TECHNICAL REVIEW OF NETWORKED TETHERED FLYING PLATFORMS AND SOME OF THEIR USE CASES

ABSTRACT:
Airborne communications can be done via free-flying platforms and tethered flying platforms. Free-flying platforms, such as unmanned aerial vehicles (UAVs) and high-altitude platforms (HAPs), have been used to communicate in some places. However, they lack endurance and backhaul capacity. Network-connected flying platforms, on the other hand, take advantage of free-flying platforms and overcome their limitations by providing a constant power supply and data stream via a tether. They are also cost-efficient. NTFPs have wide applications beyond communications, such as energy harvesting, entertainment, science, research, public safety, disaster relief, government, and defense.
This paper provides an extensive overview of the types of NTFPs, their components and characteristics, their applications, advantages, and challenges. It also provides some case studies that have been used and the major companies related to NTFPs.

1. INTRODUCTION

Since the dawn of time, humans always needed communication. Today, its importance has increased. Furthermore, the unavailability of both public broadcasting technology and internet access, even temporarily, leads to numerous issues for individuals. During epidemics, communication is vital. For instance, the COVID-19 pandemic enforced remote learning and broadcasts. In areas where there is currently no internet and broadcast access, and in areas where communication has been destroyed during natural disasters, communication access must be provided quickly.

There are different ways to provide Broadcast and Broadband coverage, each with its advantages and disadvantages.

- Terrestrial communication: expensive and suitable for users at lower altitudes
- Satellite communications: Extensive coverage, especially low orbit (LEO) satellites, but its launch cost is very high and its deployment time is long, in addition to long delays due to the satellite distance from the user
- Air communications: include various items (this paper examines air communication).

Air communication has recently attracted much attention from researchers due to its features that allow broadcast and broadband coverage. They combine some of the terrestrial and satellite communication systems' best characteristics while avoiding many drawbacks. Air communication has the advantages of satellite communication systems, featuring flexibility of network planning and construction, wide bandwidth, wide coverage, and terrestrial communication systems that ensure timely supply meeting the demands, easy maintenance, and so on.

These air communications include different types of flying platforms. Some of these flying platforms are:

- Unmanned aerial vehicles (UAVs) fly at lower altitudes
- High-altitude platforms (HAPs) fly at higher altitudes

Airborne platforms are vehicles that can fly in the air by opposing the force of gravity using either a static lift or a dynamic lift. They are classified into two types as shown in ***Figure 1***:

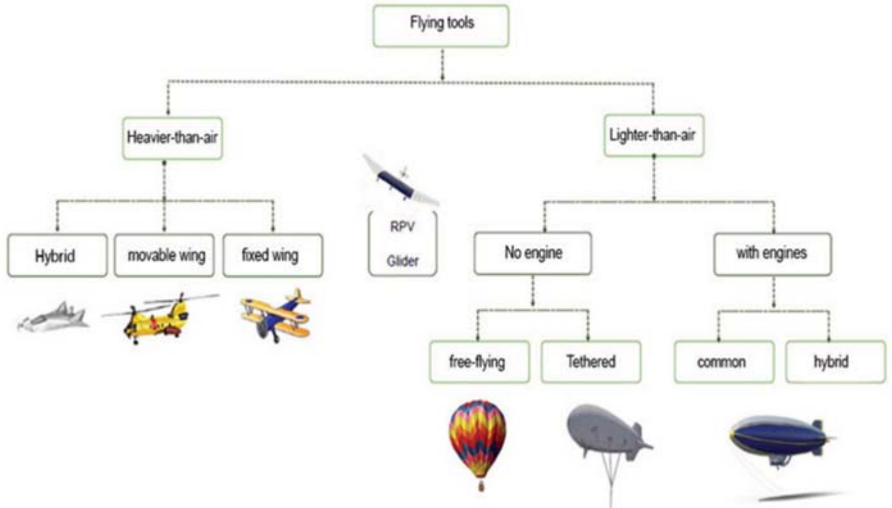
- Lighter-than-air (LTA): They use static lift or aerostatic lift; they are filled with a low-density LTA gas such as helium or hydrogen
- Heavier-than-air (HTA): They use dynamic lift or aerodynamic lift; their lift is produced by the relative motion between the HTA platform and the air, which pushes the platform upwards by Bernoulli's principle.

