Bachelor Thesis

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Proposing a Classification for Aeronautics, Astronautics and Aerospace Sciences

Fakultät Technik und Informatik

Department Fahrzeugtechnik und Flugzeugbau

Faculty of Engineering and Computer Science

Department of Automotive and Aeronautical Engineering

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Proposing a Classification for Aeronautics, Astronautics and Aerospace Sciences

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Abstract

Purpose – This thesis presents an aerospace classification and explains its logic. The classification is checked and presented throughout the thesis in various forms. Furthermore, HTML, PDF, and Excel versions have been made available online.
Methodology – A review of aerospace classifications was conducted. A classification authored originally for the "Aims & Scope" section of the journal *Advances in Aerospace Science and Technology* (AAST) was selected and applied to the requirements from DIN 32705.
Findings – The classification from AAST was found to be the most suitable classification in the field of aerospace (aeronautics, astronautics, and aerospace sciences) thus far. It largely corresponds to the standard in terms of content and structure. Some minor changes were introduced.
Practical implications – The new classification can be used in the publishing industry in libraries and archives. It can also be used in all situations in aerospace where a logical structure of the domain is required. It could be used, for example, to structure organizations or statistical investigations. Moreover, this thesis can be used as an example for establishing other classifications according to DIN 32705.
Originality – Thus far, a standard classification does not exist in the field of aerospace. This new classification, published for the first time in this thesis, has the potential to fill this role.

Name des Studierenden
Schaugar Taher Gulani

Thema der Bachelorarbeit
Vorschlag einer Klassifikation für die Luft- und Raumfahrt sowie die Luft- und Raumfahrtwissenschaften

Stichworte (GND)
Luftfahrt, Raumfahrt, Wissenschaft, Klassifikation, Bibliothek, Bibliothekswesen, Dezimalklassifikation, Archivierung, Taxonomie, Kategorisierung, [Luftfahrtwissenschaft, Raumfahrtwissenschaft]

Kurzreferat

Zweck – In dieser Arbeit wird eine Klassifizierung der Luft- und Raumfahrt vorgestellt und ihre Logik erläutert. Die Klassifizierung wird in der gesamten Arbeit in verschiedenen Formen geprüft und präsentiert. Außerdem wurden HTML-, PDF- und Excel-Versionen online zur Verfügung gestellt.
Methodik – Es wurde eine Überprüfung der Klassifikationen für die Luft- und Raumfahrt durchgeführt. Eine ursprünglich für den Abschnitt "Aims & Scope" der Zeitschrift Advances in Aerospace Science and Technology (AAST) erstellte Klassifizierung wurde ausgewählt und auf die Anforderungen der DIN 32705 angewandt.
Ergebnisse – Die Klassifikation der AAST erwies sich als die bisher am besten geeignete Klassifikation im Bereich der Luft- und Raumfahrt (Luft- und Raumfahrt, Raumfahrttechnik und Raumfahrtwissenschaften). Sie entspricht inhaltlich und strukturell weitgehend der Norm. Es wurden einige kleinere Änderungen vorgenommen.
Bedeutung für die Praxis – Die neue Klassifikation kann im Verlagswesen, in Bibliotheken und Archiven verwendet werden. Sie kann auch in allen Situationen in der Luft- und Raumfahrt verwendet werden, in denen eine logische Struktur des Bereichs erforderlich ist. Sie könnte zum Beispiel zur Strukturierung von Organisationen oder statistischen Untersuchungen verwendet werden. Darüber hinaus kann diese Abschlussarbeit als Beispiel für die Erstellung anderer Klassifikationen nach DIN 32705 verwendet werden.
Originalität / Wert – Bislang gibt es im Bereich der Luft- und Raumfahrt keine einheitliche Klassifizierung. Diese neue Klassifizierung, die in dieser Abschlussarbeit zum ersten Mal veröffentlicht wird, hat das Potenzial, diese Aufgabe zu erfüllen.

DEPARTMENT OF AUTOMOTIVE AND AERONAUTICAL ENGINEERING

Proposing a Classification for Aeronautics, Astronautics and Aerospace Sciences

Task for a *Bachelor Thesis*

Background

Classifications are the heart of science and go back to Aristotle. A term more general is taxonomy. "Taxonomy is the practice and science of categorization or classification" "especially [as] a hierarchical classification, in which things are organized into groups or types." "Among other things, a taxonomy can be used to organize and index knowledge (stored as documents, ...), such as in the form of a library classification system." What is a Classification (German: Klassifikation)? Examples of classifications are DDC (German), ICD-11, and other standard classifications. For the task here, please have a look at this Aerospace Classification (written by myself). Please consider "Dimension 1: Classification – Aeronautics, Astronautics, Aerospace Sciences" on that page. This is my favorite so far. What other classifications exist in our field of Aerospace (Aeronautics, Astronautics, and Aerospace Sciences)? What are merits and deficiencies of existing approaches to an aerospace classification? Does a (published) suitable classification already exist in aerospace?

Task

Task of this Bachelor Thesis is 1.) to check my proposed aerospace classification in light of DIN 32705, 2.) to improve it as far as necessary, 3.) to present the improved aerospace classification, and 4.) to consider, if there are other applications for such an aerospace classification apart from the publishing industry. The thesis could be structured like this:

- Classification Fundamentals
- Classifications in Aerospace
- Towards a New Aerospace Classification
- Documentation of the Aerospace Classification (DIN 32705)
- Online Versions of the Aerospace Classification
- Usage of the Aerospace Classification
- Other Dimensions of Categorization in Aerospace

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

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List of Definitions

This section presents definitions of the terms used in the Aerospace Classification presented in this thesis. They are listed in alphabetical order. This list is crucial for fulfilling the requirements of a classification system, as explained in detail at the end of *Chapter 4.1*.

Acoustics
"Acoustics [is] the science concerned with the production, control, transmission, reception, and effects of sound" (Berg 2019).

Aeroelasticity and Structural Dynamics
"A branch of mechanics which treats the phenomena resulting from the interaction of aerodynamic, inertia and elastic forces. Specifically, [it concerns] the tendency of aircraft wings and compressor or turbine blades to deflect under a load causing cyclic changes in the aerodynamic lift pattern" (AGARD 1980, p. 11).

Aeronautics
"The science and art of designing, constructing and operating aircraft; more narrowly the science or art of operating aircraft" (AGARD 1980, p. 12).

Aeronautics and Society
This refers to aeronautics from the perspective of society and its impacts.

"A large group of people who live together in an organized way, making decisions about how to do things and sharing the work that needs to be done. All the people in a country, or in several similar countries, can be referred to as a society" (Cambridge Society 2022).

Aerospace Philosophy (mostly Space)
"The making and operating of aircraft or spacecraft" (Cambridge Aerospace 2022).

Philosophy is "a group of theories and ideas related to the understanding of a particular subject" (Cambridge Philosophy 2022).

Aerospace Sciences (for Air and Space)
"[Knowledge from] the careful study of the structure and behavior of the physical world, especially by watching, measuring, and doing experiments, and the development of theories to describe the results […]" (Cambridge Science 2022).

Air and Space Economics
"The way in which trade, industry, or money is organized, or the study of this" (Cambridge Economics 2022).

Aviation and Space Medicine

Aviation medicine

"That branch of medicine dealing with the effects on man of the environment of flight. More specifically, the effects of flight, the performance by man of those tasks inherent in the control of aircraft and the prevention or alleviation of the physiological and pathological effects of stresses associated with flight" (AGARD 1980, p. 48).

Space Medicine

"A specialized extension of aviation medicine to include those stresses associated with flight beyond the atmosphere, such as weightlessness, radiation hazards and the sealed cabin" (AGARD 1980, p. 403).

Air Space Management (ASM)

"Airspace management refers to the coordination, integration, and regulation of the use of airspace of defined dimensions" (Definition ASM 2022).

Air Traffic Control (ATC)

"Air traffic control aims to move aircraft safely and efficiently through the airspace system. Controllers keep aircraft set distances apart while moving them from airport to airport using set routes" (CAA 2022).

Air Traffic Flow Management (ATFM)

"A service established with the objective of contributing to a safe, orderly and expeditious flow of air traffic by ensuring that ATC capacity is utilized to the maximum extent possible, and that the traffic volume is compatible with the capacities declared […]" (Skybrary 2022a).

Air Traffic Management (ATM)

"The dynamic, integrated management of air traffic and airspace including air traffic services, airspace management and air traffic flow management – safely, economically and efficiently – through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions" (Skybrary 2022b).

Air Traffic Services (AIS)

"A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service, area control service, approach control service or aerodrome control service" (AGARD 1980, p. 25).

Air Transportation

The transportation of persons or goods from one place to another by air (Cambridge Transportation 2022).

Aircraft
"A vehicle designed to travel through the air dependent on the lift support other than reactions of the air against the Earth's surface" (AGARD 1980, p.16).

Aircraft and Spacecraft Design
The planning process of aircraft and spacecraft (Cambridge Design 2022).

Aircraft Avionics
(a) "The technology of the use of electronics in all its forms in airborne and aerospace vehicles";
(b) "Airborne equipment produces by the use of such technology."
(AGARD 1980, p. 48).

Aircraft Construction and Design
The work of building and planning aircraft (Cambridge Construction 2022).

Aircraft Performance
"Aircraft manufacturers publish full details of aircraft performance in the Aeroplane Flight Manual (AFM), together with the approved aircraft operating technique necessary to achieve AFM performance. Aircraft must be able to operate safely throughout their flight regime in such a way that a safe outcome will result from specified malfunctions (e.g. power unit failure), occurring at any point throughout the flight range" (Skybrary 2022c).

Aircraft Stability and Controls
"The term stability characterizes the motion of an aeroplane when returning to its equilibrium position after it has been disturbed from it without the pilot taking action. Aircraft control describes the response to actions taken by a pilot to induce and maintain a state of equilibrium or to execute manoeuvres" (Torenbeek, 2009).

Airframe
"The fuselage, booms, nacelles, cowlings, fairings, aerofoil surfaces (including rotors but excluding propellers and rotating aerofoils of engines) and landing gear of an aircraft and their accessories and controls" (AGARD 1980, p. 20).

Airline Finances
This term refers to the management of the supply of money for operating an airline (Cambridge Finances 2022).

An airline is "a business that operates regular services for carrying passengers and/or goods by aircraft" (Cambridge Airline 2022).

Airline Partnerships
"Airline alliances are partnerships between or among airlines. Within these collaborations, airlines can share resources, pick up or extend partner routes and even offer the ability to earn and redeem miles through each other's rewards programs" (Crail 2022).

Airline Planning, Operation, Management
The planning, operation, and management of an airline concern the decisions regarding how to do certain things and control processes (Cambridge Planning 2022; Cambridge Management 2022).

Airport Planning, Operation, Management
Airports are places "where aircraft regularly take off and land." Their planning, operation, and management concern the decisions regarding how to do something and control relevant processes (Cambridge Airport 2022).

Airside
"The movement area of an aerodrome, adjacent terrain and buildings or portions thereof access to which is controlled; [the] area used for the operation of aircraft as opposed to the handling of passengers and cargo" (AGARD 1980, p. 23).

Airworthiness, MRO
Airworthiness refers to compliance with "the regulations prescribed by the competent authority certifying the fitness for the flight of an aircraft" (AGARD 1980, p. 26). MRO stands for maintenance, repair, and operations (Sphera 2021).

Alerting Service (ALRS)
"A service provided to notify appropriate organizations regarding aircraft in need of search and rescue aid, and to assist such organizations as required" (AGARD 1980, p. 26).

Animal Flight
"Flight, in animals, either powered, or true, flight and gliding. Winged (true) flight is found only in insects (most orders), most birds, and bats" (Britannica 2016).

Astrionics
"Astrionics is the science and technology of the development and application of electronic systems, sub-systems, and components used in spacecraft" (WIKI 2022a).

Astrodynamics
Astrodynamics is "[t]he study of the motion of natural and artificial bodies in space" (Collins 2022).

Astronautics
Astronautics is "[t]he science of the construction and operation of vehicles for travel in space beyond the earth's atmosphere" (Merriam 2022a).

Astronautics and Society
This refers to astronautics from the perspective of society and its impacts.

Autogyro
"A heavier-than-air aircraft, supported in flight by the reactions of the air on one or more rotors which rotate freely on substantially vertical axes" (AGARD 1980).

Aviation Accident and Incident Investigation
Accident
"An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:
(a) a person is fatally or seriously injured
(b) the aircraft sustains damage or structural failure
(c) the aircraft is missing or is completely inaccessible" (EMSA 2021).
Incident
"An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation" (EMSA 2021).

Investigation
"A process conducted for the purpose of accident prevention which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes and, when appropriate, the making of safety recommendations" (EMSA 2021).

Aviation Law
"Air law, the body of law directly or indirectly concerned with civil aviation. Aviation in this context extends to both heavier-than-air and lighter-than-air aircraft" (Cheng 2019).

Avionics
"The technology of the use of electronics in all its forms in airborne and aerospace vehicles" (AGARD 1980, p. 48).

Avionics and Mission Technologies
"The technology of the use of electronics in all its forms in airborne and aerospace vehicles." (AGARD 1980, p. 48)
"The practical, especially industrial, use of scientific discoveries" (Cambridge Technology 2022).

Balloons
"A non-power-driven lighter-than-air aircraft" (AGARD 1980, p. 54).

Blimps
"A large aircraft without wings, consisting of a large bag filled with gas that is lighter than air and driven by engines. In the past passengers were carried in a structure hanging below" (Cambridge Blimps 2022).

Cabin Systems
The area in which passengers sit during a flight on an aircraft (Cambridge Cabin 2022). The cabin system refers to all systems related to the cabin.

Data Processing and Automation
Data processing
"Data processing is the method of collecting raw data and translating it into usable information. It is usually performed in a step-by-step process by a team of data scientists and data engineers in an organization. The raw data is collected, filtered, sorted, processed, analyzed, stored, and then presented in a readable format" (Duggal 2022).

Automation
"The use of machines and computers that can operate without needing human control" (Cambridge Automation 2022).

Documentation and Knowledge Management
"Knowledge management is the process by which an enterprise gathers, organizes, shares and analyzes its knowledge in a way that is easily accessible to employees. This knowledge includes technical resources, frequently asked questions, training documents and people skills" (Amsler 2021).

Engines/Propulsion
"Any machine that converts energy in one form into another form suitable for the required use e.g., heat to torque in a reciprocating engine" (AGARD 1980, p. 161).

Environmental Aspects of Aviation
Aviation causes emissions that result from fossil fuel combustion. Aircraft engines produce gases, noise, and particulates (Wiki 2022b).

Experimental and Numerical Aerodynamics (CFD)
"Computational Fluid Dynamics (CFD) is the process of mathematically modeling a physical phenomenon involving fluid flow and solving it numerically using the computational prowess" (Simscale 2022).

Fixed-Wing Aircraft
"An airplane or glider whose wing is rigidly attached to the structure, or is other-wise [!] adjustable" (Encyclopedia 2005).

Fleet Planning
"Fleet planning (selecting the "right" aircraft at the "right" time) is one of the most important steps in the airline planning process" (DLR 2022).

