Sky Station International Inc. – Sky Station HAPS

Peter Lobner, updated 12 January 2024

1. Introduction

Sky Station International, Inc. was founded in the mid-1990s in Chantilly, VA, and lists former US Secretary of State, General Alexander M. Haig Jr., among its founders. The other founders were Alexander P. Haig, Martine A. Rothblatt, Moses Thompson and William Wood Prince.

The business goal was to develop a fleet of unmanned Sky Station high altitude platform station (HAPS) and deploy them to geo-stationary positions above 250 or more major metropolitan areas worldwide to deliver high capacity wireless broadband internet and 3G cellular services. Multiple Sky Station platforms may be needed over very large population centers, such as Tokyo and London.

The telecommunications system onboard each Sky Station stratospheric platform was designed to deliver high-speed wireless communications (T1/E1) directly to millions of subscribers within its 400 kilometer (249 mile) diameter service area. From its operating altitude of 21 km (68,898 feet), each Sky Station could generate 700 to 1,000 dynamically steerable spot beams within a single metropolitan area. Sky Station International planned to offer T1/E1 service (2 Mb/s uplink and 10 Mb/s downlink) for fixed sites for as little as $1/ day. Users could access the wireless Internet service with a dedicated broadband user terminal costing less than $100, or by adding a PCMCIA card to their laptops. Data rates for mobile services were expected to be 9.6 to 16 kbps for voice and 384 kbps for data. 3G cellular services could be accessed with a standard 3G cellphone handset.

Remote sensing and monitoring systems also could be installed on the Sky Station HAPs to increase the range and value of services offered to customers.

In connection with their business, Sky Station International filed trademarks in 1997 and 1998 for the following terms: Sky Station, SkyMessage, Sky Chat, Video Messaging, Stratus Communicator, and Corona Ion Engine. Only the "Sky Station" trademark was issued, but was subsequently cancelled in 2006.

In November 1997, the International Telecommunication Union (ITU) granted worldwide regulatory approval for the use of stratospheric platforms. On 31 July 1998, the US Federal Communications Commission (FCC) approved, for the first time ever, the use of stratospheric platforms as telecommunications stations in the US. The ruling stated that stratospheric platforms were expected to be the dominant users of 1,000 MHz of spectrum in the range from 47.2 to 48.2 GHz.

On 23 April 1998, Sky Station International announced their global industrial team for the Sky Station stratospheric project, which included Aerospatiale (France), Alenia Spazio (Italy), Dornier Satellitensysteme GmbH (Germany), Thomson CSF (France), Comsat Labs, United Solar, Stanford Telecom and NASA's Jet Propulsion Laboratories (USA). Lindstrand Balloons Ltd. (UK) was contracted to build the hull. In September 1999, Sky Station International designated Lockheed Martin Global Telecommunications as its system integrator. Sky Station Africa was formed on 1 July 1998 to provide Sky Station technology and service throughout Africa.

In September 1998, Jack Frohbieter joined Sky Station as Chairman & CEO. At the time, Sky Station planned to launch its stratospheric telecommunications service in 2001. The Platform Conceptual Design Review was completed in June 1999 by Airship Technologies Services, Ltd.. The cost of the entire project for a worldwide broadband infrastructure was estimated at $2.5 billion.

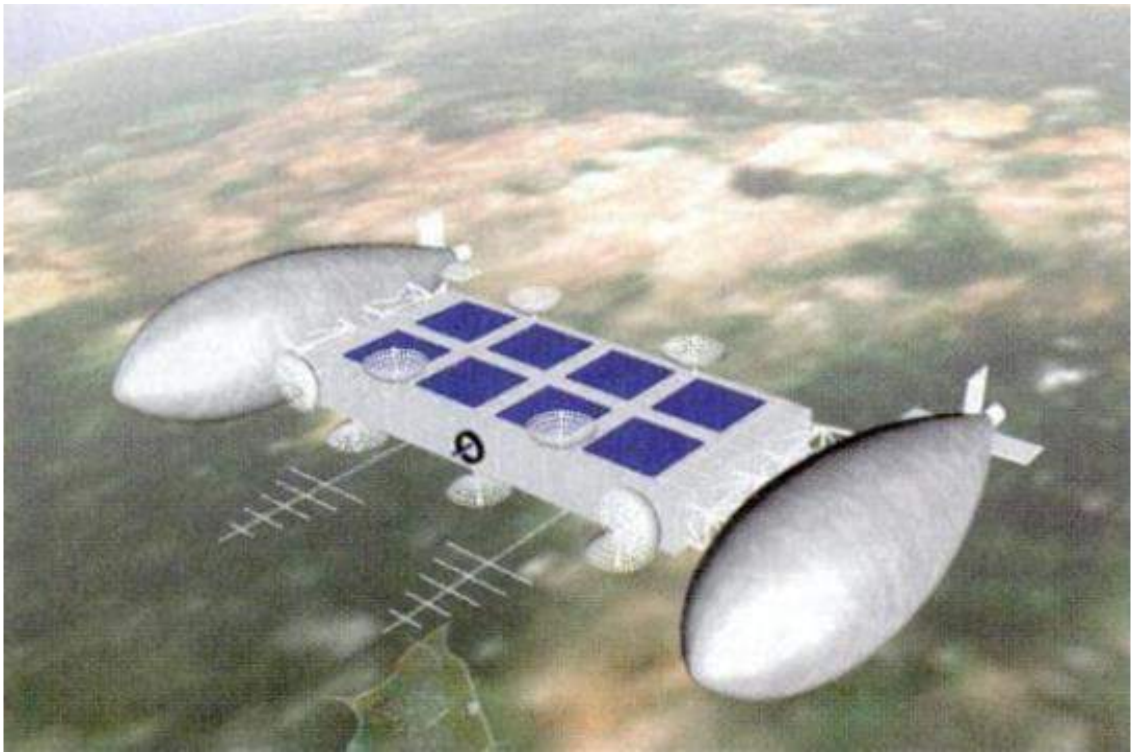
In spite of an apparently successful startup period from 1996 to 1999, no Sky Station HAPS was ever built. The firm failed in the early 2000s.

The Sky Station International website is archived here:
http://anciensdefcr.eu/histoire/ASE_web_janv2000/19nov99/d014/www.skystation.com/

2. Evolution of the Sky Station stratospheric airship

The original design concept for the Sky Station HAPS appears to have been a huge 36.3 metric ton (40 ton) catamaran airship that supported a football field size platform between two semi-rigid airship outriggers. The platform supported a solar array and antennas for transmission and reception of signals to and from a large number of individual users on the ground.

