

Project

Preliminary Sizing of Propeller Aircraft (Part 23)

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Abstract

Purpose – Preliminary sizing and optimization of propeller aircraft certified under EASA CS-23 Amendment 6 or FAA FAR Part 23. Considering relevant certification constraints and typical propulsion concepts for small aircraft. Integration of the method into a user interface known already from other tools being part of Simple Aircraft Sizing and Optimization (SAS) and PreSTo-Classic at HAW Hamburg.

Methodology – The tool uses the proven methodology based on the Matching Chart (power-to-mass versus wing loading), the Excel-Solver and Differential Evolution (DE). Conventional propulsion: Piston engines (Otto, Otto with Turbo Compressor, Diesel) and Turboprop engines are considered. Altitude-dependent power modelling for all engines, and extended propeller efficiency calculations for variable-pitch and fixed-pitch propellers are used. The resulting tool is evaluated with the redesign of a Cessna 172.

Findings – The existing SAS and PreSTo Excel environment known from FAA FAR Part 25 was adapted to ensure continuous user experience. The new optimization tool is "SAS-Part23-Prop". The tool reproduces the selected Cessna 172 reference parameters almost exactly. The redesign shows that consistent assumptions for propeller efficiency, rotational speed, field-length requirements, and validated statistical parameters are essential for obtaining plausible sizing results. In addition, a simple sizing tool "PreSTo-Classic-Part23-Prop" for use in the Aircraft Design lectures is available.

Research Limitations – The results are limited by the simplified equations and statistical parameters used in preliminary sizing. No new statistical database for modern CS-23 aircraft was developed. Electric propulsion concepts are not yet included. The tool is intended for conceptual design and cannot replace detailed analysis in later design phases.

Practical Implications – The tool provides a structured environment for students and designers to evaluate CS-23 propeller aircraft concepts, compare manual and solver-based sizing workflows, and investigate the influence of engine and propeller concepts together with matching power-to-mass and wing loading. Highly automated aircraft preliminary sizing and optimization for new and redesign is possible (SAS-Part23-Prop). Alternatively, a simple tool for hand calculations is offered (PreSTo-Classic-Part23-Prop). The tools are designed to give users a steep learning curve.

Originality – A didactically enhanced design, redesign, and optimization tool (on preliminary sizing level) for small propeller driven aircraft is made openly available. It is especially suited for students and fills a perceived gap.

Preliminary Sizing of Propeller Aircraft (Part 23)

Task for the Project

Background

The Preliminary Sizing Tool (PreSTo-Classic) was developed by the Aircraft Design and Systems Group (AERO) at Hamburg University of Applied Sciences under the supervision of Prof. Dr.-Ing. Dieter Scholz (MSME). It provides a transparent environment for manual aircraft sizing and has been used by over a thousand students for Part 25 jet and propeller aircraft. To extend its capabilities, the Simple Aircraft Sizing (SAS) system was introduced as an optimization-based improvement, linking empirical design equations with solver algorithms. Although SAS-Part25-Prop is available, a corresponding Part 23 propeller version has not yet been implemented. This project therefore continues the AERO tool line — PreSTo-Classic → SAS — by extending the sizing environment to CS-23 propeller aircraft and aligning it with the requirements of EASA CS-23 Amendment 6.

Task

The project aims to adapt and extend the preliminary sizing environment for CS-23 propeller aircraft:

The subtasks are:

- Review EASA CS-23 Amendment 6 and examine whether the sizing procedures implemented in the existing Excel model (Heinemann 2012) remain consistent with current certification requirements.
- Apply the standardized layout and workflow used by *SAS-Part25-Prop* (Krull 2022) to develop a corresponding *SAS-Part23-Prop* version.
- Create a simplified manual version of PreSTo-Classic-Part23-Prop based on Heinemann's Excel model and align it with the structure used by other PreSTo-Classic tools.
- Demonstrate the application of the developed tools using an example CS-23 propeller aircraft configuration implemented within the sizing environment.

The report has to be written in English based on German or international standards on report writing.

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List of Symbols

C_D	Drag coefficient
C_{D0}	Zero-lift drag coefficient
c_h	Empirical correction parameter
C_L	Lift coefficient
$C_{L,max}$	Maximum lift coefficient
D	Propeller diameter
e	Oswald factor
$f(x)$	Fixed-pitch relative efficiency function
J	Advance ratio
k_{App}	Approach parameter
k_E	Glide ratio parameter
k_L	Landing parameter
k_{TO}	Take-off parameter
m	Mass
m_F	Fuel mass
m_{MTO}	Maximum take-off mass
m_{OE}	Operating empty mass
m_{PL}	Payload mass
n	Propeller rotational speed
n_{PAX}	Number of passengers
P_{CR}	Cruise power
P_S	Shaft power
$P_{S,SL}$	Shaft power at sea level
$P_{S,TO}$	Shaft power at take-off
P_{TO}	Take-off power
P/m	Power-to-mass ratio
S_W	Wing area
S_{Wet}	Wetted area
V	Speed
V_{APP}	Approach speed
V_{CR}	Cruise speed
x	Relative advance ratio

Greek Symbols

ρ	Density
ρ_0	Density at sea level
σ	Density ratio
σ_{krit}	Critical density ratio
η_p	Propeller efficiency
$\eta_{p,FP}$	Fixed-pitch propeller efficiency
$\eta_{p,FP,design}$	Fixed-pitch design-point efficiency

List of Abbreviations

AAA	Advanced Aircraft Analysis
AEO	All Engines Operating
AMC	Acceptable Means of Compliance
ASTM	American Society for Testing and Materials
CS	Certification Specification
DE	Differential Evolution
DOE	Design of Experiments
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FLOPS	Flight Optimization System
JPAD	Java Programs for Aircraft Design
KCAS	Knots Calibrated Airspeed
LSA	Light Sport Aircraft
LTF-UL	Lufttüchtigkeitsforderungen an ein aerodynamisch gesteuertes Ultraleichtflugzeug Airworthiness requirements for an aerodynamically controlled ultralight aircraft
MDO	Multidisciplinary Design Optimization
MTOW	Maximum Take-Off Weight
NASA	National Aeronautics and Space Administration
MDAO	Multidisciplinary Design Analysis and Optimization
OEI	One Engine Inoperative
OpenVSP	Open Vehicle Sketch Pad
UL	Ultralight
PreSTo	Preliminary Sizing Tool
PS	Preliminary Sizing
RDSwin	Raymer Design System for Windows
SAS	Simple Aircraft Sizing
S.C.	Service Ceiling
SUAVE	Stanford University Aerospace Vehicle Environment
TC	Turbocharger
VLA	Very Light Airplanes
VSPAERO	Vehicle Sketch Pad Aerodynamics

List of Definitions

Design Point

The design point is defined as the intersection of all performance constraints in the matching chart and represents a feasible combination of wing loading and power-to-mass ratio (Scholz 2015).

Matching Chart

The matching chart is a graphical method used in preliminary aircraft sizing to solve a two-dimensional optimization problem. It represents the relationship between key design variables, typically wing loading and thrust-to-weight or power-to-mass ratio, and combines performance constraints from different flight phases to determine a feasible design point. (Scholz 2015; Heinemann 2012)

Power-to-Mass Ratio

The power-to-mass ratio describes the ratio between installed engine power and aircraft mass and is a primary sizing parameter for propeller-driven aircraft (Heinemann 2012).

Preliminary Sizing

Preliminary sizing refers to the early design phase in which key aircraft parameters are estimated using simplified analytical relations and statistical methods (Scholz 2015).

Wing Loading

Wing loading is defined as the ratio of aircraft mass to wing area and is a fundamental parameter influencing aircraft performance and sizing (Scholz 2015).

1 Introduction

1.1 Motivation

Preliminary sizing is one of the most important steps in aircraft design, as it defines the basic mass, geometry, and performance parameters before detailed design activities are performed. Within the Aircraft Design and Systems Group (AERO), several tools have been developed for this purpose, including PreSTo-Classic and Simple Aircraft Sizing (SAS).

While these tools exist for Part 25 jet and propeller aircraft, a corresponding implementation for Part 23 propeller aircraft has not yet been developed. As a result, students and designers lacked a standardized environment to perform reliable sizing studies for smaller aircraft categories.

Developing a Part 23 version closes this gap. It enables direct comparison between certification levels (CS-23 and CS-25) and provides an accessible educational platform for both manual and optimization-based aircraft sizing. The simplified Excel environment also enhances understanding of aircraft design fundamentals, supporting both academic teaching and practical application.

1.2 Title Terminology

Preliminary Sizing refers to the first stage of aircraft design in which key mass, performance, and geometric parameters are estimated based on a limited set of mission and certification requirements. At this stage, the aircraft is represented through simplified analytical relations rather than a detailed geometric model (based on Scholz 2015).

Part 23 (FAA) and CS-23 (EASA) define certification requirements for normal, utility, aerobatic and commuter airplanes. These regulations apply to smaller aircraft categories. In earlier versions, CS-23 covered aircraft with up to 19 passengers and a maximum take-off mass of 8618 kg, while recent amendments adopt a performance- and risk-based approach (EASA 2015; EASA 2023).

The title therefore reflects the development of a preliminary sizing methodology and corresponding tool specifically adapted to propeller aircraft in the CS-23 category.

1.3 Objectives

The main objective of this project is the development of a consistent preliminary sizing environment for CS-23 propeller aircraft based on the existing AERO tools PreSTo-Classic and Simple Aircraft Sizing (SAS). The tool is adapted to allow the application of the current regulatory framework defined by EASA CS-23 Amendment 6.

A further objective is the transfer of the standardized layout and workflow implemented in SAS-Part25-Prop to a corresponding SAS-Part23-Prop version, thereby establishing a consistent structure within the AERO sizing tool family. In addition, a simplified PreSTo-Classic-Part23-Prop tool is developed to enable transparent manual sizing studies and to support educational applications as well as parameter evaluation in preliminary aircraft design.

1.4 Previous Research

This project builds upon previous research in the field of preliminary aircraft sizing conducted within the Aircraft Design and Systems Group (AERO) at Hamburg University of Applied Sciences. The methodological basis is the matching chart approach for conceptual aircraft design, which has been described and applied in several studies on aircraft preliminary sizing and performance estimation (Scholz 2008).

A consistent preliminary sizing framework for smaller aircraft categories was developed by Heinemann (2012), who implemented a structured Excel-based environment for the analysis of FAR-23 and CS-23 aircraft configurations. This work established the foundation for later tool developments within the AERO group.