Flight and Ground Crew Management
Flight Crew
"Those members of the aircrew whose primary concern is the operation and navigation of the aircraft and its safety in flight" (AGARD 1980, p. 184).

Ground Crew
"Ground crew are personnel that service aircraft while on the ground, during routine turn-around; as opposed to aircrew, who operate all aspects of an aircraft whilst in flight" (Wiki 2021a).

Flight Control Systems
A flight control system refers to "[t]he arrangement of all control elements which enable control forces and moments to be brought into play by the human pilot or by an automatic device" (AGARD 1980, p. 184).

Flight Information Service (FIS)
"A service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flight" (AGARD 1980, p. 185).

Flight Mechanics and Flight Guidance
Mechanics
This term refers to the study of the effects that make flight work (Cambridge Mechanics 2022).

Guidance
This refers to a service that delivers advice regarding how to fly and deal with the problems connected to flying (Cambridge Guidance 2022).

Flight Simulation
"A type of synthetic flight trainer which provides an accurate representation of the flight deck of a particular aircraft type, to the extent that the mechanical, electrical and electronic aircraft system control functions, etc., the normal environment of the flight crew members, and the performance and flight characteristics of that type of aircraft are realistically simulated" (AGARD 1980, p. 186).

Flight Testing
"The testing of an aircraft or other vehicle by actual flight or launching. Flight tests are planned to achieve specific test objectives and gain operational information" (AGARD 1980, p. 186).

Fluid Dynamics and Thermodynamics
Fluid Dynamics
"A branch of fluid mechanics that deals with fluid motion (as flow and wave motion)" (Merriam 2022b).

Thermodynamics
"The area of physics connected with the action of heat and other types of energy" (Cambridge Thermodynamics 2022).

Free (Balloons)
"A balloon floating freely in the air" (AGARD 1980, p. 192).

Fuel Systems
"The system that stores fuel for present use and delivers it as needed to an engine" (Encyclopedia 2003).

Fuselage
"The main structural body of an aircraft other than a flying boat or boat amphibian" (AGARD 1980, p. 198).

Gliders
"A non-power-driven, heavier-than-air aircraft which derives its lift in flight chiefly from aerodynamic reactions on surfaces which remain fixed under given conditions of flight" (AGARD 1980, p. 204).

Ground Infrastructure
"The basic systems and services, such as transport and power supplies" on Earth for astronautics (Cambridge Infrastructure 2022).

Gyrodyne
"A helicopter which derives its lift from a single power-driven rotor, while torque correction and forward propulsion are provided by an offset propeller. During forward flight, the rotor may provide autorotative lift; lift may also be provided by wings" (AGARD 1980, p. 214).

Heating, Ventilation, Air Conditioning and Refrigeration (HVAC&R)
"Heating, ventilation, and air conditioning (HVAC) is the use of various technologies to control the temperature, humidity, and purity of the air in an enclosed space. Its goal is to provide

thermal comfort and acceptable indoor air quality. […] "Refrigeration" is sometimes added to the field's abbreviation as HVAC&R" (Wiki 2022c).

Heavier-than-Air Vehicles
"An aircraft which derives its lift in flight chiefly from aerodynamic forces" (AGARD 1980).

Helicopter
"A heavier-than-air aircraft, supported in flight by the reactions of the air on one or more power-driven rotors which operate on substantially vertical axes" (AGARD 1980, p. 218).

History of Aeronautics
The study of past events related to aeronautics (Cambridge History 2022).

History of Astronautics
The study of past events related to astronautics (Cambridge History 2022).

Human Factors and Ergonomics (HF&E)
Human Factors
"The psychophysical, psychological, and physiological variables which affect man's performance in an operational system" (AGARD 1980, p. 225).

Ergonomics
"The scientific study of people and their working conditions, especially done in order to improve effectiveness" (Cambridge Ergonomics 2022).

Human-Powered Flight
Human-powered flight refers to the use of a human-powered aircraft (HPA), which is an aircraft powered by human energy (WIKI 2022l).

Hydraulics and Pneumatics
"Hydraulics and pneumatics are both examples of fluid power. The difference lies in the fluid used and how those fluids are used. Only fluid power systems are capable of providing constant force or torque despite speed changes" (Essentra 2021).

Hypersonic
This term pertains to
(a) hypersonic flow; or
(b) speeds of Mach 5 or greater
(AGARD 1980, p. 228)

Interior and Exterior Design
This refers to the art of planning the decoration of the inside and outside of an aircraft (Cambridge Exterior 2022; Cambridge Interior 2022).

Jet
"A strong, well-defined stream of fluid, either issuing from an orifice or moving in a concreted duct, such as the jet of combustion gases issuing from a reaction engine, or the jet in the test section of a wind tunnel" (AGARD 1980, p. 248).

Kinematics
"Kinematics [is a] branch of physics and a subdivision of classical mechanics concerned with the geometrically possible motion of a body or system of bodies without consideration of the forces involved" (Britannica 2022).

Kites
"A framework, covered with paper, cloth, metal, or another material, designed to be flown at the end of [a] rope or cable and having, as its only support, the wind moving past its surfaces" (AGARD 1980, p. 251).

Landing Gear System
"That part of an aircraft (other than the hull of a flying boat) provided for its support and the movement over land, water, or some other surface, and for absorbing the shock on landing. It comprises the main supports (incorporating wheels, skids, skis) and auxiliary items such as nose-wheels, tail-wheels or skids, and wing-tip floats" (AGARD 1980, p. 254).

Landside
"The landside of an airport defines those areas and activities within the airport boundaries, exclusive of the airside. The landside may accommodate a variety of aviation and non-aviation related activities such as passenger processing, public access, commercial zones and airport cities. The access to the landside is normally not restricted and open for the public" (ACP 2022).

Launch and Reentry Vehicles
Launch Vehicle
"A rocket used to launch a satellite or spacecraft" (Merriam 2022c).

Re-Entry Vehicle
"Any payload-carrying vehicle designed to leave the sensible atmosphere and then return it through it to Earth" (AGARD 1980, p. 356).

Lighter-than-Air Vehicles
"An aircraft which is supported chiefly by its buoyancy in air" (AGARD 1980, p. 261).

Manned Aircraft
“[A] vehicle occupied by one or more persons who normally have control over the movements of the vehicle, as in a manned aircraft or spacecraft, or who perform some useful function while in the vehicle” (AGARD 1980, p. 273).

Manufacturing
“Manufacturing is the production of goods through the use of labor, machinery, tools and biological or chemical processing or formulation. Manufacturing can either mean transforming raw materials into finished goods on a large scale, or the creation of more complex items by selling basic goods to manufacturers for the production of items such as automobiles, aircraft, or household appliances” (TWI 2022).

Marketing
“The business activity that involves finding out what customers want, using that information to design products and services, and selling them effectively” (Cambridge Marketing 2022).

Materials and Lightweight Structures
“Typical lightweight structures include cable-, membrane-, shell-, and folded structures as well as space grids, braced vaults and domes, arched-, stayed-and trussed systems. […] Lightweight structures are widely employed in architecture, engineering and building construction” (LSAA 2022).

Mechanical and Electrical Engineering
“Electrical engineers work with electrical systems, designing, developing and testing them. This can include communication, radar and navigation” (CSE 2020).

“Mechanical engineering is the study of objects and systems in action. Unlike electrical engineering, it focuses on the design and testing of systems that convert or transform energy” (CSE 2020).

Missiles
“Any object thrown, dropped, fired, launched, or otherwise projected with the purpose of striking a target. Short for ‘ballistic missile’, ‘guided missile’” (AGARD 1980, p. 283).

Mission Avionics
“The technology of the use of electronics in all its forms in airborne and aerospace vehicles” (AGARD 1980, p. 48).

Moored (Balloons)
“A tethered, moored or captive balloon is a balloon that is restrained by one or more tethers attached to the ground and so it cannot float freely” (Wiki 2022j).

MRO Management and Spares Logistics
"MRO [maintenance, repair, and operations] ensures facilities, equipment, systems and tools are stocked, maintained and safe to use" (Sphera 2021).

Multidisciplinary Design Optimization (MDO)
This refers to optimizing the final design by involving different subjects (Cambridge Multidisciplinary 2022).

Navigation
"Finding the way from one place to another is called navigation. Moving of an aircraft from one point to another is the most important part for any kind of mission" (Navigation 2007).

Orbital and Mission Spacecraft, Space Stations
Orbital Spaceflight
"An orbital spaceflight (or orbital flight) is a spaceflight in which a spacecraft is placed on a trajectory where it could remain in space for at least one orbit" (Wiki 2022d).

Space Station
"Space station, an artificial structure placed in orbit and having the pressurized enclosure, power, supplies, and environmental systems necessary to support human habitation for extended periods. Depending on its configuration, a space station can serve as a base for a variety of activities" (Harland, 2022).

Overall Aircraft Design (OAD)
This refers to the design process for the whole aircraft.

Overall Spacecraft Design
This refers to the design process for the whole spacecraft.

Payload
"That part of the useful load from which revenue is derived (i.e., passengers, mail and freight)" (AGARD 1980, p. 312).

Photovoltaics
"Photovoltaics (PV) is the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon studied in physics, photochemistry, and electrochemistry. The photovoltaic effect is commercially utilized for electricity generation and as photosensors" (Wiki 2022e).

Piston Engine
"An engine in which the working fluid is expanded in a cylinder against a reciprocating piston" (AGARD 1980, p. 318).

Powered Aircraft
"A powered aircraft is an aircraft that uses onboard propulsion with mechanical power generated by an aircraft engine of some kind" (WIKI 2022f).

Project and Quality Management
Quality Management
"Quality management is the act of overseeing all activities and tasks that must be accomplished to maintain a desired level of excellence. This includes the determination of a quality policy, creating and implementing quality planning and assurance, and quality control and quality improvement" (Barone 2022).

Project Management
"Project management is the use of specific knowledge, skills, tools and techniques to deliver something of value to people" (PMI 2022).

Propulsion
"The force produced by a system for moving a vehicle or other object"
(Cambridge Propulsion 2022).

Protection Systems
A protection system prevents damage to an aircraft or spacecraft by detecting problems (Cambridge Protection 2022).

Remote Sensing and Data Transmission
Remote Sensing
"Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object" (Wiki 2022g).

Data Transmission
"Data transmission is the process of sending digital or analog data over a communication medium to one or more computing, network, communication or electronic devices" (Techopedia 2013).

Rotorcraft
"An assembly of aerofoils, together with a hub, hinges etc., that rotates about a substantially vertical axis to provide lift and thrust or lift only for a helicopter, an autogiro or the like" (AGARD 1980, p.370).

Sanitation
"Sanitation refers to public health conditions related to clean drinking water and treatment and disposal of human excreta and sewage" (Wiki 2022h).

Satellites
"A device sent up into space to travel around the earth, used for collecting information or communicating by radio, television, etc" (Cambridge Satellite 2022).

Sciences Applied to Aerospace Systems
"[Knowledge from] the careful study of the structure and behavior of the physical world, especially by watching, measuring, and doing experiments, and the development of theories to describe the results […]" (Cambridge Science 2022).

Secondary Power Systems
A system that supplies the hydraulic and electrical systems with energy (Eurofighter 2022).

Security, Safety, Reliability and related human Factors
These terms refer to the protection of aircraft/spacecraft and a state in which the craft is not at risk. They also concern how people interact with systems and technology (Cambridge Safety 2022; Cambridge Security 2022; Cambridge Human 2022).

Software Engineering
"A branch of computer science that deals with the design, implementation, and maintenance of complex computer programs" (Merriam 2022d).

Space Debris
"Space debris, also called space junk, [is] artificial material that is orbiting Earth but is no longer functional. This material can be as large as a discarded rocket stage or as small as a microscopic chip of paint" (Gregersen 2022).

Space Infrastructure and Robotics
Space Infrastructure
"Space infrastructure, like its terrestrial counterpart, is an invisible backbone for services used by people all over the world. Like terrestrial infrastructure, space infrastructure is increasingly relied upon for convenience, services, and national security/defense" (Spacereport 2022).

Robotics
Robotics is the science of producing machines that perform tasks automatically (Cambridge Robotics 2022).

Space Law
Space law is a system of rules regarding space (Cambridge Law 2022).

Space Suits
This is a "popular term for a pressure suit specifically designed for use in spacecraft or for excursions therefrom" (AGARD 1980, p. 403).

Spacecraft
A spacecraft is a "vehicle designed to operate, with or without a crew, in a controlled flight pattern above Earth's lower atmosphere" (Britannica 2021).

Spacecraft Construction and Design
"The design of spacecraft covers a broad area, including the design of both robotic spacecraft (satellites and planetary probes), and spacecraft for human spaceflight (spaceships and space stations)" (Wiki 2021b).

Spacecraft Operation
The way that parts of a spacecraft work together, or the process of making parts of a spacecraft work together (Cambridge Operation 2022).

Strength of Materials and Structures
"The field of strength of materials, also called [the] mechanics of materials, typically refers to various methods of calculating the stresses and strains in structural members, such as beams, columns, and shafts. The methods employed to predict the response of a structure under loading and its susceptibility to various failure modes take into account the properties of the materials, such as its yield strength, ultimate strength, Young's modulus, and Poisson's ratio" (Wiki 2021c).

Structures
"The way in which the parts of a system or object are arranged or organized, or a system arranged in this way" (Cambridge Structure 2022).

Subsonic
"For aircraft speeds which are very much less than the speed of sound, the aircraft is said to be subsonic. Typical speeds for subsonic aircraft are less than 250 mph, and the Mach number M is much less than one, $M << 1$" (NASA 2021).

Supersonic
"Vehicles that fly at supersonic speeds are flying faster than the speed of sound. [The] Mach number M is between 1 and 5, $1 < M < 5$" (NASA 2017).

Systems (Aircraft)
"A set of connected things or devices that operate together" (Cambridge System 2022).

Systems (Spacecraft)
"A set of connected things or devices that operate together" (Cambridge System 2022).

Systems Engineering and Management
"Systems engineering management is distinguished from general project management by its focus on the technical or engineering aspects of a project. SEM also encompasses exploratory research and development (R&D) activities at the enterprise level in commercial or government operations" (Madachy 2022).

Tail
(a) "The rear part of a body, as of an aircraft, a rocket, etc.
(b) The tail surfaces of an aircraft or rocket"
(AGARD 1980, p. 431)

Thermal Management
"In spacecraft design, the function of the thermal control system (TCS) is to keep all the spacecraft's component systems within acceptable temperature ranges during all mission phases. It must cope with the external environment, which can vary in a wide range as the spacecraft is exposed to the extreme coldness found in the shadows of deep space or to the intense heat found in the unfiltered direct sunlight of outer space" (Wiki 2022i).

Transonic
This term pertains to "that which occurs or is occurring within the range of speed in which flow patterns change from subsonic to supersonic or vice versa, about 0.8 to 1.2, as in transonic flight, transonic flutter. Also applied to something which operates within this regime as in transonic aircraft, transonic wing. It is characterized by transonic flow or transonic speed, as in transonic region, transonic zone" (AGARD 1980, p.453).

Turboprop
Turboprop Engine
"A gas-turbine engine in which a proportion of the net energy is used to drive a propeller" (AGARD 1980, p. 458).