The airship was to be propelled at high altitude by UCLA professor Dr. Albert Wong's Corona Ion Engine. A test platform was expected to fly in 1998.



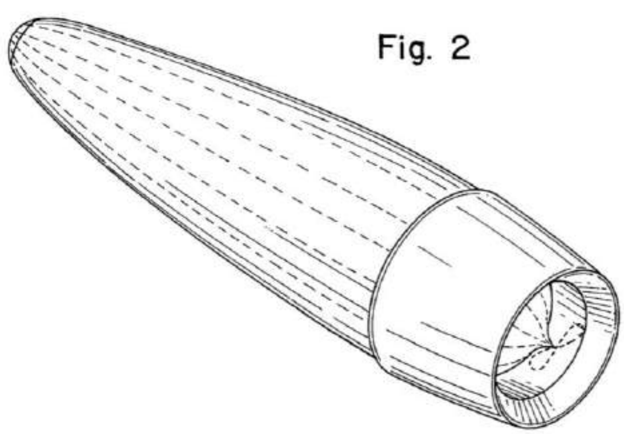
Original Sky Station HAPS concept.
Source: Popular Science, Oct 1996, p. 40

Later Sky Station airship designs had a more compact single hull.

Mid-vintage Sky Station HAPS. Source: Sky Station International

Sky Station airships were intended to be built in different sizes and deployed to match the airship's communications capacity with the local market service demand.

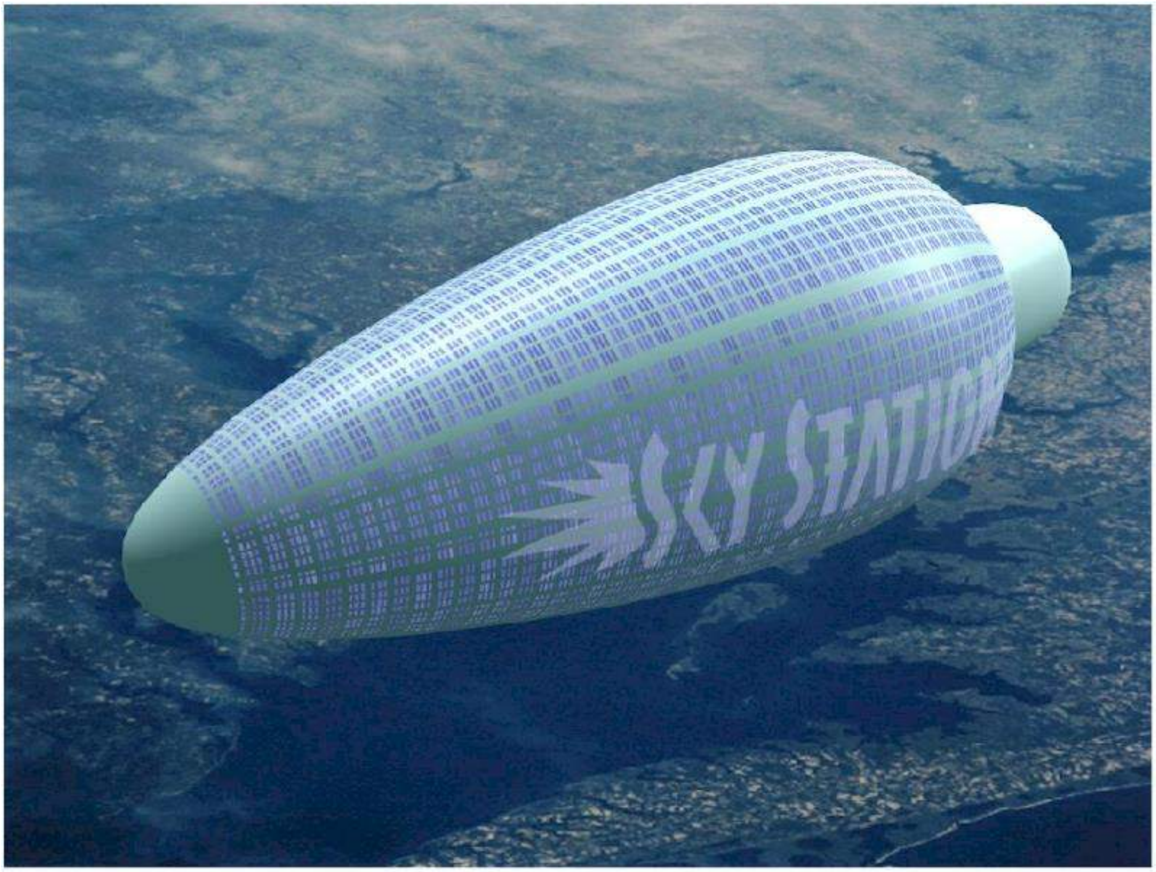
In March 1998, Sky Station International filed a patent application for the "ornamental design" of a novel airship shape with no explanation of its attributes. Patent D427137 was granted on 27 June 2000 and assigned to Sky Station International Inc.



Source: Patent D427137, Fig. 2

This novel airship shape apparently is optimized for laminar flow, with an annular inlet near the tail to direct the boundary layer to a stern mounted propeller within an annulus. There were no conventional control surfaces.

The final conceptual design for the Sky Station, circa mid-1999, had a more unusual hull shape, similar to the ESA / Lindstrand HALE high altitude airship design, but without the aerodynamic fins.

