Design and Infrastructure of Space ICT via Stratospheric Platform Systems (SPS) for Aeronautical Applications – Part 1

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Abstract: In this paper is introduced design and infrastructure of Space Information and Communication Technology (ICT) via Stratospheric Platform Systems (SPS) for aeronautical applications, which has to provide communication and navigation data transfer for improved Air Traffic Control (ATC) and Air Traffic Management (ATM). Today there are in use two significant communication facilities, such as well known Terrestrial Communication Network (TCN) and Satellite Communication Systems (SCS), while SPS as an alternative has attracted the attention of the communication infrastructures worldwide. The new SPS networks are the latest space techniques with advanced technology for fixed and all mobile applications including military and rural solutions. The SPS unit is a station located as space object at an altitude of 17 to 50 km as a specified and fixed point relative to the Earth. The SPS systems employ unmanned or manned, solar or fuel energy airships or aircraft carrying payloads with transponders and antennas. The SPS networks and solutions are considered in this paper as a novel aeronautical application for providing Communications, Navigation and Surveillance (CNS) systems and techniques for any hypothetical flight air corridors and airport infrastructure. The CNS applications for development of aeronautical tracking, determination and transfer of Global Navigation Satellite Systems (GNSS) data via SPS, such as Global Aircraft Tracking (GAT), Space Data Link (SDL), GNSS Augmentation SDL (GASDL), Space Automatic Dependent Surveillance - Broadcast (SADS-B) and Space Automatic Identification System (S-AIS) are proposed.

Key words: ICT, SPS, ATC, ATM, TCN, SCS, GNSS, GAT, SDL, GASDL, SADS-B, S-AIS, WCS, IMO, SOLAS, VHF, SAS, GEO, MEO, LEO, CNS Applications

1. Introduction

Stratospheric Platform Systems (SPS) are the latest space technology integrated with cutting-edge CNS technologies for fixed and mobile applications, including military solutions. These systems are using unmanned or manned on solar or fuel energy aircraft and unmanned on solar power airships only, both carrying payloads onboard with transponders, antenna systems and Telemetry, Tracking and Command (TT&C) equipment.

With a few very cost effective remote controlled and solar powered airships as a better solution, a territory of some province, region or country can be covered for fixed and mobile applications including urban, suburban rural and remote areas, farms, forests and other environments with a low density of population. Today there are four general telecommunications architectures, which can be used to deliver broadband wireless local loop service to fixed and mobile consumers. Two of these architectures are space-based Geostationary Earth Orbit (GEO) and Non-GEO or Low (LEO and Medium Erath Orbit (MEO) satellite systems and the other two are terrestrial rooftop cellular-like millimetre wave repeaters and stratospheric relay platforms.

The SPS network offers better solutions than all cellular systems, with greater speed of transmission than even optical modes, with better roaming, with reduced shadowing problems and disturbances between hills and inside buildings and service will cost less. Moreover, the SPS mission can be integrated with current satellite and cellular systems to provide more reliable fixed and mobile solutions, and what is significant the SPS network is more autonomous and discrete than all other networks, and will be the best solution for mobile and military applications.

For instance, the Halo Broadband SPS Millimeter Wavelength (MMW) Network of the Angel Company provides data densities nearly one thousand times higher than proposed satellite GEO and LEO systems, presented in Table 1, while having round trip time delays appropriate for interactive broadband services. Whereas, the delays through GEO satellite network nodes, even through LEO satellite nodes, are too long for many interactive applications, delays are 25 or 1,000 times longer for LEO or GEO then for Halo Networks, respectively. On the other hand, the parameters of Halo SPS are similar to a variety of metropolitan environment spectrum bands of the Local Multipoint Distribution Service (LMDS) band near 28 GHz.

Table 1. Comparison of Data Density and Signal Delays

Node Type	Node Data Density		Round Trip Delay	
	Min ($Mb/s/km^2$)	Max ($Mb/s/km^2$)	Min (millisec)	Max (milieu)
LMDS	3	30	0.003	0.060
Halo	2	20	0.10	0.35
LEO (Broadband)	0.002	0.02	2.50	7.50
GEO	0.0005	0.02	200	240

The increasing demands for modern, reliable and cost effective communication services grow very rapidly, s a pressure on the radio spectrum allocations can therefore be a trigger to a move towards higher frequency bands, which are less heavily congested. At this point, the use of millimeter wavelengths implies Line-Of-Sight (LOS) propagation for cellular systems that represent a challenge compared with lower frequencies. The local obstacles will cause some problems because each user needs to have a LOS in cellular communication towards a base station. This problem again implies a large number of base stations that has to be deployed as well, what SPS systems don't need.

In recent years, a novel wireless concept of SPS that has been attracting much the attention of the national and international telecommunications community is proposed, which also need LOS. These systems are the SPS crafts or High Altitude Platforms (HAP) based on reusable unmanned or manned air vehicles, carrying transponders with antenna and operating in the stratosphere in almost quasi-stationary position at altitudes up to 25 Km above the Earth's surface.

Such altitudes have not been used much by telecommunication services except perhaps for those related to scientific researches. However, these systems are acting as very low altitude spacecraft and have both azimuth and elevation angles. Elevation angles are providing better coverage and penetration in the building or shadowing than one tower of cellular systems. Thus, SPS can be used for fixed and mobile solutions including for CNS systems for all mobile applications, such as space tracking, determination, augmented navigation and data transmissions.

1.1. Overview to SPS Networks

The SPS or HAP (HAPS) denomination was defined in the World Radio Communications Conference (WRC) in 1997, in the Radio Regulations (RR) No. S1.66A as 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 [WRC-122, 97]. However, in this Chapter the use of the acronym HAP or HAPS will be replaced by SPS as a more common and adequate designation in the field of Space Communications. In this definition, it has not been determined yet if the object is manned or unmanned or even how is it powered. Several countries are now proposing many alternative technologies for the development of such an object in stratosphere.

In **Figure 1** is illustrated integration of GEO, MEO and LEO satellites with unmanned SPS (HAP) powered by solar cells and three types of Unmanned Aerial Vehicle (UAV) powered by fuel engine propulsion. Here can be also included Manned Aerial Vehicle (MAV) for operating on a daily basis, which with UAV are usually serving for military applications.

The systems based on SPS networks represent a technological alternative that has been under study and development for the last several years, although the investigation of Unmanned Aerial Vehicles (UAV) had started at a few universities and research centres around the world as early as the late 1950s. These platform systems could have many advantages compared with both, terrestrial and satellite communication systems, while at the same time avoiding many of the pitfalls [ITU-Q/2, 98], which can be solved.

Thus, several countries are now proposing alternative technologies for the development of hovering and flying object in stratosphere. The SPS stations are to be positioned well above commercial airplane at an altitude that is high enough to provide service to a large area or spot footprint for Communication, Navigation and Surveillance (CNS), broadcasting and environment observation services with minimal ground network infrastructure.