Turboshaft
Turboshaft Engine"A gas-turbine engine in which a proportion of the net energy is used to drive a main output shaft other than driving a propeller or ducted fan" (AGARD 1980, p.459).

Undercarriage
"A major assembly of the landing gear (main, nose, tail)" (AGARD 1980, p. 462).

Unmanned Aerial Systems (AUS)
An "[u]nmanned aircraft system (UAS) means an unmanned aircraft and the equipment [used] to control it remotely" (Skybrary 2022d).

Unmanned Aircraft
An "[u]nmanned aircraft (UA) means any aircraft operating or designed to operate autonomously or to be piloted remotely without a pilot on board" (Skybrary 2022d).

Unpowered Flight
"Unpowered flight is the ability to stay airborne for a period of time without using any power source" (Wiki 2022k).

Utility Systems
A system that supplies things such as electricity, gas, or fuel (Cambridge Utility 2022).

Wing
"A main supporting surface of an aircraft. This may be divided into inner, outer, and wing tip sections" (AGARD 1980, p. 481).

Zeppelins
A zeppelin is a large airship; specifically, it is "an aircraft without wings, containing gas to make it lighter than air, and with an engine" (Cambridge Zeppelin 2022).

1 Introduction

1.1 Motivation

Classifications are the backbone of science. They provide a clear overview and subdivision of the various subject areas and thus facilitate knowledge acquisition. They also arrange knowledge in a logical order, enabling it to be recalled easily. Classifications can be used in libraries, archives, and anywhere where knowledge needs to be structured and classified. The requirement is that such a classification might be considered in libraries with a thematic focus on aerospace; thus, it could be used for study purposes.

This thesis aims to examine the work involved in the preparation of the proposed classification. Then, it aims to evaluate the results based on the standards of the classification and to correct it if necessary.

The classification should guide the user through the different topics of the multifaceted field of aerospace. Moreover, an intention is to highlight the hierarchical relationship between the terms and groups.

1.2 Title Terminology

Classification:
Classifying refers to the formation of groups from a variety of things according to their characteristics, resulting in a logical order (Hjørland 2017).

Aeronautics:
"The science and art of designing, constructing and operating aircraft; more narrowly the science or art of operating aircraft" (AGARD 1980).

Astronautics:
"The science of the construction and operation of vehicles for travel in space beyond the earth's atmosphere" (Merriam 2022a).

Aerospace sciences:
This refers to knowledge from the study of the structure and behavior in aerospace (Cambridge Science 2022).

1.3 Objectives

The goal of this thesis is to create a classification for aerospace. To achieve this, the proposed Aerospace Classification from the journal *Advances in Aerospace Science and Technology* (AAST) must be analyzed and, if necessary, optimized. To successfully master this task, an understanding of classifications is indispensable. Thus, existing classifications must be analyzed to ensure a full mapping of aerospace and to determine how they are structured differently.

To fulfill the task, as many subdivisions and topics must be included as necessary. The goal is to establish a classification that is useful for all professions in the field. Moreover, the classification must stand the test of time, which necessitates the option of further development.

Across topics, this thesis can serve as a blueprint for creating a classification in other subject areas. That is, the procedure used can be applied to any subject area.

1.4 Literature

This thesis discusses the Aerospace Classification by Prof. Dr. Dieter Scholz (AAST 2022), which was published by AAST. This thesis aims to analyze the proposed classification according to the DIN 32705 standard and to improve it if necessary. While the classification has four dimensions, the focus is on the first dimension. The other dimensions are also highlighted but are not analyzed in as much detail.

DIN 32705 (1987), titled *Classification systems – Establishment and development of Classification systems,* provides all necessary information regarding the task of classification. This standard indicates what must be included in a classification and how to structure the information therein, thus enabling the user to easily acquire much knowledge.

The Multilingual Aeronautical Dictionary (MAD; AGARD 1980) is a dictionary for the field of aerospace. It was used to find explanations for terms relevant to the classification presented in this thesis; however, not all terms and classes were found in the MAD.

1.5 Structure of the Work

This thesis consists of eight main chapters, which are structured as follows:

Chapter 2	This chapter presents theoretical aspects for early classifications, library classifications, and the standards for developing a classification.
Chapter 3	This chapter presents various existing classifications for either aeronautics, astronautics, or other related sciences.
Chapter 4	This chapter evaluates the proposed classification from AAST according to the standards for classification. Features are added to meet the requirements.
Chapter 5	This chapter presents the documentation for the classification. It concerns the publication of the aerospace classification as a standalone classification.
Chapter 6	This chapter links different versions of the aerospace classification.
Chapter 7	This chapter describes the usage of the aerospace classification. It also highlights the area of application.
Chapter 8	This chapter lists other dimensions of aerospace and forms different classes.
Chapter 9	This chapter presents a summary of the entire thesis as well as the knowledge gained from it.

2 Classification Fundamentals

2.1 Classifications

Classifying is the act of forming classes from a variety of things while simultaneously arranging them in a logical order in which they relate to each other. A class is a group of objects with the same characteristics, while a classification consists of several classes in a certain order. The order can be defined by purpose, principal, or interest (Hjørland 2017).

The DIN 32705 standard for establishing and developing a classification system provides instructions for structuring classifications. DIN 32705 is covered later in this chapter (Section 2.4).

Classifying the things around us is deeply rooted in human nature, and furthermore, it occurs in all subjects. For example, in mathematics, numbers are classified from *natural numbers* to *imaginary numbers*. Even celestial bodies have been categorized into *stars*, *planets*, and *moons*, and the more people have learned about the universe, the more accurate the classifications have become.

2.2 Early Classifications

The first records of a systematic classification can be traced back to Aristotle, who was one of the first to classify and systematically record what he observed in nature. Moreover, he classified things as animals if they moved and as plants if they did not move. His classification also grouped animals with similar characteristics into genera. Notably, Aristotle gave genera a broader meaning than today's biologists do, differentiating between animals with blood and those without blood. This classification approach largely complies with the modern distinction between vertebrates and invertebrates. He also went further by classifying animals by their habitat and how many legs they had (UCMP 2022).

2.3 Library Classification

Library classification, a part of library and information sciences, is a system according to which a library organizes its materials (e.g., books, manuscripts, and files). Every entry is classified into a group and each item has a signature, which helps the user to understand which subject an entry is from. For example, the letter ***T*** stands for ***Technology*** in the Library of Congress

Classification (***LCC***). With this information, the user knows what type of subject that he or she can expect. The number of the signature provides the location where the book can be found (NEW 2018).

Library of Congress Classification

The Library of Congress Classification (LCC) was developed by the Library of Congress. It is used by most academic libraries in the United States and other countries. The LCC focuses on the books in a library and is not a classification of the world (NEW World Encyclopedia 2018).

Dewey Decimal Classification

One of the most well-known classification systems is the Dewey Decimal Classification (DDC). It classifies all knowledge into 10 main classes, and each hierarchical level has 10 subclasses. Thus, it fans out the deeper it goes. The DDC provides every class with a *notation*, and every notation consists of at least three digits. At the two uppermost levels, zeros are used to fill up to three digits, where the first digit stands for the main class. For example, “Social Sciences, Sociology & Anthropology” is 300 and “Political Science” is 320. The third digit is followed by a dot, which serves the purpose of visual structuring. A notation never ends with a dot and never with a zero after the dot (Alex, 2018, p. 69).

It is crucial to consider that every classification has a bias. The DDC, for example, has a bias in the class of Religion toward Christianity due to its emergence in the Christianized United States in the 19th century (Ainsworth 2018).

2.4 DIN 32705

Classification systems are tools for organizing objects or knowledge about them. The DIN 32705 standard is used in the creation of classifications. According to DIN 32705, a structure can be achieved by sorting after the following:

- Technical/practical purpose: sorting and grouping/subordinating/assigning them;
- Scientific task: for appropriately presenting knowledge units/statements about subjects/ objects;
- Convey knowledge task: illuminating/clarifying the connection/context with the aid of structured knowledge.

As a result, classification systems can be in the rational handling of knowledge as well as in knowledge recognition (DIN 32705, Ch. 3.1).

Classes and separate *terms* are elements of classification systems. Terms, the relations between terms, and the names of terms and notations must be considered for the structure, development, and revision of classification systems. A term is a knowledge unit that contains all of the necessary information about a subject, while a description is an expression for a term (DIN 32705; Ch. 3.2.1). Therefore, a term is the most basic element in a classification. It is crucial to separate them for the understanding of classification systems.

Every statement about an object provides a characteristic, which provides an opportunity to sort terms with common characteristics into groups as well as to separate terms with different characteristics. This is the prerequisite for creating classes and is associated with classification systems. If a characteristic is chosen for differentiation, it is called a ***classification characteristic***. For example, DIN 32705 presents this point with the classification characteristic of “stone fruit” for the class that groups fruits such as “cherry,” “peach,” and “plum.” The superior class to “stone fruit” would obviously be “fruit.” The purpose of the classification system determines which characteristics become *classification characteristics* (DIN 32705, Ch. 3.2.2).

Categories are terms of a general type. They are used in classifications as subdivision viewpoints. The result of a categorical subdivision is called a *facet* (DIN 32705, Ch. 3.2.3.1). Common categorical terms include the following:

- Objects
- Properties
- Activities
- Dimensions

These categories can be differentiated even further. The terms “talking,” “running,” and “writing” are categorized under “activities.” One term can be categorized into several categories; for example, “health” can be included in objects and properties. The main purpose of the classification system defines the depth of expressions (DIN 32705, Ch. 3.2.3.1). It also determines the type of classification system, of which there are two. The first is the universal classification, which classifies all fields of knowledge (DIN 32705, Ch. 4.1.1), a well-known example of which is the DDC. The second type is the subject area classification, which covers just one field of knowledge (DIN 32705, Ch. 4.2.1).

To provide a broad overview, it is crucial to order facets for the classification, as in 4.3.2. Facets describe the knowledge field in one form (DIN 32705, Ch. 4.3.2). Different facets could mean different approaches and points of view. They determine the expression and provide the user with different points of view to achieve a complete mapping of the topic. Facets like the engineering approach, infrastructure, law, and society diversify the spectrum, but facets do not sort them within a class, which is where categories are required. Categories sort and bring order to the different approaches. As stated earlier, categories are terms of a general nature. Terms with the same characteristics are included in the same category. The selection of categories determines the purpose of the classification and the creator. Categories are used to gain a structured class and are critical for a well-ordered classification. They serve the purpose of subdivision (DIN 32705, Ch. 3.2.3.1). To put it in clearer terms, facets are different points of view, such as a technical approach or an economical approach. The categories are subdivision tools within the facet. An example, in a technical approach, could be dividing by strength requirements.

A full classification reveals the relations between terms in a hierarchical manner. Depending on the purpose of the classification system, there is either a *monohierarchical* or a *polyhierarchical* structure, as presented in Figure 2.1. On the left side, a monohierarchical order with one superior category is depicted, while on the right side there is a polyhierarchical order, which has more than one superior category. In this case, the combination of the two superior categories leads to *boat*, which has characteristics of both superior terms (DIN 32705, Ch. 3.3.2.1).

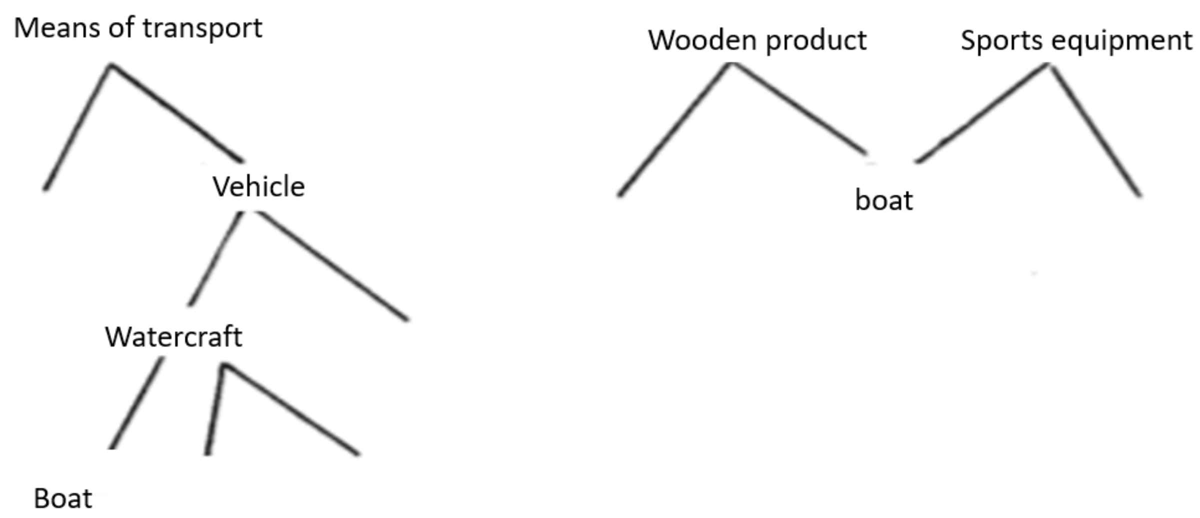

Figure 2.1 Hierarchical term relationships (DIN 32705).

Between two terms, an abstraction relation can exist if they have the same characteristic, but one term has an additional differentiating feature.

Metal – generic term

Precious metal – subterm

The term *precious metal* has the characteristics of metal as well as a differentiating feature. The order between the generic term and the subterm is called an ***abstraction relation*** and, if there are several subterms, the level is called an ***abstraction series*** (DIN 32705, Ch. 3.3.2.1.1). Categories help to cluster terms and groups in a hierarchical relation.

In a hierarchical order, a *partitive relationship* can appear. A partitive relationship can exist between two terms when one term refers to a whole and the other to a part of that whole. The first term is the *association term*, and the hierarchically subordinate term is the *part term*. DIN 32705 provides the following example: “vertebrate body” is the association term, while the terms “skin,” “bones,” and “muscles” are the part terms. Part terms on the same level are considered to be *stock series.* The hierarchical order is called a *stock ladder* (DIN 32705, Ch. 3.3.2.1.2).

Chapter 4.3.3 highlights that most of subject classifications are *precombined classifications*, which have defined complex links from the outset. They are mostly used in subject classifications (DIN 32705, Ch. 4.3.3). The combination and compliance of these listed rules completes a full and useful classification system.

As mentioned in Chapter 6.1, two types of structure exist, the first of which is the *deductive structure*. This is a top-down strategy with fewer top terms. The classification is developed from the generic terms (top) and classes to the specific terms (down). The opposite of this is the *inductive structure*, in which the starting point is a special term. In the inductive type of classification, the development goes in both directions – to the top, which is the generic term, or to the bottom, where it is a more specified group or term. Both approaches can complement each other. Notably, the use of categories is required in both approaches (DIN 32705, Ch. 6.1).

The principles for class formation are listed in Chapter 6.2. The classes of a classification system should be mutually exclusive. In addition, the classes should be accessible and easy to determine. The classification characteristics should be chosen so that they can be maintained. As previously mentioned, classification systems can be constantly improved (DIN 32705, Ch. 8). The classification characteristics should be in an order that is relevant to several classes, and furthermore, the order should be repeated in similar cases. The term ladders should be without gaps and the hierarchy of conceptual relations should be complete (DIN 32705, Ch. 6.2).