Further development of these sizing tools focused on improving usability, structure, and automation. In particular, Krull (2022) introduced the SAS framework, which extends the PreSTo methodology by integrating numerical optimization algorithms into the sizing process and by standardizing the workflow of the Excel-based tool environment.

In addition, the author's Bachelor project (Gmelin 2021) analyzed statistical parameters relevant to preliminary aircraft sizing using microlight aircraft as a reference class. These results provide useful background for the present work, which focuses on extending the sizing environment to propeller aircraft in the CS-23 category.

1.5 Literature Review

Previous research within the Aircraft Design and Systems Group (AERO) has established a methodological framework for preliminary aircraft sizing based on simplified analytical relations and statistical aircraft data. The educational sizing tool PreSTo-Classic, developed under the supervision of Scholz, provides a transparent environment for manual aircraft sizing and has been widely used for conceptual design studies of CS/FAR Part 25 jet and propeller aircraft. Heinemann (2012) extended this approach by implementing a structured Excel-based sizing environment for smaller aircraft categories. His work provided a consistent framework for analyzing FAR-23 and CS-23 aircraft configurations.

The SAS (Simple Aircraft Sizing) concept was later introduced to complement the PreSTo methodology with solver-based optimization capabilities derived from the more advanced OPerA tool environment. Further development of the sizing tools focused on improving structure and usability. In this context, Krull (2022) developed PreSTo-Classic-Prop and SAS-Part25-Prop and established the standardized layout and workflow that is now used across the SAS tool family.

In addition to the development of the sizing tools, several studies refined empirical relations relevant for preliminary aircraft design. These include statistical models for wing mass, operating empty mass and mass growth factors (Scholz 2020a, 2020b). For propeller aircraft, performance relations based on the work of Marckwardt (1998) and Truckenbrodt (1999) provide the aerodynamic basis for simplified propeller efficiency estimation.

Together, these developments form the methodological and statistical foundation for the present work, which extends the PreSTo and SAS environments to propeller aircraft in the CS-23 category.

The developed Excel-based sizing tools SAS-Part23-Prop and PreSTo-Classic-Part23-Prop are provided as supplementary material to this work. The datasets and tools are available via the following DOIs:

SAS-Part23-Prop:

<https://doi.org/xxxxxxx>

PreSTo-Classic-Part23-Prop:

<https://doi.org/xxxxxxx>

1.6 Structure of the Work

The content of this project is structured as follows:

- Chapter 2** presents the background and state of the art. It provides an overview of the existing PreSTo and SAS systems, their development history, and the regulatory context, including differences between CS-25, CS-23 and microlight regulations.
- Chapter 3** reviews the EASA CS-23 Amendment 6 framework with particular emphasis on aspects relevant for preliminary aircraft sizing and discusses the main differences compared with earlier CS-23 requirements. This chapter forms part of the methodological foundation of the work.
- Chapter 4** describes the adaptation of the existing PreSTo and SAS Excel tools to the CS-23 certification framework. The chapter focuses on the structural and methodological adjustments required to enable consistent preliminary sizing of small propeller-driven aircraft and represents the main results of the work.
- Chapter 5** provides a concise quick-start guide to the SAS Part-23 Excel tool. It explains the basic workflow and illustrates how a typical sizing run is prepared and executed, thereby demonstrating the practical application of the developed methodology.
- Chapter 6** summarizes the results of the project and discusses limitations as well as possible directions for future work.

2 Background and State of the Art

2.1 Preliminary Sizing Tools and Positioning of SAS

Preliminary aircraft design is supported today by a broad spectrum of tools that range from transparent spreadsheet-based sizing environments to highly integrated multi-disciplinary conceptual design frameworks. These tools differ substantially in fidelity, level of automation, accessibility, and intended application domain. While some systems are optimized for rapid educational use and conceptual trade studies, others are tailored to industrial workflows and early-stage product development with integrated aerodynamics, structures, mission analysis, and optimization capabilities. The selection of a suitable tool therefore depends on the certification context (e.g. CS-23 vs. CS-25), required transparency, and the desired balance between manual traceability and automated design-space exploration.

Within this landscape, the PreSTo and SAS tools developed at Hamburg University of Applied Sciences represent a transparent and didactically structured approach to preliminary sizing. In order to position SAS within the broader tool ecosystem, the most relevant existing preliminary design environments are briefly outlined below.

SUAVE (Stanford University Aerospace Vehicle Environment) is an open-source conceptual aircraft design framework written in Python, developed by the Stanford University Aerospace Design Lab. It enables multi-fidelity analysis by coupling aerodynamics, propulsion, mission simulation, weight estimation, and optimization within a flexible and extensible architecture. SUAVE is primarily applied in academic research, particularly for unconventional configurations and electric or hybrid-electric aircraft concepts, where modular analysis and rapid configuration changes are required (Lukaczyk et al. 2015).

OpenVSP (Open Vehicle Sketch Pad) is an open-source parametric aircraft geometry tool developed by NASA. It allows rapid parametric modeling of aircraft geometries and includes aerodynamic analysis capabilities through **VSPAERO**. While OpenVSP does not constitute a full preliminary sizing environment with integrated performance and weight loops, it is widely used in early conceptual design phases to generate consistent geometries that can be coupled to external performance, mission, or optimization tools (NASA 2026).

The **Java Programs for Aircraft Design (JPAD)** framework was developed at Hamburg University of Applied Sciences as a modular software environment for preliminary aircraft design. JPAD allows structured object-oriented modeling of aircraft components and supports parametric studies and integration of analysis modules. Compared to PreSTo and SAS, JPAD represents a more software-oriented and extensible approach while maintaining academic accessibility (De Marco 2015).

RDSwin (Raymer Design System for Windows) is a commercial conceptual aircraft design software developed by Daniel P. Raymer. It provides an integrated environment for conceptual design, including statistical mass estimation, mission analysis, performance sizing, geometric definition, cost estimation, and constraint evaluation. Based on the methodology presented in *Aircraft Design: A Conceptual Approach* (Raymer 1992), the software automates classical handbook methods through iterative routines, internal databases, and parametric trade-study capabilities (Raymer 2026).

The Raymer Design System was also investigated in the diploma thesis *Flugzeugentwurf mit dem Programm RDS* (Walde 2000). The study showed that the software enables efficient design iteration once the input parameters are properly defined but also emphasized that engineering judgement and preliminary hand calculations remain necessary to interpret the results correctly.

Advanced Aircraft Analysis (AAA) is a commercial software tool developed by DARcorporation for conceptual and preliminary aircraft design. It integrates statistical weight estimation, aerodynamic and propulsion performance analysis, mission simulation, constraint evaluation, stability and control assessment, and cost estimation within a structured design environment. The software supports iterative trade studies and parametric investigations across different aircraft configurations. While AAA offers a higher degree of automation and integrated database support compared to spreadsheet-based sizing tools, its methodological foundation remains rooted in classical regression-based weight estimation and constraint-based preliminary sizing approaches (DARcorp 2023).

FLOPS (Flight Optimization System) is a multidisciplinary conceptual design program originally developed at NASA Langley Research Center. It integrates modules for weight estimation, aerodynamics, propulsion, mission performance, take-off and landing analysis, noise estimation, and cost analysis. Due to its complexity and focus on transport aircraft, FLOPS is primarily used for transport-category design studies and represents a comprehensive but less didactically transparent approach compared with spreadsheet-based sizing environments (Wells et al., 2017).

OpenMDAO (2026) is a general-purpose open-source framework for multidisciplinary design optimization developed in Python. According to its official documentation, it provides modular model integration, analytic derivative support, parallel computing capabilities, and gradient-based optimization algorithms. The framework is domain-independent and serves as an infrastructure for coupling discipline-specific analysis models rather than as a dedicated aircraft preliminary sizing tool. Applications documented in recent aerospace studies, including investigations of the NASA X-57 Maxwell and boundary layer ingestion configurations, illustrate its use for tightly coupled aero-propulsive system analysis and optimization (Gray et al., 2018).

OpenConcept is an open-source conceptual design and optimization toolkit built on the OpenMDAO framework, introduced by Brelje and Martins (2018) specifically for aircraft incorporating electric and hybrid-electric propulsion. It provides a library of conceptual-level propulsion component models, mission analysis routines for aircraft sizing, and full gradient-based multidisciplinary design optimization through analytically differentiated code. OpenConcept additionally supports parametric cost modeling and thermal management at the component level, enabling realistic constraints in optimization studies (Brelje and Martins 2018). Compared to more generalist frameworks such as SUAVE, OpenConcept places stronger emphasis on optimization-driven design exploration and emerging propulsion technologies.

Taken together, these tools illustrate a wide spectrum of contemporary preliminary aircraft design environments, ranging from transparent spreadsheet-based sizing systems to highly integrated multidisciplinary optimization frameworks and commercial conceptual design platforms. Research-oriented frameworks such as SUAVE, OpenConcept, or OpenMDAO emphasize tight disciplinary coupling and optimization-driven design exploration, while commercial systems such as RDSwin or AAA focus on integrated workflows and database-supported analyses.

Within this landscape, SAS occupies an intermediate position. By deliberately retaining Excel-based architecture, SAS ensures full traceability of equations and direct insight into the matching chart methodology while also incorporating automated optimization routines. This approach bridges the gap between manual spreadsheet sizing and fully integrated MDO environments and is therefore particularly well suited for educational applications where methodological transparency and conceptual understanding are essential.

2.2 PreSTo-Classic and SAS Systems

The preliminary sizing tool PreSTo-Classic and the Simple Aircraft Sizing (SAS) system were developed within the Aircraft Design and Systems Group (AERO) at Hamburg University of Applied Sciences as educational tools for preliminary aircraft sizing, under the supervision of Dieter Scholz. PreSTo-Classic provides a transparent, Excel-based environment for manual aircraft sizing based on established design methods, while SAS extends this approach by introducing automated optimization capabilities. Both tools share a common conceptual foundation based on the matching chart method and have been applied to various certification contexts, including microlight, CS-23, and CS-25 aircraft. (Scholz 2008; Heinemann 2012)

The theoretical background, mathematical formulations, and optimization algorithms implemented in PreSTo and SAS are documented in detail in previous work by Scholz (2008), Heinemann (2012) and Krull (2022) and are therefore not repeated in this project.