These flying platforms overcome some of the limitations of satellite and terrestrial communications such as the items listed in **Table 1**.

Table1: Advantages and Disadvantages of flight platforms

Advantages	Disadvantages
Low installation cost	Low stability
Low delay	Low endurance
Low deployment time	Backhaul connection

Figure 1: *Types of flying platforms*



Taking account these restrictions, another type of flight platform is currently used by governments, militaries, and telecommunication companies: Networked Tethered Flying Platforms (NTFPs).

NTFPs are flying platforms tethered to a ground unit and data and its power are supplied from the ground unit continuously. Due to the existence of this tether, it eliminates many problems that exist in free flying instruments and provides advantages for NTFPs. These advantages are:

- Cost-efficient and inexpensive
- Endurance and persistence
- Backhaul capacity, endurance, persistence, constant
- Power supply, and security

2. TYPES OF NTFPS

In this article, only NTFPs lighter than air are considered. They are filled with low-density gases such as helium. The difference between the density of the air outside the envelope (envelope) and the density of the LTA gas creates buoyancy based on Archimedes' principle. The most popular LTA (lighter than air) NTFPs are balloons and blimps:

2.1 BALLOONS

The cost of their design and construction is low. The height at which they are placed and the load they bear is also less. This model of tied balloons shown in ***Figure 2*** can withstand wind speeds of about 20 to 40 km/h.

Figure 2: *Balloons*

2.2 BLIMPS

This type of NTFP can carry heavier loads and withstand high-speed winds at higher altitudes (***Figure 1***). Blimps vary in size, height and load-bearing capacity. TCOM Company categorises them into three classes. [See *https://repository.kaust.edu.sa/items/aa86f135-cda6-4074-b2ea-b7e36c6a570b*]:

- Tactical Class: These balloons are 20 meters long, can carry 27kg at 300m height, and are quickly installed. The deployment duration at altitude is 7 days, and can withstand winds up to 100 km/h. ***Figure 3*** shows its use by the US military in Iraq and Afghanistan. It has also been utilised for monitoring the US-Mexico border.

Figure 3: *Tactical TCOM blimp*

- Operational Class: The balloons are of medium size, approximately 30 meters (***Figure 4***). They are highly portable and flexible, allowing for quick deployment and recovery. They can carry a load of up to 200 kg and can be installed up to a maximum height of 1 km. The duration of installation at a height is about two weeks. This type of balloon is suitable for monitoring operations in areas where land operations are not possible, such as the sea and borders, and can withstand speed of up to 130 km/h.

Figure 4: *Operational TCOM blimp*

- Strategic Class: These balloons have a size range of 50-75 meters and can carry up to 2300 kg of cargo, making them the largest NTFPs (***Figure 5***). These objects are capable of staying airborne for up to 30 days, reaching a height of 4.6 kilometers, and surviving a maximum wind speed of 166 kilometers per hour. They are designed for long-term surveillance missions and are useful in detecting low-altitude aircraft and cruise missiles.

Figure 5: *Strategic TCOM blimp*

The differences between the parameters of NTFP types are summarised in **Table 2**.

Properties	Balloons	Blimps		
		Tactical	Operational	Strategic
Payload	5 Kg - 50 Kg	27 Kg	200 Kg	2300 Kg
Altitude	150 m - 700 m	300 m	1 Km	5 Km
Wind Speed	20 Km/h - 40 Km/h	74 Km/h - 100 Km/h	92 Km/h - 130 Km/h	130 Km/h - 166 Km/h
Flight Duration	1 day - 7 days	7 days	14 days	30 days
Deployment Time	Low/Moderate	Moderate/High	Moderate/High	Moderate/High

Table 2: Comparisons among types NTFPs

3. COMPONENTS OF NTFPS

NTFPs have various components that are described in this section:

3.1 ENVELOPE/SHELL

The balloon is made of synthetic materials such as polyester, polyurethane, and polyvinyl. It also contains laminates to prevent damage from UV rays and abrasions. These blimps are powered by wind. Some envelopes have spherical forms (balloons), others have a fish-shaped or streamlined forms (blimps).

