Volume XXI, Issue (1) (2025) 289-296

International May Conference
on Strategic Management

DOI: 10.5937/IMCSM25289I

Original Research

HIGH-ALTITUDE PLATFORM SYSTEMS: PERSPECTIVES ON CURRENT AND FUTURE TECHNOLOGICAL DEVELOPMENTS

Damir Ilić[1] *, Vladimir Tomašević[1], Tatjana Ilić-Kosanović[2]

[1]University "Union – Nikola Tesla", The School of Engineering Management, Belgrade. Republic of Serbia
[2]University "Union – Nikola Tesla", Belgrade, Republic of Serbia

Abstract: High-Altitude Platform Systems (HAPS) is a promising technology with excellent future potential. HAPS may find application as standalone platforms or as a supplement to satellites in Earth orbit for the provision of a variety of services. The applications of HAPS technology are diverse, ranging from communications and photogrammetry to disaster response and other critical applications. Three large HAPS platforms—airships, winged HAPS, and balloons—are currently in the experimental phase, with each trying to maximize present technological possibilities to achieve the full potential of this innovation. The aim of this paper is to identify which platform holds the greatest promise for future application. To compare the potential of both platforms, the Analytical Hierarchy Process (AHP) methodology was applied. It is seen from the results that the winged HAPS have the highest potential for future development, and that airships can be also very valuable platform for specific missions, either independently or in combination with winged HAPS. The report notes the need for further, more extensive development of this new technology to fulfill its potential.

Keywords: HAPS, balloons, airships, winged HAPS, AHP.

1. INTRODUCTION

High-Altitude platform Station (HAPS) is a "station located on an object at an altitude of 20 to 50 km and at a specified, nominal, fixed point relative to the Earth" (ITU, 2016, p.13). HAPS platforms are engineered for high endurance and capable of performing various missions at altitudes of approximately 20 km. They can remain airborne for months, continuously operating above the designated target area (Delgado et al., 2024). In order to successfully realize missions, it is necessary to meet certain energy requirements for maintaining the wireless communication subsystem. It is necessary to precisely determine how much solar energy is

---

* *Corresponding author: damir.ilic@fim.rs*

Damir Ilić, ORCID: 0000-0003-1671-2785
Vladimir Tomašević, ORCID: 0000-0001-9845-2950
Tatjana Ilić-Kosanović, ORCID: 0000-0001-9813-7379

needed to maintain the desired position and operate the payload during the day, as well as how much energy needs to be collected and stored for night time use (Arum et al., 2020a). HAPS has the potential to become a key component of next-generation wireless networks, which will come as a result of technological advances in avionics, solar panel efficiency, battery energy levels and densities, and the overall proliferation of technological advances that are an integral and indispensable part of the aforementioned ecosystem (Mittal et al., 2024). HAPS provide the ability to provide reliable and continuous coverage of communication services to a targeted area, thereby enabling the provision of highly reliable communications for a wide range of applications such as disaster scenarios, support for ship and aircraft communications, and communication services for remote and hard-to-reach areas (Yuki et al., 2022). Their defining feature is their ability to remain at high altitudes for extended periods, ensuring reliable communication and coverage over wide areas. These platforms come in different forms, including fixed-wing aircraft, balloons, and airships (Arum et al., 2020b; HAPS Alliance, 2024a; Takabatake et al., 2024). This research focuses on which of the platforms offers the greatest potential in terms of materializing HAPS for performing various missions in light of technological progress.

2. LITERATURE REVIEW

There are two basic types of HAPS platforms: aerodynes and aerostats. Aerodynes use dynamic forces created by moving through air, while aerostats use lift to hover.

Aerodynamic lift, which enables flight of aerodynes, is based on two fundamental principles: Bernoulli's principle and Newton's third law of physics. On the other hand, platforms that provide lift without moving through the surrounding air mass are called aerostats. Aerostats, like balloons and airships, use gas within an envelope to achieve lift, making them lighter than the surrounding air mass (Grace & Mohorčić, 2011; Bagarić et al., 2025).

Altitudes of around 20 km are ideal for HAPS operation, requiring minimal effort to counteract wind-induced movements. Vertical winds have little impact at this level, and the stratosphere is largely stable due to its low water content, with minimal turbulence and mild winds (Grace & Mohorčić, 2011).