In PreSTo-Classic, the sizing process is divided into several worksheets reflecting the sequential design steps of the matching chart method. The core worksheets typically include input data, preliminary sizing for take-off and landing (PS I), cruise and climb performance (PS II), the matching chart, and supporting documentation (Scholz 2008).

The Simple Aircraft Sizing (SAS) system was introduced later as an optimization-based extension of PreSTo-Classic. According to Heinemann (2012), SAS was derived from the advanced OPerA tool by simplifying its structure while retaining its optimization logic. SAS provides solver-based optimization using Design of Experiments (DOE) and Differential Evolution (DE) algorithms implemented in VBA, allowing automated variation of key design parameters such as wing loading and power-to-mass ratio to minimize maximum take-off mass or another selected objective. (Heinemann 2012)

The common methodological core of both tools is the matching chart method. In preliminary sizing, a selected aircraft configuration — defined by a rough wing and fuselage layout and a propulsion system — is graphically optimized using a design diagram. The matching chart represents the interaction of performance constraints from different flight phases and allows identification of a feasible and balanced design point. A schematic illustration of the matching chart principle is shown in Figure 2.1 (Scholz 2015).

For jet-powered aircraft, the matching chart is based on the thrust-to-weight ratio $T_{TO}/(m_{MTO}g)$ plotted against the wing loading m_{MTO}/S_W . Each performance requirement (take-off, climb, cruise, landing) defines a limiting curve in this diagram, and the intersection of all constraints defines the design point. (Scholz 2015)

For propeller-driven aircraft, thrust is replaced by power. Accordingly, the matching chart is formulated using the power-to-mass ratio P_{TO}/m_{MTO} on the vertical axis and the wing loading m_{MTO}/S_W on the horizontal axis. The underlying principle remains identical: each flight-phase requirement restricts the feasible design space and the design point is selected at the intersection of all relevant constraints. A schematic illustration of the matching chart principle is shown in Figure 2.1 (Gmelin 2021; Scholz 2015).

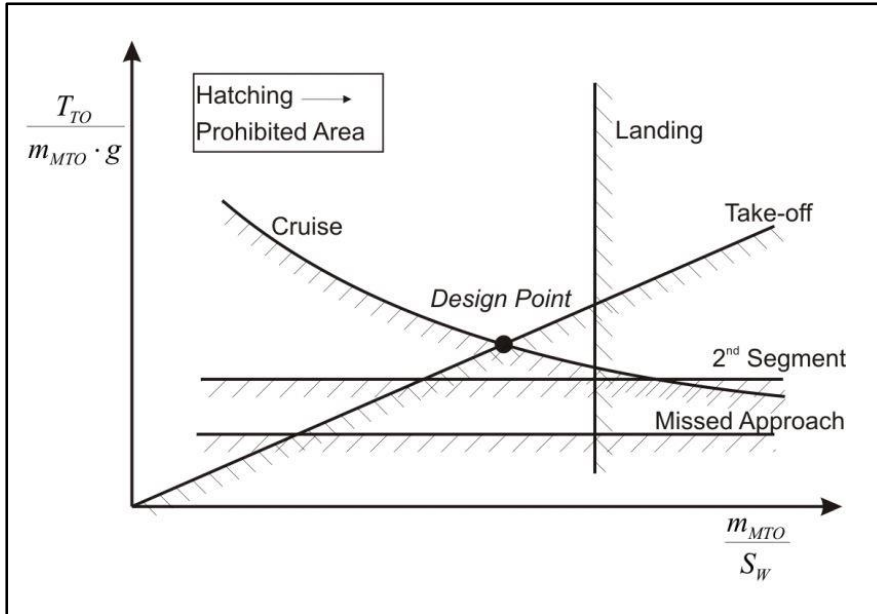


Figure 2.1 Matching Chart for Aircraft with Jet Engines (Scholz 2015, Chapter 5)

The PreSTo series emphasizes transparency and didactic clarity, while SAS focuses on automation and reproducibility for parametric studies. Together, they form a coherent educational framework for preliminary aircraft sizing across multiple aircraft classes. The present project extends this framework by introducing dedicated PreSTo-Classic-Part23-Prop and SAS-Part23-Prop tools, thereby closing the methodological gap between small and large propeller-driven aircraft. (Scholz 2008; Heinemann 2012)

2.3 Light Aircraft Reference and Statistical Basis

Microlight aircraft represent the lower end of the performance and mass spectrum in aircraft design and are characterized by strict limitations on maximum take-off mass, stall speed, and field length. The author's Bachelor project *Microlight Aircraft* applied the PreSTo methodology to this aircraft class and serves as a direct reference for the present work. Due to their low kinetic energy and simplified certification requirements, microlight aircraft provide a suitable baseline for understanding the transition from national ultralight regulations to the more comprehensive international CS-23 framework.

The overall design objective is to achieve the lowest possible power-to-mass ratio while maintaining acceptable field lengths and climb capability. This optimization can be performed manually in *PreSTo-Classic* by adjusting the design point, or automatically in *SAS* using differential-evolution algorithms that minimize maximum take-off mass (MTOM). Empirical parameters such as the approach-speed coefficient k_{APP} , the take-off parameter k_{TO} , the climb parameter k_E , the relative operating empty mass ratio m_{OE}/m_{MTO} , and the wetted-area ratio S_{wet}/S_W represent statistically derived characteristic values within the SAS framework.

These parameters condense historical aircraft data into simplified performance and mass relationships suitable for preliminary sizing. The coefficient k_{APP} relates stall speed to approach speed and therefore directly influences landing constraints and allowable wing loading. The parameter k_{TO} characterizes take-off field-length behavior, while k_E represents climb performance characteristics. The relative operating empty mass ratio captures typical structural and systems mass fractions, and the wetted-area ratio is used for drag estimation within simplified aerodynamic modeling.

Most of these statistical relationships have historically been derived from transport-class or larger general aviation aircraft datasets. For smaller aircraft categories such as microlight, LSA, or LTF-UL, comprehensive statistical validation remains limited. Consequently, careful calibration against comparable reference aircraft is required when applying these parameters to small CS-23 or ultralight configurations.

In summary, the AERO sizing methodology unifies the manual transparency of PreSTo with the optimization capability of SAS, following a consistent theoretical foundation. This provides a consistent basis for preliminary aircraft sizing across certification levels.

2.4 Certification Context: CS-25, CS-23 and Microlight

Aircraft certification requirements differ significantly between transport aircraft (CS-25), small and medium general aviation aircraft (CS-23), and microlight aircraft. These categories reflect different operational risks, system complexity, and intended use, which directly influence preliminary sizing assumptions.

Transport aircraft certified under CS-25 represent the highest certification level and are intended for commercial passenger and cargo operations. They are characterized by high maximum take-off masses, large seating capacities, and extensive system redundancy. Performance requirements emphasize payload capability, range, and efficiency, and certification rules impose strict numerical margins for take-off, climb, and landing performance. As a result, CS-25 aircraft are typically optimized using conservative design assumptions and substantial performance reserves, making CS-25 sizing methodologies unsuitable for direct application to smaller aircraft classes without significant adaptation. (Heinemann 2012)

CS-23 applies to small propeller-driven aircraft with a maximum of 19 occupants, and a historical maximum take-off mass of approximately 8.6 t. Typical applications include general aviation, training, utility, and commuter aircraft. Compared to CS-25, CS-23 aircraft feature simplified systems, reduced redundancy, and lower operational risk. From a preliminary sizing perspective, CS-23 aircraft are mainly constrained by stall speed (typically $V_{S0} \leq 61$ kt for

single-engine aircraft), take-off and landing distances, and climb capability (e.g. climb gradients of approximately 3–4 %), rather than by payload–range optimization. (Heinemann 2012)

In addition, certification performance definitions differ between aircraft categories. For both CS-23 and CS-25 aircraft, take-off performance is typically evaluated with respect to an obstacle height of 35 ft, while landing performance refers to an obstacle height of 50 ft. However, transport aircraft certified under CS-25 are subject to significantly more complex performance requirements, including balanced field length considerations and multiple climb segments following an engine-failure scenario. These additional requirements strongly influence preliminary sizing and often govern the selection of thrust-to-weight ratio and wing loading for transport-category aircraft. (Heinemann 2012)

With the introduction of CS-23 Amendment 6, the certification philosophy shifted from prescriptive numerical limits to a performance- and risk-based framework. Consequently, traditional sizing constraints are no longer interpreted as fixed regulatory thresholds but as design targets that must be justified through acceptable means of compliance. This shift has direct implications for preliminary sizing tools such as PreSTo and SAS. (EASA, 2023)

Microlight aircraft form a distinct category below CS-23 and are not regulated under EASA certification specifications, but under national regulations. In Germany, microlight aircraft are certified according to LTF-UL and are limited to two occupants and a maximum take-off mass of 600 kg (for landplanes), with strict limits on stall speed (typically $V_S \leq 45$ kt) and simplified airworthiness requirements. Microlight regulations emphasize minimal mass, low kinetic energy, and short-field capability (typically below 300 m), and system complexity is intentionally kept low. As a result, preliminary sizing is primarily driven by maximum take-off mass and stall speed constraints. (Gmelin, 2021; LTF-UL 2019)

In the United States, no direct equivalent to the European microlight category exists. Aircraft of comparable performance are typically operated as Light-Sport Aircraft (LSA), which are approved under ASTM consensus standards rather than under FAR-23. LSA are limited to two occupants, a maximum take-off mass of approximately 600 kg (1 320 lb), a maximum stall speed of 45 kt, and a maximum level-flight speed of 120 kt, but do not require a conventional type certificate. (Heinemann, 2012; ASTM International, 2023)

Between microlight/LSA aircraft and CS-23 aircraft, CS-VLA (Very Light Aircraft) represents a simplified EASA certification category for aircraft with up to two occupants and a maximum take-off mass of 750 kg. CS-VLA aircraft are fully certified but follow reduced requirements compared to CS-23. (EASA, 2018)

From a preliminary sizing perspective, CS-25, CS-23, and microlight aircraft therefore represent three distinct design regimes. CS-25 focuses on efficiency and payload capability at high mass levels, CS-23 balances performance and simplicity for general aviation aircraft, while microlight aircraft prioritize minimal mass and regulatory simplicity. The present project builds on the CS-23 framework and uses microlight statistics and established CS-25 sizing methodologies as reference points, without repeating their full theoretical derivation. (Heinemann, 2012; Gmelin, 2021)

3 CS-23 Certification Framework and Amendment 6

The designation “Part 23” originates from the Federal Aviation Regulations (FAR Part 23) issued by the Federal Aviation Administration (FAA) in the United States. In Europe, the corresponding regulatory framework is defined by the Certification Specifications CS-23 issued by the European Union Aviation Safety Agency (EASA). While both systems were historically developed independently, they have been progressively harmonized over recent decades.