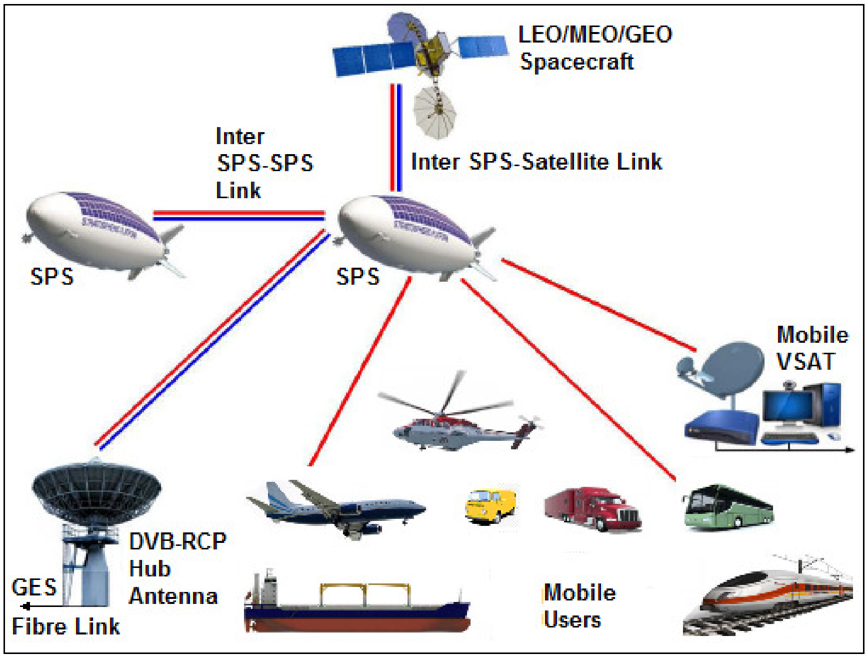

Figure 1. Integrated SPS and Satellite Networks – Source: Ilcev

The SPS network is to be positioned well above commercial airplane at an altitude that is high enough to provide service to a large area or spot footprint, providing digital telecommunication, broadcasting and environment observation services with minimal ground network infrastructure. The common vision predicts that this system will consist of one or more quasi-stationary SPS with Inter-Platform Links (IPL) as depicted in **Figure 1.** On the other hand, the same network can be developed without IPL, so all platforms have to communicate via Ground Earth Stations (GES) or Gateways located in the overlapping arrears. The common vision predicts that this system will consist of one or more quasi-stationary SPS with Inter-Platform Links (IPL) integrated with GEO, MEO or LEO satellite systems via Inter SPS-satellite links, all connected to the onboard mobile Very Small Aperture Terminal (VSAT) and all mobile users.

On the other hand, the same network can be developed without IPL, so all platforms have to communicate via Ground Earth Station (GES) located in the overlapping arrears. In such a way, the SPS network is providing local backhaul links between User segment via SPS terminals to the Base Station (GES) connecting Fiber optics or TCN. The SPS infrastructures spread network coverage using IPL via any GES or alternative backhaul via satellite for remote areas. The SPS network is providing continuous fixed or mobile Digital Video Broadcasting-Return Channel via Platforms (DVB-RCP) services over months or years, which includes Voice Data and Video over IP (VDVoIP), computer networking, access to the public network and Internet at relatively low cost and provides better transmission and penetration in the buildings than current Cellular systems. The next important issues of new SPS infrastructure are high elevation angles, broad coverage, low propagation delay and cost operation, easy and incremental deployment, ability to move around in emergency situation and can provide high-speed multimedia wireless communication service.

General SPS architecture has proposed that footprints of a radius more than 150 km. The lower radius the minimum elevation angle, the larger the coverage environment but the propagation or blocking loss becomes high at the edge of the servicing area. A practical minimum elevation angle for broadband wireless access is 5°, while 15° is more commonly considered in order to avoid excessive ground clutter problems. This implies that for a space platform positioned at an altitude of 20 km the radius of the coverage area is approximately 400 - 500 km. Ground stations, which connect the SPS network with other terrestrial networks, can be placed on roofs of buildings or onboard mobiles. For remote areas where there is no substantial terrestrial telecommunication network satellites can be used as backhaul. That is why most of SPS stations are to be located at the altitude above of about 25 – 30 km and coverage will up to approximately 600 km.

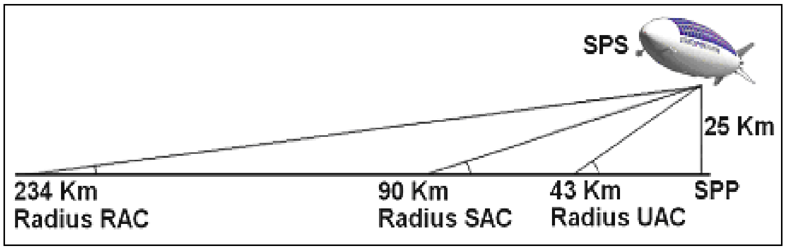

Figure 2. Coverage Area Radius in SPS Networks – Source: Zavala

The systems based on SPS represent a technological alternative that has been under study and development for the last several years, although the investigation of unmanned aerial vehicles had started at a few universities and research centres on the world as early as the late 1950s. These systems could have many advantages compared with both, terrestrial and satellite systems, while at the same time avoiding many of the pitfalls [ITU-Q/2, 98], which can be solved. Various CNS and ICT applications and services are planned to be provided by SPS networks that could be classified as narrowband or broadband service, depending on the bandwidth required. Different subscribers will transmit their information directly to the platform, where onboard switching devices will route traffic directly to other fixed and mobile subscribers within the same platform coverage area or through heterogeneous networks.

The global vision foresees that SPS networks will consist of one or more quasi-stationary SPS, each associated with a number of gateway stations on the ground located in urban or suburban coverage areas to provide interconnection with telecommunications networks. These networks can be fixed terrestrial, satellite, private and public networks, and with numerous mobile and fixed subscriber stations. A system based on SPS will allow a better signal quality to be obtained in the receiver, owing to the fact that during most of the transmission time, the system is under a Line-of-Sight (LOS) condition. This reduces shadowing effects in comparison with terrestrial systems. The SPS also experiences less propagation delay with regards to satellite systems. On the other hand, SPS and satellite systems suffer less from shadowing and multipath distortions because they are exposed to high angle-of-arrival signals. Each SPS can deploy a multi-beam antenna capable of projecting numerous spot beams within its potential coverage area.

The platforms act as the highest cell tower in urban areas. In a system based on SPS, the platform is positioned above the ground to create a radio electric coverage area or a service area of up to 500 km in diameter. The ITU-R defines three coverage areas: Urban Area Coverage (UAC), Suburban (SAC) and Rural (RAC), which are determined by the position of the receiver; i.e. coverage depends on the minimum elevation angle accepted from the subscriber's location and the distance from the Sub-Platform Point (SPP). These areas are shown in **Figure 2**, while some important parameters related to them are listed in **Table 2**, where **h** represents height above ground level.

