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7 July 2006

Mr. Remy Denos
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European Commission Research Directorate-General
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21 Rue du Champs de Mars B-1050 Brussels

Dear Mr. Denos,

Re: USE HAAS WP 2 - 2nd Deliverable – D5

Attached please see the 2nd revised deliverable of the WP2 document - D5, to include also your comments of 24 August 2006 and as required in the Technical Appendix of the "USE HAAS" EC Contract Number 516081.The work presented in this deliverable consist of:

WP 2.1
Objectives: Analysis of the state of the art in the world in HAAS - type system development (update).
Description of work: A report will be produced by UoY with contributions of all other participants summarising all existing works.

WP 2.2
Objectives: Analysis of the European Global infrastructure for HAAS system development and capabilities (update).
Description of the work: A report will be produced by UoY with contributions of all other participants summarising all existing and possible European infrastructure. The workshops organised in the frame of WP4 will also be used for the revision of the results of WP 2.2.

On July 8, 2005 I have submitted to Mr. Jean-Pierre Lentz the WP2 1st deliverable. I would appreciate your approval of D9. I'll mail to you a CD with the WP2-Deliverable D5.

With kind regards,

Prof.Dr.Arie Lavie

Project Co-ordinator

USE-HAAS

WP2

2nd Deliverable – D5

Deliverable D5 supersedes Deliverable D2

Analysis of works and underway programmes: Final Report

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Abstract:

This Report provides an overview of the principal players and projects involving High Altitude Aircraft and Airships (HAAS). It concentrates upon those projects which may be classed as involving true 'High Altitude' platforms, although attention is also given to other unmanned aircraft, such as UAVs, which may have an evolutionary role towards HAAS. Brief summaries are given of various projects together with observations and discussion. All known relevant major projects worldwide are dealt with, and mention is also made of some other small projects and activities. Some general conclusions are drawn.

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EXECUTIVE SUMMARY

This Report provides an overview of the principal players and projects involving High Altitude Aircraft and Airships (HAAS). It concentrates upon those projects which may be classed as involving true 'High Altitude' platforms, although attention is also given to other unmanned aircraft, such as UAVs, where relevant. Brief summaries are given of various projects together with observations and discussion. All known major HAAS-related projects worldwide are dealt with, and mention is also made of other small projects and activities.

Among the major projects described are:

- The Japanese National Project
- NASA-funded Programmes
- AeroVironment and SkyTower
- The Korean National Project
- US defense projects (Lockheed Martin et al)

A number of other projects and activities are also described.

Known EC-funded projects and Actions are outlined, as is other European activity. There is also extensive description of some UAV programmes, which may be regarded as significant in the evolution towards true long endurance 'High Altitude' aircraft.

Some general conclusions are drawn. It is apparent that activity in Europe is relatively piecemeal, and that the major successes seem likely to come from outside Europe.

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LIST OF ACRONYMS

ARC	Airborne Relay Communications
ATG	Advanced Technologies Group
AVCS	Aerial Vehicle Communications System
CEPT	European Conference of Postal and Telecommunications Administrations
CGS	Carlo Gavazzi Space (Italy)
COST	Cooperation on Scientific and Technical Research
CRL	Communications Research Laboratory of Japan
CSEM	Swiss Center for Electronics and Microtechnology
CTI	Creative Technologies Israel
DAB	Digital Audio Broadcast
DVB	Digital Video Broadcast
DBF	Digital Beam Forming
DoD	Department of Defense (USA)
ERAST	Environmental Research Aircraft Sensor Technology
ESA	European Space Agency
ETOM	Enterprise Telecoms Operations Map
ETRI	Electronics and Telecommunications Research Institute
FAB	Fulfilment, Assurance, Billing
FCAPS	Fault, Configuration, Accounting, Performance, Security
HAA	High Altitude Airship
HAAS	High Altitude Aircraft and Airships (or High Altitude Aircraft and Airship Stations)
HAIRSHIP	High Altitude Airship
HALE	High Altitude Long Endurance
HAP	High Altitude Platform
HAPS	High Altitude Platform Station
HDTV	High Definition Television
IAI	Israel Aircraft Industries

ITU	International Telecommunications Union
ITU-T	International Telecommunications Union – Telecoms sector
JAXA	Japan Aerospace Exploration Agency
JSC	Japan Stratosphere Communications
KARI	Korean Aerospace Research Institute
NAL	National Aerospace Laboratory of Japan
NASDA	National Space Development Agency of Japan
NASA	National Aeronautics and Space Administration
NICT	National Institute of Information and Communications Technology (Japan)
NOE	Network of Excellence
QoS	Quality of Service
REAP	Rapidly Elevated Aerostat Platform
RFC	Regenerative Fuel Cell
ROA	Remotely Operated Aircraft
ROI	Return on Investment
UAV	Unmanned Aeronautical Vehicle
UHF	Ultra High Frequency
SOLEO	Sub-Orbital Long Endurance Observer
TAO	Telecommunications Advancement Organisation (Japan)
TMF	Telemanagement Forum
TSI	Techsphere Systems International
WRC	World Radio-communications Conference

1. Introduction

1.1 Purpose

This document is a summary of state-of-the-art in high altitude platforms and their applications. It represents the outcome of work within the USE-HAAS consortium, and takes cognisance of many inputs made to the USE-HAAS project, including two Workshops. It represents Deliverable D5 in the USE-HAAS contract.

The overall objectives of WP2 are:-

> "Analysis of the world state of the art including European works done in HAAS-type system and European/Global infrastructure for HAAS system deployment, and programs and tests underway in USA, in Japan, in Korea and in China. The prepared analysis will also describe future scenarios on which expected HAIRCRAFT and HAIRSHIP are to be deployed and provide services with regard to prospective projects to be launched."

The specific sub-tasks within WP2 are: Analysis of the state of the art in the world in HAAS-type system development; and Analysis of the European Global infrastructure for HAAS system deployment and capabilities.

1.2 Terminology

There are two fundamental types of platform technology capable of stratospheric flight: unmanned aircraft and unmanned airships. The acronym *HAAS* ('High Altitude Aircraft and Airships' or alternatively 'High Altitude Aircraft and Airship Stations') is taken to mean such high altitude airships and aircraft. The term *HAP* ('High Altitude Platform') is similarly commonly used, as is the term 'HALE' ('High Altitude Long Endurance [craft]'); in this document we will regard these as essentially synonymous. Other platform technologies, such as manned aircraft and tethered aerostats, and lower altitude UAVs ('Unmanned Aerial Vehicles') may also have a developmental role towards HAAS.

The two distinguishing requirements here are that of high altitude and long endurance operation, and a combination of the two perhaps represents the ultimate goal for HAAS. However, considerable further development is required before these can be reliably achieved, and aerial platforms such as UAVs may represent an important evolutionary route towards these ends. In many ways the UAV sector is relatively mature – it is certainly well funded – and considerable space is given in this document to some UAV projects.