The technical structure of FAR Part 23 and CS-23 has been substantially harmonized following the comprehensive regulatory reform introduced by the FAA in 2017 and subsequently adopted by EASA in CS-23 Amendment 5. Both authorities transitioned from prescriptive design requirements toward performance- and objective-based airworthiness standards (FAA, 2017; EASA, 2017). Remaining differences primarily concern administrative implementation and regional regulatory procedures rather than fundamental flight-mechanical performance criteria.

In the context of the present work, the term “SAS-Part23” refers to the historical naming convention of the Excel tool developed within the AERO group. However, the certification analysis performed in this project is based on the current EASA Certification Specifications CS-23, including Amendment 6.

For consistency within this project, the regulatory framework is therefore referred to as CS-23 when discussing certification requirements. The term “Part 23” is retained only where it explicitly refers to the historical naming of the SAS tool or to earlier literature sources.

3.1 CS-23 Framework Before Amendment 6

Prior to Amendment 6, CS-23 followed a predominantly prescriptive certification philosophy, closely aligned with earlier versions of FAR Part 23. Compliance was demonstrated by satisfying explicit numerical requirements that directly constrained aircraft performance. Aircraft categories were primarily defined by maximum take-off mass and seating capacity, resulting in uniform certification requirements across a wide range of aircraft types. From a preliminary sizing perspective, this led to a deterministic design space, where key performance parameters such as stall speed, take-off and landing field length, and climb gradients could be implemented as fixed boundaries in sizing tools. The most relevant parameters affecting preliminary sizing under the pre-Amendment-6 CS-23 framework included a maximum allowable stall speed in the landing configuration, defined relationships between stall and approach speed, fixed margins for take-off and landing field lengths, and predefined

climb-gradient requirements for both all-engines-operating and engine-failure conditions. These parameters formed the numerical basis of classical preliminary sizing methods and are partially reflected in the constraint formulation presented in the following chapter.

3.2 Key Certification Parameters and Sizing Constraints

Under the former CS-23 framework, compliance with fixed numerical limits resulted in clearly defined sizing constraints. These certification limits translated directly into performance boundaries that could be implemented in the matching chart. In practical preliminary sizing, the constraints can be grouped into three main categories: stall-related limits governing wing loading, field-length requirements influencing both wing loading and installed power, and climb-gradient requirements primarily determining minimum engine power. Table 3.1 summarizes the most relevant certification parameters affecting preliminary sizing prior to Amendment 6.

Table 3.1 Key CS-23 Certification Parameters Prior to Amendment 6
(based on Heinemann 2012; EASA 2015)

Parameter	Pre-Amendment-6 CS-23	Sizing relevance
Stall speed V_{S0}	≤ 61 kt (single engine ≤ 2722 kg)	Direct limit on wing loading
Approach speed V_{APP}	$\geq 1.3 \cdot V_{S0}$	Governs landing performance
Take-off field length	$\leq$ balanced field length + 15 %	Limits power loading
Landing field length	Defined margin to landing distance	Limits wing loading
Climb gradient (AEO)	Positive climb required	Minimum installed power
Climb gradient (OEI)	≥ 4.0 % (twin engine)	Dominant power sizing driver

From a preliminary sizing perspective, stall speed and landing requirements mainly limit how high the wing loading may be. In contrast, take-off and climb requirements determine how much power must be installed. For many light single-engine aircraft, landing performance often defines the upper wing-loading boundary, whereas for twin-engine aircraft, climb performance in engine-failure conditions frequently drives the required installed power.

Because these numerical limits were fixed and explicitly defined, they provided hard constraint boundaries for preliminary sizing. The matching chart could therefore be constructed with clearly defined limits, allowing optimization to be performed directly against these regulatory thresholds without significant interpretative adjustment.

3.3 CS-23 Amendment 6: Performance and Risk-Based Certification

With CS-23 Amendment 6, EASA fundamentally restructured the certification philosophy for normal category airplanes. The former prescriptive framework, which relied on fixed numerical performance limits embedded directly in the regulation, was replaced by a performance- and risk-based approach. Instead of mandating explicit design solutions or universally applicable numerical thresholds, the regulation now defines safety objectives that must be achieved under the intended operating conditions. Compliance is demonstrated through acceptable means of compliance (AMC), consensus standards, or equivalent safety arguments provided by the applicant.

A central structural element introduced with Amendment 6 is the classification of aircraft into four certification levels. The level assignment is primarily determined by the maximum passenger seating configuration, denoted as n_{PAX} . The certification levels are defined as follows:

- Level 1: Aircraft with a maximum passenger seating configuration of 0–1 passenger
- Level 2: Aircraft with 2–6 passengers
- Level 3: Aircraft with 7–9 passengers
- Level 4: Aircraft with 10–19 passengers

The parameter n_{PAX} refers exclusively to passenger seats and does not include flight crew. A configuration with “0 passengers” therefore corresponds to a single-seat aircraft (pilot only). CS-23 applies exclusively to manned airplanes; unmanned aircraft systems are certified under separate regulatory frameworks and are not covered by CS-23. As the certification level increases, the required depth of safety assessment becomes progressively more demanding. Higher levels require more comprehensive system safety analyses, stricter failure-condition classification, more detailed reliability demonstrations, and increased substantiation of structural and system integrity. In particular, quantitative probability targets for hazardous and catastrophic failure conditions become more stringent with increasing level.

It should be noted that within the SAS tool the parameter n_{PAX} in the Input tab is typically defined including the pilot, which differs from the formal CS-23 definition where n_{PAX} refers exclusively to passenger seats and explicitly excludes flight crew. The interpretation in the SAS environment therefore depends on the statistical data used for mass calibration. If manufacturer data for operating empty mass m_{OE} are taken from published specifications, these values are usually defined without pilot mass. In that case, the number of people entered as n_{PAX} in the SAS tool must correspond to the total number of occupants on board, including the pilot. Conversely, if relative operating empty mass ratios or statistical mass fractions are defined including pilot mass, the input convention must be adapted accordingly. Consistency between

n_{PAX} definition and reference mass data is therefore essential in order to avoid systematic mass misinterpretation during preliminary sizing.

In addition to certification levels, CS-23 distinguishes between performance classes based on aircraft speed capability. The classification is defined by the design cruise speed V_C and the design dive Mach number M_D . An aeroplane is considered high-speed if V_C exceeds 250 KCAS (463 km/h) or if M_D exceeds 0.6. Aircraft below these thresholds are classified as low-speed airplanes. This distinction affects the applicability of requirements related to compressibility effects, Mach buffet margins, flutter substantiation, high-speed controllability, and structural divergence. High-speed airplanes must demonstrate compliance with additional aerodynamic and structural criteria associated with transonic or high-Mach operation, whereas low-speed airplanes are not subject to these requirements. (EASA 2023)

Under the pre-Amendment-6 framework, parameters such as maximum stall speed, take-off and landing field length, and climb gradients were explicitly prescribed as fixed numerical limits for certain aircraft categories. Under Amendment 6, these parameters are no longer universally embedded as mandatory numerical thresholds within the regulation itself. Instead, they are evaluated in the context of safety objectives related to controllability, operational safety, hazard severity, and system reliability. The underlying aerodynamic and flight-mechanical relationships remain unchanged; wing loading continues to determine stall behavior and thrust- or power-to-mass ratio continues to govern climb and take-off performance. What has changed is the interpretation of the regulations: compliance is now demonstrated on the basis of performance targets rather than generally defined numerical limits that are directly derived from the regulations.

3.4 Implications for Preliminary Sizing Tools

Although CS-23 Amendment 6 fundamentally changes the certification philosophy, it does not introduce a methodological break in preliminary aircraft sizing. The aerodynamic and flight-mechanical relationships governing aircraft performance remain unchanged. Stall behavior is still determined by wing loading and maximum lift coefficient, climb capability remains governed by power-to-mass ratio, and field performance continues to depend on thrust or shaft power relative to aircraft mass. The physics underlying the matching chart methodology therefore remains fully valid.

What has changed is not the technical foundation of sizing, but the regulatory interpretation of performance limits. Under the former prescriptive framework, fixed numerical thresholds such as maximum stall speed or defined climb gradients acted as hard constraint boundaries within preliminary sizing tools. Under Amendment 6, these numerical limits are replaced by safety objectives and performance intents. As a result, the definition of acceptable constraint

boundaries now requires greater engineering judgement and consideration of the intended operational environment.

For preliminary sizing tools such as PreSTo and SAS, this development does not reduce their relevance; rather, it enhances their role. Instead of optimizing strictly against rigid regulatory thresholds, the tools now support the definition of technically plausible and safety-consistent design targets. The matching chart constraints continue to represent performance boundaries, but these boundaries are interpreted as engineering design objectives aligned with the selected certification level and risk category.

This shift allows for greater flexibility in the conceptual design process. It enables designers to explore trade-offs with a clearer understanding of their safety implications rather than simply satisfying fixed numerical minimums. Preliminary sizing tools therefore remain essential for consistency checks in the early stages, ensuring that a concept aircraft can realistically achieve the performance intent of CS-23 within its assigned certification level. This methodological continuity allows the existing PreSTo and SAS framework to be adapted to the CS-23 Amendment 6 philosophy without altering its fundamental sizing logic. The specific adaptations implemented in the tool structure are described in the following chapter.

4 **Adaptation of PreSTo and SAS to CS-23 (Methods and Results)**

The adaptation of the existing PreSTo and SAS sizing tools to the CS-23 certification framework required both structural and methodological modifications. An original SAS-Part23 Excel file, provided internally by the supervising professor, served as the starting point and contained a preliminary example based on a Cessna 172 configuration. However, its internal logic and user interface were not fully aligned with the standardized SAS-Part25 design philosophy.

The present work therefore focused on harmonizing the overall structure, improving propulsion modeling consistency, and implementing a flexible engine-type switching logic suitable for small propeller-driven aircraft. The propulsion module now allows selection between *Piston (Otto)*, *Piston (Otto, TC)*, *Piston (Diesel)*, and *Turboprop* configurations. This structured engine selection ensures a consistent representation of altitude-dependent power behavior and matching chart formulation across different propulsion concepts while maintaining compatibility with the established SAS framework.