Table 2. Characteristics of Coverage Area Radius for SPS

Areas	Elevation Angle (Degree)	Coverage Radius (km)	
		h = 21 km	h = 25 km
UAC	90 - 30	0 - 36	0 - 43
SAC	30 - 15	36 - 76.5	43 - 90.5
RAC	15 - 5	76.5 - 203	90.5 - 234

As stated earlier, currently there are two well-established methods for providing wireless (radio) communication services. First method is terrestrially based systems, as it is widely used in cellular and Personal Communications Systems (PCS) and the second method is the space systems using GEO, MEO and LEO satellites. Those wireless systems are currently used worldwide for delivering communication services from a low-speed to a very high-speed data rate. Each concept indeed has its specific advantages and disadvantages. In terrestrial systems, huge number of base stations is required to provide the needed coverage.

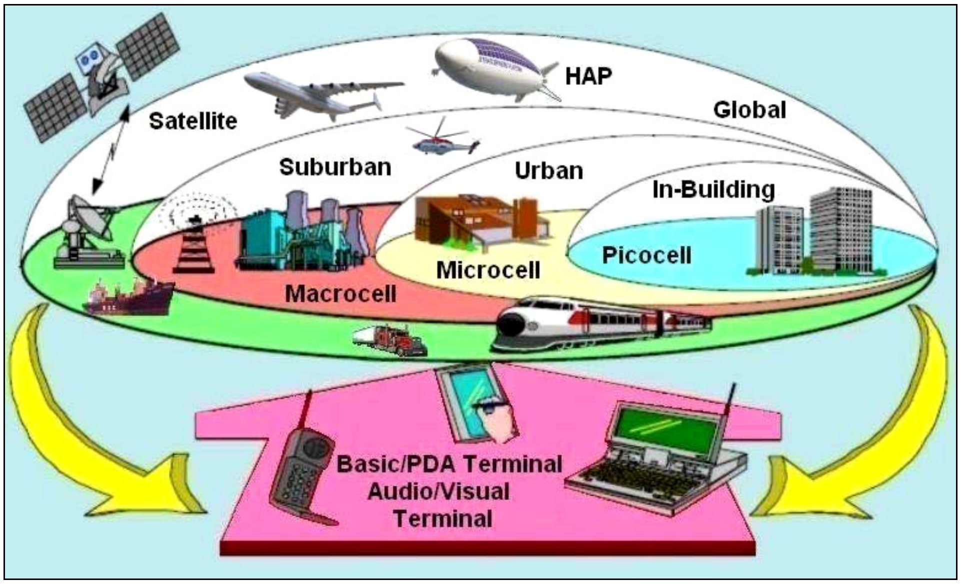

Figure 3. Integration of IMT-2000/UMTS with Satellite/SPS Solutions – Source: Ilcev

Thus, to increase the capacity, the cell size must be reduced or antenna sectorizations have to be applied. Both schemes are allowing the spectrum to be reused more often within a given geographical area called as a frequency reuse technique. This philosophy leads to the concept of microcells for areas of high user density, with a base-station on perhaps every street corner, shown in **Figure 3.** In fact, this scheme is presenting integration of IMT-2000 with SPS and cellular networks for coverage in radius of metropolitan in-building picocell networks, urban microcell network, suburban macrocell and global satellite networks. Except basic handheld, PDA and audio or visual terminals can be implemented modern Wi-Fi and WiMAX solutions for fixed and mobile applications. Therefore, SPS networks are playing huge role and providing a significant impact for developments of advantage local and regional communication systems. They can be very suitable for design of corporate and transportation CNS systems, especially for seaport and airports areas for improved traffic control and improved safety and security.

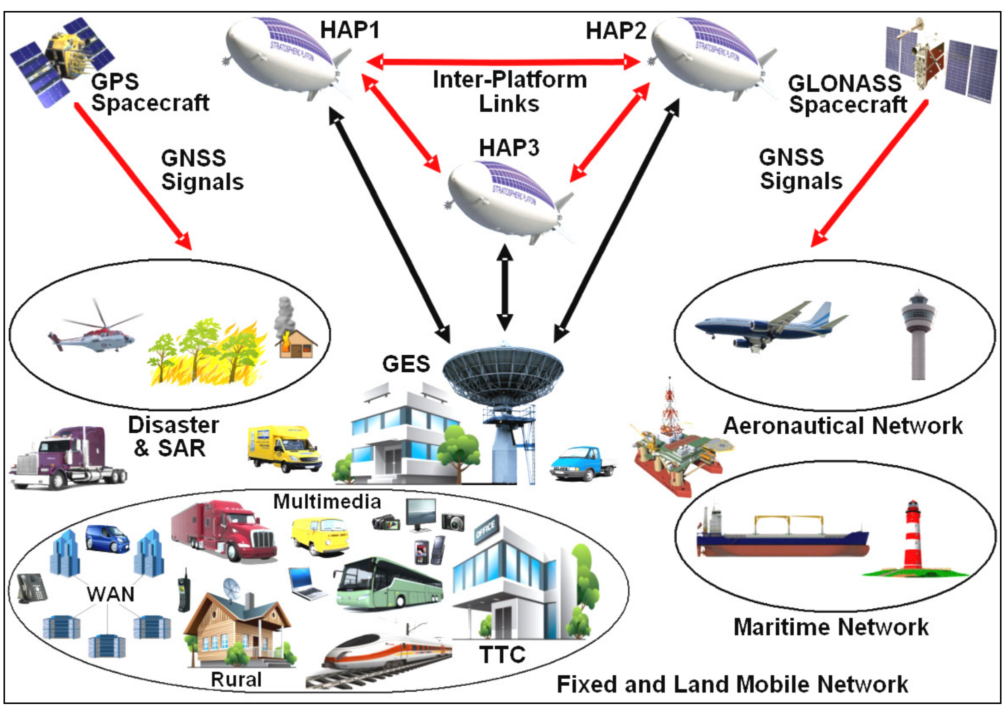

Figure 4. Integration of IMT/UMTS and GNSS/SPS Solutions – Sources: Ilcev

1.2. Architecture and Applications of SPS Networks

The Cellular system is one of the fastest growing sectors of the communications industry, thus SPS integrated with GEO/MEO/LEO satellite systems recently becomes the focus of world's attention and future developments and improvements. The SPS network contains large single-station that depending on altitude can provide coverage in range up to 600 km.
On the other hand, to provide independent CNS and other services, the SPS architecture has to be structured by integration of Terrestrial and Global Navigation Satellite Systems (GNSS), such as the US GPS and Russian GLONASS, as is illustrated in **Figure 4.** In comparison to terrestrial cellular or landline telecommunication technologies, SPS network requires considerably less communications infrastructure, they can serve potentially large coverage areas from a single site, the cell planning is more straight forward since they are able to provide LOS links and finally they are more cost effective.
All these characteristics make SPS network also suitable for the provision of broadcast and multicast services, so they can be designed for the following applications:
- Fixed and mobile communication systems for urban, suburban and rural solutions;
- Communication, Navigation and Surveillance (CNS) for all mobile applications;
- Traffic control and management at sea, on the ground and in the air;
- Tracking and monitoring of mobiles, peoples, animals and assets;
- Remote Earth sensing and weather observation;
- Disaster monitoring, emergency response and security management;
- Broadcast contents, newsgathering, broadband, multimedia and fast Internet;
- Service Providers Platforms (SPP), enterprises and private networks; and
- Defense and police information management.