Moreover, the individual terms are analyzed by defining them. First, the definitions and the terms must be gathered and the source of the definition noted. Analyzing these terms yields content references (DIN 32705, Ch. 6.4.2). On the basis of the analyzed terms, the important categories are opened (DIN 32705, Ch. 6.4.3). Here, the DIN standard indicates that terms should be pooled within the same group. Groups in this case can have different meanings: In science, they can be divided into subdisciplines; for example, biology would be divided into various subdisciplines such as molecular biology, genetics, ecology, and human biology. Due to the very broad spectrum of physics, it may be useful to structure the terms under the following facets: objects, phenomena, aggregated matters, and interactions, as discussed in Section 6.4.3

(DIN 32705, Ch. 6.4.3). If the subject area only consists of objects, it can be structured according to several aspects to avoid having only one category. Aspects can include functions, constructions, and uses. It must be ensured, as far as possible, that all facets that are relevant to the subject area are considered and that the system leaves possibilities for new additions (DIN 32705, Ch. 6.4.3).

In addition, principles exist for the sequence and order, namely *time*, *space*, *quantity*, and *quality*. Similar class formations that recur in a system should always be subdivided in the same order. If classes are repeated in the system point by combinations of terms that have already occurred in the system or occur at a later point, then they should be listed in the same order (DIN 32705, Ch. 6.4.5).

The basics that a classification system requires (in the correct order) are as follows (DIN 32705, Ch. 7):

- Title
- Introduction
- User guide
- Guide for further development
- Classification tablet
- Register

The introduction must state the purpose of the system, the scope of application, and possibly the exclusion of other areas. Moreover, which group of users it is accessible to must be clear. The history of the origin should be presented with all necessary information (e.g., year, procedure, and research methods). In addition, who was involved in the development process, which sources were used, which structural principles underlie the development, and which standards and other recognized recommendations have been considered must be evident. Lastly, the compatibility with other classification systems of a formal or content-related nature must be stated (DIN 32705, Ch. 6.4.10).

The user guide is intended to inform each user about the handling of the classification system. Therefore, it is necessary to use examples to present the structure of the system, the possibilities for its use and application, formal regulations, and the abbreviations used (DIN 32705, Ch. 6.4.9).

The guide for further development can be submitted separately, since only a few people would be able to improve the classification. A committee must be appointed to ensure cancellations, changes, or new entries. The manner of revision must be specified along with all possibilities and exceptions. The guide should contain the complete official rules of the classification system (DIN 32705, Ch. 8).

An essential criterion for the flawless usability of a classification system is its presentation. This means presenting the order structures in an insightful manner. Classification systems are generally accompanied by notations that serve several purposes, and they must function expediently. For this, an optimal notation system is required (DIN 32705, Ch. 5.2).

The most important type of representation of hierarchical structures is the hierarchical list. The hierarchical order is made visible by using various typographic tools and/or indentations (DIN 32705, Ch. 5.2.5.1). To achieve this, the DDC is used as an example, where the hierarchy is made visible through indentations.

Every classification should have an alphabetic part besides the classification tablets. The aim should be for every term (input) to be listed with its notation (output), which should lead to the class in which the term is classified. Another vital aim is for the relation between the terms to be made apparent. If no alphabetic part exists in the classification, there must in any case be a register that enables complete access. With as little effort as possible, the user should find what he or she is looking for, whether that is different terms, names, hierarchical levels, or types of search features (DIN 32705, Ch. 6.4.8).

With this knowledge about classification systems, existing classifications can now be evaluated.

3 Classification in Aerospace

3.1 Technical University of Munich (TUM)

The Technical University of Munich (TUM) has its own classification system for its university library. This is not a special classification like the aerospace classification is required to be. Rather, it is a universal classification that covers all topics that are important for teaching at the university. TUM has also made its own notation system. The aerospace field is classified under "VER" – Vehicle Engineering. For this research, the focus is on the classes of VER 500, VER 600, VER 700, VER 800, and VER 900. Crucial to note is that the notes and hints in the TUM system have been left out for a clearer visual overview. The indentations were taken from TUM without alterations.

- **VER 500**: Aeronautics; Aviation
    - **VER 505**: Aeronautical Aerodynamics
        - **VER 512**: Subsonic Flight
        - **VER 514**: Transsonic Flight
        - **VER 516**: Supersonic Flight; Hypersonic Flight
        - **VER 518**: Other
        - **VER 520**: Airfoils, Wings, Fuselage and their Aerodynamics
        - **VER 525**: Aerodynamics of Air-Screws
        - **VER 528**: Inboard Aerodynamics
    - **VER 530**: Flight Mechanics; Flight Dynamics
        - **VER 533**: Flight Path
        - **VER 536**: Flight Performance; Flight Attitudes; Flight Characteristics
        - **VER 539**: Stability and Steering; Control
    - **VER 540**: Flight Simulation; Flight Testing; Airworthiness
    - **VER 550**: Flying Vehicles
        - **VER 553**: Balloons; Airships
        - **VER 560**: Aircraft
            - **VER 562**: Rotary-Wing Aircraft (Helicopters, Gyrocopters, ...)
            - **VER 564**: Fixed-Wing Aircraft
            - **VER 565**: Gliders; Motor Gliders
            - **VER 566**: Motorized Aircraft
                - **VER 567**: Waterplanes; Flying Boats; Floatplanes
                - **VER 568**: Hovercrafts
                - **VER 570**: Ground-Landing Planes
                    - **VER 572**: Propeller Aircraft
                    - **VER 574**: Jet Aircraft
                - **VER 579**: Other Motorized Aircraft

        - **VER 580**: Jet-Powered Aircraft
            - **VER 582**: Rocket Planes
        - **VER 590**: Vtol (Vertical Take-Off and Landing) Aircraft, STOL (Short Take-Off and Landing) Aircraft
        - **VER 593**: Unmanned Aerial Vehicles (UAV), Drones
        - **VER 599**: Other

- **VER 600**: Aircraft Construction; Aviation and Aerospace Industry
    - **VER 605**: Airfoils
    - **VER 610**: Empennage and Control Device
    - **VER 615**: Fuselage
    - **VER 620**: Undercarriage
    - **VER 625**: Installations and Equipment; Avionics
    - **VER 630**: Aircraft Engines
        - **VER 632**: Piston Engines
        - **VER 634**: Compound Engines
        - **VER 636**: Turbine and Jet Engines; Air-Breathing Engines
        - **VER 639**: Other
    - **VER 650**: Aircraft Piloting; Cockpit Technology
        - **VER 653**: Taking-Off and Landing
    - **VER 660**: Aircraft Operation; Operational Safety
    - **VER 670**: Flight Navigation
    - **VER 680**: Air Traffic Control; Flight Safety (Night Flight, Instrument Landing, ...)
    - **VER 685**: Aviation Meteorology
    - **VER 690**: Air Traffic (Technical Aspects); Technical Airport Operations
    - **VER 699**: Others on Aviation and Aeronautics
- **VER 700**: Rocket Engineering and Astronautics
    - **VER 720**: Rockets According to Type of Propulsion; Rocket Engines
        - **VER 723**: Jet Propulsion
            - **VER 726**: Chemical Propulsion Rockets; Chemical Propulsion Engines
            - **VER 729**: Nuclear Propulsion Rockets
            - **VER 732**: Electric Propulsion Rockets; Solar (Cell) Powered Propulsion; Plasma Propulsion
            - **VER 735**: Ion Propulsion; Photon Propulsion
            - **VER 738**: Other
        - **VER 760**: Aerodynamics of Rockets and Spacecraft
            - **VER 765**: Re-Entry; Heat Shield
        - **VER 770**: Flight Mechanics; Ballistics
        - **VER 780**: Steering; Navigation; Stabilization
        - **VER 790**: Instrumentation
        - **VER 799**: Other
- **VER 800**: Astronautics

- **VER 810**: Basic Principles; Aerospace Physics
- **VER 820**: Aerospace Engineering in General; Spacecraft (Construction and Function)
  - **VER 823**: Energy Supply
  - **VER 826**: Electronics
  - **VER 829**: Propulsion Devices and their Control
  - **VER 832**: Spacecraft Protection (against Meteorites, Solar Radiation, ...)
  - **VER 835**: Other
- **VER 840**: Spacecraft Conducting; Spacecraft in Operation
  - **VER 843**: Stability and Steering; Satellite Dynamics; Navigation
  - **VER 846**: Space Rendezvous Technology
  - **VER 849**: Other
- **VER 860**: Human Space Flight (Space Station, Space Transporter, Space Shuttle, Space Laboratory, ...)
- **VER 870**: Space Flight According to Destinations
  - **VER 873**: Earth Satellites (including Unmanned Space Flight in General); Remote Sensing in General
  - **VER 876**: Flight to the Moon
  - **VER 879**: Flight to the Sun and to Solar Planets
- **VER 890**: Applications of Space Flight in General; Space Exploration (Microgravitation)
- **VER 900**: Ground Station and Mission Control of Rocket Technology and Space Flight
  - **VER 905**: Launching Sites
  - **VER 915**: Authorities and Institutions
  - **VER 925**: Other
- **VER 950**: Utopian and Extraterrestrial Spacecraft (UFO, Flying Saucers, ...)
- **VER 990**: Others on Astronautics

The evaluation of the TUM classification only refers to VER 500–VER 900, which is a subject area classification (DIN 32705, Ch. 6.4.8 and Ch.4.2.1). Here, the TUM classification covers different facets, each of which has its own approach to the topic.

This is a deductive setup, which means that the TUM classification is a top-down structure. It has few top terms and classifies the classes, groups, and terms under it (DIN 32705, Ch. 6.1).

TUM has developed a precombined classification, which becomes clear when one examines the groups in the classification. There are many complex terms for defining the groups. For example, the first group in *VER 500: Aeronautics; Aviation* is *VER 505: Aeronautical Aerodynamics*. A viable alternative could be *Aircraft* as the first class in *VER 500: Aeronautics; Aviation*. However, it seems as though the overall sequence in VER 500 is alphabetical (TUM Class 2022).

VER 500: Aeronautics; Aviation

- **VER 505**: Aeronautical Aerodynamics
- **VER 530**: Flight Mechanics; Flight Dynamics
- **VER 540**: Flight Simulation; Flight Testing; Airworthiness
- **VER 550**: Flying Vehicles

Sorting by alphabetical order is a simple approach for sorting the topic. The benefit is that new entries can easily be allocated by their name. However, considering the DIN standard, this is not a given possibility (DIN 32705, Ch. 6.4.5 and Ch. 6.2).

This classification uses flight speed as one classification characteristic. The division into flight speed is classified under "VER 505 Aeronautical Aerodynamics." Aeronautical aerodynamics contains, besides the flight speed, the main parts of an aircraft that are important or the aerodynamics, such as the wings, fuselage, airfoils, and airscrews. Considering DIN 32705, a more precise classification could be made by separating flight speed from aerodynamics. Connecting the travel speed to the aircraft may be more useful. This would connect, for example, "fixed-wing aircraft" with "transonic flight." Yet, it may also be better to stick to the existing structure. If the focus is on the travel speed and not on which aircraft flies with the mentioned travel speed, possibilities for interpretation exist. Every classification has its own purpose, and the author has the possibility to choose freely.

Going slightly further, *Flying Vehicle* is its own group, which contains "Balloons; Airships," "Aircraft," "Jet-powered Aircraft," "Unmanned Aerial Vehicles (UAV)," "Drones," and "Other." Sticking to DIN 32705, these can be all classified as **aircraft**. Also notable is that there is no separation between *lighter-than-air* and *heavier-than-air vehicles*. Adding these two as classification characteristics could close a gap in the *abstraction ladder* (DIN 32705 , Ch. 3.2.2 and 6.2). Fixed-wing aircraft could be its own subclass with more specified subgroups, such as travel speed or number of wings, as previously mentioned. The structure would be as follows:

Heavier-than-Air Vehicles

- Fixed-Wing Aircraft
  - Transonic Flight
  - Subsonic Flight

The TUM classification includes *VER 505: Aeronautical Aerodynamics* for aerodynamics and *VER 760: Aerodynamics of Rockets and Spacecraft* for aeronautics. While there is nothing wrong with this as DIN 32705 does not prohibit it, this could be solved more cleverly. Ultimately, how this is perceived depends on the user. According to DIN 32705, the TUM classification also has an alphabetical register. That is, it places terms in alphabetical order as input and the associated notation as output.

It is striking that some terms are listed twice in this classification. Fuselage is classified under VER 520 and mentioned under VER 615. These double mentions must be in the register. Double-named terms must be explained in more detail in the register. As DIN 32705 mentions, if necessary, additional explanations should be used (DIN 32705, Ch. 6.4.8). This is unfortunately not fulfilled, as there are two "Aerodynamics" entries in the register:

Aerodynamics	MTA 390
Aerodynamics	PHY 220

The only differentiation can be made through the notation. A note in this case could help the user to determine the differences between the two entries. Another way to describe the terms more precisely for the user might be to list the entries with their superordinate term (DIN 32705, Ch. 6.4.8):

Aerodynamics	MTA 390	in	*MTA 300: Fluid Mechanics*
Aerodynamics	PHY 220	in	*PHY 210: Continuum Mechanics*

This would make it easier for the user to understand the differences between both entries through the addition of the superordinate term. This can also be achieved by adding notes to the register. The example of *Fuselage* is presented as follows:

VER 520: Airfoils, Wings, *Fuselage* and their Aerodynamics
In terms of aerodynamics

VER 615: *Fuselage*
In terms of construction

The same term *Fuselage* is used here in different approaches. The notes help the user to obtain an enhanced understanding of in which case the term is meant. The italic words are the notes that have been added for ensuring said enhanced understanding.

VER 800 concerns astronautics, while VER 900 concerns the infrastructure of rocket technology and spaceflight. Obviously, rocket engineering is part of astronautics but it is not categorized under Astronautics, and the same applies to infrastructure – that is, they are both separately listed. Knowing the fundamentals provided by DIN 32705, another arrangement could make more sense. The standard leaves room for interpretation.

Aerodynamics for Rockets and Spacecraft is listed under *VER 700 Rocket Engineering and Astronautics*. Aerodynamics and physics are not listed together; rather, they are classified under Aeronautics and Astronautics. Thus, they are not universal but are special for the class. This might be a negative point. Classifying physics and mechanics into one class that covers them for all areas of application might be more suitable.

VER 810 Basic Principles; Aerospace Physics is found under *VER 800 Astronautics*; while *VER 760 Aerodynamics of Rockets and Spacecraft* is found under *VER 700 Rocket Engineering and Astronautics*.

This is just one example that these topics repeat (TUM Class 2022). By creating a separate class in which every topic that is applied in both *Aeronautics* and *Astronautics* is grouped, the problem could be solved differently. A class regarding the cross-cutting topics could classify topics such as aerodynamics, which are important for more than one subject areas. By doing so, a clearer and more user-friendly design would be achieved. Furthermore, a favorable side effect would be a reduction in the number of entries in the register, which should be kept in mind.