The classification of HAPS platforms includes the following types, each with distinct characteristics:

Fixed-wing aircraft (designed for high-altitude flight, these can carry a significant payload, be manned or unmanned, operate autonomously, and may be solar-powered);

Airships (utilize buoyancy for flight, offering high payload capacity and greater available power, they can reach altitudes up to 30 km and also operate on solar power);

Balloons (achieve lift through lighter-than-air gases, can be manned or unmanned, and have significant payload capacity) (Arum et al., 2020b).

Three alternative energy sources have been explored for HAPS operation in the stratosphere: Conventional sources (fuel tanks and electrical batteries onboard), Renewable sources (solar panels paired with batteries or hydrogen fuel cells for storage) and Microwave power transmission (energy beamed from the ground to HAPS) (Grace & Mohorčić, 2011).

The major challenges to the broader use of HAPS platforms in terms of liability are security, safety, and legal status. Safety concerns are related to national security and aviation safety, whereas security considerations relate to potential risks due to the transmission of sensitive information such as banking data and passwords. Unauthorized individuals gaining access to such information may lead to serious legal consequences. In regard to legal liability, there exist two doctrines: the functionalist doctrine, where the legal regime is decided based on purpose, design, and risk of collision, and the spatial doctrine, which applies the location of the object in defining legal frameworks (Mahardika Putro et al., 2023).

HAPS platform and its payload in the stratosphere face challenges related to temperature and pressure. During the day, solar radiation heats up the equipment further, while at night the temperature can drop dramatically. Therefore, efficient thermal management is necessary to ensure the proper functioning of the payload. In addition, the ambient pressure plays a crucial role, especially with regard to electrical insulation. Under certain conditions, air can no longer serve as an insulator for electrical energy, which can lead to technical problems (HAPS Alliance, 2022).

2.1. Balloons

The HAPS platform materialized in the form of a balloon allows users to have greater power and a longer flight time (several months). It offers a stable position and eliminates the need for long runways, which makes it somewhat more efficient compared to Unmanned Aircraft Systems (UAS). Compared to geosynchronous satellites in Earth orbit (GEO), stationary balloons are characterized by lower operating costs, lower complexity and significantly lower risk. They have the ability to provide higher resolution images with lower consumption of electrical energy for transmission. They are simple to manufacture and their deployment is fast. What should be emphasized as a serious disadvantage of stationary balloons is the fact that they have a small coverage area and that they are very difficult to maintain a continuous position, especially in terms of latitude and longitude (van Wynsberghe & Turak, 2016). Long-term aerostat operations at high altitudes face challenges with helium retention in ultra-thin coatings, as structural weight impacts payload capacity. Over time, helium loss necessitates complex logistics for replenishment, including safe landing and lifting. Temperature fluctuations between day and night affect the aerostat's coating and internal helium, requiring buoyancy adjustments to maintain altitude. Additionally, lateral gusts cause unwanted horizontal movement (Knap et al., 2021). Prominent representatives of this type of platformers are Raven Aerostar and Project Loon (HAPS Alliance, 2021).

2.2. Airships

Airships are a combination of a balloon and an airplane - they use lighter-than-air buoyancy, but also have the ability to navigate using lateral propulsion (HAPS Alliance, 2024b). High-flying airships have wide applications in both the military and civilian sectors, as they enable long-duration flight with low operating costs. Solar energy, converted into electricity by photovoltaic cells, plays a key role in their endurance. Among all HAPS platforms, only airships can carry heavy payloads (around 2000 kg or more) at high altitudes while staying airborne for months or even years. This makes them uniquely suited for long-duration missions compared to other platform types. (Xu et al., 2020). Like fixed-wing platforms, they provide precise positioning control. However, their large size adds operational challenges, making their management more complex (GSMA, 2021). When the operating altitude of airships in the operational area is fixed, the attitude angles, including the pitch angle and roll angle, do not change. By changing the wind direction and the cruising direction, the yaw angle of the airships can be adjusted. When observing a target located on the ground, a small change in the operating altitude has little effect on the observation of the target. Despite the fact that the wind speed is different at varying altitudes, it is easy to adjust the operating altitude of airships by inflating and deflating. It is advisable to reduce energy consumption by changing the operating altitude where there are lower wind speeds (Zhu, et al., 2021). The airship tries to reach the most optimal position during the day, using more energy to reach the desired position. During the night, the wind gently pushes it back at a slower speed, reducing overall energy consumption (Delgrado et al., 2024). Prominent representative of this type of platformers is project Sceye (HAPS Alliance, 2021).