These missions can be handled separately on an integrated basis, lowering the total costs. Some of them are associated with scientific research or with business case and others are directly related to security and military applications. The SPS networks are expected to be an attractive solution when there is a need for fast system deployment and redeployment for maintenance as no right-to-pass is required, by system components or remotely. Thus, the operation with SPS station might start instantly with minimal configuration and initial costs, and be upgraded later, what in contrary the satellite systems cannot be redeployed or upgraded during their lifespan.
The main task of SPS networks have to provide backbone to terrestrial ITC application and services, such as proposal to deliver modern broadband services, very high-speed Internet, High-Definition Television (HDTV) and 4KTV, Local Multi Point Distribution (LMDS), Multi Channel Multimedia Distribution Service (MMDS) and Wireless Interoperability for Microwave Access (WiMAX). All these SPS services require wide bandwidth and high capacity. In the general sense these applications can be thought to equip base stations with technologies based on well-established terrestrial system onboard, but they have new challenges, e.g. cell structures, handover controls and dynamic channel assignment.
Broadband Wireless Access (BWA) services operate in the higher frequency bands, i.e. the mm-wave bands at several GHz, to provide the required radio frequency bandwidth allocation. The frequency bands allocated for land mobiles in most countries in the world are around 30 GHz. ITU have assigned frequency bands of 47-48 GHz to SPS networks worldwide. The 28 - 31 GHz bands have also been assigned to HAP in some regions.
The SPS constellation are one of the most important communication infrastructures for International Mobile Telecommunications (IMT-2000) 3/4G networks, since SPS networks can offer new means to provide IMT-2000 service with a less number of infrastructures, shown in **Figure 3** IMT-2000 standard has included provision for GES deployment and still needs further study before the deployment from SPS constellation in the areas of cell planning and antenna development. Employing access technologies and techniques such as Code Division Multiple Access (CDMA), Wideband-CDMA (W-CDMA) based IMT-2000 and CDMA based Universal Mobile Telecommunications System (UMTS) from SCP system to provide 3G communications have been examined for the following solutions:

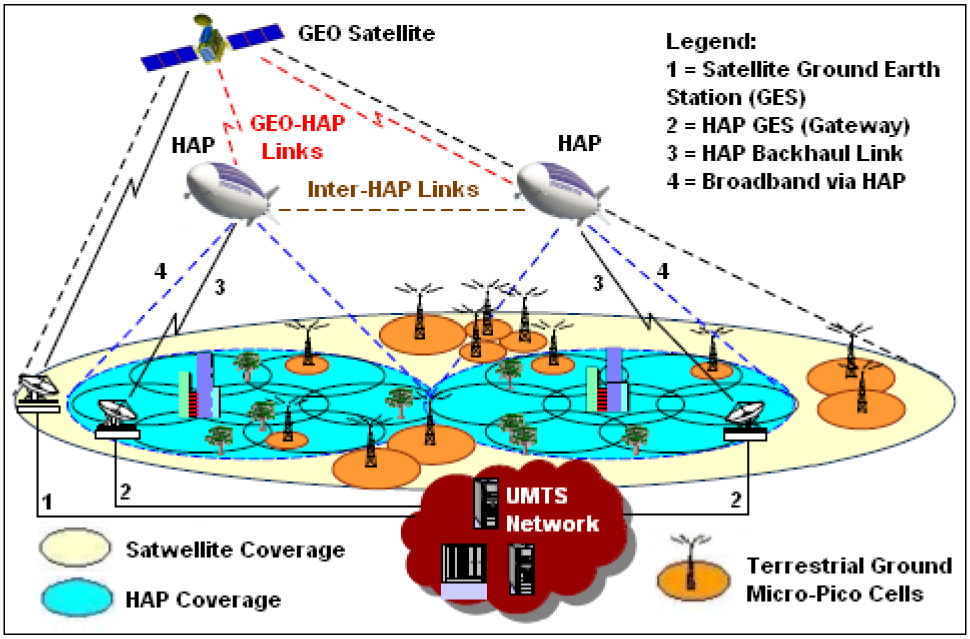

Figure 5. Integration of Cellular and Space Networks – Sources: ESA

1. Data Traffic Network: The systems of LAN and WAN configurations, infrastructures and interconnections; VoIP, VDVoIP; High-Speed Data (HSD); WiFi, WiMAX; and Backhauling of WiFi spots.
2. Telecommunication Network: Fixed and Mobile convergence; Mobile services for 2, 3 and 4G; Interoperability of telecom infrastructures; Video conferencing; and City networks.
3. Broadcast Network: The systems of TV and TV on demand; IPRV; Digital Radio and Audio; Video on demand; and Interactive TV (iTV);
4. CNS Network: It provides important Communication, Navigation and Surveillance solutions including Intelligent Transport System (ITS) for all mobile applications.
5. Surveillance, Intelligence and Border Monitoring: The SPS network integrated with M2M solutions can provide monitoring and protecting network systems (e.g. electricity, oil, gas, water, traffic networks and communication against sabotage etc.) and detecting damages and threats (e.g. to power plants, power lines, oil or gas pipelines, roads, railway lines, vehicles and communication systems).
6. Disaster Management: These solutions are very important problem that SPS network can provide. Disaster can be happening any where at any time, so action related to the disaster management has to be done in a quick and proper manner. At the very first chance, immediate survey over the area must be done via SPS network to get as much as possible data and information concerning the disaster, such as flood detection, seismic monitoring, and remote sensing as well as for disaster management. The SCP service can also support any hypothetical country in protecting individuals, reconnaissance, providing emergency communications, forecasting, detecting natural disasters and supporting relief action; and
7. Homeland Security System (HSS): It provides protection of border crossings, sites security, trade corridors, securing airports, railway, seaports and coasts including impacted area surrounding the precise spot where a weapon or mass destruction is unleashed.

1.3. Technical and Geometry Aspect of SPS

From the geometrical point of view, SPS networks would enable communication services that take much advantage of the best features of both terrestrial micro/pico cellular and satellite multipurpose communications, which scenario is shown in **Figure 5.** In addition, however, the system could bring advantages of its own, not available in current systems.