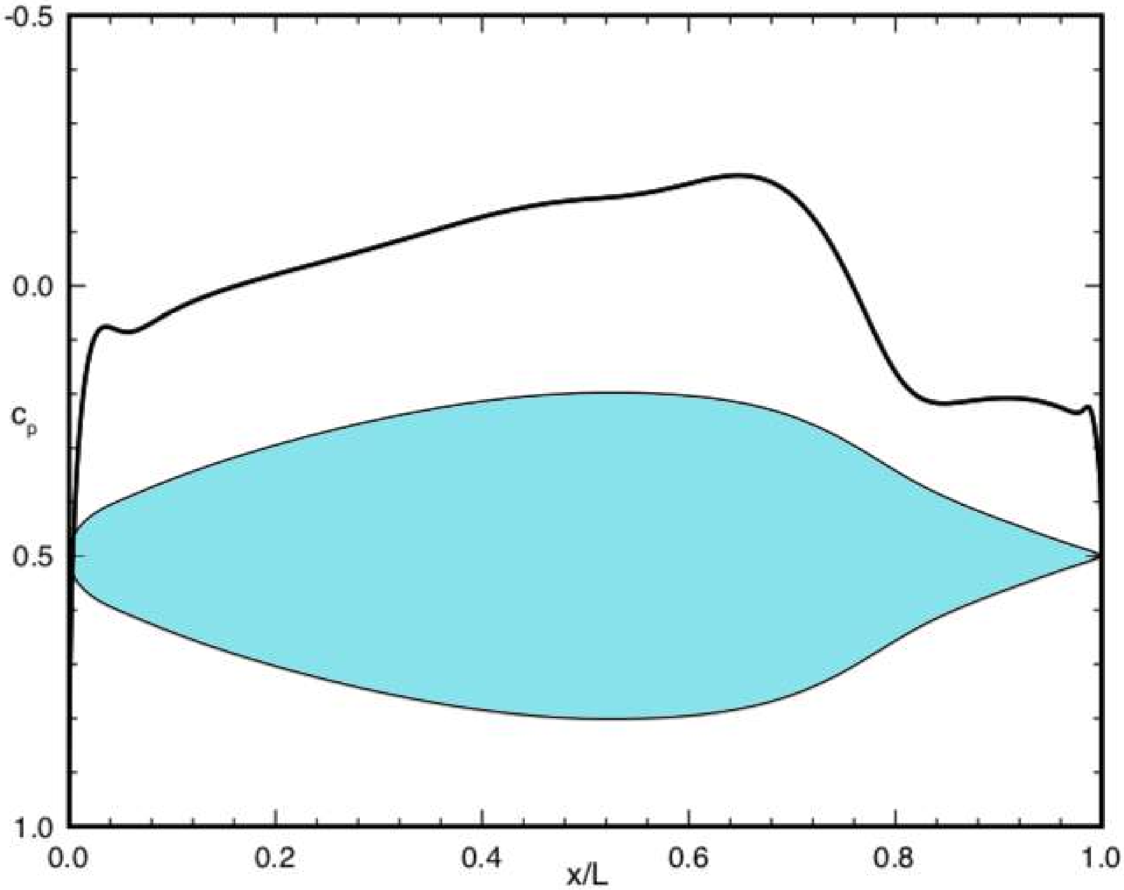


Artist's rendering showing the final Sky Station HAPS configuration at high altitude above a metropolitan area. Source: Sky Station International

The unusual profile shape of the SkyStation airship resembles the shape of a hull optimized for laminar flow. An example of such optimization is described by Lutz and Wanger (1997) and is shown in the following figure.

> "This …. body is characterized by its far aft position of the maximum thickness point and by moderate, almost constant acceleration upstream of this point. This slightly favorable pressure gradient is sufficient to keep the boundary layer laminar up to 75% of the body length… Enlarging the body diameter is limited by the maximum pressure recovery possible

without boundary-layer separation arising in the rear part of the body. “



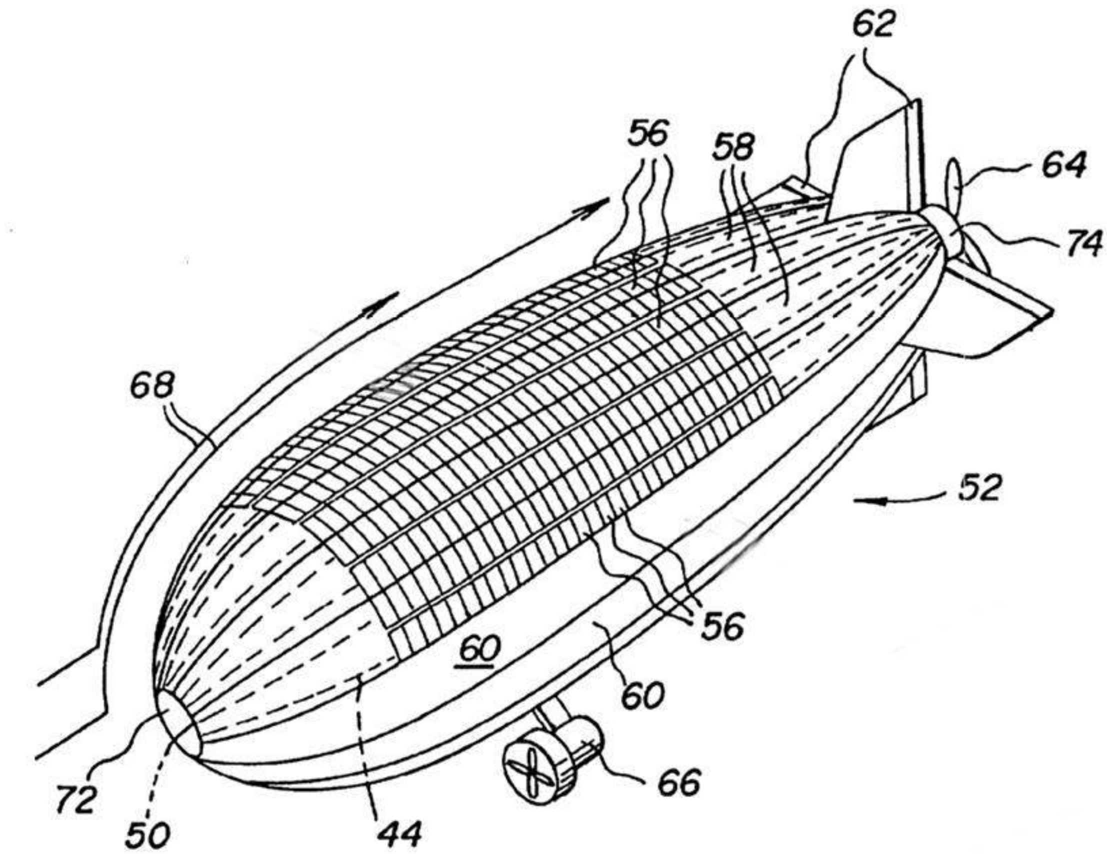
Pressure distribution (top curve) over the optimized body (blue shape), bow at left, tail at right. Source: Adapted from Lutz and Wanger (Fig. 9, 1997)

General characteristics of a Sky Station HAPS, circa 1999

Parameter	**Sky Station**
Length	157 m (515 feet)
Maximum diameter	62 m (203 feet)
Mass	10 metric tons (11 tons)
Operating altitude	21 km (70,000 ft)
Payload	1,000 kg (2,200 lb)
Power	Thin film solar array generating up to 157 kW to supply loads & charge batteries for operation at night.
Propulsion	Ion engines for station keeping
Platform lifetime	10 years

3. Solar photovoltaic power system

The Sky Station airship was designed to employ a large, thin film solar array to generate the power needed to supply airship systems and the communications payload during the day and charge batteries or regenerate fuel cells to enable 24/7 operation through the night. Peak generating capacity was 157 kilowatts.