2.3. Winged HAPS

Aerodynamic HAPS platforms, by design, rely on forward speed to efficiently generate and maintain lift. In the stratospheric environment characterized by low air density, for long-duration missions, aircraft fuselages are constructed of lightweight materials with fixed wings, low Reynolds numbers, and travel through the stratosphere at low speeds (Bagarić et al., 2025). Solar-powered high-altitude, long-endurance aircraft (HALE) have become a focus of research around the world in recent years. Their greatest advantage is that they can fly at high altitudes, hover, or circle over specific areas, all while using solar energy. This makes them ideal for a variety of applications, including telecommunications, surveillance, terrain monitoring, battlefield management, and even crop and forest analysis. Their ability to stay airborne for long periods of time without the need for constant recharging makes them extremely useful for many sectors (Gao et al., 2023). Fixed-wing aircraft designed for high endurance are not immune to challenges. Such platforms must be lightweight with a high aspect ratio for efficiency, while at the same time the batteries required for night operation add weight, making it necessary to realize a flexible, ultralight structure. Flying at high altitudes without a high-lift system due to weight limitations also results in a very narrow speed range (Hasan et al., 2022). Prominent representatives of this type of platformers are ERAST and Zephyr (HAPS Alliance, 2021).

Table 1. Overview of different HAPS platforms and their characteristics (HAPS Alliance, 2021)

Balloon	Airship	Winged platform
Long-duration missions; Quickly reach desired position; Wide area coverage; High payload capacity; Low-cost platform.	Good maneuverability; Large payload capacity; Long-duration missions; Relies on thrust (helium, hydrogen) rather than buoyancy at cruise Potential for large solar cell area.	High maneuverability due to (small size and low drag); Wide operational range; Long-duration missions; Operational flexibility; Good coverage of the area of interest.

2.4. Hybrid platform

In recent years, there has been growing interest in unconventional hybrid airship configurations. A representative of such a new concept is the Dynalifter, designed and developed by Ohio Airships (Ohio Airships, n.d.). However, at the current stage of development, the winged hybrid airship represents a poorer solution compared to conventional airship solutions, since the disadvantages caused by the increase in mass due to the mass of the wing and the large dimensions have neutralized all the advantages of the wing as an integral part of the structure (Gangadhar et al., 2022).

3. DATA AND METHODOLOGY

The Analytic Hierarchy Process (AHP), invented by Saaty in 1980, helps simplify complex decision-making by breaking problems down into smaller parts and then ranking them in order of importance. The Analytic Hierarchy Process (AHP) method facilitates decision-making by enabling a structured development of a hierarchy of problems. This involves defining the objective, identifying criteria and sub-criteria, and listing possible alternatives. Once the hierarchy is established, pairwise comparisons are made to assess the relationships between these parameters – objectives, criteria, and alternatives, moving from the highest level downwards (Radovanović & Stevanović, 2019). The Expert Choice software solution uses AHP to make this process much more efficient and user-friendly, guiding decision-makers toward logical conclusions (Expert Choice, n.d.). Using the Analytic Hierarchy Process (AHP), we will evaluate and rank the criteria and alternatives to identify the platform with the highest potential for future development. This systematic approach will ensure that the decision-making process is both structured and guided by priorities aligned with our goal.

4. RESULTS AND DISCUSSION

Applying the AHP methodology, we identified the global importance of criteria that play a crucial role in selecting the most promising HAPS platform for further development (Table 2.)

Table 2. Global importance of criteria that play a crucial role in selecting the most promising HAPS platform for further development (Authors)

Criteria	Global importance of criteria
Ability to maintain a stationary position	0.219
Payload	0.147
Manoeuvrability	0.091
Environmental impact	0.040
Speed	0.032
Structural strength	0.089
Endurance	0.161
Mission duration	0.120
Versatile Applications	0.050
Launch and Deployment	0.031
Cost	0.021
CR=0.04	

Global importance of criteria shown in Table 2.is presented in form of matrix Wcriteria:

$$\mathrm{Wcriteria} = \begin{bmatrix} 0.219 \\ 0.147 \\ 0.091 \\ 0.040 \\ 0.032 \\ 0.089 \\ 0.161 \\ 0.120 \\ 0.050 \\ 0.031 \\ 0.021 \end{bmatrix} \qquad (1)$$