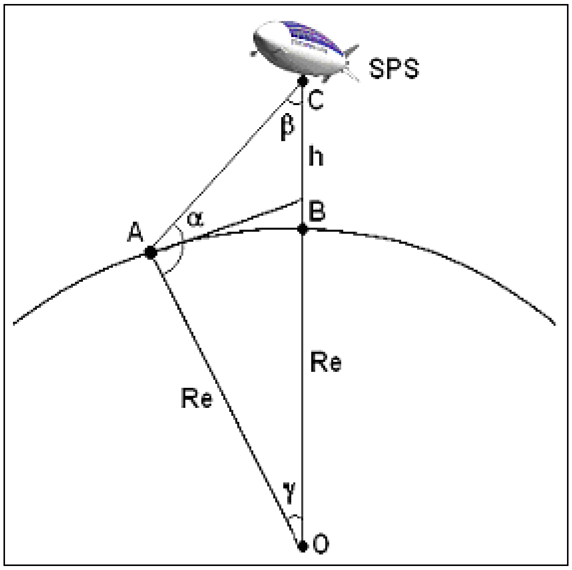

Figure 6. Geometry Aspect of SPS Coverage – Source: Ilcev

The most important advantages of employing SPS are high elevation angles, broad coverage, low propagation delay, low-cost operation, easy and incremental deployment and ability to move around in emergency situation. Although immature SPS airship technology, stabilization system and onboard antenna technology of the platform are challenging that has to be investigated, the SPS network is expected to avoid some inherent limitations belongs to the traditional systems and to provide backbone to cellular systems. Those are in the sense of a huge number of base stations required by the terrestrial communication system, limitation of the minimum cell size on the ground involved in GEO satellite system, and suffer from handover problem faced by LEO/MEO satellite system. With these great advantages, the ITU has allocated the spectrum to this system at 2 GHz for 3G mobile systems, 48/47 GHz for the usage worldwide, and 31/28 GHz band is allocated to a certain Asian countries.

Moreover, the SPS network, also known as Lighter Than Air Systems (LTAS), is designed to have capability of flying for long endurance on-station, fed only by solar energy, offering the possibility to play the role of artificial very low altitude satellites, with the advantages of being close to earth and more flexible.

In fact, such platforms are attracting increasing interest for a variety of CNS and ICT applications such as delivering of a wide range of communication services to rural and remote areas lacking in telecommunications infrastructure (either wired and wireless), provision of basic different emergency communications systems to areas hit by catastrophes or just supply of broadband telecommunication services to residential zones, with a relative low cost, quick deployment and acceptable data rate. It is also expected that the SPS would deliver a high quality TV broadcasting and video. The flexibility of the system allows its utilization for remote sensing and for earth observation purposes as well. With these great advantages, the ITU has allocated the spectrum to this system at 2 GHz for 3G mobile systems, 48/47 GHz for the usage worldwide, and 31/28 GHz band is allocated to a certain Asian countries.

Although the SPS may realize many significant advantages not possessed by the terrestrial and satellite systems, there are still unreported important matters that have to be proven before the deployment in real implementation of this system. One among those matters is the channel characteristic of communication link between the SPS and mobile users on the ground. This thesis deals with the channel modeling and characterization as well as investigation to propagation aspects of communication link for mobile users using the concept of SPS networks. It is important first to look at the system geometry of SPS stations before design and evaluate its communication characteristic so that the difference from other system is clearly shown in **Figure 6** describes the geometry of the SPS system by involving the Earth's curvature.

The SPS station is positioned at an altitude *h* (point C of SPS) with the sub-platform point, that is the point vertically below the intended platform location is in point B. Point A denotes the position of user served by the SPS having elevation angle α. Point O in the figure represents the Earth centre and R_e is the Earth's radius. From the principle of trigonometry it can be expressed that:

$$OA/\sin\beta = OC/\sin(90 + \alpha) - OC/\cos\alpha \quad (1)$$

$$\sin\beta = (R_e/R_e + h) \cos\alpha \quad (2)$$

Assuming the Earth surface is perfect sphere, the arc AB indicates the radius (d) of SPS coverage on the ground and might be expressed through the following equation:

$$AB = R_e \gamma \quad (3)$$

The triangle OAC as the total angle of 180° so that the angle γ can satisfy this equation

$$\gamma = 90^0 - \beta - \alpha \quad (4)$$

After substitution of relations (12.2.) to (12.4.), it will be able to rewrite the radius of the SPS coverage by the following relation:

$$d = R_e \{\cos^{-1} [(R_e/R_e + h) \cos \alpha] - \alpha\} \quad (5)$$

According to the above geometrical analysis, the SPS at 20 Km altitude has the capability to cover an area on the ground up to 504 km in radius for 0^0 of elevation angle. In this sense, **Figure 6** shows a radius of coverage area as a function of elevation angle with the assumption of platform altitude of 20 km. In this altitude, the SPS can therefore be considered as an ultrahigh-altitude tower compared with terrestrial radio tower. As a result, the SPS can easily provide LOS communication with a high elevation angle, whereby the links are relatively free of the influence of obstacles. The antenna and the radio equipment can be made smaller because the electric power supply required can be decreased. Furthermore, there is minimal voice delay when used for voice for telephone service or the like including data transfer, because the stratospheric platform is much closer to the ground than satellites, and hence the delay propagation is almost not an issue in this system.

1.4. Recent Developments of Space Segments

There have been several recent developments in the space platforms arena of SPS scenario, especially for design of data transfer and surveillance system on many international borders has demonstrated them to be a reliable and proven technology. A number of trials of small-scale airship have been conducted by companies in Japan, USA, and Switzerland (StratoComm). Several programs are now focusing on space platforms providing fixed and mobile wireless broadband using WiMAX and WiFi services.

In the interim, StratoComm (http://www.stratocomm.net/about.php) formed in 1992 has designed network for Transitional Telecommunication Project (TTP) tethered system as a means to immediately enhance telecommunications capacity in under-served areas. This network became commercially available to provide service for about half million customers and seamless transition from the aerostat-based systems to its SPS network that will serve about three million customers, which coverage is shown in **Figure 7.** The StratoComm TTS space platform is a lighter-than-air aerostat system positioned at an altitude of approximately 1,500 meters over the region to which it is providing wireless telecommunications services. The aerostat is connected via high-strength steel and Kevlar tether to the ground cite, thereby maintaining its position and ability to support subscriber services, as well as providing access to power, operational control and data service via fiber optic cable and electrical conductors embedded within the tether.