2. HAAS Technologies: Major Players

This Section provides detailed information on the major HAAS players and their current activities. Where these are known, information is also provided concerning the applications and business models and plans.

This work has been accomplished largely through association and informal contact, input from USE-HAAS workshops and other activities, and literature and web searching. The assistance of many partners and external contributors is gratefully acknowledged.

2.1 The Japanese National Project

This government funded millennium project commenced in 1998, with the primary splits being between aeronautics, telecommunications, and earth observation. The Japan Aerospace Exploration Agency (JAXA) is coordinating the aeronautics aspects, with the telecommunications activities under the coordination National Institute of Information and Communications Technology (NICT). The aeronautics and telecommunications activities are described separately below.

2.1.1 Japan Aerospace Exploration Agency (JAXA)

JAXA [1], was formed in 2003 following a merger of three organizations, the Institute of Space and Astronautical Science (ISAS), the National Aerospace Laboratory of Japan (NAL), and the National Space Development Agency of Japan (NASDA). Only NAL has been active in the National Project since its inception in 1998. It is responsible for all the aeronautics aspects of the Japan National Project. They have a three-phase stratospheric airship development programme:

- Phase 1 (completed 2005) – Technology familiarisation, including development of scaled prototype platforms.
- Phase 2 – Completion of a full size stratospheric airship (approx 200 m long), in 4 years from commencement (which is notionally 2006).
- Phase 3 – Full commercialisation by Japanese industry.

Since 1998 they have had several significant technical achievements. These have mainly been centred on the launch and landing phases of the stratospheric airship, which are seen as the most difficult aspects, airship materials and construction, station-keeping and power management. More specifically:

- Basic research into the properties of airship materials and construction techniques suitable for long-term stratospheric flights.

- Regenerative fuel cell (RFC) and solar power research and development. They currently have a RFC working prototype capable of delivering 400 Wh/kg and have a design on the drawing board to deliver 700 Wh/kg.

- Airship deflation tests using small explosive charges, to open up a hole in the envelope to ensure controlled decent.

This R&D was used in two major experiments:

- August 2003 - they successfully launched vertically an unmanned 47 m long airship shaped balloon (using ATG's patented launch sequence), at Hitachi Port in Ibaraki as shown in Figure 1. Under test were the buoyancy control and deflation strategies. The balloon reached the 16.4 km test height, where the deflation strategy described previously was used to successfully bring the balloon back to earth in conjunction with a parachute. Additionally, the experiments enable JAXA to operate a simple payload that was responsible for the collection and analysis of green house gases in the atmosphere.

Figure 1 Launch of Airship Type Balloon

- November 2004 - they successfully completed tests of an unmanned remotely/automatically piloted 67 m long airship carried out at 4 km altitude, at the Taiki test range in Hokkaido, Japan (see Figure 2). The craft had a payload weight capability of 400 kg, including the mission battery. Tests included
    - Heat and buoyancy control,
    - Station keeping,
    - Ground handling
    - Establishment of a flight operations system

- Observation of vegetation and traffic system from the airship
- Telecommunications tests (described below).

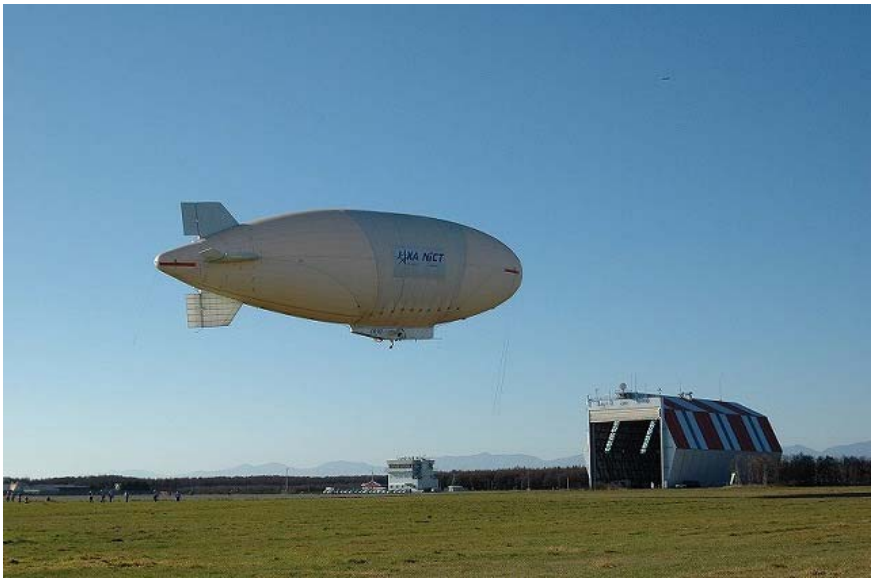


Figure 2 Low-Altitude Station-Keeping Airship

2.1.2 National Institute of Information and Communications Technology

NICT was formed in 2004 following a merger of Communications Research Laboratory of Japan (CRL) and Telecommunications Advancement Organisation (TAO), both of which have been active in the National Project since its inception in 1998.

NICT has concentrated on communications, broadcasting and radiolocation payloads [2] for HAAS, with the end applications being:

- Disaster relief/event servicing, both 3G and broadband
- Broadcast HDTV
- Broadband fixed access to users
- Broadband mobile access to long distance trains and other vehicles.

These applications were selected primarily because HAAS have the potential to provide users over a wide area with various services at reasonable cost. For example, the project has calculated that 15000 HDTV terrestrial transmitters are needed to deliver broadcast TV over Japan's mountainous terrain, can be delivered with around 15 HAAS.

In close coordination and cooperation with JAXA, they have examined tracking and control techniques for stratospheric flight [3], and developed the following hardware for use with experiments:

- Mechanical antenna beamsteering for a multibeam horn antenna at 47/48 GHz
- A 31/28 GHz digital beamforming (DBF) antenna, capable of delivering 9 Mbps to 9 fixed-beams and 3 adaptive beams. They are currently working on a new version that will deliver data rates in excess of 50 Mbps.
- UHF antenna for broadcast HDTV
- Radiolocation payload
- Free space optical transmitter and receiver.