Legend:

44 – Positive conductive conduit runs the entire length of an upper gore, 50 - Negative conductive conduit runs the entire length of an upper gore, 52 – The stratospheric airship, 56 - Flexible solar cells, 58 – Upper gores in the airship skin fabric, 60 – Side and lower gores in the airship skin (no solar panels), 62 – Conventional rudder and elevator, 64 – Electric-powered main engine, 66 – Electric-powered maneuvering engine, 68 – Stratospheric wind, 72 – Nose cap, 74 – Tail cap

Solar photovoltaic power system for a propeller-driven stratospheric airship. Source: adapted from US6224016B1, Fig. 2.

In March 1997, Sky Station International filed a US patent application in which they described their invention as follows:

> "….novel energy producing flexible material ….. particularly suited for high altitude and stratospheric applications. The flexible energy producing covering includes a flexible solar cell layer, a flexible substrate which preferably matches the shape and size of the airship gore as well and an electrically conductive conduit disposed in a flexible electrically non-conductive adhesive connecting the flexible solar cell substrate to the airship substrate….The novel process provided by the invention for joining the airship substrate to the flexible solar cell substrate includes heat, pressure and the selection of substrate materials and, in certain applications, the use of a vacuum."

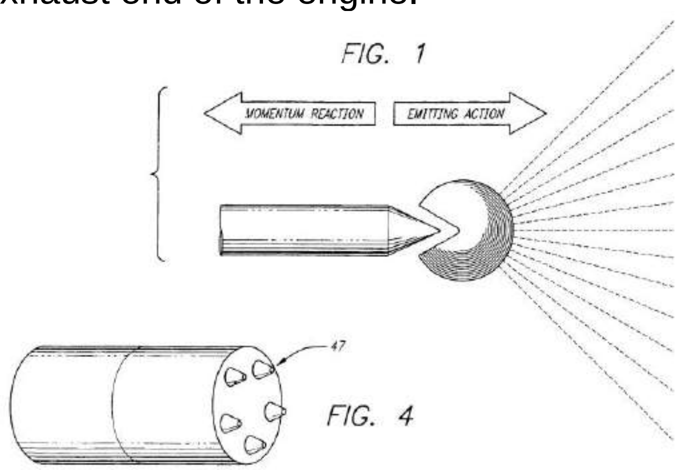
The application, which describes design details of the multi-layer, flexible, photovoltaic array and methods of production and installation, was granted in May 2001 as patent US6224016B1 and was assigned to Sky Station International Inc.

4. Ion propulsion for station keeping

<u>Alfred Wong's Corona Ion Engine</u>

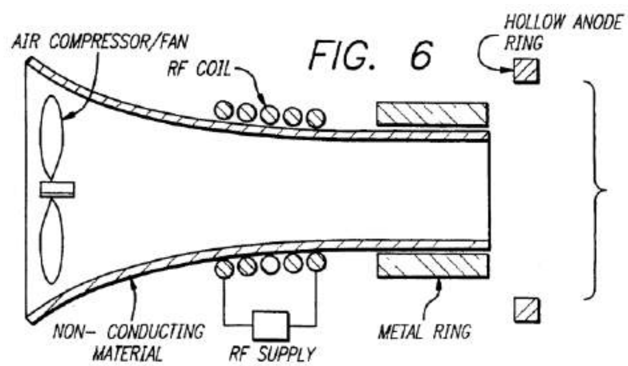
From the beginning, Sky Station intended to use ion engines for station keeping in the stratosphere. Dr. Alfred Wong, director of the Plasma Physics Laboratory at University of California Los Angeles (UCLA), and one of the founders of Sky Station International, designed the Corona Ion Engine originally planned for the Sky Station HAPS. Wong separately filed an international patent application in March 1996 for his Corona Ion Engine, which was published in September 1997 as [WO1997/034449A1](WO1997/034449A1).

Wong's described his Corona Ion Engine in the patent application as follows: "This invention relates to propulsion systems used for station-keeping in the atmosphere. The Corona Ion Engine has no moving parts, utilizes the ambient atmosphere as a propellent, is solar powered and has an efficiency that approaches 90%. Corona Ion Engines utilize the principle of corona ionization to produce thrust by introducing negatively charged (cathode) emitter electrodes at a tip into the atmosphere to eject, by field emission, energetic electrons…… These electrons will attach to the positive side of neutral atoms causing them to become negative ions, thus forming a plasma of electrons" and ions that accelerate downstream toward an anode at the exhaust end of the engine.

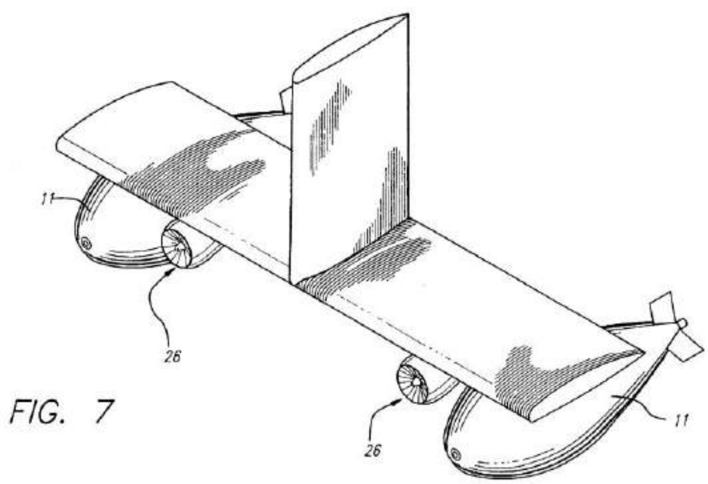


Basic operating principle of Alfred Wong's Corona Ion Engine emitter (cathode). Source: WO1997/034449A1, Fig. 1.

The patent notes, "…propellant density (N) is the most important factor in the engine's performance as it has a direct multiplying effect on the engine's thrust (momentum). Since the Corona Ion Engine uses ambient atmosphere as the propellant, it would follow that the engine intake should be configured to increase the air density at the electrode…..Ion engines can be used with conventional propellers…"



Schematic view of a Corona Ion Engine utilizing an air compressor / fan at the air inlet to increase static pressure inside the engine, and a radio frequency coil to ionize the incoming air (instead of an emitter cathode). The ionized gas stream exhausts to the right, through an anode ring. Source: WO1997/034449A1, Fig. 1.