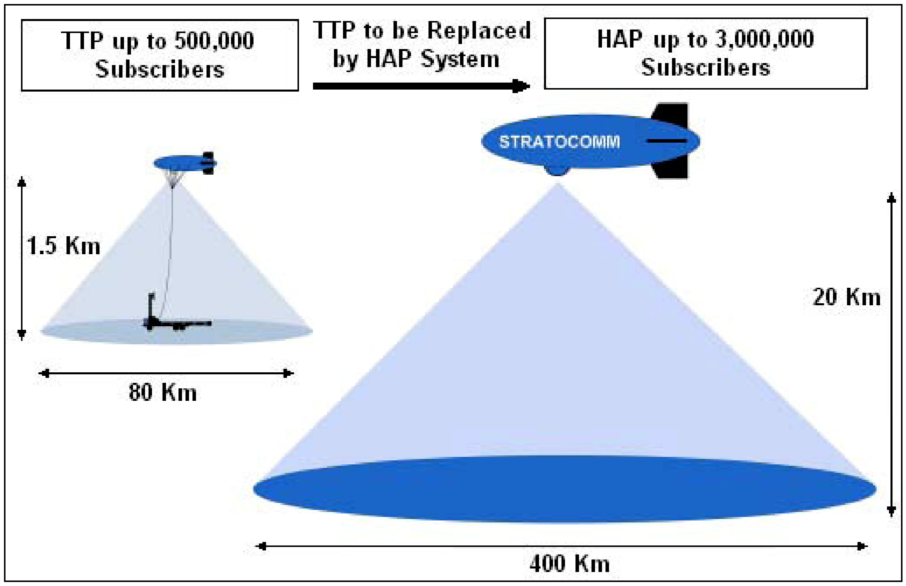

Figure 7. Transition from TTS to SPS Infrastructure – Source: Ilcev

The transitional aerostat is approximately 37 meters in length and 12 meters at its widest point. It meets all US FAA requirements, including the presence of an emergency flight termination system and proper lighting. The aerostat carries an internally designed telecommunications payload weighing approximately 225 Kg, which is capable of supporting subscribers with broadband Internet, voice, data and video transmission with various combinations in a coverage area of 80 Km in diameter.

On the other hand, SPS doesn't interfere aircrafts flights, because SPS are located over 10 Km, airship itself leverages Lighter-Than-Air (LTA) technology being made of very high strength and lightweight materials, it is accompanied by advanced propulsion systems that maintain proper positioning, it is equipped with autonomous navigation, radio controlled command (TT&C) and communications payload stabilization systems.

As is shown in **Figure 7** if airship is located at 20 Km position over Earth, it can cover about 400 Km radius areas. The stratospheric airship is launched using a specified volume of helium separated from the air to maintain its shape. As the SPS rises the helium expands and at the proper altitude displaces all of the air within the STS. Once it is in the stratosphere the SPS is remotely controlled and moved into determined position. A combination of solar cells, batteries and fuel cells will power the SPS during its five-year planned deployment.

Thus, the SPS also incorporates telemetry to remotely transmit data (TT&C) and redundant systems to serve as back-up measures, then features that are designed to provide the airship with a high level of availability, reliability and safety. The STS is being designed to hold approximately 1,000 Kg of communications payload capable of supplying focused fixed and mobile broadband, narrowband and wireless backbone services to approximately 3 million subscribers.

At this point, the configurations can be dynamically changed in milliseconds to reallocate capacity as needed, such as to highly trafficked commuter routes during peak travel times, to business districts on weekdays, or to stadiums during events.

As state earlier, there are two main solutions of SPS, aircraft and airships, which can be divided into four categories:

1. Manned aircraft (aeroplanes) on fuel, which are flying in small circles for purpose as special SPS stations and in any destination for air and ground observation and imaging applications around 48 hours or until fuel lasts;
2. Unmanned aircraft on fuel, which can fly until fuel lasts;
3. Unmanned plane on solar power can fly for minimum 6 month and get maintenance; and
4. Unmanned airship on solar power can hover in certain position for minimum 6 months and has to be landed for maintenance, so in its place will be located another airship.

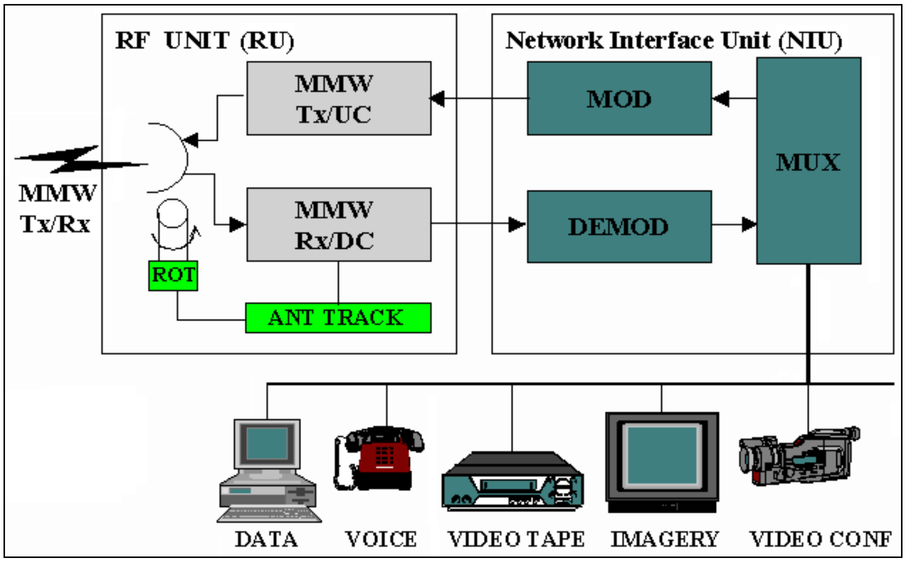

Figure 8. Functional Block Diagram of the Subscriber Equipment for the SPS Ground Segment – Source: Ilcev

2. Ground Segment of the SPS Network

The High Altitude Long Operation (HALO) aircraft or HAP/SPS stations will maintain space station at an altitude of 52 to 60 thousand feet by flying in a circle with a diameter of about 5 to 8 nautical miles. Three successive shifts on platform station of 8 hours each, for example, can provide continuous service for 24 hours per day and 7 days per week. Moreover, such a system can cost-effectively to provide broadcast and broadband multimedia communications to diverse business groups and to the general public.

Therefore, if a viewing angle of 20º or higher is chosen to facilitate good LOS coverage at MMW RF of 20 GHz or higher, one such HALO or HAP/SPS platforms will cover an area of about 2800 square miles encompassing a typical metropolitan area operations enables broadband systems to be realized, by providing spectrum bandwidths of 1 to 6 GHz. In addition, the MMW systems also permit very narrow beamwidths to be realized with small aperture antennas. The HALO Network can utilize a cellular pattern on the ground so that each cell uses one of four frequency sub-bands, each having a bandwidth up to 60 MHz each way. A fifth subband can be used for gateways (connections to the public network or to dedicated users). Each cell will cover an area of a few square miles.

The total capacity of the network supported by a single airborne platform can be greater than 100 Gb/s. This is comparable to terrestrial fiber-optic networks and can provide two-way broadband multimedia services normally available only via fiber-optic networks.