In addition to the engine-type selection, the propeller type was introduced as a further input option. The user can now distinguish between a variable-pitch propeller and a fixed-pitch propeller. This extension is required because many CS-23 piston aircraft, such as the Cessna 172, use fixed-pitch propellers. In contrast to a variable-pitch propeller, a fixed-pitch propeller cannot maintain an optimum blade angle over the complete flight envelope. Its efficiency therefore varies with the relative advance ratio and is represented separately from the variable-pitch formulation, using phase-specific rotational speeds.

The objective was not to redesign the sizing methodology itself, but to ensure that the CS-23 tool remains fully consistent with the established AERO matching chart philosophy while accurately reflecting the performance characteristics of piston and turboprop propulsion systems.

Additionally, minor adjustments were implemented to improve numerical robustness and ensure stable design-point determination across different solver configurations. These modifications do not alter the underlying sizing logic but enhance reproducibility and computational consistency.

4.1 Structural Harmonization and Interface Standardization

The restructuring of the SAS-Part23-Prop tool aimed at achieving full structural consistency with the standardized SAS design architecture. User-defined inputs, internal calculation blocks, and result areas were systematically separated and visually distinguished in order to prevent unintended modifications and to align the reporting structure with the established SAS-Part25 standard, thereby maintaining methodological transparency.

In addition, uniform naming conventions for key variables were introduced across worksheets to avoid ambiguities in solver referencing and cross-sheet dependencies. Cell-link consistency was verified to eliminate redundant or legacy references originating from earlier tool versions. Parallel to the SAS adaptation, a corresponding PreSTo-Classic-Part23-Prop tool was created by transferring the established PreSTo-Classic-Part25-Prop layout to the CS-23 context. While the structural framework and workflow philosophy were retained, performance assumptions and statistical parameter sets were updated to reflect the characteristics of small propeller-driven aircraft.

Through this harmonization, both tools now follow a consistent structural logic, enabling direct comparability between manual preliminary sizing in PreSTo and solver-based optimization in SAS.

4.2 Matching Chart and Power-to-Mass Representation

For CS-23 propeller-driven aircraft, the matching chart is formulated using the power-to-mass ratio P/m expressed in W/kg. This representation follows the classical preliminary sizing methodology for propeller aircraft, where shaft power rather than thrust constitutes the governing performance variable (Roskam 1989; Scholz 2015). Power-based formulation allows a direct coupling of take-off, climb, and cruise requirements within a consistent performance framework, since the corresponding constraints are formulated in terms of available shaft power and propeller efficiency. In contrast, jet aircraft performance is thrust-driven, and matching chart formulations therefore employ the thrust-to-weight ratio T/W as the primary optimization variable (Loftin 1980; Scholz 2015).

From a methodological perspective, these formulations are independent of certification category. Therefore, when applying the SAS-Classic (Jet) framework, originally developed for CS-25 transport aircraft, to a CS-23 jet configuration, no structural modification of the matching chart formulation is required. The governing flight-mechanical relations remain valid, as they are derived from fundamental performance equations rather than regulatory assumptions.

However, certification-specific boundary conditions must be adapted when transitioning between CS-25 and CS-23 applications. These include stall speed limitations, climbing gradient requirements, take-off and landing field-length constraints, and statistical mass estimation parameters representative of smaller aircraft classes. In practical implementation, this requires transferring and adjusting the statistical datasets and design assumptions from the SAS-Part23 environment within the SAS-Classic (Jet) framework.

Consequently, the structural sizing methodology and matching chart logic remain unchanged, while regulatory constraints and statistical reference values are tailored to the applicable certification context. This approach ensures methodological consistency across propulsion concepts and certification categories while avoiding unnecessary duplication of sizing tools.

4.3 SAS Propeller Efficiency

During the development of the SAS-Part23-Prop tool, the propeller efficiency calculation was reviewed in detail. In the SAS structure, propeller efficiency is not handled in a separate worksheet, but calculated within the PS II worksheet and used directly in the matching-chart constraints. Since propeller efficiency directly affects the required shaft power, it is a sensitive parameter in the sizing logic and influences take-off, climb, missed approach, and cruise performance.

Initially, the Propeller Efficiency worksheet from the PreSTo-Classic Prop version was examined and temporarily integrated into the CS-23 SAS environment. The objective was to allow the user to select between three alternative methods: the empirical formulation by Wolf (2009), based on the Marckwardt (1998) diagram, and the analytical formulations Truckenbrodt 1 and Truckenbrodt 2. From a structural point of view, this integration was feasible because the required cell references could be recreated and the propeller efficiency value in PS II could be calculated according to the selected method.

During further testing, however, it became evident that this extension increased the numerical sensitivity of the SAS tool significantly. The propeller efficiency value is linked to several dependent calculations and is also affected by the Stability 1 and Stability 2 macro routines. Therefore, any method-switching logic for this central value must be handled with particular caution. Temporary undefined or non-physical values can propagate through the coupled Excel calculation structure and may lead to unstable solver behavior. For this reason, the dedicated Propeller Efficiency worksheet was not retained in the SAS tool.

After the removal of the separate Propeller Efficiency worksheet, the Truckenbrodt 2 formulation was retained as the standard analytical method for the Variable Pitch option. This formulation includes the influence of flight speed, propeller circumferential speed, and disk

loading. The relevance of disk loading, advance ratio, and propeller tip speed for propeller efficiency is discussed by Scholz (2020a), where the Truckenbrodt formulation is presented as a function of flight speed, circumferential propeller speed, and disk loading. Scholz also notes that practical losses can be accounted for by applying a quality factor of approximately 0.85 to 0.9. Accordingly, the Truckenbrodt 2 formulation provides a physically plausible estimate for variable-pitch or constant-speed propeller operation in conceptual sizing (Scholz 2020a; Truckenbrodt 1999).

A further extension introduced in the present work is the distinction between Variable Pitch and Fixed Pitch propellers. The propeller type is selected in the SAS Input worksheet. In the Variable Pitch case, the existing Truckenbrodt 2 formulation is used, representing a propeller that can adjust its blade angle and operate close to a suitable efficiency condition over a broader range of advance ratios.

In the Fixed Pitch case, the propeller efficiency is not calculated from the Truckenbrodt 2 formulation. A fixed-pitch propeller has a fixed blade angle and therefore follows a separate efficiency characteristic. Its efficiency is determined from the relative advance ratio with respect to the design point. The design point is assumed to be the cruise condition. The required rotational speeds for the individual flight phases are entered in the PS I worksheet.

The advance ratio is defined as

$$J = \frac{V}{n \cdot D} \quad (4.1)$$

where V is the flight speed, n is the propeller rotational speed, and D is the propeller diameter. Since the same propeller diameter is used for all flight phases, the diameter cancels in the ratio J/J_{design} . With the cruise condition selected as design point, the relative advance ratio becomes

$$x = \frac{J}{J_{design}} = \frac{V}{V_{design}} \cdot \frac{n_{design}}{n} = \frac{V}{V_{CR}} \cdot \frac{n_{CR}}{n} \quad (4.2)$$

where V and n are the speed and rotational speed of the respective flight phase, and V_{CR} and n_{CR} are the cruise design values.

The fixed-pitch efficiency curve used for the implementation is shown in Figure 4.1. It gives the relative efficiency $\eta_p/\eta_{p,design}$ as a function of the relative advance ratio J/J_{design} . The curve is approximated by the sixth-order polynomial

$$f(x) = -29.861 x^6 + 142.93 x^5 - 279.60 x^4 + 283.66 x^3 - 157.15 x^2 + 46.202 x - 5.195 \quad (4.3)$$

The fixed-pitch propeller efficiency used in the SAS performance constraints is then calculated as

$$\eta_{p,FP} = \eta_{p,FP,design} \cdot f(x) \quad (4.4)$$

where $\eta_{p,FP,design}$ is the fixed-pitch design-point efficiency specified by the user.

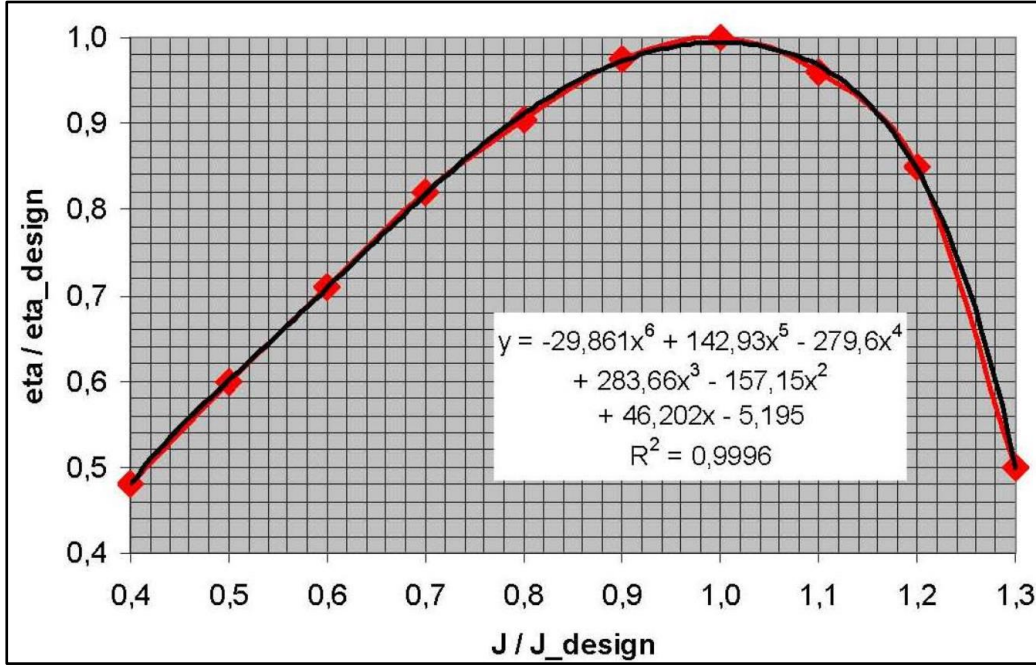


Figure 4.1 Fixed-Pitch Propeller Relative Efficiency over Relative Advance Ratio (Scholz 2020a)

In cruise, $x = 1$ because the cruise condition is used as the fixed-pitch design point. The propeller efficiency is therefore equal to the specified design-point efficiency. In take-off, second-segment climb, and missed approach, the aircraft operates at different speeds and rotational speeds. This usually leads to $x < 1$, reducing the propeller efficiency according to Figure 4.1 and increasing the required shaft power.