The importance of alternatives (systems) relative to the criteria can be represented in the form of Matrix Walt-crit:

$$\text{Walt} - \text{crit} = \begin{bmatrix} 0.097 & 0.081 & 0.091 & 0.122 & 0.105 & 0.157 & 0.111 & 0.109 & 0.169 & 0.637 & 0.655 \\ 0.333 & 0.784 & 0.218 & 0.320 & 0.637 & 0.249 & 0.444 & 0.345 & 0.443 & 0.258 & 0.250 \\ 0.570 & 0.135 & 0.691 & 0.558 & 0.258 & 0.594 & 0.444 & 0.547 & 0.387 & 0.105 & 0.095 \end{bmatrix} (2)$$

Matrix of importance of alternatives is then calculated and presented in form of matrix:

$$\text{Walternatives} = \text{Walt} - \text{crit x Wcriteria} = \begin{bmatrix} Balloons \\ Airships \\ Winged\ HAPS \end{bmatrix} = \begin{bmatrix} 0.135 \\ 0.402 \\ 0.463 \end{bmatrix} \qquad (3)$$

Based on the results obtained in Matrix 3, the conclusion is that the most promising HAPS platform is the one embodied in the form of winged HAPS. The ranking of the platforms based on the weight factor is presented in Table 3.

Table 3. Ranking of platforms based upon weight factor (Authors)

Rankings	Platform	Weight factors
1.	Winged HAPS	0.463
2.	Airships	0.402
3.	Balloons	0.135

5. CONCLUSION

Based on the results shown in Table 3, it is obvious that the most promising platform is the winged HAPS platform. According to the obtained results, HAPS in the form of Airships have a slightly lower weight factor.

The superiority in terms of ability to maintain a stationary position, maneuverability, environmental impact, structural strength, mission duration goes in favor of winged HAPS systems. These features make winged HAPS ideal for tasks like telecommunications, disaster relief, and environmental monitoring, etc.

Airships deserve special attention when it comes to payload, speed, endurance and versatile application. What should be emphasized is the high payload and large surface area on which solar panels can be placed, which is a big problem for balloons and winged HAPS solutions. It should also be noted that HAPS Airships do not require a runway.

What might be expected is the development of both types of aircraft that would adapt to specific missions, and the construction of hybrid platforms is certainly not new. There have been such attempts in the past, but a major obstacle to the further development of HAPS platforms is the abundant use of satellite constellations, legal challenges, as well as the current level of technological development.

It is expected that, in line with all the advantages of these platforms, this situation will change in the near future and that HAPS solutions will become a significant part of our everyday life.

REFERENCES

Arum, S. C., Grace, D., & Mitchell, P. D. (2020b). A review of wireless communication using high-altitude platforms for extended coverage and capacity. *Computer Communications*, 157, 232–256. https://doi.org/10.1016/j.comcom.2020.04.020

Arum, S. C., Grace, D., Mitchell, P. D., Zakaria, M. D., & Morozs, N. (2020a). Energy Management of Solar-Powered Aircraft-Based High Altitude Platform for Wireless Communications. *Electronics*, 9(1), 179. https://doi.org/10.3390/electronics9010179

Bagarić, T., Rezo, Z., & Steiner, S. (2025). High-Altitude Pseudo-Satellite platforms as support to air traffic management. *Transportation Research Procedia*, 83(1), 593–600. https://doi.org/10.1016/j.trpro.2025.03.030

Delgado, A., Domínguez, D., Gonzalo, J., & Escapa, A. (2024). Station-keeping HAPS mission through optimal sprint and drift trajectories. *Aerospace Science and Technology*, 152. https://doi.org/10.1016/j.ast.2024.109365

Expert Choice (n.d.) Expert Choice solutions. https://www.expertchoice.com/

Gangadhar, A., Manikandan, M., Rajaram, D., & Mavris, D. (2022). Conceptual Design and Feasibility Study of Winged Hybrid Airship. *Aerospace*, 9(1), 8. https://doi.org/10.3390/aerospace9010008

Gao, Y., Qiao, Z., Pei, X., Wu, G., & Bai, Y. (2023). Design of Energy-Management Strategy for Solar-Powered UAV. *Sustainability* (2071-1050), 15(20), 14972. https://doi.org/10.3390/su152014972

Grace, D., & Mohorčić, M. (2011). Broadband Communications Via High Altitude Platforms. John Wiley & Sons Ltd.