3.2 Aircraft Classification by Natarajan

Classifications of aircraft are more common than classifications for the whole field of aerospace. The existing methods of classification are as follows (Natarajan 2020):

- Type of lift generation
- Propulsion system
- Mach number (speed)
- Purpose
- Range
- Mode of take-off and landing
- Size and payload capacity
- Others

Figure 3.1 presents a general classification for aircraft, which only classifies aircraft, not the overall aeronautics. In addition, it has no exposure. The second hierarchical level divides the class into lighter or heavier than air. The third level classifies them according to whether they are power-driven or non-power-driven. This division is made on both paths. Changing level 2 *lift generation* and level 3 *propulsion* would solve the problem of two power-driven groups and two non-power-driven groups. Thus, each classification characteristic would only be used once.

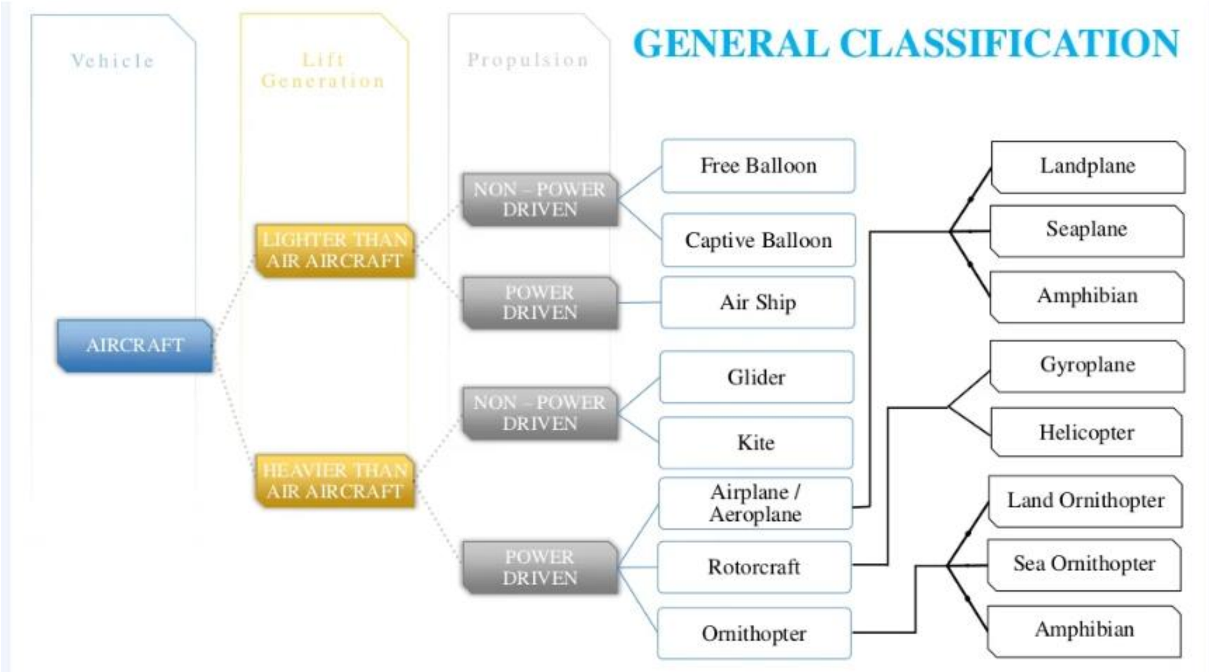

Figure 3.1 General classification (Natarajan 2020).

Other classification can be based on the Mach number:

- Subsonic
- Transonic
- Supersonic
- Hypersonic

Alternatively, they can be based on the type of engine:

- Propeller
- Turboprop
- Turbofan
- Turbojet
- Ramjet

Alternatively, they can be based on the purpose, size and payload capacity, number of wings, range, or the mode of take-off and landing (Natarajan 2020). Through defining a focus, the classification characteristics are determined. These characteristics can be used for the subdivision of *Aircraft*. A division according to the Mach number makes sense for the lower level, where there are more specific terms.

3.3 Aerospace and High Technology Database Classification

Overall, this classification is neither broad nor deep. There are only two abstraction levels. The first two classes are *Aeronautics* and *Astronautics*, which is a common style. The next positive point is that both have similar terms in a similar order, exactly as DIN 32705 describes it. The second term in the respective group is *Aerodynamics* or *Astrodynamics.* As already suggested after investigating the TUM classification, classes should be formed in which similar topics are pooled together.

The terms *Aircraft Design, Testing and Performance* and *Spacecraft Design, Testing and Performance* should also be covered in the classification, but divided into several terms. Therefore, *Aircraft Design*, *Flight Testing*, and *Aircraft Performance* would be included, which would ensure that the terms can be allocated adequately into their position (Pro Quest 2013).

This classification has five classes, much of which is unnecessary for the task. The class engineering is general. A special classification already starts deeper into the topic. The only term that can be included can be *Fluid Mechanics*. The last class contains only two terms that are important to aerospace, namely *Remote Sensing* and *Environment Pollution*. The same applies for chemistry and materials, where the only term that can fit into an aerospace classification system is *Materials Processing.*

[Aeronautics]
1 Aeronautics (General)
2 Aerodynamics
3 Air Transportation and Safety
4 Aircraft Communications and Navigation
5 Aircraft Design, Testing and Performance
6 Aircraft Instrumentation
7 Aircraft Propulsion and Power
8 Aircraft Stability and Control
9 Research and Support Facilities (Air)

[Astronautics]
12 Astronautics (General)
13 Astrodynamics
14 Ground Support Systems and Facilities (Space)
15 Launch Vehicles and Space Vehicles
16 Space Transportation
17 Space Communications, Spacecraft Communications, Command and Tracking
18 Spacecraft Design, Testing and Performance
19 Spacecraft Instrumentation
20 Spacecraft Propulsion and Power

[Chemistry and Materials]
23 Chemistry and Materials (General)
24 Composite Materials
25 Inorganic and Physical Chemistry
26 Metallic Materials
27 Nonmetallic Materials
28 Propellants and Fuel
29 Materials Processing

[Engineering]
31 Engineering (General)
32 Communications and Radar
33 Electronics and Electrical Engineering
34 Fluid Mechanics and Heat Transfer
35 Instrumentation and Photography
36 Lasers and Masers
37 Mechanical Engineering
38 Quality Assurance and Reliability
39 Structural Mechanics

[Geosciences]
42 Geosciences (General)
43 Earth Resources and Remote Sensing
44 Energy Production and Conversion
45 Environment Pollution
46 Geophysics
47 Meteorology and Climatology
48 Oceanography

3.4 Standard Industrial Classification – Aerospace

The Standard Industrial Classification (SIC) is used for classifying industry areas. It is no longer used, but that should not affect the classification; therefore, it can still provide insights. Relevant classes are Aircraft (divided into military and civilian aircraft), *engine and engine parts, parts and auxiliary equipment, guided missiles and space vehicles, radio and television communications equipment, space propulsion units and parts, space vehicle equipment, communication equipment, search, detection, navigation, guidance, aeronautical and nautical systems, instruments and equipment,* and *measuring and controlling devices* (EOOP 1987).

3.5 International Organization for Standardization (ISO)

The International Organization for Standardization (ISO) has a catalog titled ***49: Aircraft and Space Vehicle Engineering***, which contains 13 groups. Furthermore, the catalog has its own notation system, which starts with *49.020 Aircraft and space vehicles in general*. The next four groups are *Materials for aerospace construction*, *Fasteners for aerospace construction*, *Components for aerospace construction*, and *Coatings and related processes used in aerospace industry*. They are all of the same type. The terms *Materials* and *Components* can be included, but the *fasteners* and *coating and related processes* would not fit into an aerospace classification because they are too general. Components would be more differentiated by dividing them into components for aircraft and spacecraft, which is one takeaway.

On the other hand, this classification has terms that might be suitable for a different aerospace classification. Terms such as *49.095 Passenger and cabin equipment* and *49.120 Cargo equipment* are more suitable for other purposes (ISO 2022).

3.6 German Society for Aeronautics and Astronautics (DGLR)

Hardly any classifications could be found, which led to the expansion of the search to determine how departments are divided up. While the **German Society for Aeronautics and Astronautics** (DGLR) has not published a classification, it does list its various departments, and knowledge can be gained from their breakdown. The DGLR divides topics into the following three major departments: *Aviation* (**L**), *Space travel* (**R**), and *cross-cutting issues* (**Q**) (DGLR 2022). Here, the problem with the TUM Classification is highlighted, as it has been elegantly solved by simply creating a separate department **Q** for topics relevant to both aeronautics and astronautics. Obviously, this breakdown only covers the topics that are important to the work of the DGLR. The following overview of departments was translated from German to English using Google Translate:

- L1 Air Transport
- L2 Manned Aircraft
  - L2.1 Aircraft Design
  - L2.2 Systems
  - L2.3 Rotorcraft
  - L2.4 Lighter-than-Air Aircraft
- L3 Unmanned Aerial Vehicles
  - L3.1 Unmanned Aerial Vehicles (UAV)
  - L3.2 Missile Systems
- L4 Cabin
- L5 Aircraft Engines
- L6 Flight Mechanics/Flight Guidance
  - L6.1 Flight Performance
  - L6.2 Flight Characteristics and Flight Test Technique
  - L6.3 Flight Controls
  - L6.4 Anthropotechnics
  - L6.5 Navigation
- L7 Aviation and Society
  - L7.1 Aviation Law
  - L7.2 History of Aviation
- R1 Space Technology
  - R1.1 Satellites and Space Probes
  - R1.2 Space Transportation Systems
  - R1.3 Propulsion
  - R1.4 Space Infrastructures/Exploration and Robotics
  - R1.5 Ground Infrastructure and Operations
- R2 Space Science and Application
  - R2.1 Earth Observation
  - R2.2 Satellite Communications and Navigation
  - R2.3 Extraterrestrial
  - R2.4 Research under Space Conditions
  - R2.5 Security and Defense
  - R2.6 Space Debris - Collection and Analysis
- R3 Space and Society
  - R3.1 Future
  - R3.2 Outer Space Law
  - R3.3 History of Space Travel
  - R3.4 Mars Society

    - R3.5 Space and Philosophy
    - R3.6 Space and Culture
- Q1 Materials - Processes - Construction Methods
    - Q1.1 Strength and Construction Methods
    - Q1.2 Aeroelasticity and Structural Dynamics
    - Q1.3 Materials and Manufacturing Technology
- Q2 Fluid and Thermodynamics
    - Q2.1 Numerical Aerodynamics
    - Q2.2 Experimental Aerodynamics
    - Q2.3 Flow Acoustics/Aircraft Noise
- Q3 Avionics and Mission Technologies
    - Q3.1 Telemetry and Data Transmission
    - Q3.2 Avionics and Sensors
    - Q3.3 Information Processing and Automation
    - Q3.4 Software Engineering
- Q4 Systems Engineering and Management
    - Q4.1 Project and Quality Management
    - Q4.2 System Analysis and Technology Assessment
    - Q4.4 Documentation and Knowledge Management
- Q5 Aerospace Medicine (DGLRM)

Various considerations should be made. First, abstraction ladders should be without any gaps; second, there will be different facets in which different points of view are illuminated; and third, overlapping topics for aeronautics and astronautics should be allocated in a separate class to avoid double listings, just like the DGLR did. Through doing so, the register would be easier to use. Both options were investigated, the first of which was the TUM classification, in which the overlapping topics were listed in both classes, and the second was the DGLR classification, in which the topics were bundled together. The conclusion to be drawn from this is that if topics are relevant to both aeronautics and astronautics, they should be classified into one class together. Furthermore, the classification characteristics should be chosen wisely, as doing so would ensure that classifying them more than once would be unnecessary. This refers back to Figure 3.1, in which two groups were power-driven and two were non-power-driven.

3.7 Regensburger Verbundklassifikation (RVK)

The *Regensburger Verbundklassifikation* (RVK) is a classification for recording entries in libraries. The RVK is maintained by the University of Regensburg and is used by academic libraries in Germany (UB 2022e). The following subsections provide insights into topics that are relevant to aerospace:

3.7.1 Space Travel

Space travel has 11 entries in the RVK: general *space travel*, *history of space travel*, *propulsion of rocket*, *rocket technology*, *spacecraft engineering*, *spacecraft, ground organization*, *space travel systems*, *remote sensing*, *satellites*, and *security* (UB 2022d).

3.7.2 Space Science

Space science has four entries: *general*, *manned space flight*, *space technology*, and *interplanetary and interstellar communication* (UB 2022c).

3.7.3 Aeronautics

Aeronautics has the following entries: *air traffic control*, *air traffic organization*, *airlines*, *aviation staff*, *simulation*, *history of aviation*, *airport*, *aircraft engineering*, *aerodynamics*, *wind tunnel technology*, *flight mechanics*, *aircraft*, *flight operations*, *repair and maintenance*, *testing and measurement*, *flight safety*, and *aviation meteorology and aviation in individual countries* (UB 2022a).

3.7.4 Aircraft

Aircraft has the following seven entries: *rotorcraft, balloon, airships, glider, motorized aircraft, jet plane, rocket plane,* and *jet aircraft.* For a clearer overview, a broader categorization could make sense. By combining the terms here with the knowledge already acquired would lead one to classify aircraft as "heavier than air" or "lighter than air." Classifying according to travel speed instead of propulsion type might be another consideration. The focus on propulsion could make more sense in another class, which could lead to engine/propulsion being its own group (UB 2022b).

After screening existing approaches, the next step is to evaluate and improve the existing classification. This will be done in *Chapter 4*.

4 Towards a New Aerospace Classification

4.1 Evaluating the Proposed Classification

In the previous chapter, the different approaches for classifying aerospace were examined. Before the proposed AAST classification is evaluated, the process that led to the initial situation must be described. The first step was to collect every term that could be found in existing classifications; then, the next step was to sort them in a logical manner – differentiating between tasks, vehicles, fields of competence, and sciences, among others. Features that stood out positively in the inspected classifications were included in the classification.

The next task was to name the terms and classes adequately, including the use of standardized names and terms for easy access and, if possible, the naming of similar classes (thinking of the rule of repetition in similar cases). The characteristics of other classifications that did not fit into the classification were changed and improved. Some ideas were even discarded because they did not fit the classification system. Terms and classes that could not be integrated into the classification due to its orientation can be found in Chapter 8 (*Other Dimensions of Categorization in Aerospace*).

First, the basics must be clarified. The DIN 32705 standard from 1987 provides the necessary information for the classification system. The research on DIN 32705 was presented in Chapter 2. For a suitable notation system, the DDC method was used. Furthermore, the order was monohierarchical to sort the knowledge easily and clearly for the user. Since the goal was a classification in the fields of aeronautics, astronautics, and aerospace sciences, a special classification, as described in Section 4.1.2, was required (DIN 32705, Ch. 4.1.2). The other option was a universal classification (DIN 32705, Ch. 4.1.1); however, this would have missed the point. The research revealed the need for a subject area classification (DIN 32705, Ch. 4.2.1). Revealing the whole expertise of *aeronautics*, *astronautics*, and *aerospace sciences* was the task, and therefore, the subject classification was most suitable for sorting the classes and terms in different fields. The other option – object classification – would exclude operations (DIN 32705, Ch. 4.2.2).