This reflects the fundamental difference between fixed-pitch and variable-pitch propellers. A variable-pitch or constant-speed propeller can select a more suitable blade angle over a range of operating points. A fixed-pitch propeller is optimized only for a limited design condition and cannot maintain optimum blade angle at lower speeds or different rotational speeds. The implemented switch allows both propeller assumptions to be represented within the existing SAS sizing logic.

The statistical regression for estimating propeller rotational speed remains available in the SAS tool as the default calculated option in the PS II worksheet, mainly for the existing variable-pitch efficiency calculation. It should be noted, however, that this regression was originally derived for cruise speeds between 86 m/s and 185 m/s and propeller diameters between 2.6 m and 4.2 m, with an average deviation of approximately five percent.

In the CS-23 category, and especially for smaller aircraft, propeller diameters are often below this range. When applied to such configurations, the regression must therefore be regarded as a simplified assumption rather than a validated prediction within its original statistical bounds. A statistically consistent formulation specifically derived from representative CS-23 propeller data would be required for higher fidelity. Since such data is not available within the scope of this work, the existing regression is retained as a pragmatic approximation.

To address this limitation, the SAS tool allows the user to override the calculated rotational speed by specifying an individual value directly in the PS II worksheet. This enables designers to define realistic rotational speeds based on comparable aircraft or known engine–propeller combinations, while still providing an automatic estimate when no reference data is available. In addition, a blade tip Mach number check is implemented and linked to the input worksheet, allowing the user to verify immediately whether the current configuration remains within an acceptable propeller tip velocity range.

The user can also specify a direct propeller efficiency value in PS II by selecting Own value. This is useful for sensitivity studies or for comparing the Variable Pitch and Fixed Pitch options under consistent reference efficiency assumptions. If both switch positions are compared directly, the same design efficiency should be used in PS II and in the fixed-pitch input in PS I. This prevents differences caused by unequal reference efficiency assumptions from being interpreted as physical differences between propeller types.

Both propeller assumptions are therefore represented within the existing SAS structure without reintroducing a separate Propeller Efficiency worksheet.

4.4 Engine Switching Logic and Power Modeling

A central modification introduced in the present work is the implementation of generalized engine-type switching logic. The propulsion model is selected via a dedicated input field allowing the user to choose between turboprop, naturally aspirated piston (Otto or Diesel), and turbocharged piston engines.

The switching logic is implemented using boolean arithmetic to ensure language-independent functionality and numerical robustness in Excel. Instead of nested conditions, the propulsion

model uses logical expressions that activate only the selected engine type. The formulation ensures smooth transitions between propulsion options. The detailed implementation is documented directly within the Excel tool and is not reproduced here.

The altitude dependency of available shaft power is treated differently for turboprop and piston engines. For turboprops, the classical SAS power lapse formulation based on Mach number and relative density is retained.

For piston engines, however, the previous simple density power-law formulation was replaced by a physically more consistent model following Young (2001). In piston engines, shaft power is approximately proportional to the intake air mass flow, which itself scales with ambient air density. Young (2001) derives a linearized relation for the power lapse of naturally aspirated engines of the form

$$\frac{P_S}{P_{S,SL}} = \sigma(1 + c_h) - c_h \quad (4.5)$$

where $\sigma = \rho/\rho_0$ denotes the relative air density and $c_h = 0.132$ is an empirical correction parameter accounting for non-ideal volumetric efficiency and mixture effects. This formulation captures the near-linear decrease in power with altitude more realistically than a pure density power law and provides a smooth representation suitable for preliminary sizing applications. For simplification, take-off rated power at sea level is defined as the reference value, i.e.

$$P_{S,TO} \equiv P_{S,SL} \quad (4.6)$$

Under this assumption, the cruise-to-takeoff power ratio becomes directly:

$$\frac{P_{CR}}{P_{S,TO}} = \frac{P_S}{P_{S,SL}} = \sigma(1 + c_h) - c_h \quad (4.7)$$

For turbocharged piston engines, a critical density ratio σ_{krit} is introduced. Up to this critical density, constant sea-level power is assumed, reflecting the ability of the turbocharger to maintain manifold pressure. Above the critical altitude, power decreases according to the same Young-based relation, normalized to ensure continuity at σ_{krit} .

The resulting formulation is as follows:

For $\sigma \geq \sigma_{krit}$:

$$\frac{P_{CR}}{P_{S,TO}} = 1 \quad (4.8)$$

For $\sigma < \sigma_{krit}$:

$$\frac{P_{CR}}{P_{S,TO}} = \frac{\sigma(1 + c_h) - c_h}{\sigma_{krit}(1 + c_h) - c_h} \quad (4.9)$$

Normalization ensures exact continuity at the critical density and prevents non-physical power values exceeding the sea-level take-off rating.

Figure 4.2 illustrates the resulting engine power lapse behavior up to an altitude of 15 km for turboprop, naturally aspirated piston, and turbocharged piston engines using the implemented Excel formulations. In the illustrated example, $\sigma_{krit} = 0.74$, which corresponds approximately to a critical altitude of 3 km. Up to this altitude, no power reduction occurs for the turbocharged engine, whereas naturally aspirated piston engines exhibit a nearly linear power decrease from sea level onward. The turboprop model shows a more moderate but continuous reduction driven by the SAS Mach–density formulation.

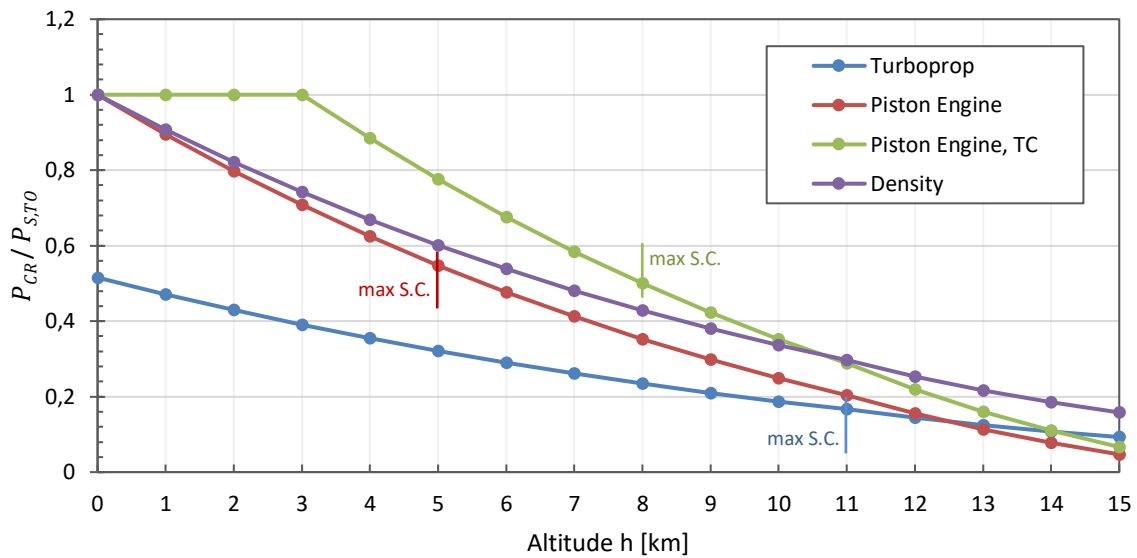


Figure 4.2 Engine Power Lapse vs. Altitude

In Figure 4.2, typical operational service ceilings can be identified for the different propulsion concepts. Naturally aspirated piston-engine aircraft usually exhibit a maximum service ceiling (max S.C.) of approximately 5 km. Turbocharged piston aircraft extend this range to roughly 8 km; however, CS-23 Amendment 4 specifies a maximum certified operating altitude of 7,625 m (25,000 ft). Amendment 6 relaxes this explicit altitude threshold, but operations above 25,000 ft require substantially increased certification effort. Turboprop aircraft typically reach service ceilings of up to approximately 11 km. These values represent practical upper limits derived from published aircraft flight manuals of representative types.

The parameters c_h and σ_{krit} are introduced in the PS II worksheet as adjustable empirical tuning parameters. They allow adaptation of the propulsion model to different piston engine concepts without modifying the overall sizing framework.

The governing theoretical basis for this modeling approach follows Young (2001).

4.5 Applicability to Additional Aircraft Categories

As already discussed in Section 4.2, the present SAS-Part23-Prop framework is fundamentally based on a shaft-power and fuel-mass driven mission model. The implemented matching chart formulation and performance constraints assume a decreasing fuel mass according to a Breguet-type mission analysis.

For battery-electric propulsion systems, this assumption no longer holds. The energy carrier mass remains approximately constant during flight, and mission range is governed by an energy balance rather than a specific fuel consumption model. A consistent treatment of electric propulsion would therefore require structural modifications to the mass breakdown, mission segment formulation, and power availability constraints. For this reason, incremental adaptation of the existing fuel-based framework is not recommended. A dedicated SAS-Electric derivative would provide a more consistent solution.

With respect to jet-powered aircraft, no structural modification of the sizing logic is required. As stated in Section 4.2, the existing SAS-Part25-Jet framework remains fully applicable from a methodological standpoint. The governing thrust-based matching chart formulation is independent of certification category. When analyzing a CS-23 jet configuration, only certification-specific boundary conditions (e.g. stall speed, climb requirements, statistical mass assumptions) must be adapted, while the underlying sizing logic remains unchanged.

Beyond propulsion type, the SAS-Part23 framework is also directly applicable to additional light-aircraft certification categories such as CS-VLA ($m_{MTO} \leq 750 \text{ kg}$), LSA ($m_{MTO} \leq 600 \text{ kg}$), and LTF-UL ($m_{MTO} \leq 600 \text{ kg}$). From a flight-mechanical perspective, the governing preliminary sizing equations remain identical. The matching chart formulation, power-to-mass representation, and constraint analysis are not altered by certification class.

What changes between these categories are primarily boundary conditions and regulatory limits, such as maximum take-off mass, number of occupants, stall speed limits, maximum operating speed, climb requirements, and statistical reference parameters. These differences do not affect the underlying flight-mechanical formulation but rather require consistent adaptation of the respective design assumptions and input parameters within the sizing process.