GSMA (2021) High Altitude Platform Systems. Towers in the Skies. https://www.gsma.com/futurenetworks/wp-content/uploads/2021/06/GSMA-HAPS-Towers-in-the-skies-Whitepaper-2021-1.pdf

HAPS Alliance (2021). Driving the potential of the stratosphere. https://hapsalliance.org/wp-content/uploads/formidable/12/Driving_the_potential_of_the_stratosphere_HAPSAlliance_082021.pdf

HAPS Alliance (2022). Guidelines for Payload Operation in the Stratosphere. https://hapsalliance.org/wp content/uploads/formidable/12/Guidelines_for_Payload_Operation_in_the_Stratosphere_WhitePaper_2022.pdf

HAPS Alliance. (2024a). Creating an Enabling Regulatory Environment for HAPS Deployment.https://hapsalliance.org/wp-content/uploads/formidable/12/HAPS_Alliance_TWG_Regulatory_Positions_Paper_2024.pdf

HAPS Alliance. (2024b). HAPS Reference Architecture Series. Cell Towers in the Sky. https://hapsalliance.org/wp-content/uploads/formidable/12/2024_HAPS_Reference_Architecture_Series_Cell_Towers_In_The_Sky_White_Paper.pdf

Hasan, Y. J., Roeser, M. S., Hepperle, M., Niemann, S., Voß, A., Handojo, V., & Weiser, C. (2023). Flight mechanical analysis of a solar-powered high-altitude platform. *CEAS Aeronautical Journal*, 14(1), 201–223. https://doi.org/10.1007/s13272-022-00621-2

ITU (2016). Radio Regulations. Articles. Edition of 2016. https://www.itu.int/pub/R-REG-RR-2016 p.13

Knap, L., Świercz, A., Graczykowski, C., & Holnicki-Szulc, J. (2021). Self-deployable tensegrity structures for adaptive morphing of helium-filled aerostats. *Archives of Civil & Mechanical Engineering* (Elsevier Science), 21(4), 1–18. https://doi.org/10.1007/s43452-021-00292-6

Yuki, H., Yoshihisa, K., & Takahiro, A. (2022). Studies toward Practical Application of HAPS in the Space RAN. NTT Technical Review, 20(12), 28-35. https://doi.org/10.53829/ntr202212fa3

Mahardika Putro, Y., Aditya Nugraha, R., Rachmat Nugraha, T., Christiawan, R., Bodhihanna, A., Pratama Ong, J., & Testarosa, M. R. (2023). Legal Issues Pertaining to High Altitude Platform Station Implementation in Indonesia as an Archipelagic State. *Udayana Journal of Law and Culture*, 7(2), 144–164. https://doi.org/10.24843/UJLC.2023.v07.i02.p06

Mittal, N., Ivanova, N., Jain, V., & Vishnevsky, V. (2024). Reliability and availability analysis of high-altitude platform stations through semi-Markov modeling. *Reliability Engineering & System Safety*, 252, 110419. https://doi.org/10.1016/j.ress.2024.110419

Ohio Ships. (n.d.) Dynalifter-drone-runner. http://www.ohioairships.com/dynalifter-faq-s.html.

Radovanović, M., & Stevanović M. (2019). Analysis of the construction characteristics of automatic domestic production rifles for the purpose of equipping units of the Serbian Army. *Serbian Journal of Engineering Management*, 5(1), 40–49. https://doi.org/10.5937/SJEM2001040R

Saaty, T. L. (1980). The Analytic Hierarchy Process. McGraw-Hill, New York.

Takabatake, W., Shibata, Y., Hoshino, K., & Ohtsuki, T. (2024). Time-Efficient Neural-Network-Based Dynamic Area Optimization Algorithm for High-Altitude Platform Station Mobile Communications. *Future Internet*, 16(9), 332. https://doi.org/10.3390/fi16090332

van Wynsberghe, E., & Turak, A. (2016). Station-keeping of a high-altitude balloon with electric propulsion and wireless power transmission: A concept study. *Acta Astronautica*, 128, 616–627. https://doi.org/10.1016/j.actaastro.2016.08.017

Xu, Y., Zhu, W., Li, J., & Zhang, L. (2020). Improvement of endurance performance for high-altitude solar-powered airships: A review. *Acta Astronautica*, 167, 245–259. https://doi.org/10.1016/j.actaastro.2019.11.021

Zhu, W., Zhang, B., Zhang, L., Xu, Y., & Yang, K. (2021). Spatial path analysis for high-altitude solar-powered airship with maximum net energy. *Aerospace Science and Technology*, 117. https://doi.org/10.1016/j.ast.2021.106922