These have formed the core of a number of experiments:

- June-July 2002 – World first telecommunications trials using NASA's Pathfinder Plus solar powered aircraft in Kauai, Hawaii, USA at approximately 20km altitude. 3G [4] and HDTV [5] applications were demonstrated and specific tests included:
  - Technical data for the operation of equipment in the stratosphere, including temperature, wind speed, and station-keeping behaviour
  - Interference suppression using on-board array antenna at 2 GHz
  - HDTV transmission with 1W transmission power
  - Video connection to off-the shelf terrestrial 3G (W-CDMA) videophone

Pathfinder-Plus flight in Hawaii

Figure 3 Pathfinder Plus carrying Onboard Equipment

- November 2002 – Video-on-demand, IP phone, Web access and HDTV video transmission were demonstrated [6]. Tests of both the DBF and multibeam horn antennas on a helicopter at 3 km altitude. Specific tests included:
    - Multibeam forming
    - Remote array calibration
    - Beamsteering and tracking
    - Beam stabilisation
    - Link performance
- September-November 2004 – Digital Broadcasting [7], Radiolocation [8] and optical communications [9] were demonstrated from a low altitude airship (See JAXA section above for more details on the aeronautics aspects). Specific tests included:
    - Evaluation of airship to ground channel at 2 GHz
    - Evaluation of coverage, using conventional digital HDTV receivers
    - Radio location from platform to ground
    - Free space optical communications ground-platform (acquisition and tracking only)

Future tests are planned in 2006 using one of the Aerovironment / NASA HAPs. These will include tests of:

- A new version of DBF antenna for the 31/28 GHz band
- Radio Location
- Free Space Optic Transmission (in conjunction with CAPANINA)
- Craft attitude measurements

Spectrum regulation is the second area where the Japanese project has had significant impact. NICT are active on several ITU-R Working Parties, e.g. WP9B, and have been responsible for originating six ITU-R Recommendations, and contributing to others originated by, for example, SkyStation [10] and ETRI Korea. They have been instrumental in opening up the 31/28 GHz spectrum to HAPs for secondary status at World Radiocommunication Conference in 2000 (WRC-2000) [11]. .

2.1.3 Discussion

The Japan National Project has been extremely well funded since its inception in 1998 – spending has been in excess of €100M to date. JAXA's Phase 1 has been completed, and although it has taken slightly longer than originally planned it has demonstrated key aspects of the technology and allowed Japanese industry to develop the skills necessary to proceed with Phase 2. At the present time, JAXA is believed to be still finalising its negotiations with the Japanese government for funding for Phase 2, where it is anticipated that the total financial package will be a mix of public and industry funding. The aerospace industry is keen for Japan to become a world leader in this technology and given its high-tech manufacturing base it is well positioned to do so. It does however recognise that it cannot achieve this alone, and there is a wish to further strengthen ties with European and USA players to ensure that it has the necessary technology to reach its goals.

NICT's activity is still continuing with funding available through until at least March 2007. It is the undisputed world leader in HAAS communications hardware development and trials, probably achieving more than all other HAP projects put together. Just as with JAXA, NICT believes its end goal is for Japan to be a world leader, and to achieve this requires worldwide collaboration (e.g. ITU-R and CAPANINA). HAAS will only succeed in Japan and Asia if they succeed on a worldwide basis. They see the ITU-R and spectrum regulation as being a significant building block. Their abilities to get spectrum licensed in the 31/28 GHz bands originally in Region 3, but later extending to 40 countries worldwide is an important way of HAPs gaining credibility. They also use partnerships, e.g. with NASA/Japan Stratosphere Communications (JSC) and the European FP6 programme CAPANINA to help fill in gaps in their expertise. Collaboration with JSC enabled it to carry out stratospheric trials where they have achieved several world firsts. This approach has been used because Japan's airship programme was at a different stage of maturity to communications. They have entered into collaboration with CAPANINA because it enables them to access complementary (more theoretical) skills as well as helping to strengthen European HAP capabilities, which currently are funded at a much lower level than the other main programmes (mentioned in this report) worldwide.

The long-term future for the Japan programme is not yet secure. It is at a key point: Phase 2 of the programme will require significantly more funding than Phase 1, and carries the associated risks common to any new technology. Probably the biggest factor controlling its future is the success of the other programmes worldwide. These will help reduce the risks of going it alone and provide added impetus to Japan to ensure that it does not lose the leads it has in specific aspects of HAP technology.

2.2 The Korean National Project

The Korean national activities have been running for a number of years. They are split into the aeronautics part coordinated by the Korean Aerospace Research

Institute (KARI), which has been running since December 2000, R&D aspects of communications coordinated by the Electronics and Telecommunications Research Institute (ETRI) which has been running since February 2002, and analysis of communications services by SK Telecom [12]. We now describe each aspect of the project.

2.2.1 Korean Aerospace Research Institute (KARI)

The Korean project has a 10-year plan to build an unmanned stratospheric airship capable of supplying 10kW of power to a payload, weighing up to 1 tonne. The activities commenced in December 2000 and are divided into three phases [13]:

- First Phase – Familiarisation with airship technologies
- Second Phase (4 years) – To build a 200m long stratospheric airship
- Third Phase – Operational test of a stratospheric airship

Phase 1 has been completed in 2005, which included the development and test of a 50 m unmanned airship, capable of flying to an altitude of 3 km height and carrying a 100 kg payload, as shown in Figure 4. This phase of development also included:

- Building of ground facilities including a large hanger in Goheung in the far South of Korea.
- The development and test of electric motors to power the vehicle
- Launch, landing and station keeping
- Safety critical systems, including the transfer of control between automatic and manual control
- Communication system tests
- Power management of a regenerative fuel cell
- Basic research into high strength materials, heat management and operational technology for large airships

Figure 4 50m Long Unmanned Airship developed by KARI for Phase 1 [14]

Phase 2 notionally commenced in 2006, to undertake the following:

- Envelope material development for stratospheric applications using Vectran
- Acquisition of test data for envelope design
- Manufacturing process refinement through scaled envelope application
- Facilities and equipment for large envelope fabrication
- Conceptual study for airship sizing, configuration and performance
- Thermal analysis for Superheat/cool control
- Adiabatic climb and descent analysis
- Climb/descent path optimisation
- Setup of environmental database for stratospheric operations

2.2.2 Electronics and Communications Research Institute (ETRI)

ETRI's activities commenced in February 2002. This has included analysis of possible HAPs services and business models [12] for the Korean market, as well as the development of core technologies [15]. They have been very active participation in the ITU-R working parties 9B, 9D, and 4-9S which cover HAPs and have originated (and contributed to) several of the ITU-R recommendations in force on HAAS. and active participation in ITU-R working parties on HAAS. Additionally they have played an important role within the World Radiocommunications Conference 2003 (WRC), where they were instrumental in extending the use of the 28/31GHz for secondary use within Region 2. They plan also to play a significant role within WRC 2007. Additionally they have also produced material to support WRC2003 resolution #734 to extend the frequency bands beyond those currently allocated [16].

Core technologies and studies developed include:

- Development of a direct beamforming multibeam receiving system for S and Ka band
- Development of mechanical beamsteering for 47/48 GHz horn antennas
- Interference analysis and sharing studies for WCDMA
- Interference analysis and sharing studies for 28/31 GHz and 47/48 GHz

2.2.3 Discussion

The Korean national project is one of the most significant research-led projects around the world. Their work so far has contributed on a technical basis at the highest level, and their activity within the ITU is extremely significant, with ETRI responsible for much of the pressure to get the 28/31 GHz bands licensed in Asian countries. Additionally, their work in trying to extend the allocated frequencies beyond the existing bands, in order to support WRC Resolution #734 is world leading.