Concept drawing of a high altitude catamaran airship with podded Corona Ion Engines mounted under the wing-shaped centerbody. Source: WO1997/034449A1, Fig. 1.

Wong left Sky Station International in 1997. The Washington Post reported, "The departure was not amicable: He sued Silansky, Darlington and co-founder Moses Thompson in a Virginia district court, but the case was quietly settled. Sky Station now plans to use engines with propellers powered by solar cells."

Kenneth Burton’s Atmospheric Fueled Ion Engine

Recognizing that propellers are not efficient at high altitudes, Sky Station International sponsored a separate patent application in May 1997 by inventor Kenneth Burton, Jr. The resulting patent, US6145298A, “Atmospheric Fueled Ion Engine,” was granted on 14 November 2000 and assigned to Sky Station International Inc.

Burton’s “novel ion engine” design is described in the patent as follows:

> “The invention relates to propulsion systems for accelerating charged particles to generate propulsive force particularly adapted for use at high altitudes. More particularly, the invention pertains to an ion engine having a cathode ion thruster or emitter for ionizing an ambient atmospheric gas in combination with an electrically insulative housing and a ring-shaped anode in which ions are accelerated and propelled through the ion engine to generate thrust from an ambient atmospheric gas.”
>
> “The novel ion engine ionizes only a portion of the ambient atmospheric gas which ions are accelerated through an electric field from the cathode to the anode at which point ions bombard and collide with the remaining portion of ambient atmospheric gas to create propulsion during the lifetime of the ions existing between the cathode and anode. The cathode is charged to a potential of from about -18 to -110 kilovolts (kV) and possibly less in high altitude applications.”
>
> “The novel ion engine is designed to produce low thrust and operate at low velocities which, as used herein, means a thrust sufficient to maintain an airship in a geostationary position in the stratosphere.”

This novel ion engine (50) shown in patent Figure 7 is comprised of a cathode (20) with a tapered tip (24) at the center of a circular cathode supporting assembly (80) that defines the engine air inlet and is adjustable to set the axial distance from the anode electrode ring (22) at the exhaust end of the engine. Between the cathode and anode is the engine housing (58, 60, 78), which is made of non-conductive nylon.

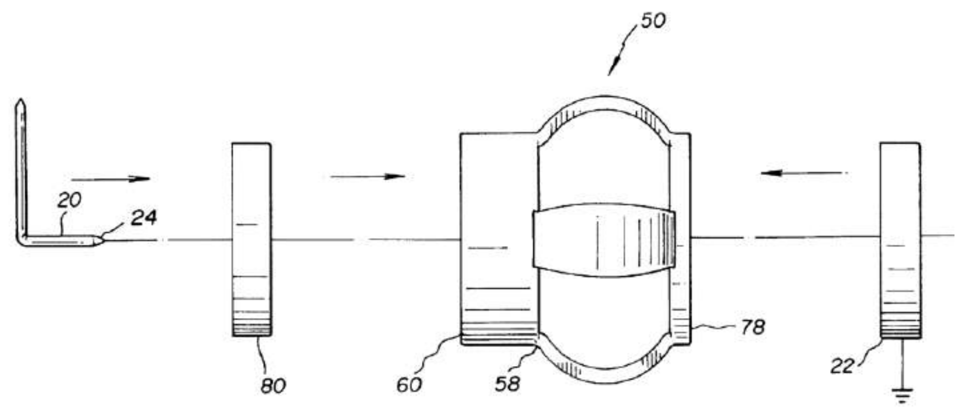
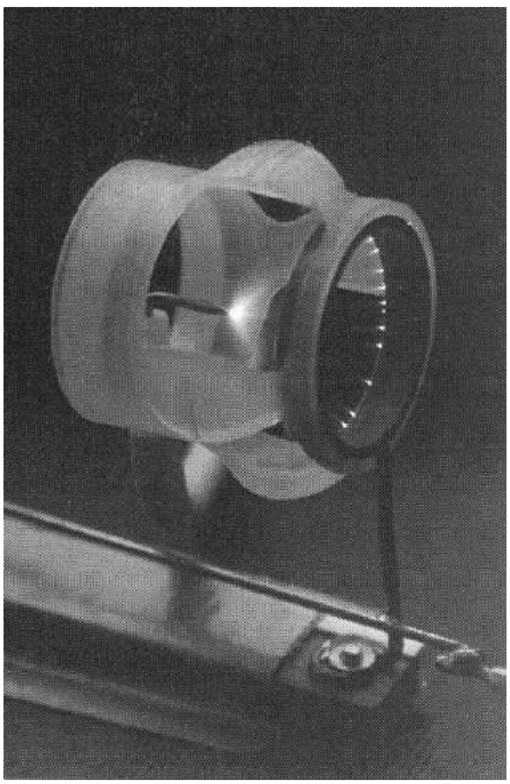


FIG. 7

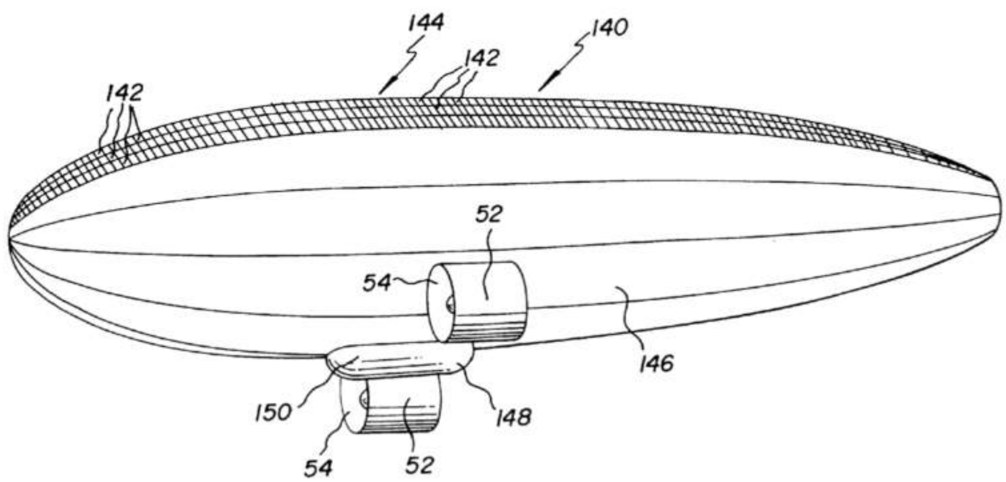
Exploded view of Burton's novel ion engine components.
Airflow and ion flow are from cathode (20, 24 left) to anode (22, right).
Source: US6145298A, Fig. 7



A demonstration model of Burton's novel ion engine.
Source: US6145298A, Fig. 20

The following figure from the patent US6145298A shows an example application on a generic stratospheric airship (140), where solar cells (142) charge batteries (150) and power the novel ion engines installed within nacelles (52) with non-conducting inlets (54).