A subdivision according to the facets made sense in this case because the whole field is thoroughly multifaceted. Different facets were used to take different points of view for obtaining an all-round overview (DIN 32705, Ch. 4.3.2 and Ch. 3.2.3.1 and Ch. 6.4.3).

The bullet points from the AAST were not adopted, as they are newly developed. The sequence is as follows:

- ➢ First
    - ■ Second
        - • Third
            - o Fourth
                - ▪ Fifth
                    - - Sixth

The following list contains the top-level classes in the class of *Aeronautics*, without the subgroups and terms in them, which are highlighted later. Each class covers one approach, and every approach equals one facet. In the *Aircraft* class, the different aircraft are listed and grouped. In the second class, the different components and sections, such as the engines/propulsion of an aircraft, are gathered. The third class indicates which different parties are involved in the field of transportation and infrastructure. In this class, the operations are listed according to the areas of responsibility. For example, the airline is responsible for its fleet planning, maintenance, repair and operations (MRO), and spares logistics. The airport operator, on the other hand, takes care of the working process at the airport for customers and airlines.

Aeronautics

- ➢ Aircraft
- ➢ Aircraft Construction and Design
- ➢ Air Transportation
- ➢ Aeronautics and Society

The last class covers the point of view of society and is subdivided by history, aviation law, accident and incident investigation, and aviation's environmental aspects.

A closer examination of the classes is crucial for evaluating the classification system. As already mentioned, facets do not sort the classes – they only provide an opportunity to approach the topic from different directions. For the structure within the groups, categories are used. To make a suitable judgment about the use of categories, an investigation of the classes is required. Starting with aeronautics, the first major class is aircraft.

- Aircraft
  - Manned Aircraft (powered)
    - Heavier than Air Vehicles
      - Fixed Wing Aircraft (subsonic, supersonic, transonic, and hypersonic)
      - Rotorcraft (helicopter, autogiro, gyrodyne)
    - Lighter than Air Vehicles
      - Airships (blimps and zeppelins)
  - Unmanned Aircraft (powered)
    - Unmanned Aerial Systems (UAS)
    - Missiles
  - Unpowered Flight
    - Gliders
    - Kites
    - Balloons (moored and free)
  - Human Powered Flight
  - Animal Flight

This is the class of *Aircraft* in the classification from AAST (AAST 2022). The bullet points are from AAST and are changed later in this chapter. *Aircraft* has five categories and, as mentioned earlier, they are called an abstraction series due to being on the same hierarchical level.

- Manned Aircraft (Powered)
- Unmanned Aircraft (Powered)
- Unpowered flight
- Human Powered Flight
- Animal Flight

These are classification characteristics. The categories are all terms of a general nature (DIN 32705, Ch. 3.2.3.1), and they group aircraft according to whether they are powered/unpowered or manned/unmanned. Now comes the first possible correction. There are two subclasses with the same characteristic – namely *powered*. Thus, they could be reordered into four categories if rearranged. The classification characteristic would be *Powered Aircraft:*

- Powered Aircraft
- Unpowered Flight
- Human Powered Flight
- Animal flight

Under the hierarchical order of *Powered Aircraft*, there would be the following subcategories:

- Powered Aircraft
    - Manned Aircraft
    - Unmanned Aircraft

Powered Aircraft in this case is the generic term, while the subterms are *Manned Aircraft* and *Unmanned Aircraft*. As considered in Subsection 3.3.2.1.1, they have the same characteristic as their superior class *Powered Aircraft*, but they also have an additional differentiating feature, namely being either *manned* or *unmanned* (DIN 32705, Ch. 3.3.2.1.1). Recall that this was one point of criticism in Figure 3.1.

Yet, as seen in the structure, *Manned Aircraft* has two subcategories, which also have subgroups. This might be a reason not to allocate manned and unmanned under *Powered Aircraft*, thereby avoiding absurdly long abstraction relations. This must be considered in the notation. The longer the abstraction relation, the longer the notation for the terms on this level. This is the balancing act. The author must choose between more abstraction relations or more abstraction series.

Next, we advance to the next step on the ladder. *Manned Aircraft (powered)* has two subcategories, namely *Heavier than Air Vehicles* and *Lighter than Air Vehicles*. There is nothing wrong with this categorization, and it was also found during the research. Under *Heavier than Air Vehicles*, there are *Fixed Wing Aircraft* and *Rotorcraft*. *Lighter than Air Vehicles* has only one subgroup, namely *Airships*, which is not recommended, as it has only one subterm (Scholz 2006, p. 43). Yet, then again it groups blimps and zeppelins, which could form two subgroups instead of *Airships*. The categorization of airship is right for both, but one has a framework while the other does not, which is the differentiating feature that allows them to be grouped separately.

- Manned Aircraft (powered)
    - Heavier than Air Vehicles
        - Fixed Wing Aircraft (subsonic, supersonic, transonic, and hypersonic)
        - Rotorcraft (helicopter, autogyro, gyrodyne)
    - Lighter than Air Vehicles
        - Airships (blimps and zeppelins)

The subclasses of *Heavier than Air Vehicles* are two groups with several more pieces of detailed information, which could again form another sublevel. This means a more precise abstraction relation. Under *Fixed Wing Aircraft*, there would be four terms and the rotorcraft would get an additional sublevel with three terms. *Fixed Wing Aircraft* gets four subclasses, which are divided by their flying speed, and *Rotorcraft* are grouped by their flight mechanics.

The following is a full overview of a possible abstraction relation:

- Aircraft
  - Manned Aircraft (powered)
    - Heavier than Air Vehicles
      - Fixed Wing Aircraft
        - Subsonic
        - Supersonic
        - Transonic
        - Hypersonic
      - Rotorcraft
        - Helicopter
        - Autogiro
        - Gyrodyne
    - Lighter than Air Vehicles
      - Blimps
      - Zeppelins

The revised version has more classification levels (abstraction relation) and broader levels (abstraction series). It has five hierarchical levels and abstraction series (on the same level) of a maximum of four. The first one is therefore compact with four classification levels and not as wide-ranged within one level. The DIN 32705 standard leaves some leeway in this regard. Classes should be selected according to whether they are easily accessible (DIN 32705, Ch. 6.2).

Now, we move on to the next subpoints under *Aircraft*, namely *Unmanned Aircraft (powered)*, which contains *Unmanned Aerial Systems (UAS)* and *Missiles*.

Unpowered flight has three subpoints, namely *Gliders*, *Kites,* and *Balloons (*moored *and free)*. Considering the fact that *Heavier than Air Vehicles* are in the same abstraction series as *Balloons (moored and free)* and also has subpoints, there could be a new level under Balloons with the two terms *Moored Balloons* and *Free Balloons*. The last two points do not look like they fit into the same level as the groups within *Aircraft* because they do not have any subgroups. Moreover, they are not as complex as the other terms, so whether rearrangement could make sense is questionable. As mentioned previously, if *Powered Aircraft* is chosen as a major class, then *Human-Powered Flight* could also be in there. This would appear as follows:

- Aircraft
  - Powered Aircraft
    - Engine-Powered
      - Manned Aircraft
      - Unmanned Aircraft
    - Human-Powered
  - Unpowered Aircraft

Yet, then again, *Engine-Powered* aircraft would be deeper with all the branches and derivates, and *Human-Powered* aircraft would have no differentiating level. Thus, the original order with *Human-Powered* and *Animal Flight* on the top level under *Aircraft* makes sense, and it would be easier to look up for research purposes. The idea of classifying *Human-Powered* under *Powered Aircraft* is therefore discarded.

In general, classification characteristics should exclude themselves (DIN 32705, Ch. 6.2), which was done correctly. There is no term that could be suggested in another subclass. Classification characteristics should be easy to understand and identify. Regardless of whether the user is familiar with aeronautics, the user would be able to imagine what is meant to be in the classification just by reading the classification relation. Putting this all together, the following new variation emerges:

- Aircraft
  - Powered Aircraft
    - Manned Aircraft
      - Heavier than Air Vehicles
        - Fixed-Wing Aircraft
          - Subsonic
          - Supersonic
          - Transonic
          - Hypersonic
        - Rotorcraft
          - Helicopter
          - Autogiro
          - Gyrodyne
      - Lighter than Air Vehicles
        - Blimps
        - Zeppelins
    - Unmanned Aircraft
      - Unmanned Aerial Systems (UAS)
      - Missiles
  - Unpowered Flight
    - Gliders
    - Kites
    - Balloons
      - Moored
      - Free
  - Human-Powered Flight
  - Animal Flight

This new variation goes deeper into the abstraction ladder. One must keep in mind that every abstraction level must be represented in notations. The deeper the abstraction ladder, the longer the notation can be. If a limit is set of, for example, four digits for a notation, it would restrict the depth of the classification. Since the aerospace classification has no restriction for the notation length or the abstraction ladder, nothing would limit the depth of the classification system. This variation has the new bullet point hierarchy. The following classes are all displayed with this new system.

Next, we move on to the second class in *Aeronautics*, namely *Aircraft Construction and Design*:

- Aircraft Construction and Design
  - Overall Aircraft Design (OAD)
  - Airframe
    - Fuselage
    - Wing
    - Tail
    - Undercarriage
  - Engines/Propulsion
    - Piston Engine
    - Turboprop
    - Turboshaft
    - Jet
  - Systems
    - Avionics
      - Aircraft Avionics
      - Mission Avionics
    - Utility Systems
      - Secondary Power Systems
      - Protection Systems
      - Cabin Systems
      - Fuel Systems
      - Flight Control Systems
      - Landing Gear Systems

This class divides the aircraft into different components and sections. This subdivision applies the *partitive relation* (DIN 32705, Ch. 3.3.2.1.2). Airframe is the *association term* for the part terms of *Fuselage*, *Wing*, *Tail,* and *Undercarriage*. *Engines/Propulsion* is the association term for the hierarchically subordinate part terms of *Piston Engine*, *Turboprop*, *Turboshaft*, and *Jet*. The last class in *Aircraft Construction and Design* is *Systems*, which has two subordinate part terms in it, namely *Avionics* and *Utility Systems*. Each of the part terms forms a category as they contain several terms. *Avionics* is the *generic term,* while the *subterms* are *Aircraft Avionics* and *Mission Avionics. Utility Systems* covers the subordinate terms *Secondary Power Systems*, *Protection Systems*, *Cabin Systems*, *Fuel Systems*, *Flight Control Systems*, and *Landing Gear Systems*. One can recognize that even the classes on the same level are well-structured. The first class is the overall design, which is followed by the *Airframe*, and this is divided into several sections. The third is propulsion, while the last class covers the different systems. The further the class goes, the more detailed it becomes. The class goes from a rough structure to individual systems.

The third class in *Aeronautics* is *Air Transportation,* which covers the different parties of the transport system and their areas of responsibility.

- Air Transportation
    - Airport Planning, Operation, Management
        - Airside
        - Landside
    - Airline Planning, Operation, Management
        - Fleet Planning
        - MRO Management and Spares Logistics
        - Flight and Ground Crew Management
        - Marketing
        - Airline Partnerships
        - Airline Finances
    - Air Traffic Management (ATM)
        - Air Space Management (ASM)
        - Air Traffic Flow Management (ATFM)
        - Air Traffic Services (AIS)
            - Air Traffic Control (ATC)
            - Flight Information Service (FIS)
            - Alerting Service (ALRS)

This is a good example of the expressions and characteristics of the different facets. The second class was more for engineering purposes. This class is for cargo and passenger transport, as the class of *Air Transportation* indicates. The three categories sort the tasks by their area of responsibility. The first is airport management, the second is airline management, and the third is air traffic management. The categories in this class are all "Planning, Operation, Management" and are all terms of a general nature. The terms in the three categories are the part terms for their respective superordinate association term (DIN 32705, Ch. 3.3.2.1.2).

The classification system is developed with the top-down strategy or the *deductive structure*. Starting with a few top terms, an increasing number of specified categories and terms are added, which are categorized further down. The deductive structure was fulfilled throughout the classification (DIN 32705, Ch. 6.1).

The first principle for class formation is that classes should exclude themselves. The next rule is that the classes should be easily identified. Here, both were followed correctly.

The *Landing Gear System* is classified under *Utility Systems*, although it is part of the *Undercarriage*. The categorization in *Systems* → *Utility Systems* is more suitable. The *Landing Gear* is classified under *Airframe*, as is the whole undercarriage. The focus of the systems orders the landing gear under utility systems. The creation of a classification requires this process of consideration, where a term fits optimally.

For the next rule, the field of *Aeronautics* should be contrasted with that of *Astronautics*. Since these topics have a certain proximity, it is possible to compare them in Table 4.1:

Table 4.1 Comparison between aeronautics and astronautics

Aeronautics	Astronautics
➢ Aircraft	➢ Spacecraft
➢ Aircraft Construction and Design	➢ Spacecraft Construction and Design
➢ Air Transportation	➢ Spacecraft Operation
➢ Aeronautics and Society	➢ Astronautics and Society

Crucial to note is that in this consideration, the *facets* used to divide the different fields are compared. A statement about the depth of the different classes or the correct use of categories can only be made upon closer inspection. A positive note is that the facets in both classes are identical, just as the DIN 32705 standard described. Class orders should be repeated in similar cases (DIN 32705, Ch. 6.2). They should not just repeat, they should also be in the same order (DIN 32705, Ch. 6.4.5). With the information that the facets are identical, the categories in their respective facets should be compared.

Since aircraft have many more derivates, there would obviously be more categories and subgroups than for spacecraft. Therefore, this might not be useful for comparison, for which the second class is better suited. However, to compare them, the class of *Spacecraft Construction and Design* must be investigated.

- ➢ Spacecraft Construction and Design
  - ■ Overall Spacecraft Design
  - ■ Structures
  - ■ Propulsion
  - ■ Systems
    - Astrionics
    - Utility Systems
    - Photovoltaics
  - ■ Payload
  - ■ Space Suits

Striking in *Spacecraft Construction and Design* is that there are hardly any subgroups or subterms in the categories. This is probably due to the lack of a large number of derivates in the field of astronautics and thus also a lack of variety in the construction and design process.

This also becomes clear when one examines the first class of astronautics:

- Spacecraft
  - Launch and Reentry Vehicles
  - Satellites
  - Orbital and Mission Spacecraft, Space Stations

A more detailed description is not possible here or, in other words, there is not such a variety of spacecraft as that which exists for aircraft.

One of the principles is that the abstraction ladder should be without gaps (DIN 32705, Ch. 6.2). This was also correctly ensured.