The airship developed as part of Phase 1 did under go a small accident when near to the ground towards the end of last year, but KARI has used this a learning experience. The project should be commended for the excellent facilities it has built, and its plans for the future hangars for the full size airships are well developed. Phase 2 is believed to be on track, although there are understood to have been some temporary uncertainties regarding the continued funding from the Korean government, and unfortunately the long-term future of this project is by no means fully assured.

Nevertheless, the Korean government clearly anticipates that HAAS will be a significant future technology that it can use to further strength its technical and manufacturing base. They clearly see significant Asian and worldwide export potential for both the platforms and electronics.

The Korean partners have been keen to maintain collaboration with expertise elsewhere, having for example established a Memorandum of Understanding with the University of York (who are leaders of CAPANINA), and have demonstrated willingness to share ideas with other European partner, e.g. through active participation in USE-HAAS Workshops.

2.3 NASA-funded Activity

NASA has been responsible for building a variety of high altitude plane based craft, including the Pathfinder, the Pathfinder Plus (which will be used for CAPANINA trial 3) and Helios, which were developed as part of the ERAST project [17]. Helios currently maintains the altitude record of some 98,863 ft established in July 2001. It has also demonstrated capability of 17 hours flight duration carrying a payload of

35 kg, mainly for telecommunications. Subsequently, it suffered a 'mishap' in which the vehicle was lost. At the time of loss the vehicle was carrying a 250 kg fuel cell beneath the central part of the wing. The investigation has attributed the loss of the craft to a flexing of the wing, attributed to the payload being too heavy for the particular design of the craft. This flexing caused lift to be lost and the vehicle to stall, resulting in the loss of the vehicle [18]. The investigation has resulted in new recommendations for the design of future vehicles, with the result that future designs will be based on the more conventional fuselage, wing and control surfaces (see below), and less reliant on the unique 'flying wing' designs used in the Pathfinder Plus and Helios. More details can be found in [17] and [18].

Figure 5 HELIOS Craft

The 15 year HALE ROA (Remotely Operated Aircraft) was established last year as the follow-on to ERAST it will *'develop policies, procedures and technical standards to enable remotely or autonomously operated aircraft to fly reliably and routinely in civil airspace with an equivalent level of safety as planes flown by on-board pilots'*

In the financial year 2004 NASA secured $103M from the US Government and $36M from industry to cover its first five-year period [19]. It has established a formal working agreement between six industrial members: AeroVironment, Aurora Flight Sciences, Boeing, General Atomics Aeronautical Systems (GA-ASI), Lockheed Martin and Northrop Grumman. Four government agencies are also involved: NASA, DoD, FAA and DHS.

Over this period it intends to deliver 4 types of stratospheric craft (both plane and airship based) with a range of payload and mission duration capabilities. These have been developed to cover a range of missions put forward by interested parties [17], and as such the aircraft vary in capability and endurance, and are aimed at a

variety of different end applications ranging from event servicing/disaster relief in the near term through to 24/7 deployments of mass-market communications and other applications in the long term. They are also designed to catalyse the development of new technologies and tools, including the development of advanced multidisciplinary (structures, aerolastic, aerodynamics, materials, propulsion, controls etc) 'time domain' analysis methods appropriate to highly flexible, 'morphing' vehicles.

The four vehicles are [17]:

- **Sub-Orbital Long Endurance Observer (SOLEO)** – work is already underway, with the aircraft capable of flight in 2009. It will have the following technical attributes:
    - 7 to 14 days endurance
    - 200 kg payload
    - Hydrogen powered fuel cell or internal combustion engine
    - Hydrogen stored in a liquid form
    - Low stiffness wing technologies
    - Control via satellite communications

  It is likely to be used for: hurricane tracking/research, disaster mitigation, defence/surveillance, and commercial communications.

- **Global Observer** – work is underway on the propulsion systems, and is expected to be available in 2012. It will have the following technical attributes:
    - 30 days endurance
    - 150 kg payload
    - Solar powered – high efficiency array
    - Regenerative fuel cells
    - Low stiffness wing technology
    - Control via satellite communications

  It is likely to be used for: long dwell time scientific research, disaster mitigation, defence/surveillance, and commercial communications

- **Global Ranger** – The main emphasis of this vehicle is for it to travel anywhere around the globe, collect data, and return within 48 hours. Work will start in few years time on the craft. It is likely to have the following technical attributes:
    - 48 hour endurance
    - 1000 kg payload
    - Global range

- Superconductor motors
- Multifunction liquid hydrogen tanks
- 500 kW Solid oxide fuel cells
- Intelligent vehicle systems management
- Continuous aero-trim optimisation
- Control through satellite communications

It likely to be used for: urgent earth science research, disaster mitigation and defence/surveillance

- **Heavy Lifter** – Unlike the other three craft this will be an airship. The main purpose is to carry a large suite of scientific instruments and will take into account technical progress on the Lockheed Martin craft being developed for the US DoD, and will be developed in the final phase of the HALE ROA programme. It will have the following characteristics:
  - 30 – 90 day endurance
  - 10 000 kg payload
  - Solar powered
  - Inflatable deployable aerostructures
  - High power long endurance electric propulsion
  - Control through satellite communications

It is likely to be used for: long-dwell earth science research, defence / surveillance, and commercial communications.

2.3.1 Discussion

The NASA programme underway clearly indicates an unparalleled long-term commitment by the USA to development of high altitude vehicles. The four vehicles above are designed to fit in with future technology and regulatory roadmaps, and as such there is a high probability of success. There is a strong expectation it will catalyse further activity in the sector worldwide. NASA's track record on the development of such vehicles is strong, and is one of a few organisations worldwide that have stratospheric vehicles. Three out of four of the above craft as well as the Pathfinder Plus are capable of supporting communications applications, with event servicing/disaster relief applications being possible in near term, with more permanent applications being possible in the longer term.

2.4 AeroVironment and SkyTower

AeroVironment [20] is a subsidiary company of NASA whose objective is to exploit and commercialise NASA technology. They have for a number of years been

commercialising NASA's UAV activities. They have specific interests in High Altitude Solar Electric Airplanes, and are currently developing the energy technology to provide around the clock solar powered flight, based on a combination of solar powered arrays and regenerative fuel cells. They have a full size fuel cell and electrolyser storage system for such craft operating in their test facilities.

The craft themselves are aimed at telecommunications, remote sensing and atmospheric measurement, and they have specifically established SkyTower Inc [21] as a separate company to market HAP communications activities. SkyTower's business strategy is based on using AeroVironment's solar-powered aircraft based platforms, such as Helios and Pathfinder, with the aim of delivering a range of applications such as:

- Fixed Broadband
- 3G-Mobile
- Narrowband
- Direct Broadcast
- Event servicing

They have been pursuing market opportunities on a worldwide basis, and have been specifically targeting developing countries, where there is an absence of infrastructure.