In fact, a block diagram describing the Consumer Premise Equipment (CPE) or Business Premise Equipment (BPE) is shown in **Figure 8**. It entails 3 major sub-groups of hardware: the RF Unit (RU) that contains the MMW Antenna and MMW Transceiver; the Network Interface Unit (NIU); and the application terminals such as PC, telephones, video servers, video terminals, etc. The RU consists of a small dual-feed antenna and MMW Transmitter (Tx) and Receiver (Rx), which are mounted to the antenna.

An antenna-tracking unit of the Subscriber Equipment uses a pilot tone transmitted from the HALO Aircraft to point its antenna at the airplane. The MMW Tx accepts an L-band (950 -1950 MHz) IF input signal from the NIU, translates it to MMW RF, amplifies the signal using a power amplifier to a transmit power level of 100- 500 mW of power and feeds the antenna. The MMW receiver couples the received signal from the antenna to an LNA, down converts the signal to an L-band IF and provides subsequent amplification and processing before outputting the signal to the NIU. Although the MMW transceiver is broadband, it typically will only process a single 40 MHz channel at any one time.

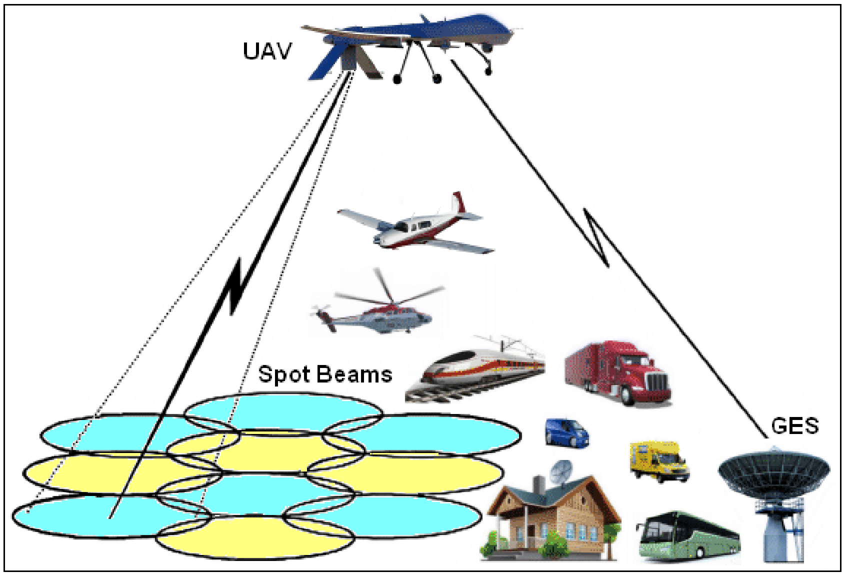

Figure 9. General Atomic AVCS Network – Source: Ilcev

The particular channel and frequency is determined by the NIU. The NIU interfaces to the RU via a coax pair, which transmits the L-band Tx and Rx signals between the NIU and the RU. The NIU comprises an L-band tuner and down converter, a high-speed (up to 60 Mb/s) demodulator, a high-speed modulator, multiplexer and de-multiplexers and data, telephony and video interface electronics. Each user terminal will provide access to data at rates up to 51.84 Mb/s each way via SPS and GES or Gateway.

In some applications of this bandwidth may be used to incorporate spread spectrum coding to improve performance against interference, what will decrease the user information rate. Thus, the NIU equipment can be identical to that already developed for LMDS and other broadband services, what will reduce the cost of the customer service. Also, the HALO RU can be very close in functionality to the RU in the other services (like LMDS) since the primary difference is the need for a tracking function of antenna. The electronics for the RF data signal would be identical if the same RF band is utilized. The subscriber equipment can be readily developed by adapting from existing equipment for broadband services.

3. Aircraft SPS Network

The new aircraft projects offer cost-effective systems by using special unmanned and solar powered engines with an estimated endurance of several months and piloted aircraft with fuel engine propulsion for operating on a daily basis. This system will be more effective by development new systems such as: General Atomic, Halostar/Halo, Heliplat/HeliNet Hale, SkyTower Global and other forthcoming networks.

3.1. General Atomic SPS Network

Building upon its worldwide leadership in the contemporary, design, manufacture, development and deployment of Unmanned Aerial Vehicles (UAV). Thus, General Atomics Aerial Vehicle Communications System (AVCS) is developing the next generation of UAV, shown in **Figure 9**. By using a stabilized aerial platform as the electronic interface between mobile, car-mounted or home/office-based wireless local loop subscribers and the necessary cellular infrastructure, it is possible to minimize the requirement to build any cell sites, towers and other related, very expensive components of typical cellular or PCS networks. In such a way, eliminating these costs and increasing geographic coverage new SPS systems can make serving many low-density and rural areas cost-effective and can be deployed in a fraction of the time it takes to build PCS.

Figure 10. Prototype of High Altitude Aircraft Altus Fuel Powered UAV – Source: General Atomic

3.2. Aerial Vehicle Communications System (AVCS)

As stated, the General Atomics Company is working on a special project of SPS named an AVCS, shown in **Figure 7.9**. This system consists of the space segment of UAV as a high-altitude aircraft carrying communication payload and the ground segment. The payload is equipped with corresponding transponder and antenna systems, while the main parts of the ground segment are user terminals and AVCS ground stations. The AVCS user terminals can be as usual fixed, mobile and handheld equipment roaming within the radiation of the aircraft spot beam antenna system. The users calls are routed through the aircraft's transponder and AVCS ground station to terrestrial subscribers and vice versa. The ground station is actually Base station equipped with suitable transceivers for receiving and sending signals from and to aircraft and with facilities to control the aircraft's position and condition of its payload equipment.
Therefore, everyone in a position under the CDMA coverage umbrella can communicate using the latest CDMA air interface from subscribers unlinking to the UAV and down linking to the ground station, which delivers the signals to the look-like cellular or other system signal-processing platform. At the same time, the base station equipment controls the flight of aircraft to ensure that it stays in the proper relationship to the coverage areas on the ground, allowing the on-board antennas to do their work. The UAV carries sophisticated guidance control equipment that utilizes the GPS system to maintain its flight integrity. Traffic from the PSTN simply uses the reverse path to be connected.

3.2.1. Altus High-Altitude Aircraft

The research team of the General Atomic experts together with the NASA, the US Navy and the Department of Energy (DOE) developed a prototype high-altitude aircraft, Altus, for the future AVCS Network project, shown in **Figure 10.** In fact, this stratospheric aircraft will be ideal for Telecommunications Relay, Cellular Relay and Commercial Applications. At first,
Altus was deployed in support of atmospheric research for the DOE, with future plans to use the high altitude capabilities to understand the genesis of and predict hurricane paths and damage potential, as well as many other advanced scientific applications.
Using the proven technology of previous GNAT and Predator aircraft there were two aircraft prototypes developed: Altus I for operations at about 13.70 km and Altus II for operations at 19.80 km. Both aircraft are using fuel as a motive power, which is a disadvantage in comparison with aircraft using solar energy. The wingspan of the aircraft is 16.76 m, the length is about 6.71 m and they can be equipped with a special large payload capacity of about 148.5 kg to carry transponders and antenna systems.