3.2 LIFTING GAS

The envelope contains lift gas, which creates buoyancy by being less dense than air and following Bernoulli's principle. Hydrogen and helium are the most common and lightest gases:

- Hydrogen is the lightest gas and can be produced easily, but it is very flammable.
- Helium is the second lightest and non-flammable gas, but it is very expensive, scarce and a non-renewable resource. Helium is the most common gas for NTFPs.

Some companies design using hydrogen and helium.

3.3 PAYLOAD

The weight that the blimps can bear at the desired height, excluding its weight and the weight of its tether. The total payload capacity is divided into two categories:

- The support payload includes all the necessary equipment to launch the platform.
- The operational payload includes equipment related to the mission (the type of equipment varies from one mission to another).

3.4 TETHER

The tether connects the winch to the envelope or shell of the non-rigid lighter-than-air (LTA) craft. Typically made of synthetic fibers, the tether's length, diameter, strength, and weight vary depending on the type and size of the LTA craft. The tether serves several purposes:

- Maintain and stabilise the platform in the air from the ground.
- Supply power to the platform through the power line.
- Transmit data to the platform through the optical fibers.

The strap must be resistant to weather conditions (temperature, humidity, rain, snow, lightning, etc.).

3.5 MOORING STATIONS AND ANCHOR UNITS

A system for maintaining the balloon's envelope before launch, after a flight and during maintenance. These stations vary in size, shape, and complexity depending on:

- The size of their balloons.
- The environment in which the NTFPs will be used.

3.6 ANCHOR POINTS

The unit to which the balloons are anchored and holding them in place above the ground. This unit also has different types and sizes.

3.7 WINCHES

A winch is a device that is used to release and adjust the tether during launch, as well as pull it back during the recovery process. The size and type of winch used varies depending on the size and height of the blimps. Winches can be operated manually, electrically or with a motor. *[See P. K. Chopra et al, A New Topology for Telecom and Broad Band Services in Spars, Remoteand Hilly Areas; WSEAS Transactions on Communications]*

3.8 GROUND CONTROL STATIONS

These stations serve as operational bases for NTFPs and for:

- Platform height control.
- Storage and in some cases process of mission-related data such as videos and images.

Depending on the mission type, it can be a vehicle, a container, or a tent that also acts as a shelter *[See B E Y Belmekki, M S Alouini; On the Usage of Networked Tethered Flying Platforms for Massive Events -Case Study: Hajj Pilgrimage]*. All components of the balloons are shown separately in ***Figure 6***.

4. COMPANIES RELATED TO NTFPS AND CASE STUDIES

In America, the TCOM Company started working on aerostat systems as a global authority in airborne persistent surveillance solutions in 1971. The balloons were originally used for TV and FM radio broadcast, radio repeaters, and microwave relays. Later, in the HALLMARK project, the US Coast Guard utilised the same balloons to search for drug smugglers and illegal drug shipments. Among other projects of this company are BORDER PATROL, from the Department of Homeland Security (DHS), and Customs and Border Protection (CBP), used to monitor difficult situations in the US-Iraq wars, as well as to monitor Texas's southwest borders. These systems provide the possibility of quick monitoring in a wide radius. *[See https://tcomlp.com/hallmark-aerostat-system/]*

In Russia, RosAeroSystems operates in the field of blimps and also offers low-cost alternatives to satellites called TA. Payloads and connected equipment can transmit digital signals for TV, internet, communication, and radio, as well as monitor surveillance cameras and display advertisements. The Lynx model from this company is capable of remaining airborne for up to 15 days. Its wind resistance is approximately 100 kilometers per hour. For longer missions, the aircraft requires a brief landing of 1-2 hours to perform maintenance and address any issues that may arise. *[See http://rosaerosystems.com/]*