In July 2002, they were jointly responsible for providing the successful tests of various communications for the Japanese project (as discussed in Section 2.1).

2.4.1 Discussion

AeroVironment/SkyTower are significant players in the commercialisation of HAAS. They have detailed business models and excellent technical capabilities. They are one of the few companies worldwide that has the proven capabilities to launch such mission and their on-going research programmes into energy storage could prove critical in the development of HAAS.

The Helios mishap has slowed down their marketing of this technology. The fuel cell critical to round the clock deployments was being tested when Helios failed. Helios, Pathfinder and Pathfinder Plus are experimental vehicles, so AeroVironment/ SkyTower are largely dependent on NASA proceeding with their development plans. The Global Observer is currently being developed, and a scale-size prototype is understood to have flown for a duration of one week, with its power system based upon non-regenerative hydrogen fuel cells.

Business models are being revised towards shorter-range missions such as event servicing and disaster relief communications, which are less reliant on solar-powered flight and advanced energy storage, and as such providing a less risky initial

exploitation path. It is expected that NASA's next generation of planes will further enhance opportunities.

2.5 Lockheed Martin, Boeing and Worldwide Aeros

Lockheed Martin, Boeing and Worldwide Aeros (USA) have completed a competitive Phase 1 of a large development program as a result of the US Homeland Defense initiative [22] in 2004. Lockheed won the competition and was selected for the Phase 2 contract of the project [23,24] funded with $40M to define and specify a solar-powered High Altitude Airship (HAA). The airship is planned to have a mission life of 1 month, operating at 65,000 ft (approx 20 km), while providing 10 kW of power to a 4000 pound (approx 2 tonnes). An artist's impression of the craft is shown in Figure 6. It is intended that it will become part of the Ballistic Missile Defense System Test bed once it has been completed in 2007. Some of the early activities will be to demonstrate station-keeping and autonomous flight. It will be used for military and civilian activities including:-

- Weather and environmental monitoring,
- Short and long range missile warning
- Surveillance
- Target acquisition

Figure 6 Artist's Impression of Lockheed Martin High Altitude Airship [24]

Phase 2 was completed in 2005. In 2006 Lockheed got the follow-on contract of $147M to develop and test a scaled demonstrator using existing technologies with a planned maiden flight in 2009.

2.5.1 Discussion

This programme is one of the more credible developing HAAS. Lockheed Martin has significant experience; their development site at Akron has been developing lighter than air vehicles since 1928. Being funded from the US military budget also provides further security that there will be significant financial resources to ensure that the craft will be built. However, there have been recent rumours that in order to keep to the tight development timescales the specification of the craft has been loosened, including providing a much reduced payload of 250 kg.

3. Key European HAAS activity

3.1 Zeppelin

Zeppelin is a well-established name in airships. Today's Zeppelin company is a successful Holding Company with a range of industrial activities and is a member of the Zeppelin Foundation. In 1993 its subsidiary ZLT (Zeppelin Luftschifftechnik) re-entered the airship business with a large modern low-altitude airship – the Zeppelin New Technology (NT). This is a man-piloted airship with a maximum flight altitude of 3000 m and capable of supporting substantive payloads (e.g. in excess of 1.5 tonne).

At the present time ZLT is probably the largest and most experienced airship company in the world with certified capabilities in aeronautical engineering, production, maintenance, operation, training and testing of airships. ZLT has undertaken several studies for HAAS, and supported the Korean Programme in its early phase, but has not so far played a further active role in high altitude programmes.

In 2005 Zeppelin established a new "German Lighter than Air Institute" (GLAI) possessing all intellectual property rights of old and new Zeppelin airships and of the bankrupt Cargolifter company, which they purchased. The objective of this institute is to bundle the airship activities in Germany through mutual contracts as a basis for international co-operation, and to initiate and to coordinate the research and technology required for future airship programmes. One of its main objectives for the near future is the support of HAAS activities. This is being supported through partnerships with smaller engineering companies already participating in US-based high altitude airship activities.

3.1.1 Discussion

For the time being Zeppelin is concentrating its resources on the consolidation of the low-altitude airship business. But they intend to offer their experience and resources

to other airship projects as well. With the foundation of the GLAI Zeppelin is preparing a basis for a future oriented strategy, looking towards leadership in future airship programs as far as these can be supported by external financing. Zeppelin has a range of technology interests and good access across the airship and aerospace industry. Should they decide to move into development of high-altitude long-endurance craft, this could prove a very significant development for HAAS. They certainly possess the required range of engineering expertise for a major HAAS development, including excellent knowledge of airship technology coupled with experience in the operation of airships, especially if they succeed realising the objectives of the institute. Zeppelin has the relative advantage of strong industrial shareholders backed by the Zeppelin Foundation and the city of Friedrichshafen

3.2 .Advanced Technologies Group (ATG)

ATG [25] in the UK have been active in their 'Stratsat' programme for a number of years, despite chronic funding difficulties. Stratsat is a solar powered airship based platform – an artist's impression is shown in Figure 7. They have some unique technology and deployment methods for their craft. Although it is proposed to power the craft using solar power, in conjunction with regenerative fuel cells/batteries for much of the time, they have also incorporated a diesel engine into some of their designs which can be operated for limited periods to keep the craft on station in the event of wind gusts. The craft is being designed for a 5-year mission and sufficient diesel will be taken on board for the full length of the mission. They have thought about the launch phase of the Stratsat, and ways to overcome the sheer size of such vehicles (up to 200 m long). They intend to launch the craft vertically out of the hangar in such a manner that it is outdoors and close to the ground for only a minimum period of time [26]. They have test facilities and hangars capable of housing such vehicles in Cardington, UK.

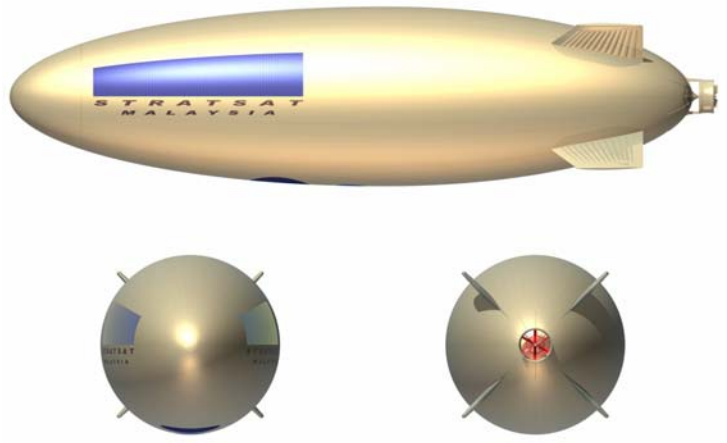


Figure 7 ATG STRATSAT Solar powered airship [25]

They have spent significant effort in pursuing Stratsat Malaysia, a project to be funded by the Malaysian government, which at one time was understood to have BT

Teleconsult (part of BT) and EADS as partners. They have been looking at a range of applications:

- Mobile Telephony
- Civil Broadband
- Civil Communications
- Maritime Communications
- Military Communications, data transmission and Surveillance
- EOIR Imagery
- Radar Imagery
- Civil Tracking/Road Usage

The project is planned in two phases:

- Phase 1 – Demonstrator System, costing $160M which would complete its first flight 24 months after project launch. The flight would take place at 60 000 ft and have a mission duration of 3 months
- Phase 2 – Objective System, costing $400M taking 30 months to complete. They would:
    - Develop operational payload, Improve airship capability margins,
    - Build out and deploy a system for Malaysia
    - Commence deployment out in ASEAN countries

(The project and the co-operation with the partners was ultimately cancelled, apparently because the Malaysian Government did not after all intend to finance the programme but instead sought private investment.)