Now, the two facets of construction and design can be compared in Table 4.2:

Table 4.2 Comparison of construction and design

Aircraft Construction and Design	Spacecraft Construction and Design
■ Overall Aircraft Design (OAD)	■ Overall Spacecraft Design
■ Airframe	■ Structure
■ Engines / Propulsion	■ Propulsion
■ Systems	■ Systems
-	■ Payload
-	■ Space Suits

The principle of repeating the structure in the same order in similar cases was also observed here (DIN 32705, Ch. 6.2 and Ch. 6.4.5). The first point is the overall design; the second is the airframe or structure, which is basically the same; and the third and fourth are the same – propulsion and systems. *Spacecraft Construction and Design* has two additional points, namely *Payload* and *Space Suits*. Comparing the last two classes leads to the following:

Table 4.3 Comparison of air transportation and spacecraft operation

Air Transportation	Spacecraft Operation
■ Airport Planning, Operation, Management	■ Ground Infrastructure
■ Airline Planning, Operation, Management	■ Space Infrastructure and Robotics
■ Air Traffic Management (ATM)	-

On the left-hand side, there is the aeronautics subordinate *Air Transportation*, while on the right-hand side there is the spacecraft subordinate *Spacecraft Operation*. Here, repetition is not possible due to the difference in the fields. Air transportation has three parties and their respective tasks, whereas spacecraft operation has only *Infrastructure*. The traffic management in space is nonexistent and therefore is not listed under *Spacecraft Operation*.

The last classes are compared in Table 4.4:

Table 4.4 Comparison of aeronautics/ astronautics and society

➢ Aeronautics and Society	➢ Astronautics and Society
■ History of Aeronautics	■ History of Astronautics
■ Aviation Law	■ Space Law
■ Aviation Accident and Incident Investigation	■ Space Debris
■ Environmental Aspects of Aviation	■ Aerospace Philosophy (mostly Space)

Even in the last classes, they are similar, as stipulated by DIN 32705. Both classes only have one subordinate level, and hence, there are no subterms. First comes history and second is law; however, in the third class they are different. Aeronautics addresses *Accident and Incident Investigation*, while astronautics addresses *Space Debris*. The rule of repeating the order in similar cases was observed throughout the classification. In addition, the terms “Aviation Debris” and “Space Accident” were not included. Both terms exist and could have been added, and they would complement a perfect system of parallelism; yet, they were not included because they lack significance in practice. Furthermore, adding them just for the sake of repeating classes would be meaningless – which is a positive point.

Here, the facet order is a central order element. The facets of both major classes of *Aeronautics* and *Astronautics* are highlighted. However, what is missing in both is the aspect of science. This is bundled into the last major class of *Aerospace Sciences (for Air and Space)*. This class contains all scientific disciplines considered in construction, dimensioning, and design. Considering all existing classification systems investigated earlier, this might be the most elegant solution.

- Aircraft and Spacecraft Design
  - Interior and Exterior Design
  - Multidisciplinary Design Optimization (MDO)
- Materials and Lightweight Structure
  - Strength of Materials and Structures
  - Aeroelasticity and Structural Dynamics
  - Manufacturing
- Fluid Dynamics and Thermodynamics
  - Experimental and Numerical Aerodynamics (CFD)
  - Thermal Management
  - Acoustics
- Flight Mechanics and Flight Guidance
  - Aircraft Performance
  - Aircraft Stability and Controls
  - Navigation
  - Astrodynamics
  - Flight Simulation
  - Flight Testing
- Avionics and Mission Technologies
  - Remote Sensing and Data Transmission
  - Data Processing and Automation
  - Software Engineering
- Sciences Applied to Aerospace Systems
  - Heating, Ventilation, Air Conditioning and Refrigeration (HVCA&R)
  - Mechanical and Electrical Engineering
  - Human Factors and Ergonomics (HF&E)
  - Hydraulics and Pneumatics
  - Kinematics
  - Sanitation
- Systems Engineering and Management
  - Air and Space Economics
  - Security, Safety, Reliability and related Human Factors
  - Project and Quality Management
  - Airworthiness, MRO
  - Documentation and Knowledge Management
- Air and Space Medicine

These are the classes in *Aerospace Sciences*. What stands out is that there are eight classes and they contain several categories. There is no sublevel under the categories.

The use of categories complied with the regulations. The appropriate use of abstraction relations cannot be judged since it was omitted here. Instead, the partitive relation is used here. Some of the classes are association terms, while the subordinate categories are part terms. For example, *Materials and Lightweight Structures* is the association term for the part terms *Strength of Materials and Structures*, *Aeroelasticity and Structural Dynamics*, and *Manufacturing*. These part terms are together called *stock series*. The partitive relation is used in all classes but *Air and Space Medicine*. The class is built up precombined as it contains complex terms that have been determined from the outset (DIN 32705, Ch. 4.3.3).

As explained previously, the sequence of terms and classes is also specified in DIN 32705. In aerospace classification, two options exist, namely the quantity (increasing or decreasing number) and the quality (increasing complexity). This is suitable for some of the classes. For example, *Aircraft* starts with *Powered Flight*, which has the most terms. The subordinate groups of powered flight are *Manned Aircraft* and *Unmanned Aircraft*. *Manned Aircraft* is the first named group, since it contains more terms than *Unmanned Aircraft*. *Manned Aircraft* has two subgroups: Again, it starts with *Heavier than Air Vehicles* since it has more terms in it than *Lighter than Air Vehicles*. Back at the top level, *Powered Flight* is followed by *Unpowered Flight*, which is not only the next class with most terms in it. Moreover, moving from powered to unpowered flight also fits in terms of content. The remaining classes have no terms in them and come at the end. This structure follows DIN 32705.

An example for a class with an increasing number of terms is *Aircraft Construction and Design*. It starts with the *Overall Aircraft Design* with no subordinate terms, followed by *Airframe* and *Engines/Propulsion*. Each has four terms, so it does not matter which comes first. The last class is *Systems*, which has the most terms. Simultaneously, this class can also be considered a sequence structured according to quality, as the class is structured from the overall structure to the different parts of an aircraft, and at the end the systems are listed.

As demonstrated, the classification is divided into three major classes, which divide the whole subject area into *Aeronautics*, *Astronautics*, and *Aerospace Sciences*. Therefore, terms and groups can be easily allocated either to Aeronautics or Astronautics. If it is a scientific aspect that applies to both, such as for thermodynamics or pneumatics, it is allocated to *Aerospace Science*. In addition to the tables, the possibility also exists of searching for terms in the register.

According to DIN 32705, classifications must be published with system tables (DIN 32705, Ch. 7.2). For the sake of completeness, the tables must be added with their hierarchical top level (DIN 2331).

To comply with the specifications of DIN 32705, a suitable introduction must be added (DIN 32705, Ch. 6.4.10), which is presented in *Chapter 5.2*. The individual terms are analyzed and listed with their source in the *List of Definitions* (DIN 32705, Ch. 6.4.2).

4.2 Adding Instructions for Use

Instructions for use must be included to fully meet the requirements of the DIN standard (DIN 32705, Ch. 7). The RVK has published a user guide. The focus of this research is on an online version. The user can either search for a notation or for a name or term in the search field. Alternatively, the user can search through the classification tree by expanding and collapsing the hierarchies. The results of the search are placed in the hierarchy with all of the superordinate terms, notations, and notes. A search for a term also delivers all of the entries in the register (UB 2022f). Moreover, the instructions can be adopted.

4.3 Adding Guide for Further Development

Over time, some new topics are bound to emerge in the field. For a full coverage of the topic, these new terms must be added to the classification system. Therefore, an instruction for maintenance and further development must be submitted (DIN 32705, Ch. 7).

To include new terms, there are two options. A new term is added to already existing classes and groups. For this purpose, a distinction must be made, and the crucial properties must be listed. It must also be checked whether the new term, based on the provided information, can be classified into an existing class or must be classified into a completely new one. With the help of the classification system, the user must simply follow the path and classify the new term. This can be done through the attached Excel file provided in *Section 6.3*.

Furthermore, a committee must be appointed that is allowed to insert new features (DIN 32705, Ch. 7.3). During the research work on classifications, there was an exchange with the university library of TUM. The librarians described the procedure for how their classification system is updated. They stated that the main initiators of changes to the system are the responsible *subject specialists*, who classify and evaluate whether a new system position should be introduced or an old one should be changed. TUM's library provided official intern documents which indicate how changes are processed. There are two types of change: the first can be made by a subject specialist without the involvement of the other subject specialists, including

- Thematic additions to existing "own" system entries;
- Referrals from one's "own" system locations;
- Changes to one's "own" register entries.

Here, the term "own" means that the subject specialist of aerodynamics can evaluate changes and referrals on his own for the class of aerodynamics. The second type of change must include the other subject specialists. This includes

- Integrating new entries;
- Changing existing entries;
- Deleting existing entries.

When integrating new entries, the other subject specialists must be informed, especially if overlaps in the profession occur, or if the change/deletion might affect their libraries. The initiating subject specialist must prepare, coordinate, and partially conduct the reclassification. They must also check which other classes and subject areas are affected. The subject specialist prepares a concept of the amended entries and consults affected subject specialists. He or she sets a deadline for comments and objections by the other specialists. All of the other subject specialists check whether they are affected by the proposed change and whether they have any objections and report them to the initiator. The actual adaptation in the system only occurs when all parties involved have been informed (Hanke 2022).

To keep things simple, the procedure can be adopted like this. Since it is already a working system, there is no reason not to adopt it. The more the classification grows, the more areas of application it will have. The more extensive the classification becomes, the more users it will have. The subject specialists will eventually increase in number. However, at the start, one responsible coordinator is sufficient because this is not as broad as a universal classification.

Since the classification will be open to use for everybody, there should be the option for external parties to suggest improvements. Here the procedure is similar: The initiator must prepare the changes and be able to justify them. Then, he or she must submit them to the responsible subject specialist, who must evaluate the submission and then inform the other subject specialists. From here, the process proceeds as usual.

With the full classification system and its instructions for use and further development, the classification must be published. This will be concerned in *Chapter 5*.

5 Documentation of the Aerospace Classification (DIN 32705)

5.1 Title and Imprint

The first Aerospace Classification was published by Prof. Dr. Dieter Scholz. The improved version of the Aerospace Classification was created by Schaugar Taher Gulani in 2022. Full responsibility for the classification lies with Prof. Dr. Scholz.

Aerospace Classification
Hochschule für Angewandte Wissenschaften Hamburg/
Hamburg University of Applied Sciences (HAW Hamburg)
Berliner Tor 5
20099 Hamburg
Deutschland
Professional coordination and responsible for the content: Prof. Dr. Dieter Scholz

The Aerospace Classification was created to develop a classification especially for aerospace with a thematic focus on librarianship.

Despite the careful control of the contents, the professional coordinator does not assume any liability for the contents of external links. The operators of the linked pages are solely responsible for their content.

This classification has been compiled with the greatest possible care. Nevertheless, the professional coordinator does not guarantee the accuracy, completeness, or timeliness of its web pages.

For any suggestions or ideas for improvement, please use the general procedure in Section 5.4 to submit your proposal.

5.2 Introduction

The following classification system focuses on aerospace. It divides the whole knowledge field into three major classes:

- Aeronautics
- Astronautics
- Aerospace Sciences

These three classes have several facets that cover the topic from one point of view. As a result, a fully developed classification is created.

The classification was created from the submission of the proposed aerospace classification by Prof. Dr. Dieter Scholz. The proposed classification was examined based on the DIN 32705 standard. Improvements were installed and the structure was aligned with DIN 32705.

DIN 32705 – *Classification systems: Establishment and development of classification systems* – was considered in the evaluation process of the aerospace classification. The notation is based on the system of the Dewey Decimal Classification (DDC system.

The classification system is open to everyone. Anyone can propose improvements to the coordinator, who will evaluate them. The order in this classification is a monohierarchical one. The terms that were not used for the classification system due to not fitting into the orientation/style/type of system are listed in Chapter 8 (*Other Dimensions of Categorization in Aerospace*).

5.3 Instructions for Use

The classification is divided into three major classes, which divide the whole subject area into *Aeronautics, Astronautics,* and *Aerospace Sciences*. Therefore, the user can easily allocate the terms and groups either to *Aeronautics* or *Astronautics*. If it is a scientific aspect that applies for both, such as Thermodynamics or Pneumatics, it would be allocated to *Aerospace Science*. In addition to the tablet, there is also the possibility of searching for terms in the *Register*. The user simply searches for the term that he or she is looking for to find it in its place along with the notation.

The *Register* is critical to the user experience. A register is a search aid for indexing. A listing contains a term, the associated notation, and – if applicable – the superordinate term. Every term in the classification system is listed in the register in alphabetical order. Therefore, users of the classification can easily find the term they are looking for. This also assists in searching for its hierarchical order. Registers should be created so that they can be used without explanations (DIN 31630), and therefore, it should be with the classification itself.

The notation system is based on the DDC. This classification follows these rules:

1. Every term has a notation;
2. A notation consists of at least three digits; the first two hierarchical levels are filled up with zeros, such as 3 → 300 and 12 →120;
3. Classes on the same hierarchical level are numbered chronologically, starting with '1';
4. Every new level starts with an additional '1';
5. The third digit is followed by a dot, which serves the purpose of visual structuring;
6. A notation never ends with a dot.

Based on these rules, the notation indicates the hierarchical level of the associated term (DIN 32705, Ch. 6.4.9).

5.4 Instruction for Maintenance and Further Development

Changes in the classification can be implemented by the coordinator. Differentiating between the type of changes is necessary:

- Thematic additions to existing entries;
- Referrals from existing entries;
- Changes of existing register entries.

These are changes that only affect the associated class, yet there might be changes that affect more classes, which are as follows:

- Adding new entries and classes: there might be overlaps with other classes and groups;
- Modification of existing entries and classes: this might affect the notations;
- Deletion of existing entries and classes: this might affect the notations.

All of the abovementioned changes must be made by the coordinator.

External parties can also submit proposals for revisions. The initiator must prepare the changes and justify them. Then, the suggestion must be submitted to the coordinator, who must evaluate the suggested change. If the suggestion is approved, the classification will be updated.

5.5 Classification System Tablets

5.5.1 Graphical Representation

For the sake of completeness, the tablets (Figures 5.1–5.3) had a hierarchical top level added as well as a second level besides *Aerospace Sciences* (Figure 5.3; DIN 2331). The complete development of the subject areas up to the last hierarchical level would go too far.

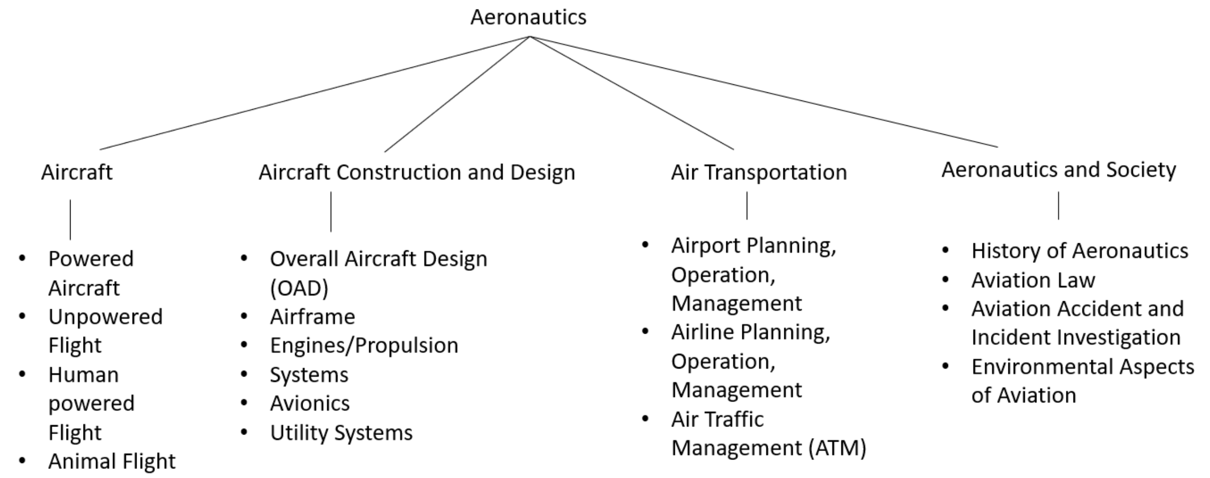

Figure 5.1 Aeronautics system tablet.