Consequently, the present SAS-Part23 implementation can be interpreted as a flexible sizing platform for light propeller-driven aircraft rather than a tool restricted to a single certification framework. By adjusting regulatory inputs and statistical assumptions, the methodology remains valid across multiple light-aircraft categories without structural modification of the core sizing algorithm.

4.6 PreSTo-Classic-Part23-Prop Tool Application

A manually controlled framework for preliminary aircraft sizing is provided by the PreSTo-Classic-Part23-Prop tool, in addition to the solver-based SAS environment. Unlike SAS, PreSTo uses a transparent, step-by-step calculation approach. This approach requires users to actively guide the sizing process, adjusting input parameters iteratively until a consistent design point is obtained.

As discussed in previous sections, preliminary sizing is heavily influenced by statistical parameters and empirical correlations. These inputs must be carefully selected and consistently applied to the intended aircraft category. Although SAS supports this process with automated optimization routines, PreSTo requires more deliberate parameter selection and continuous plausibility checking by the user.

Within the worksheet *Preliminary Sizing I*, several parameters have a dominant influence on the resulting matching chart. In particular, the approach parameter k_{APP} , the defined field lengths, the power-based disc loading, and the take-off parameter k_{TO} must be chosen in accordance with the target aircraft type. These parameters directly define landing and take-off constraints and therefore strongly influence the allowable wing loading and required power-to-mass ratio.

For CS-23 single-engine aircraft, the constraints for the second segment climb and missed approach are usually non-sizing and lie below the governing design point on the matching chart. This is primarily because an engine-out scenario is not considered in single-engine configurations. However, these constraint formulations are retained within the PreSTo structure as they originate from the CS-25 propeller framework. This enables multi-engine configurations to be analyzed within the same tool environment if required.

The worksheet *Max. Glide Ratio in Cruise* is used to define aerodynamic parameters such as the statistical glide coefficient k_E and the relative wetted-area ratio. These inputs directly affect drag estimation and therefore influence cruise performance and fuel consumption. As with all statistical parameters, they should be calibrated using comparable reference aircraft.

In the *Propeller Efficiency* worksheet, the user can select the calculation method and define relevant propeller parameters. For fixed-pitch propellers, phase-specific rotational speeds are entered for take-off, climb, missed approach, and cruise. A key output in the Propeller Efficiency sheet is the resulting blade tip velocity, which provides a direct check of the propeller design. This value must remain sufficiently below the critical Mach number to avoid compressibility effects and efficiency losses and therefore serves as an important plausibility indicator for the selected configuration.

The *Propeller Efficiency* worksheet is extended by an additional selection option labeled Fixed Pitch. The available methods now include the empirical formulation by Wolf, the analytical methods Truckenbrodt 1 and Truckenbrodt 2, and the fixed-pitch propeller representation based on the relative efficiency curve introduced in Section 4.3.

For the Fixed Pitch option, PreSTo applies the fixed-pitch efficiency relation described in Section 4.3. The required flight-phase-specific rotational speeds and the design-point efficiency are defined directly in the Propeller Efficiency worksheet.

The worksheet *Preliminary Sizing II* contains several of the most sensitive design inputs. These include the cruise Mach number M_{CR} , the design range, the specific fuel consumption (linked to engine selection), the relative operating empty mass ratio m_{OE}/m_{MTO} , the number of passengers, and the fuel density. In particular, the operating empty mass ratio has a strong influence on the resulting maximum take-off mass and therefore on the entire sizing outcome.

The *Matching Chart* worksheet provides a graphical representation of the design solution. The intersection of all relevant performance constraints defines the feasible design point. Supporting statistical reference values are provided in the *Parameter Statistics* worksheet. It should be noted that the present work focuses on the structural adaptation of the tool environment rather than on the derivation of new statistical datasets for CS-23 aircraft. A dedicated statistical evaluation for small aircraft would therefore be required for further refinement.

Finally, the *Help* worksheet provides both a default value and backup formula expressions for propeller efficiency. In cases of numerical instability, a fixed efficiency value, for example 0.8, can be introduced temporarily to stabilize the model. Once stable operation has been restored, the original analytical formulas for the different flight phases can be copied from the Help worksheet and reinserted into the corresponding cells. This approach enables recovery of the spreadsheet after a calculation failure and avoids the need to reopen or reconstruct the tool.

Overall, the PreSTo-Classic-Part23-Prop tool represents a transparent environment for manual preliminary sizing. Compared to SAS, it requires more user interaction and engineering judgement, but provides clear traceability of intermediate calculations and supports a deeper understanding of the sizing process.

4.7 Validation by Redesigning the Cessna 172

A final validation of the developed CS-23 propeller aircraft sizing environment is performed by redesigning the Cessna 172. The reference data are taken from the Cessna 172S Information Manual; therefore, all numerical reference values refer specifically to the 172S variant. For readability, the aircraft is referred to as Cessna 172 throughout this section. The aircraft is well suited for validation because it represents a typical single-engine CS-23 piston aircraft with a fixed-pitch propeller (Cessna 2004).

The objective of the redesign is not to reproduce every detailed performance chart of the original aircraft, but to verify whether the developed SAS-Part23-Prop and PreSTo-Classic-Part23-Prop tools can reproduce the main aircraft-level sizing parameters with acceptable accuracy. The comparison is based on maximum take-off mass, operating empty mass, installed take-off power, wing area, power-to-mass ratio, and wing loading.

A relevant modelling issue is the payload-range combination. The handbook range of 518 NM is specified with 53 gal usable fuel including reserve. This corresponds to approximately 144 kg of fuel. With a useful load of 895 lb, or approximately 406 kg, only about 262 kg remain for occupants and baggage when full fuel is carried. Therefore, the published range condition cannot be combined with four full standard occupants at the same time. For the redesign, three occupants are used in both tools in order to obtain a consistent payload-range assumption.

Since the Cessna 172 uses a fixed-pitch propeller, the Fixed Pitch option described in Sections 4.3 and 4.6 is applied in both tools. The propeller efficiency is therefore determined from the fixed-pitch efficiency ratio as a function of relative advance ratio. The required rotational speeds are specified for the relevant flight phases, so that the different operating conditions in take-off, climb, missed approach, and cruise are represented consistently.

For the redesign, the main input assumptions are selected to be consistent with the Cessna 172S reference aircraft. In SAS-Part23-Prop, the redesign can be obtained with input assumptions close to the handbook data. However, in PreSTo-Classic-Part23-Prop, adjustments to the landing and range inputs are required, as the tool relies more directly on selected empirical parameters and simplified matching-chart constraints. These adjustments are used to achieve a consistent design point, rather than reproducing individual handbook performance values in detail.

When comparing design parameters between SAS-Part23-Prop and PreSTo-Classic-Part23-Prop, it should be noted that the empirical take-off parameter k_{TO} is defined differently in both tools. In SAS-Part23-Prop, k_{TO} is given in $\text{W m}^4 \text{kg}^{-5/2}$, whereas the corresponding PreSTo parameter is defined in m^3/kg . The values are therefore not directly convertible and must be interpreted within their respective take-off formulations.

The resulting redesign values are summarized in Table 4.1. The table compares the SAS and PreSTo outputs with the Cessna 172S reference data. Deviations are calculated relative to the reference aircraft.

Table 4.1 Summarized Results of Redesigning the Cessna 172S (Cessna 2004)

Parameter	Reference	SAS Redesign	Deviation	PreSTo Redesign	Deviation
m_{MTO}	1157 kg	1156 kg	-0.1 %	1195 kg	3.3 %
m_{OE}	754 kg	754 kg	0.0 %	779 kg	3.3 %
P_{TO}	134 kW	134 kW	0.0 %	134 kW	0.0 %
S_W	16.1 m ²	16.1 m ²	0.0 %	16.2 m ²	0.6 %
P_{TO}/m_{MTO}	116 W/kg	116 W/kg	0.0 %	112 W/kg	-3.4 %
m_{MTO}/S_W	72 kg/m ²	72 kg/m ²	0.0 %	74 kg/m ²	2.8 %

The results show that both tools reproduce the main Cessna 172S reference parameters within the intended preliminary-sizing accuracy. SAS gives the closer agreement, with the selected aircraft-level parameters matching the reference aircraft almost exactly in rounded form. This indicates that the solver-based SAS workflow can reproduce the Cessna 172 design point consistently when the fixed-pitch propeller representation and the corresponding input assumptions are applied.

PreSTo also remains within the intended validation range. The deviations are slightly larger than in SAS, which is expected because PreSTo is a manually controlled sizing tool and depends more directly on selected empirical parameters and simplified matching-chart constraints. Nevertheless, all selected key parameters remain sufficiently close to the reference aircraft for preliminary sizing.

Overall, the redesign confirms that both tools are capable of reproducing the main characteristics of a representative CS-23 single-engine piston aircraft. The validation also shows that fixed-pitch propeller behaviour, flight-phase-specific rotational speeds, and empirical take-off and landing parameters must be treated consistently. With the implemented Fixed Pitch option and appropriate aircraft-specific input assumptions, both SAS-Part23-Prop and PreSTo-Classic-Part23-Prop provide plausible results for preliminary sizing of CS-23 propeller aircraft.

5 User Guide for the SAS Part-23 Excel Tool

This chapter provides a concise introduction to the practical use of the SAS Part-23 Excel tool. The objective is to enable the user to initialize the model correctly, understand the basic workflow, and interpret the main outputs relevant for preliminary aircraft sizing. The guide is intended for students and researchers performing conceptual sizing studies for CS-23 propeller aircraft. The theoretical background of the matching chart method and the SAS optimization concept is described in detail by Heinemann (2012) and Krull (2022). The present chapter focuses exclusively on practical operation of the implemented tool.

To start the tool, extract the provided ZIP archive to a local directory. Before opening the Excel file, right-click the file, select *Properties*, and activate the option to allow or trust the file. After confirmation, open the workbook. Since the model relies on embedded VBA procedures for optimization, solver execution, and automated parameter updates, macros must be enabled. In Excel, navigate to *File* → *Options* → *Trust Center* → *Trust Center Settings* → *Macro Settings* and enable all VBA macros. Without macro activation, the solver-based design-point determination will not function correctly.