Additionally, ATG has provided advice to JAXA to assist with airship aspects of the Japan National Project.

ATG have also been active in producing designs for other craft, e.g. their 'SkyCat', which claims to be a man-piloted airship with an available high-altitude version capable of operation to 18,000 ft altitude and carrying a payload of more than 1000 kg.

3.2.1 Discussion

ATG have significant technical experience in developing and flying airships. Their facilities in Cardington are good and are making use of the old airship hangars left over from the R101 days. The main difficulties they have seem to be on the business side. ATG is a small company and appear to have had continuing problems to maintain solvency. Stratsat Malaysia represents a significant potential

opportunity delivering applications and services to probably the best country to benefit from such deployments. However, ATG have been predicting the project's imminent start date now for a number of years with differing partners and without clear evidence of progress. (For example, it had been claimed in 2004 that the ATG Stratsat would be field-tested by end of year 2006 at altitude of 20 km and will be able to carry a payload of 1000 kg for communications and other monitoring purposes; however, the evidence that this may happen remains to be shown). As a consequence their genuine technical abilities are put into question and their general credibility suffers. Another important aspect is the size of funding required for the project, compared with their size and business capabilities, coupled with the lack of credible risk analysis and mitigation strategies in place for a project of its size.

As at May 2006, it is understood that ATG had been taken over by an Italian company, following a period of financial problems.

3.3 European Commission Funded Activities

3.3.1 CAPANINA

To further develop the state-of-the-art in broadband from aerial platforms the European Commission supported a new project, CAPANINA [27], as part of the 6th Framework Programme. The CAPANINA project (FP6-IST-2003-506745) is 3-year research project that commenced on 1st November 2003. A consortium of 13 partners is involved, representing a mixture of large industry, SMEs, and academia/research organisations*. Several of the partners previously worked together on the FP5 Helinet Project (see later in this document), which provided a firm basis of experience for CAPANINA.

CAPANINA is focussing on development of low-cost broadband technology from HAAS aimed at providing efficient coverage to users who may be marginalised by geography, distance from infrastructure, or those travelling inside high-speed public transport vehicles (e.g. trains travelling up to 300 km/h). The aim is to exploit this future wireless technology to deliver burst data rates to users of up to 120 Mbit/s anywhere within a 60 km coverage area. Both mm-wave band and free space optical communications technologies are being considered.

The project is adopting a three-strand approach:

- Identification of appropriate applications and services and associated business models. This includes the establishing the most appropriate integrated

* CAPANINA Partners are: University of York (UK)·, Jozef Stefan Institute (Slovenia), Politecnico di Torino (Italy), Universitat Politecnica de Catalunya (Spain), Carlo Gavazzi Space (Italy), Budapest University of Technology & Economics (Hungary), DLR (Germany), BTexact (UK), EuroConcepts Srl (Italy), CSEM (Switzerland), Contraves AG (Switzerland), National Institute of Information & Communications Technology (Japan), Japan Stratosphere Communications (Japan).

network architectures, and will include wireless and free space optical link technologies, and multiple platform technologies and spectrum sharing.

- The development of a system testbed that will allow nearer-term tests of broadband services/applications to fixed users, including: backhaul for terrestrial WLAN, corporate communications and video-on-demand, along with an evaluation of free space optical technology.
- Longer-term state-of-the-art research and innovation examining advanced mobile broadband wireless access. An outline system design and critical hardware will be developed for a scenario that will deliver broadband to trains, integrating with on-board wireless LAN base stations.

3.3.1.1 Second Year Trial

During the second year of CAPANINA (2005), and with support from the Swedish Space Centre at Estrange in northern Sweden, a stratospheric communication trial using a free-floating balloon was carried out.

The 12,000 cubic metre balloon (Figure 8) flew at an altitude of 24km for a duration of 9 hours allowing RF and optical trials to be conducted.

The broadband wireless access radio link equipment was designed and developed by the University of York to operate in the 28/29 GHz band. This supported data rates of 11 Mbit/s and throughputs up to 4 Mbit/s, using WiFi (IEEE802.11b), at distances ranging up to 60 km.

DLR (Germany) performed the first known optical 1,25 Gbit/s downlink from the stratosphere to an optical receiver on the ground over a maximum link distance of 64 km with nearly no transmission errors. This technique will be used for future inter platform and platform to satellite backhaul links.

CSEM (Switzerland) developed the ground signal tracking system, a crucial part of the system required to maintain the communications link between the moving balloon and the ground.

CGS (Italy) coordinated the integration of the payloads and the trials activities.

Figure 8 Stratospheric balloon during inflation phase of CAPANINA.

3.3.2 USE-HAAS

USE-HAAS [28] is an 18-month FP6 SSA under Aeronautics and Space Priority that started in March 2005. It aims to examine prospective aeronautical research agendas in High Altitude Aircraft and Airships (HAAS), along with associated mission/applications in conjunction with the European aeronautical and space industry. The coordinator of the project is Prof. Dr. Arie Lavie of CTI.

Sub-objectives include:

- To analyse the world state of the art including European work relating to HAAS aeronautical uses, as well as the programmes and tests underway in USA, Europe, Japan, China and Korea.
- To develop tentative Research Objectives for European/Global HAAS Deployment regarding a variety if end-user services and prepare an outline of a potential aeronautical research programme.
- To disseminate recommendations on the Objectives and the Aeronautical Research Agenda
- To issue a final version of the Specific Research agenda, including the impact on regulations and recommendations on such a call. It may assemble the activities in the sector, and provide appropriate technological roadmaps based on inputs made during the workshops and working groups with end users and possible industrial partners

3.3.3 COST297 –'HAPCOS'

This new 4-year duration European COST Action [29] had its pre-kick-off meeting in April 2005 and a formal commencement of September 2005, and adopted the description 'High Altitude Platforms for Communications and Other Services'. It aims to provide a forum for research and technological development into HAPs and their applications, and in particular to help bridge the divide between those concerned with the platforms themselves and those concerned with applications and services. Its main objective is:

> "To increase knowledge and understanding of the use of High Altitude Platforms (HAPs) for delivery of communications and other services, by exploring, researching and developing new methods, analyses, techniques and strategies for developers, service providers, system integrators and regulators."