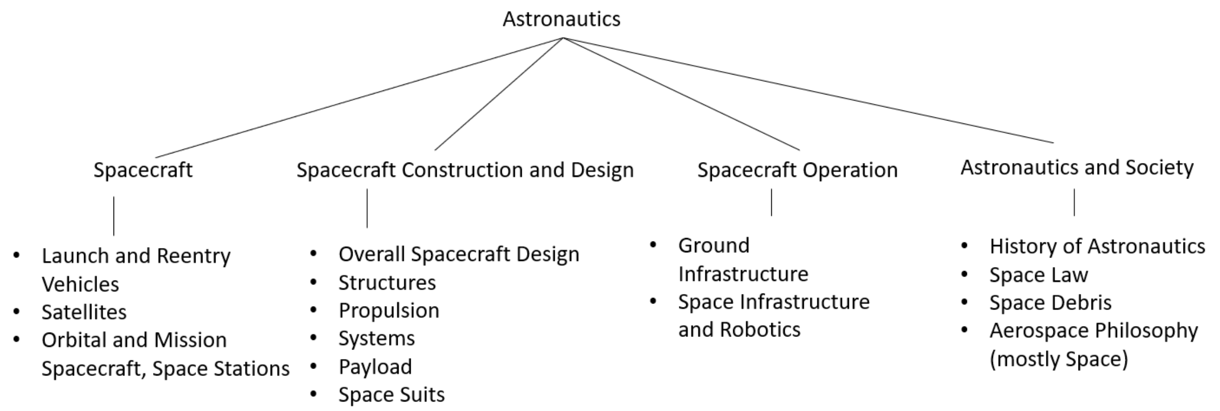

Figure 5.2 Astronautics system tablet.

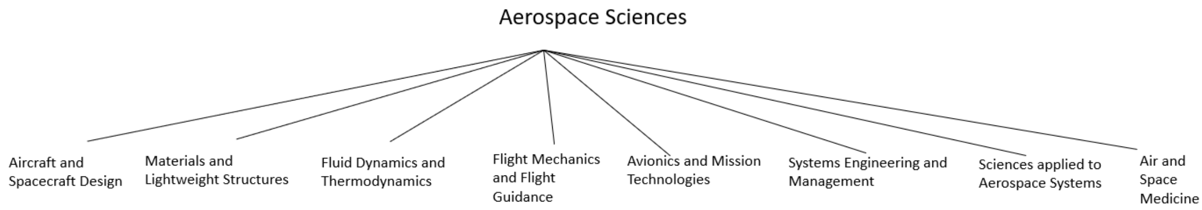

Figure 5.3 Aerospace sciences system tablet.

5.5.2 Full Version

This section presents the full classification with its notations and hierarchical relations:

Aeronautics	**100**
➢ Aircraft	110
■ Powered Aircraft	111
• Manned Aircraft	111.1
o Heavier than Air Vehicles	111.11
▪ Fixed Wing Aircraft	111.111
- Subsonic	111.111.1
- Supersonic	111.111.2
- Transonic	111.111.3
- Hypersonic	111.111.4
▪ Rotorcraft	111.112
- Helicopter	111.112.1
- Autogiro	111.112.2
- Gyrodyne	111.112.3
o Lighter than Air	111.12
▪ Blimps	111.121
▪ Zeppelins	111.122
• Unmanned Aircraft	111.2
o Unmanned Aerial Systems (UAS)	111.21
o Missiles	111.22
■ Unpowered Flight	112
• Gliders	112.1
• Kites	112.2
• Balloons	112.3
o Moored	112.31
o Free	112.32
■ Human Powered Flight	113
■ Animal Flight	114

➢ Aircraft Construction and Design	120
■ Overall Aircraft Design (OAD)	121
■ Airframe	122
• Fuselage	122.1
• Wing	122.2
• Tail	122.3
• Undercarriage	122.4
■ Engines /Propulsion	123
• Piston Engine	123.1
• Turboprop	123.2
• Turboshaft	123.3
• Jet	123.4
■ Systems	124
• Avionics	124.1
o Aircraft Avionics	124.11
o Mission Avionics	124.12
• Utility Systems	124.2
o Secondary Power Systems	124.21
o Protection Systems	124.22
o Cabin Systems	124.23
o Fuel Systems	124.24
o Flight Control Systems	124.25
o Landing Gear Systems	124.26
➢ Air Transportation	130
■ Airport Planning, Operation, Management	131
• Airside	131.1
• Landside	131.2
■ Airline Planning, Operation, Management	132
• Fleet Planning	132.1
• MRO Management and Spares Logistics	132.2
• Flight and Ground Crew Management	132.3
• Marketing	132.4
• Airline Partnerships	132.5
• Airline Finances	132.6
■ Air Traffic Management (ATM)	133
• Air Space Management (ASM)	133.1
• Air Traffic Flow Management (ATFM)	133.2
• Air Traffic Services (AIS)	133.3
o Air Traffic Control (ATC)	133.31
o Flight Information Service (FIS)	133.32
o Alerting Service (ALRS)	133.33
➢ Aeronautics and Society	140
■ History of Aeronautics	141
■ Aviation Law	142
■ Aviation Accident and Incident Investigation	143
■ Environmental Aspects of Aviation	144

Astronautics 200

- Spacecraft 210
  - Launch and Reentry Vehicles 211
  - Satellites 212
  - Orbital and Mission Spacecraft, Space Stations 213
- Spacecraft Construction and Design 220
  - Overall Spacecraft Design 221
  - Structures 222
  - Propulsion 223
  - Systems 224
    - Astrionics 224.1
    - Utility Systems 224.2
    - Photovoltaics 224.3
  - Payload 225
  - Space Suits 226
- Spacecraft Operation 230
  - Ground Infrastructure 231
  - Space Infrastructure and Robotics 232
- Astronautics and Society 240
  - History of Astronautics 241
  - Space Law 242
  - Space Debris 243
  - Aerospace Philosophy (mostly Space) 244

Aerospace Sciences (for Air and Space) 300

- Aircraft and Spacecraft Design 310
  - Interior and Exterior Design 311
  - Multidisciplinary Design Optimization (MDO) 312
- Materials and Lightweight Structures 320
  - Strength of Materials and Structures 321
  - Aeroelasticity and Structural Dynamics 322
  - Manufacturing 323
- Fluid Dynamics and Thermodynamics 330
  - Experimental and Numerical Aerodynamics (CFD) 331
  - Thermal Management 332
  - Acoustics 333
- Flight Mechanics and Flight Guidance 340
  - Aircraft Performance 341
  - Aircraft Stability and Controls 342
  - Navigation 343
  - Astrodynamics 344
  - Flight Simulation 345
  - Flight Testing 346
- Avionics and Mission Technologies 350
  - Remote Sensing and Data Transmission 351
  - Data Processing and Automation 352

Register

6 Online Versions of the Aerospace Classification

This chapter highlights the online versions of aerospace classification. The online versions are available as HTML, PDF and Excel file. Each file is linked.

This leads to the aerospace classification as a HTML file
https://purl.org/aero/classification/html

This PDF contains the hierarchical list and the register.
https://purl.org/aero/classification/pdf

This Excel spreadsheet contains the aerospace classification and the register.
https://purl.org/aero/classification/excel

7 Usage of the Aerospace Classification

Primarily the classification can be used to gather information about the whole field of aerospace. Therefore, the most likely area of application will be in libraries and archives, particularly the university library. The classification is especially suitable for classifying literature, which could help to structure the curriculum. This could spread the classification system through other universities with a similar study focus. The more the classification system is used, the more suggested improvements can be expected. This will inevitably lead to a classification system that is always up to date.

Regarding libraries, the classification can be embedded into a universal classification if required. This might happen if some libraries seek to implement our insights about aerospace into their existing library system.

Although the classification was developed from the engineering department, that the classification is useful for everyone has been ensured. This was done by illuminating the different facets in the classification. Yet, it cannot be denied that the engineering aspects are covered in greater detail. Nevertheless, it is still useful for other departments.

The different classes and terms can be expanded by adding more subpoints and subterms. To provide an example, airline operators can expand the class of *Airline Planning, Operation, Management* by adding task to the terms in the class. *Marketing* can be added by subordinate terms to divide the class. This annotation can be made by any class. It was not done here because doing so would have gone beyond the scope of the task. However, every addressed profession in this classification should gain knowledge from it.

In addition, the classification can be applied even in companies, such as for the division of labor, as was already demonstrated in *Chapter 3* with the DGLR. This can be expanded to every company in the aerospace field. There are facets for engineering, operation, management, and marketing.

8 Other Dimensions of Categorization in Aerospace

The proposed classification divides terms into Aeronautics, Astronautics, and Aerospace Sciences. Other classifications would also be possible. The DIN 32705 standard allows this leeway.

The final classification does not include every term gathered in the first process. They do not fit into the selected classes because of the orientation by dividing them into the above-listed classes. They can be found in the other dimensions, which are revealed as follows:

Dimension 2: Life Cycle (AAST 2022)

This dimension classifies aerospace products and topics into their temporal relevance. The subdivision would be made into the following:

- Research
- Development
- Design
- Production
- Operation
- Maintenance, Repair, Overhaul (MRO)
- End-of-life

Dimension 3: Usage (AAST 2022)

This dimension classifies air and space into civil and military usage:

- Civil Aviation
  - General Aviation
  - Scheduled Aviation
  - Nonscheduled Aviation
  - Experimental Aviation
  - Model and Scaled Aircraft
- Military Aviation
  - Combat
  - Noncombat

Dimension 4: Perspective, Background, Economic Sector (AAST 2022)

- Private Sector
  - Primary Sector: Extraction of Raw Material
  - Secondary Sector: Manufacturing (Original Equipment Manufacturer, Tier One, Tier Two, …)
  - Tertiary Sector: Services (Operator, Maintenance Organization, …)
- Public Sector
  - State-Owned Corporation
  - Government Agency
  - Research Establishment
  - University
    - Research
    - Teaching
- Civic Sector (NGO, NPO, …)
- General Public (Passenger, Consumer, …)

9 Summary and Conclusions

Starting with the proposed classification by Prof. Dr. Dieter Scholz, a full classification system was developed. The considerations have been presented and the fundamentals of general classifications, library classifications, and the notation system of the DDC were analyzed and used to establish a complete aerospace classification.

The proposed classification was assessed against the DIN 32705 standard and improved accordingly. However, the DIN standard was largely complied with. It was then demonstrated how the DIN standard was adhered to and what considerations arose during the creation process. The most information was provided by DIN 32705. The DDC informed the study of how a suitable notation system can be created, but the notation system of the DDC was not copied. The system was used to create new notations.

In the next step, existing classifications of aerospace (or parts of it) were investigated. The best approaches and ideas for improving the proposed classification were integrated with the aid of DIN 32705. Most importantly, classification systems were used for class structuring and grouping. The classification characteristics of the classifications indicated which changes might be adequate.

The analysis revealed the AAST classification is the most suitable in the field of aerospace thus far. In terms of content and structure, it was formally correctly oriented to DIN 32705. The classes and groups were also formed correctly. The choice of classification characteristics was logical and comprehensible. Nothing in terms of content was changed. Only a few subgroups were added to *Aircraft* and the arrangement was improved.

To fully comply with DIN 32705, the following elements needed to be added:

- A suitable notation system;
- Instruction for Use (Section 5.3);
- Instructions for Further Development (Section 5.4);
- A Register;
- Classification Tablets;
- An analysis of the Terms (cf. *List of Definitions*).

Chapter 5 (*Documentation of the Aerospace Classification*) provided all information that the Aerospace Classification needs to be published on its own. It contained the imprint; Instructions for Use, Maintenance, and Further Development; and the Register.

Chapter 7 presented what the classification can be used for. It paraphrased who can use the classification and gain knowledge from it. The other dimensions of aerospace were also mentioned and described. These included terms that did not fit into our design but are still important for aerospace. This leads to the conclusion.

Overall, it can be stated that this thesis offers deep insights into the process of creating a classification system in the field, where tension exists between covering all areas of aerospace and reaching a high abstraction level. At the beginning, all of the different terms were gathered to evaluate what was useful and what could be discarded. Once the selection process was complete, the interpretation started. Here, the following questions were addressed: What is a suitable main class? Which facets need to be covered? Which group comes first, and which facet comes first? Which classification characteristics should be used? How deep should the classification go? The most obvious conclusion is that it is a balancing act. DIN 32705 provides leeway, and this led to the results. The focus was on creating a classification system that is useful for aerospace. Chapter 8 (*Other Dimensions of Categorization in Aerospace*) demonstrated that plenty of options exist for classifying aerospace. Every classification has its tendencies and focuses, which lead to terms and classes that cannot be included in the classification. The other dimensions were not as useful as the final proposed classification. It must be clear that every author has biases. This leads to the specifications that the Aerospace Classification has. Every classification has its biases. As already demonstrated, the DDC has a bias in the class of religion toward Christianity due to its emergence in the Christianized United States in the 19th century (Ainsworth 2018). This clearly indicates that the author has a decisive influence with his personal preferences, knowing that the focus was on delivering a solution that would suit more than one department.

The classification is open to anybody and the instructions for further development will hopefully result in an evolving classification, resulting in it growing and expanding. As mentioned, the coordinator has already been chosen – a role assigned to Prof. Dr. Dieter Scholz. Through expanding the classification system, its bias could eventually vanish. The more the aerospace classification is developed, the more likely it is that its usability will expand.

The classification can be used as a library classification to structure and classify literature in the aerospace field. Since it is a special classification covering the aerospace field, it may be classified under a universal classification. The rules are the same for universal classification. However, *Aerospace Sciences* contain scientific aspects that are important for several (engineering) fields. In particular, classes like *Fluid Dynamics and Thermodynamics* and *Sciences Applied to Aerospace Systems* contain several terms that are critical for other scientific fields. Since DIN 32705 does not prohibit double mentioning, it may not be a problem, which should be considered. It could be bundled with other subject classification systems, or it could be integrated into a universal classification. In this case, the Register might be expanded through notes. If the aerospace classification is expanded with more knowledge fields, the cross-cutting topics will also expand. However, as seen in the TUM classification, it can easily be managed by adding notes to the entries.

A standard classification for aerospace does not exist, and every analyzed classification has its own interpretation. The new classification presented in this thesis has the potential to fill this gap for a standard classification.

The procedure followed in this thesis can be used as an example for any other subject. The procedure and the work are the same regardless of the subject. Therefore, other special classifications could be created by following this thesis.

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