FIG. 19



Generic stratospheric airship with podded novel ion engines.
Source: US6145298A, Fig. 19

5. Cyclical thermal management system

Managing the thermal balance of the Sky Station stratospheric airship through its daily heating and cooling cycle, and coping with significant seasonal variations, is a necessary function for maintaining the airship on station within a desired altitude range. A design and operating concept for this type of system is addressed in patent US6119979A, which was assigned to Sky Station International Inc.

The basic thermal management cycle is described in the patent as follows:

> “The novel cyclical system of the invention responds to the sun's cyclical heating and nocturnal cooling of lifting gases in geostationary high altitude platforms by a corresponding cyclical regulation or manipulation of the temperature of the lifting gas or ballast components and hence buoyancy of the

platform to maintain the platform within a particular altitude range and at a particular pitch attitude. The cyclical thermal regulation or manipulation of the lifting gas or ballast components involves not only a daily cycle responsive to the heating and cooling of the lifting gas by the sun, but also the seasonal cyclical pattern of the climate of the particular geostationary location above the surface of the earth."

Elements of one implementation of a thermal management system include a hydrogen-oxygen fuel cell (exothermic reaction), a water electrolyzer (splitter, endothermic reaction), hydrogen, oxygen and water / ice ballonets, an atmospheric air supply / discharge, lifting gas circulation fans, shutters or louvers for shielding the lifting gas from heat sources, and variable heat conductance systems. Basic aspects of system operation are summarized below.

- Hydrogen and oxygen are the reactants for a fuel cell that produces electricity, water and heat. On a daily basis, the fuel cell is operated at night to provide power and to heat the lifting gas. The water produced is additional ballast that is stored in a water ballonet to maintain trim control. At night, the water freezes and is available after sunrise to cool the lifting gas.
- During the day, the solar photovoltaic system provides the electrical energy needed for electrolysis, which is an endothermic reaction that splits water into hydrogen and oxygen and cools the lifting gas. The hydrogen and oxygen are stored in ballonets.
- In the winter, additional water ballast can be disassociated into hydrogen, which increases the gross volume of the lifting gas, and the excess oxygen can be expelled into the stratosphere.
- In the summer, oxygen can be reacquired from the stratosphere and recombined with hydrogen to produce additional water, which reduces the gross volume of the lifting gases. This results in an increased volume of recyclable energy storage materials available for managing the temperature of the lifting gas.

This process is illustrated in patent Figure 18. The patent also describes alternative thermal management system concepts.