COST297 It has three Working Groups:- WG1 dealing with RF communications from HAPs; WG2 dealing with optical communications form HAPs; and WG3 dealing with platform aspects. It is hoped to extend specifically into earth observation / remote sensing also. To date 17 countries are signatories to COST 297.

3.3.3.1 Discussion

This COST Action is already helping bring together partners with interests in HAPs and their applications. It represents a low-cost catalyst in the area, although it needs to broaden its scope to achieve maximum impact.

3.3.4 SatNEx

SatNEx (FP6-IST-2003-507052) [30] is an FP6 NOE that is integrating research activities in satellites and HAP communications in a durable manner to enable critical mass and access to a range of expertise across Europe. It involves 22 partners in 9 European countries. Workpackage 2230 of SatNEx deals with HAP systems. [It is not currently clear whether SatNEx is still operational, or has completed].

3.3.5 UAVNET

UAVNET is a thematic network funded by the European Commission Framework 5, Key Action 4 - "New Perspectives in Aeronautics" to advance the development of UAVs for civilian purposes. The goal is to optimise research efforts of civil UAV applications, by bringing together industry, universities, research centres and potential users to exchange and disseminate knowledge, and to coordinate activities.

UAVs have proven their capability within the military fields, but there are many civilian applications in environmental monitoring, communications relays, law enforcement surveillance, earth observation, etc. where the benefits of UAVs are only beginning to be understood. The thematic network will serve as a forum for information exchange, for suggesting new policies and for launching activities in critical technology research.

UAVNET, which is co-ordinated by Israel Aircraft Industries, began its activities in October 2001 and has an impressive consortium of 19 members which comprises many major aeronautical organisations:-

Airobotics (Germany), Alenia (Italy), BAe Systems (England), Brno Univ. (Czech Rep.), CIRA (Italy), DLR (Germany), EADS (France), IAI (Israel), Institute of Aviation (Poland), Nat'l Defence Univ. (Hungary), NLR (Netherlands), ONERA (France), Politecnico di Torino (Italy), Politechnika Warsaw (Poland), Snecma (France), Sonaca (Belgium), Swedish Space Corp. (Sweden), Thales (France), Vilnius Gediminus (Lithuania).

UAVNET commenced in 2001, and has so far organised 13 workshops, which were held in many locations throughout Europe and Israel. These 2-day workshops succeeded in attracting considerable interest in the aeronautical industry with an average attendance of about 70 – 80 people, and have produced a considerable amount of useful material. Although UAVNET is formally completed, it is effectively continuing its activities [31].

3.3.6 CAPECON

CAPECON is a Critical Technology (CT) programme funded by The European Commission Framework 5, to investigate new directions for future civil UAV development, applications, technologies, configurations and economic viability. Its goal is the definition of civil UAV applications and configurations.

The CAPECON scope of work includes the identification and definition of potential civil UAV applications and the definition of seven configurations for these applications (3 HALE, 2 MALE & 2 rotary). CAPECON is concerned with safety criteria in the ATC/ATM environment, whilst maintaining competitive economic advantage compared to alternative airborne (manned), satellites and ground based systems. CAPECON has considered a broad range of potential applications in the fields of Scientific, Emergency, Communications and Surveillance. It has also developed a cost model.

The CAPECON consortium, which commenced activities in May 2002, is co-ordinated by Israel Aircraft Industries and includes major aeronautical organizations representing industries, research institutes and universities. The programme is understood to be now concluded.

3.3.7 USICO

USICO is a Critical Technology (CT) programme funded by the European Community, to improve the safety of civil UAVs and enable their integration within civilian airspace. Its goal is to improve the operational capability of UAVs.

The USICO scope of work included recommendations for UAV system airworthiness, certification procedures and standards. It also produced a flight simulation of the UAV ATC/ATM process.

The USICO consortium, which commenced activities in April 2002, has recently concluded. It was co-ordinated by Airobotics GmbH and included major aeronautical organizations representing industries, research institutes and universities. The programme is understood to be now concluded.

3.3.8 IFATS

"IFATS" is an FP6 STREP project started in July 2004 under the thematic priority «Aeronautics and Space», Key action: «Improving aircraft safety and security».

The development of powerful processing technologies and efficient data links offers a potential for the evolution of automated safe air traffic control systems directly managing highly capable autopilots. This offers the possibility of a future air transport based on automating the task of piloting aircraft and managing air traffic to a point where pilot and controller tasks would no longer be separated: they could be performed together on the ground.

The goals of the project are to define a technically viable concept of an air transportation system where aircraft would be "operated" from the ground by controllers-pilots and to identify the difficulties, both technical and psychological, to be overcome in order to build such an Air Transport System. IFATS' approach is to assess what would be an extreme solution (full automation), then deduce a practicable solution and set a roadmap from the present situation to a future one.

The multinational consortium comprises:- ONERA (France), EADS (France), IAI (Israel), Thales (France), Alenia (Italy), Erdyn (France), DLR (Germany), CENA (France), CIRA (Italy), University of Patras (Greece), Technion Institute of Technology (Israel). IFATS is due to finish in January 2007.

3.4 European Space Agency (ESA) Activity

ESA has undertaken a study into broadband delivery from HAAS, as part of its long-term investigations into HAAS. This is a collaboration between Airobotics GmbH (D), Booz Allen and Hamilton (NL), University of Surrey (UK), POLITO, Fraunhofer Institute (D) and DLR [32]. The remit of their study was to examine both the aeronautics and applications. Four categories of platform were compared:

- Aerodynamic, solar powered
- Aerodynamic, fuel powered
- Aerostatic, solar powered
- Aerostatic, fuel powered

Emphasis was placed on the use of solar power, but it was found that the eventual choice of platform depended heavily on the choice of payload, and the conceptual design for a platform has been developed.

The feasibility of a range of communications applications, including broadband, 3G, and DAB/DVB-T broadcasting have been studied as shown in Figure 9. The choice of these payloads was based on technical feasibility, benefits for operators and market demands. The payloads themselves were based on three technical strategies: transparent; RF-switching; and regenerative.

This activity carries on from earlier ESA HALE study [33] which was completed a few years ago.