Figure 11. SkyTower and NTT DoCoMo – Source: AeroVironment

Putting the array of antennas in stationary orbit high enough to avoid commercial traffic and almost all adverse weather conditions can dramatically increase the amount of ground coverage for many wireless systems. The AVCS project has to eliminate some of the technical problems caused by terrestrial or satellite communication systems. If somebody would like to find out how big an area can be covered by a complement of two aircraft, which can also provide backup for each other, it is necessary to imagine sample coverage overlay for the San Francisco Bay area in function of modern communication facilities.

3.2.2. SkyTower (Helios) SPS Global Network

The AeroVironment company officially formed SkyTower, Inc. in October 2000 to pursue commercial communication opportunities enabled by its own proprietary unmanned solar-electric plane. On the other hand, the SkyTower team together with the leading telecommunications system providers initiated to validate the technical and economic viability of the SkyTower SPS for multiple applications and begin the development of commercial systems.

SkyTower conducted successful symposiums in Tokyo, Japan in February 2001 and Taipei, Taiwan in March 2001, introducing the SkyTower technology and business opportunities to industry and government representatives. The company executes agreements with multiple telecommunications service providers to jointly assess and pursue opportunities in their respective regional markets. Thus, SkyTower held its first Board of Advisors meeting in April 2001. Advisory board members include current and former executives from leading telecommunications and aerospace companies such as Cisco, Global Crossing and Loral.

3.2.2.1. Development of the SkyTower (Helios) Aircraft

The first unmanned, high altitude solar-electric aircraft designed under the NASA project was SkyTower Pathfinder, developed in 1995 with a wingspan of about 29.87 m which flew to 15.39 and 21.79 km in 1995 and 1997, respectively, shown in **Figure 11 (Left)**.

Thereafter, a second modified Pathfinder SPS program, known as Pathfinder-Plus, with a bigger wingspan of 36.88 m, flew to 24.44 km, higher than any other propeller-driven aircraft. This record flight was the 39th consecutive successful flight test of the Pathfinder platform. After climbing to this altitude above the Hawaiian island of Kauai, Pathfinder-Plus transmitted several hours of 3G mobile voice, data and video service to the ground, where it was received on a standard NTT DoCoMo 3G-video handset, shown in **Figure 11 (Right)**. The next-generation of aircraft Centurion was a wingspan of 62.78 m, which test flown in 1998 at Edwards Air Force Base in the US. The wingspan was then further extended to 75.28 m and the previous model of aircraft was renamed the Helios prototype.

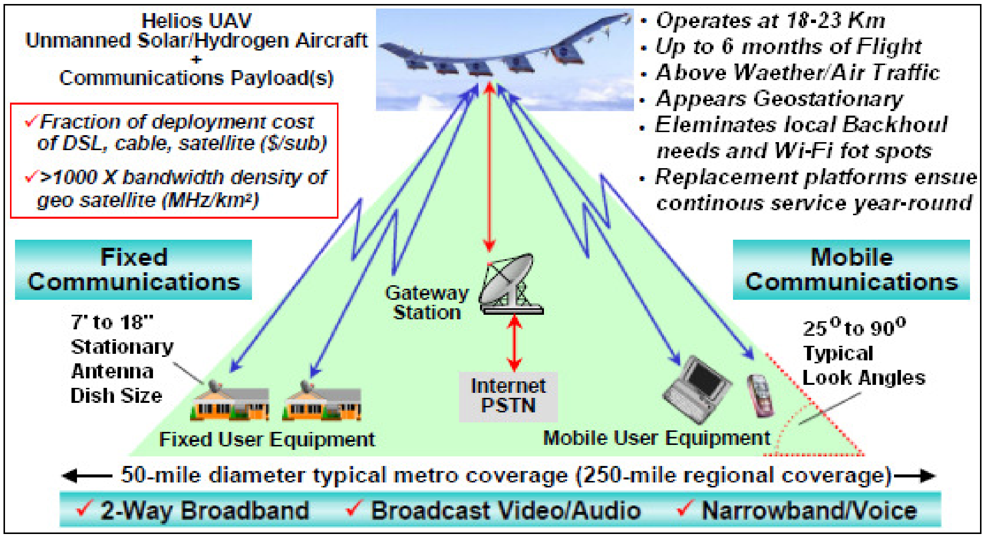

Figure 12. SkyTower Space and Ground Segment – Source: AeroVironment

In June and July of 2002, SkyTower/AeroVironment, in collaboration with the Japanese Ministry of Post and Telecommunications (CRL/TAO) and NASA, successfully completed several wireless tests in Kauai, the world's first commercial applications transmitted from over 18 km in the stratosphere. The two applications tested, HDTV and 3-G mobile, further validate the viability of the SkyTower's unmanned aircraft for use by wireless service providers for a broad range of telecommunications applications. The Helios Prototype is now operating at AeroVironment's test facility. As part of NASA's Environmental Research and Sensor Technology (ERAST) program, its weight is being reduced for integration into Helios to enable continuous multi-purpose communications service. Also in 2003, Helios performed the world's first multi-day stratospheric flight integrated with a fuel cell power system. That experiment enabled a transmission speed of more than 50 Mb/s, so that in 2004 a fixed broadband commercial service was launched.

In **Figure 12** are shown SkyTower space and ground segments consisting of Helios unmanned solar powered aircraft and communications payload operating at a minimum of 18 km in the stratosphere above all traffic and weather influence, with up to 6 months flight duration, and with access links for fixed, semi-fixed, mobile and ground communications facilities and equipment.

8. Conclusion

The SPS networks and stations are very cost-effective solutions for aeronautical CNS systems, tracking, determination and AIS applications in areas not covered by VHF-bands. The SPS doesn't need many ground facilities and huge expenses for launch and technical maintenance as spacecraft does. Similar to all satellite networks, between SPS airships can be arranged inter-link, so in this case applicability of such system becomes more efficient and the need of ground station will be reduced. Moreover, the SPS payload can be equipped by some extra equipment to provide more safety and security of flight. The problem is that out of SPS coverage has to be employed any satellite constellation to cover oceanic flights.

The main objective of SPS networks is to provide azimuth and elevation angle, similar to satellite, as well as to provide higher speed than mobile and TCN, including Fibre Optic Networks (FON). Through SPS, it will be possible to implement new Ultra-High-Speed (UHS) data transmission techniques of vortex beams transmitting 2.5 Tb/s, real-time superchannel transmission of 1 Tb/s superchannel transmission over oceanic optical OFDM distances over 10,000 km and the first worldwide transpacific transmission of 16 KAM signals. Also, the SPS network tested the world's first transpacific transmission of 16 KAM signals, photonic networks and optical time multiplexing (OTDM) systems ranging from 10 Gb/s to 10.2 Tb/s over 29 km, laser beam communication and laser light speed communication.

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