After activation, the Input worksheet serves as the central interface of the tool. The general workflow follows the classical preliminary sizing sequence described by Heinemann (2012): first, define mission and performance requirements; second, select propulsion type; third, execute solver-based matching chart determination; and finally, evaluate the resulting mass breakdown and constraint compliance.

The propulsion type is selected directly within the Input sheet. Available configurations include *Piston (Otto)*, *Piston (Otto, TC)*, *Piston (Diesel)*, and *Turboprop*. Engine selection influences altitude-dependent power modeling, cruise-to-takeoff power ratio, and the resulting matching chart constraints. Consequently, propulsion choice has a direct effect on installed power, fuel mass, and total aircraft mass.

The propeller type is selected separately in the Input worksheet. The user can choose between Variable Pitch and Fixed Pitch. For the Variable Pitch option, the existing Truckenbrodt 2 formulation is used. For the Fixed Pitch option, the efficiency is calculated from the fixed-pitch relative efficiency curve described in Section 4.3. In this case, the required rotational speeds for the relevant flight phases are entered in the PS I worksheet.

Within the Input sheet, parameters in the value section can either be defined as fixed or adjustable. Parameters marked with “YES” participate in the optimization process and may vary during solver execution, whereas parameters marked with “NO” remain fixed. This structure corresponds to the SAS optimization logic described by Krull (2022), where decision variables are separated from fixed design assumptions. After defining adjustable parameters,

the solver can be executed using the control button “Find Design Point”. This function initiates the iterative optimization routine and determines the intersection of the governing performance constraints in the matching chart. It represents the standard procedure for calculating a feasible preliminary design based on the currently defined input parameters.

For extended optimization studies beyond single design-point determination, two additional algorithms are available. The “DOE Diagonal Algorithm for Single Input” performs a structured parameter sweep along one selected design variable and is primarily intended for sensitivity analysis. The “Differential Evolution Algorithm for Multiple Inputs” enables multi-variable optimization using a stochastic search method. This routine is suitable for broader design-space exploration but requires carefully defined bounds for adjustable parameters. (Krull 2022)

As with any solver-based optimization method, the resulting design point depends on the defined parameter bounds and initial assumptions. Unrealistic parameter ranges may lead to non-physical solutions or unstable solver behavior. It is therefore recommended to select parameter limits based on comparable reference aircraft whenever possible.

If convergence issues occur or the matching chart appears inconsistent, the tool provides two internal reset functions labelled “Stability 1” and “Stability 2”. These routines reinitialize intermediate solver states and restore numerical consistency without altering user-defined input values. In practice, these functions are sufficient to recover stable design-point computation if solver iterations were interrupted or input parameters were modified abruptly.

The Output sheet presents the resulting design point, installed power, wing loading, and mass breakdown. The user must evaluate these results against certification limits and design objectives. As emphasized by Heinemann (2012), the matching chart represents the interaction of performance constraints rather than a single governing equation. Therefore, interpretation of the intersection point requires engineering judgement.

The resulting matching chart is significantly influenced by several input parameters. The relative operating empty mass ratio m_{OE}/m_{MTO} is one of the most sensitive variables. Since mass fractions directly affect feasible power-to-mass ratios and wing loading (Heinemann 2012), this parameter should be calibrated to a comparable reference aircraft before executing optimization. Unrealistic assumptions in m_{OE}/m_{MTO} shift the constraint envelope significantly and may produce misleading design points.

Another highly influential parameter is the statistical approach-speed coefficient k_{APP} . This coefficient affects landing constraints and thus the allowable wing loading. For light aircraft categories such as CS-23, CS-VLA, LSA, and LTF-UL, landing performance often represents a dominant sizing constraint. Consequently, variations in k_{APP} can noticeably alter the

matching chart intersection. A systematic investigation of this parameter across different light-aircraft categories would represent a valuable extension of the current work.

Further statistical parameters such as k_{TO} , k_E , and the wetted-area ratio S_{wet}/S_W influence take-off performance, climb performance, and drag estimation respectively. Although individually less dominant than mass fraction and approach-speed coefficient, their combined effect modifies the constraint envelope and therefore the resulting design point, consistent with the methodology described by Heinemann (2012).

In addition, propeller-related inputs require particular attention. As discussed in Section 4.3, the rotational speed in PS II can be defined either as a calculated value based on the statistical regression or as its own specified value. The calculated option provides a first-order estimate and is appropriate during early concept exploration when no specific engine–propeller combination has yet been selected. However, once a realistic propeller diameter and engine configuration are known, it is recommended to use an own value derived from comparable aircraft or manufacturer data. This ensures that blade tip Mach number and resulting efficiency remain within physically plausible limits.

Similarly, the propeller efficiency can either be calculated using the implemented analytical formulation or entered directly by the user. The calculated value represents a physically consistent approximation suitable for preliminary sizing studies. A direct input value may be preferable when verified manufacturer data are available or when conducting comparative studies to assess the influence of different efficiency assumptions on required installed power and overall aircraft mass.

Aircraft mass must be monitored carefully throughout the design process, as it directly affects the required power-to-mass ratio and the resulting wing loading in the matching chart. As shown by Heinemann (2012), performance constraints such as take-off distance, climb rate, and cruise requirement are formulated as functions of power-to-mass ratio and wing loading. An increase in aircraft mass therefore leads to higher required installed power or requires a reduction in wing loading through an increase in wing area in order to satisfy the same certification requirements.

If the resulting aircraft mass exceeds acceptable limits for CS-23, VLA, LSA, or LTF-UL categories, corrective measures must be applied within the design iteration. In practical preliminary design, this may involve reducing mission range (thereby reducing fuel mass), lowering cruise speed (reducing required installed power and engine mass), increasing allowable wing loading, increasing maximum lift coefficient through improved high-lift systems, or improving propeller efficiency to reduce required shaft power. Each of these adjustments alters the constraint balance and must therefore be evaluated consistently within the matching chart framework.

When using statistical reference values, it is important to understand the underlying assumptions of the reference aircraft data. Manufacturers often publish range values associated with reduced payload conditions rather than maximum payload. Consequently, the reported range may differ significantly from the harmonic range, which represents the achievable range at maximum payload. If statistical parameters such as the operating empty mass ratio, payload mass per passenger or fuel fraction are derived from such data without proper interpretation, the resulting sizing assumptions may be inconsistent. Therefore, it is important to verify that the selected reference values correspond to comparable payload and mission conditions before applying them within the SAS model.

Another important aspect concerns the use of the optimization algorithms. In the preliminary design stage, it is advisable to start with a small number of adjustable parameters and analyze their individual influence before activating multi-variable optimization. Once a plausible value for a parameter has been identified, additional parameters can be gradually included in the optimization process. This stepwise approach helps verify that the solver returns physically plausible results, preventing unrealistic parameter combinations or unstable solver behavior that may occur when too many variables are varied simultaneously.

In summary, the SAS-Part23-Prop Excel tool implements the established matching chart methodology within a CS-23 context and provides a structured environment for iterative preliminary sizing. Correct use of the tool requires careful definition of input assumptions, appropriate calibration of statistical parameters, and critical evaluation of the resulting design point.

6 Summary, Discussion and Conclusions

This project addressed the development and adaptation of a preliminary aircraft sizing environment for propeller-driven aircraft certified under EASA CS-23 Amendment 6. The work builds on the existing tool family developed within the Aircraft Design and Systems Group (AERO), in particular the PreSTo-Classic and Simple Aircraft Sizing (SAS) environments.

The main objective of the project was to extend these tools to the CS-23 propeller aircraft category while maintaining the transparent and educational structure of the existing sizing methodology. For this purpose, the regulatory framework of CS-23 Amendment 6 was analyzed with regard to requirements relevant for preliminary aircraft design. Based on this analysis, the existing SAS and PreSTo Excel environments were adapted to ensure compatibility with CS-23 performance constraints and aircraft characteristics typical for small propeller-driven configurations.

Within this process, the standardized structure and workflow of the SAS-Part25-Prop tool were transferred to a new SAS-Part23-Prop environment. In parallel, a simplified PreSTo-Classic-Part23-Prop version was created to support manual sizing studies and parameter investigations in a transparent spreadsheet-based environment. The resulting tools enable both manual matching chart analysis and solver-based optimization of the design point using statistical aircraft parameters and simplified performance relations. The implemented environment allows users to evaluate key design parameters such as wing loading, power-to-mass ratio, installed power, and mass breakdown for CS-23 aircraft concepts. In this way, the tools provide a structured and accessible framework for early conceptual design studies while preserving full traceability of the underlying sizing equations.

The validation by redesigning the Cessna 172S demonstrates that the adapted tools reproduce a representative CS-23 single-engine piston aircraft with sufficient preliminary-sizing accuracy. SAS-Part23-Prop reproduces the selected Cessna 172S reference parameters almost exactly, while PreSTo-Classic-Part23-Prop remains within the five-percent validation threshold.

The developed tool extends the existing SAS methodology to CS-23 propeller aircraft in a consistent manner. While previous versions of the tool mainly focused on transport aircraft, the current implementation enables the consistent application of CS-23 performance constraints within a unified sizing framework. This improves the comparability between different aircraft categories and makes the SAS methodology applicable to small propeller-driven aircraft.

At the same time, several limitations of the current implementation must be recognized. As with all preliminary sizing approaches, the accuracy of the results strongly depends on the quality of the statistical input parameters and the realism of the initial assumptions. Parameters such as the operating empty mass ratio, approach-speed coefficient, and propeller efficiency can

significantly influence the resulting matching chart intersection and therefore require careful calibration using comparable reference aircraft. In addition, the simplified aerodynamic and propulsion models used in the Excel environment are intended for conceptual-level studies and cannot replace detailed aerodynamic or propulsion analysis.

Future work could focus on refining the statistical basis of the implemented sizing parameters. In particular, a broader evaluation of modern CS-23 aircraft data could improve the robustness of parameters such as operating empty mass ratios, wetted-area relations, and characteristic performance coefficients used in the matching chart method.

Another potential extension concerns propulsion modeling. While the current implementation focuses on conventional piston and turboprop configurations, emerging electric and hybrid drive concepts may require adapted dimensioning methods. For such configurations, the development of a specialized or modified SAS environment could provide a more suitable framework for conceptual dimensioning studies.

Overall, the developed SAS-Part23-Prop environment establishes a consistent preliminary sizing framework for CS-23 propeller aircraft within the existing SAS tool family. By combining transparent matching chart methodology with automated optimization capabilities, the tool provides a structured and practical environment for early-stage aircraft design studies.

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