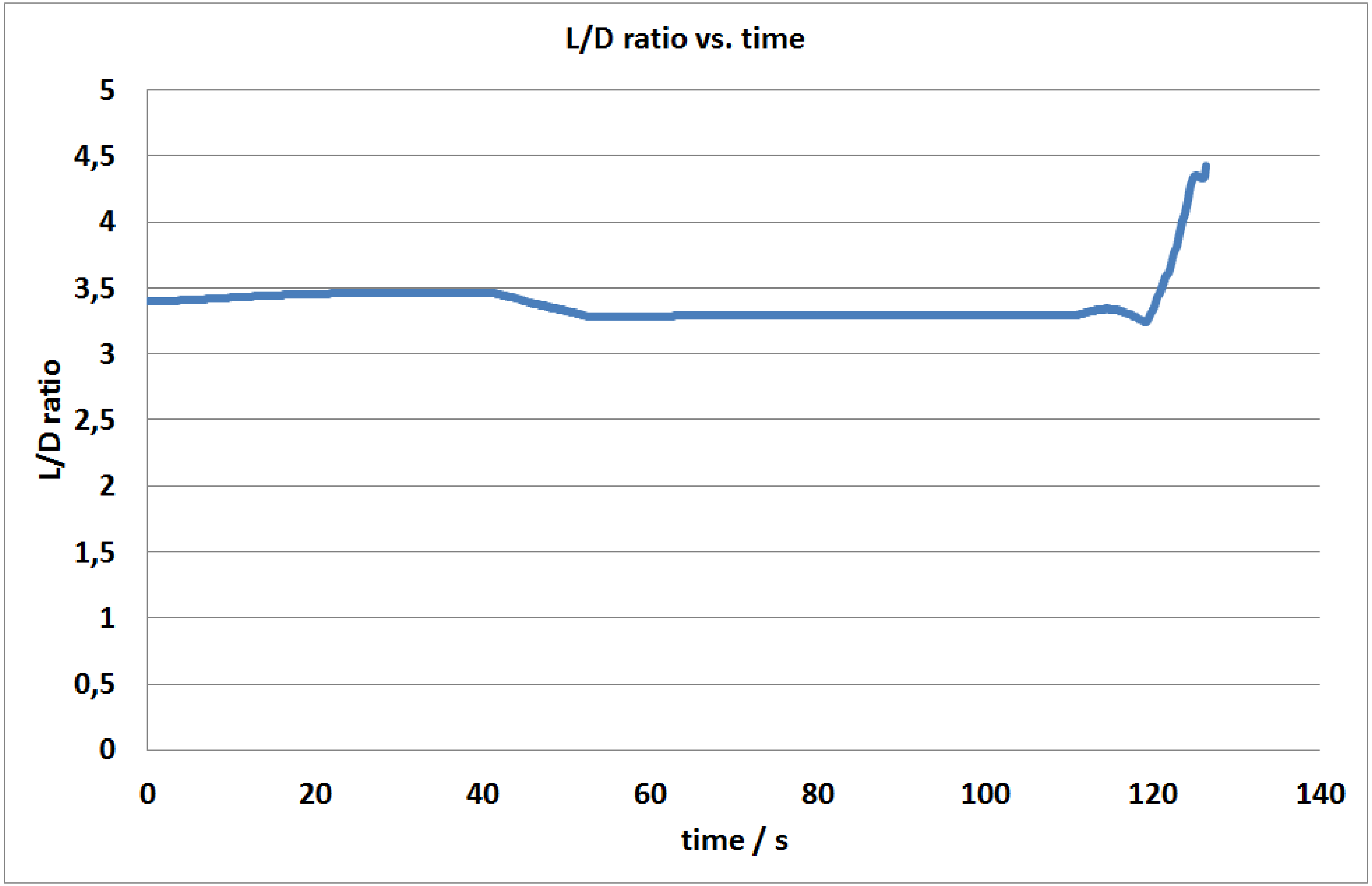

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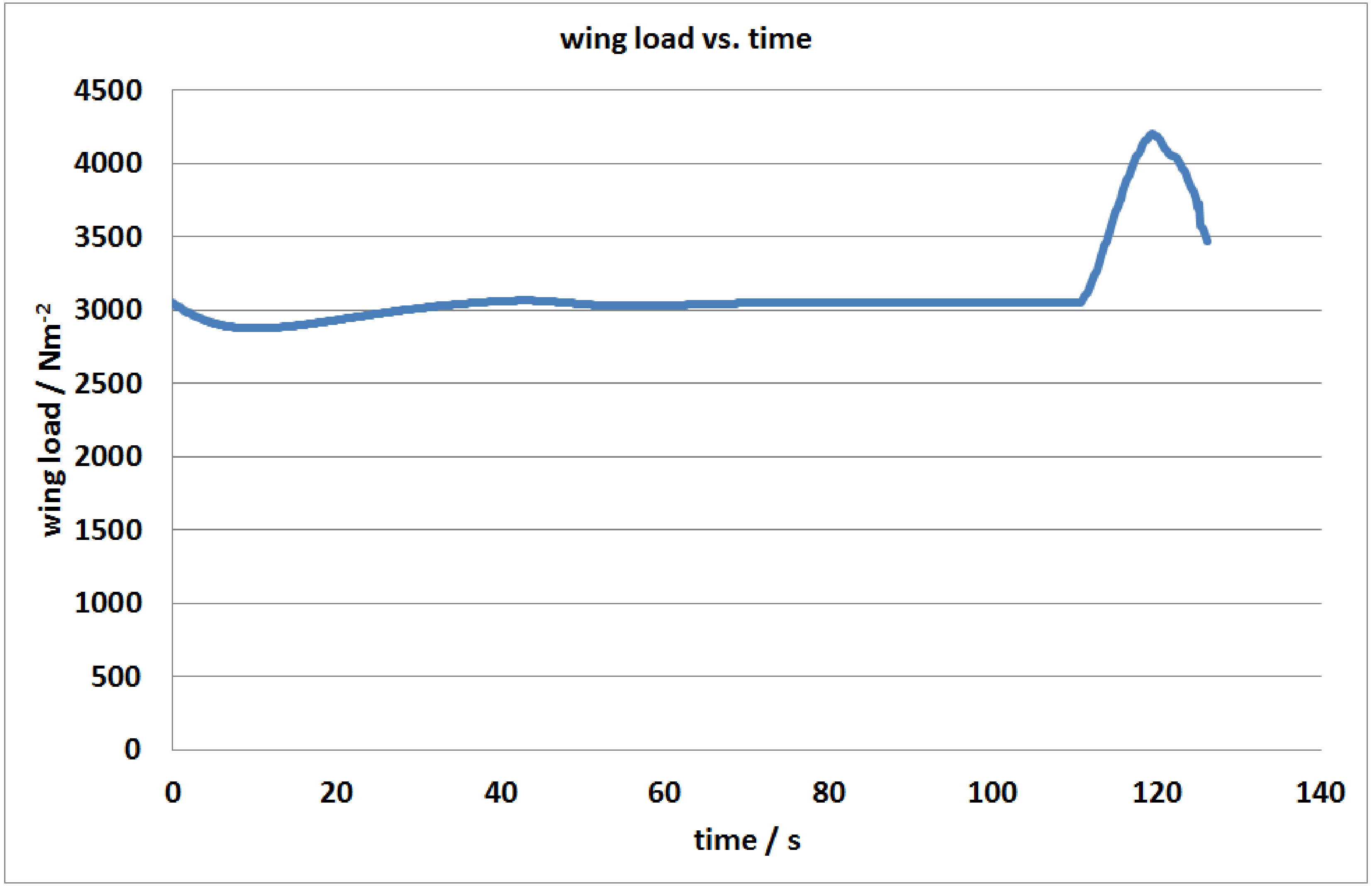

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Discussion & Outlook

- Similar whole descent decline X-Plane / TOSCA with a steep, a nearly time constant and flat decrease phase

Discussion & Outlook

- **Although compressible flow effects are considered using Prandtl-Glauert, the SpaceLiner X-Plane simulation model needs deeper investigation in its transonic and supersonic behavior, taking into account that transonic effects in X-Plane only refer to an empirical mach-divergent drag increase and the airfoil becomes an appropriate thickness ratio diamond shape under supersonic conditions.**

Discussion & Outlook

- **Smooth approach and landing with:**
  - **About 1200 ftagl flare out initiation**
  - **About 200 kts IAS**
  - **Final approach at about 250 kts**
  - **lift-to-drag ratio keeps above the acceptable value of 3.0**[1]

[1]P. M. Sforza, Manned Spacecraft Design Principles, 1st ed., Elsevier Aerospace Engineering Series, Elsevier, November 2015, pp. 175-176.

Discussion & Outlook

- **BUT**
  - **wing loading peak of 4200 N / m2 exceeded the typical maximum values of the F-104 (mod), the X-15 and the Space Shuttle in the range of 3500 to 3800 N / m2[1]**

[1] P. M. Sforza, Manned Spacecraft Design Principles, 1st ed., Elsevier Aerospace Engineering Series, Elsevier, November 2015, pp. 175-176.

Discussion & Outlook

- **Further simulated landing flare flight tests with smoother elevator actuator dynamics for target pitch mode vertical speed of 0 feet per minute and flare out initiation above 1200 ftagl are needed to find a setting not exceeding a wing loading peak 3800 N / m2.**