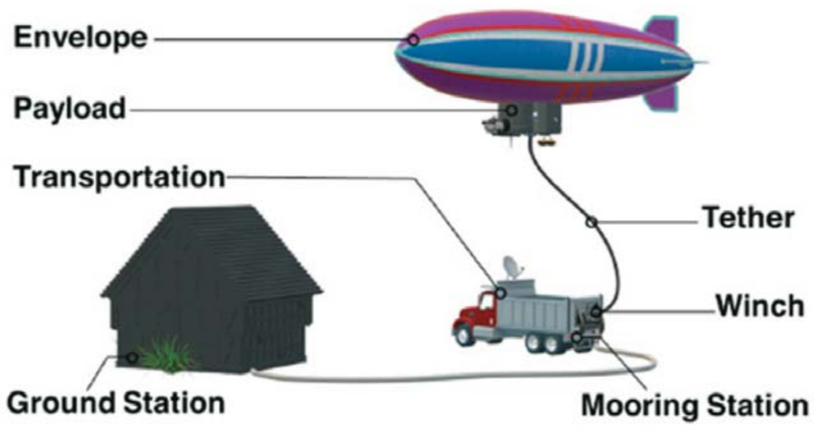


***Figure 6**: Components of NTFPs*

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***Figure 7**: Blimps of RosAeroSystem*

***Figure 8**: Blimps of A-NSE*

In France, the A-NSE Company manufactures this type of balloon for its customers, particularly African countries. Most of the products sold have been used to monitor the borders of countries such as the Ivory Coast or to monitor fires in some parts of France, such as around the Marseille River. The company offers a variety of balloon models based on payload weight and required height. *[See https://www.a-nse.com/products/tethered-balloons/]*.

The Iranian Space Research Institute, which operates under the Ministry of Communications and Information Technology, has developed a product that has been utilised in various instances. The institute has created different models of the product, namely BAM 15, BAM 50, and BAM 300. The differences between these models are highlighted in ***Figure 9***.

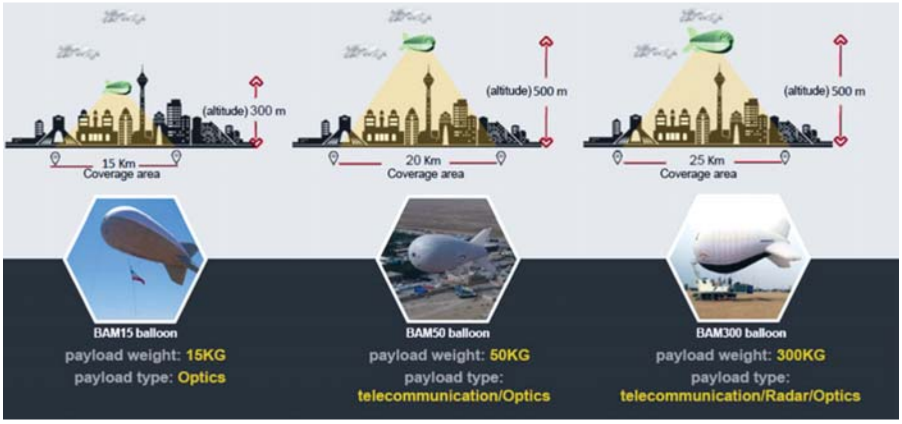

***Figure 9**: Types of Blimps made by Iran*

Blimps manufactured in Iran have been utilised in disaster relief efforts, equipped with cameras to capture images and videos of affected areas, as well as antennas to provide cellular and internet coverage. A cable is used to transfer information between the balloon and the ground station. This enables people in critical situations to communicate with their families and access important news. To explore the possibility of providing TV coverage in crisis areas, Broadcast is currently conducting feasibility studies on installing DVB-T/T2 transmission equipment on these balloons. *[See Iranian Space Research Center (ISRC); https://www.isrc.ac.ir/L9PO4]*

5. CONCLUSION

In this paper, NTFPs were reviewed in general. Its types, components, advantages, and disadvantages were investigated. Several manufacturers were introduced and several cases of their use in the world were described. NTFPs are suitable for natural disasters due to quick setup and energy/data provision via backhauls.

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Mahrokh Shojayee works at the IRIB R&D department as a senior researcher from 2001. She holds a BS in Electronic Engineering from Amirkabir University and has been involved in the Digital Radio (DAB/DAB+, DRM, DNS) projects and was active in researching and supervising the construction of their equipment such as MUX, Receiver, Transmitter (DAB, FM, Doherty). She is also active in MPEG Media Transport (MMT), High Altitude Platform Station (HAPs) and Radio DNS review projects. ■