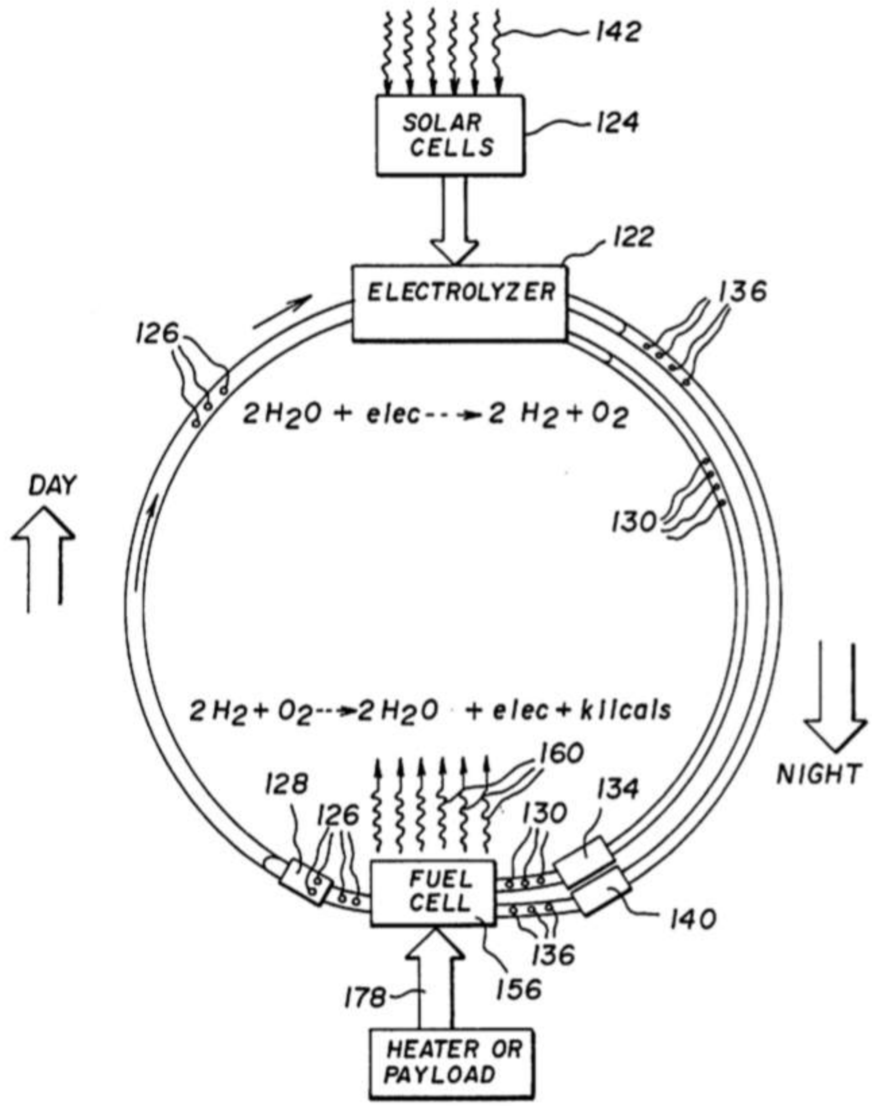


Fig. 18

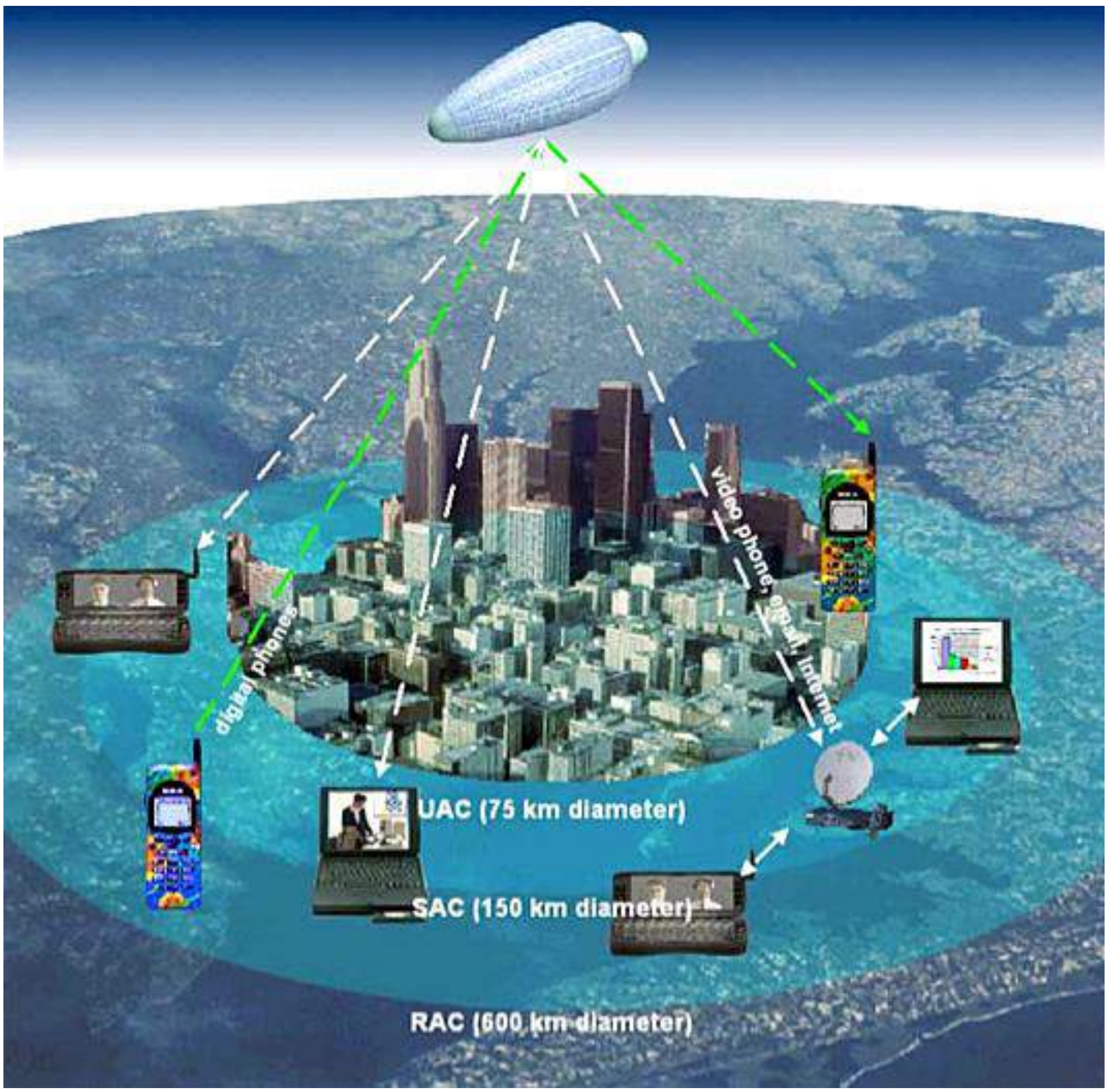
Legend

142 – Incident solar energy, 124 – Solar photovoltaic array on the exterior of the gas envelope, 122 – Electrolyzer / water splitter, 126 – Water vapor, 128 – Water & ice ballonet, 130 – Hydrogen gas, 134 – Hydrogen ballonet, 136 – Oxygen gas, 140 – Oxygen ballonet, 156 – Hydrogen – oxygen fuel cell, 160 – Heat from fuel cell operation, 178 – Generated heat from the payload pod, controlled by thermal shutters (not shown).

Thermal management system. Source: US6119979A*, Fig. 18.*

6. Sky Station's worldwide deployment plan

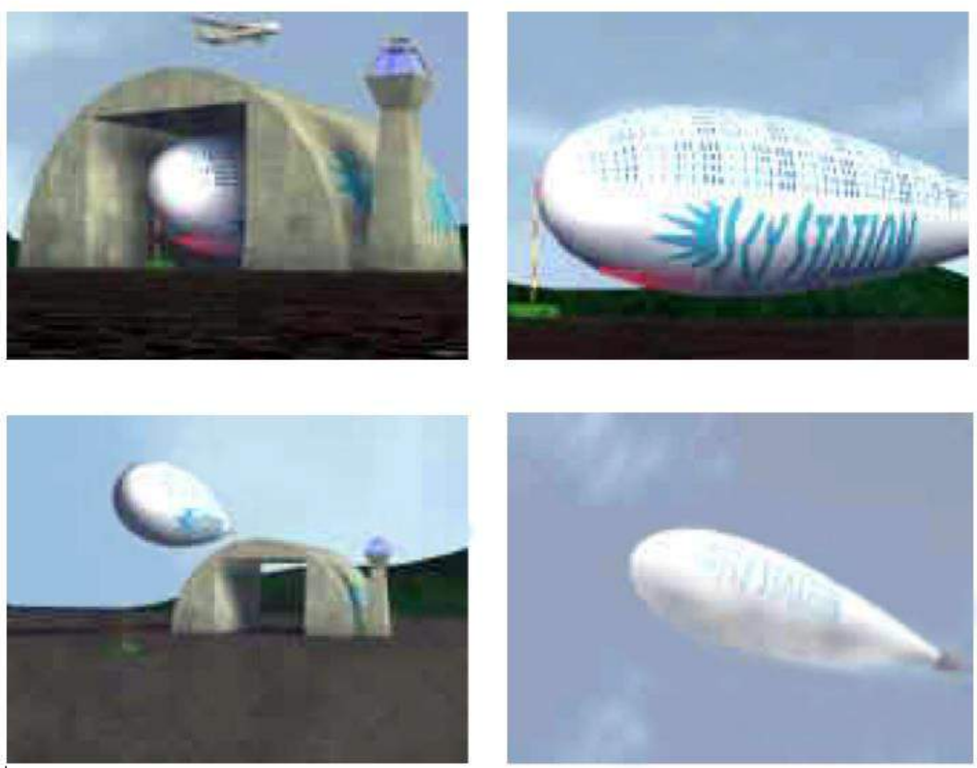
Sky Station International's business plan was to deploy at least 250 Sky Station platforms at about 21 km (68,898 feet) above every densely populated major city in the world. From this altitude, each Sky Station would have a service area of approximately 19,000 square kilometers (7,500 square miles), giving the company access to a very large base of potential customers.



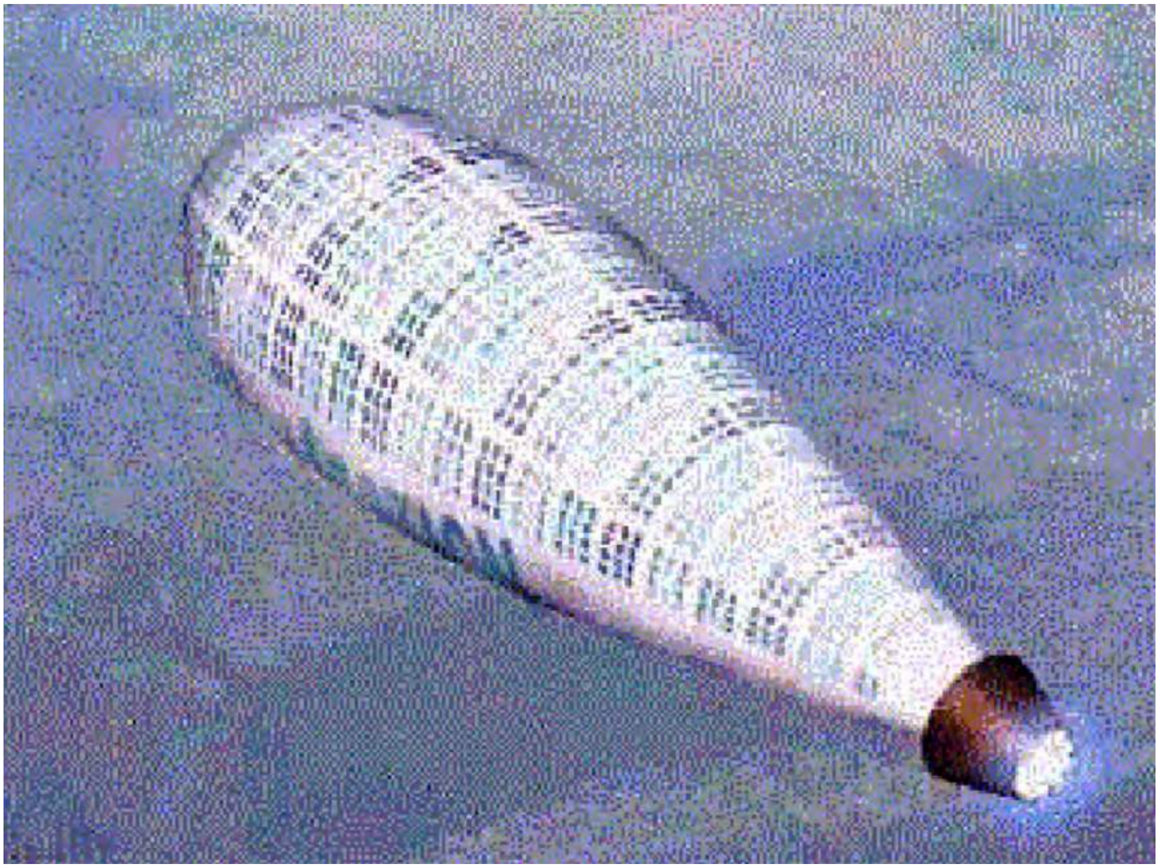
Typical Sky Station platform delivering a range of customers services via a variety of devices in three service zones: UAC (urban access area), SAC (suburban access area) and RAC (rural access area). A ground station (not shown) provides the link to the terrestrial Internet.
Source: Sky Station International via The University of York

Each Sky Station platform was equipped with a telecommunications payload providing high speed, high capacity wireless broadband and cellular service. The data rates foreseen for the fixed services were 2 Mbps for the uplink and 10 Mbps for the downlink. The data rates foreseen for the 3G mobile services were 9.6 to 16 kbps for voice and 384 kbps for data. A single Sky Station could deliver 3G cellular service to about three million customers. With dynamically steerable spot beams, capacity can be reallocated during the day to match changing patterns of user demand for service.

The original plan was for the first commercial Sky Station platform to be deployed in 2000, but that deployment date continued to slip year by year. After the first unit was deployed, Sky Station International planned to start a monumental manufacturing program to launch at least one Sky Station platform per week until service was established in all populous parts of the world. It would take about 250 weeks (5 years) to deploy the system. The cost of the entire project for worldwide broadband infrastructure was estimated at $2.5 billion.



Animated sequence of a notional Sky Station airship launching from a hangar at its operating base. Source: Sky Station International



Stern quarter view of a Sky Station airship with ion engine for station keeping at high altitude. Source: Sky Station International

The Sky Station platforms were designed for a 10-year operating life. They were designed to fly back to base for maintenance or repair when necessary. A new platform would be deployed in advance to replace the existing one so there would be no interruption of service.

While not part of the original deployment plan, individual Sky Station platforms within line-of-sight of each other could be linked (i.e., via laser optical or microwave) later to better integrate service in very large metropolitan areas or to offer broader regional coverage.

No Sky Station platform was ever built. The firm failed in the early 2000s.

7. For more information

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Patents

- WO1997034449A1, “Corona ion engine,” Inventor: Alfred Y. Wong, Filed 15 March 1996, Published 18 September 1997: https://patents.google.com/patent/WO1997034449A1/en
- US6145298A, “Atmospheric fueled ion engine,” Inventor: Kenneth E. Burton Jr., Filed 6 May 1997, Granted 14 November 2000, Assigned to Sky Station International Inc.: https://patents.google.com/patent/US6145298A/en
- US6119979A, “Cyclical thermal management system,” Filed 15 September 1997, Granted 19 September 2000, Assigned to Sky Station International Inc.: https://patents.google.com/patent/US6119979A/en

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Other *Modern Airships* articles

- *Modern Airships - Part 1:* https://lynceans.org/all-posts/modern-airships-part-1/
    - ATG – StratSat HAPS
    - CNRS – Pégase HAPS
    - Japan – SPF SkyNet HAPS
    - Skysat Communications Network Corp. – Skysat HAPS
    - KARI (South Korea) – VIA-200 HAPS
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