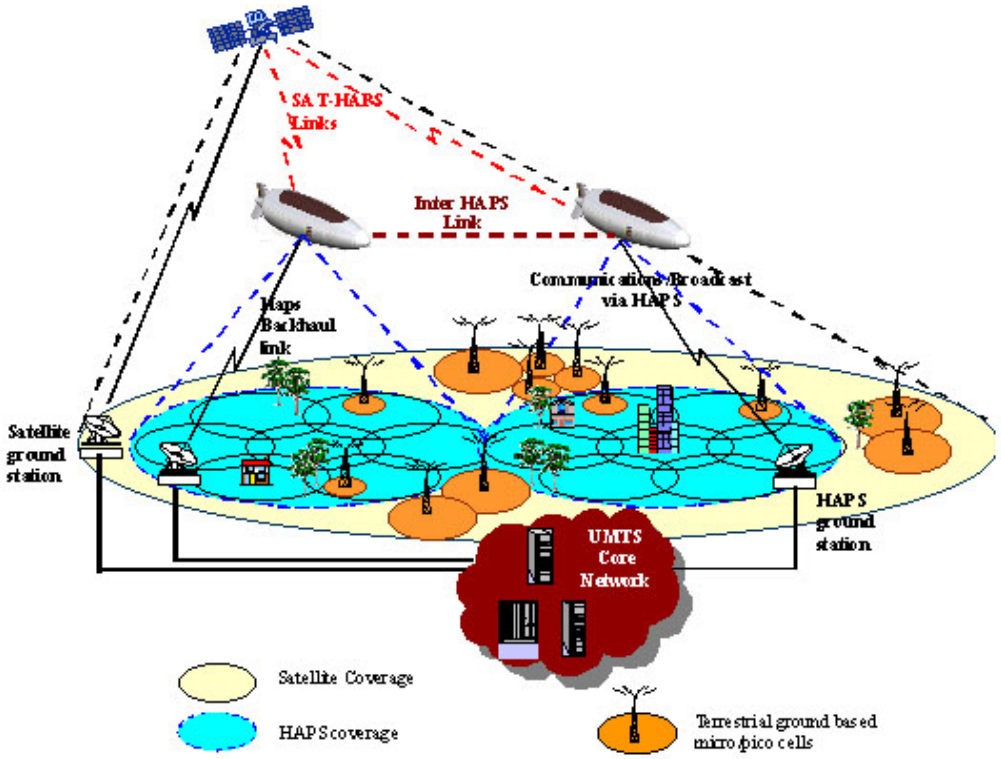


Figure 9 ESA HALE Study - Architectural Diagram [32]

4. Other Areas of HAAS Activity

This includes some projects which are small, not fully known about, or which are essentially proposals at this stage.

4.1 Techsphere Systems International (TSI)/CyberAerospace

Techsphere Systems International (TSI) [34] and CyberAerospace [35], both US-based companies, report plans to develop an AeroSphere HAP as shown in Figure 10. They plan to operate a range of wireless communications service including broadband and 3G, along with homeland security and military applications. The reason for its unique shape is to assist in launch, where craft must be launched with only 6% lifting gas by volume to cope with future expansion. With such limited volume traditional cigar shaped craft have poor control over manoeuvrability [34].

Figure 10 The Aerosphere from Techsphere Systems International (TSI)/CyberAerospace

They successfully launched the Aerosphere SA-60 in June 2004 as shown in Figure 11, which is a low altitude demonstrator.

Figure 11 Aerosphere SA 60 Launch in June 2004 [35]

4.1.1 Discussion

This is one of the newest HAAS projects, and as such little is known about their capabilities. They clearly have a funding stream and are capable of developing small-scale craft. It is not clear whether their design is suitable for stratospheric use. Spherical craft may prove to be less stable during flight than their conventionally shaped counterparts.

4.2 21st Century Airships

21st Century Airships [36] are a Canadian company promoting spherical airships and airship technology. They claim ambitions to produce a high altitude airship, but there is little evidence of this to date.

4.3 RosAeroSystems

RosAeroSystems [37] is part of a Russian consortium (Augur, RosAeroSystems, Lavochinkin Association, Myasishev Company) which plans to build a stratospheric airship. They have a detailed design for a three-stage approach based on a single full-size airship design. They have been providing support on airship development to the Korean National Project via KARI.

4.4 Russian Academy of Sciences

The Russian Academy of Sciences is involved in some tethered aerostat projects, including the delivery of communications services from a tethered aerostat at a few thousand feet altitude. They also have a design for a rotary-wing platform, operating at up to 300 m altitude and with several rotors powered up the cable.

4.5 Sanswire Networks LLC (USA)

Sanswire Networks LLC (USA) [38] is a new company in the US who claim to be in the process of launching 'Sanswire One', a 58 m scaled version of a full size version of their 'Stratellite' craft, shown in Figure 12. The aim of the company is to deliver IEEE802.11-based communications services from a height of 65 000 ft (approx 20 km).

It was announced that Kestrel Aerospace Limited [39], a UK based company, would develop and install new avionic flight control systems and propulsion systems for the Sanswire platform.

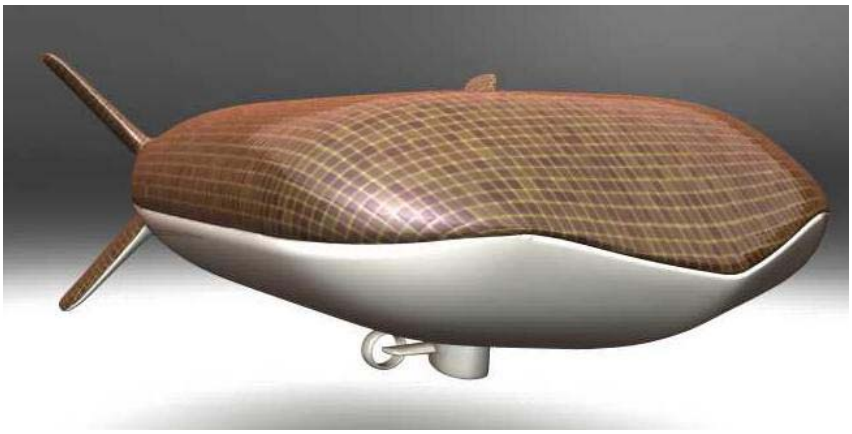


Figure 12 Artist's impression of eventual Sanswire Craft [38]

4.5.1 Discussion

Sanswire Networks appears to be a company claiming an ambitious on-going development programme. It should be noted that the craft under development is a scale-size version and the capabilities of airships do not necessarily scale with size (unlike aircraft). Although, clearly they are intending to operate long duration missions with the full size craft, it should still be possible for the Sanswire One to be used on more limited missions, operating with a smaller payload and over shorter mission durations. Additionally, Sanswire One would enable the company to assess the performance of the materials and propulsion systems.

As at May 2006 however, it was understood that the company had just gone into receivership or was in some similar kind of financial difficulty.

4.6 University of Stuttgart

The University of Stuttgart won the Körber prize in conjunction with Lindstrand in 1999 [40]. Prof Bernd Kröplin has significant experience of airships and the group have a number of innovative designs for HAP vehicles. Their knowledge of the aerodynamic properties of large airships is significant, although it is not clear how this is being exploited in real-life projects.

4.7 Other Universities

A large number Universities worldwide have developed activities or interests in HAAS and their applications. These are too many to list individually, although they may be identified by, for example, their membership of COST297.

Among the more prominent are:-

- The University of York (UK)[41], which has a significant pedigree in several HAP-related projects, including HeliNet, CAPANINA, USE-HAAS and COST297.
- Politecnico di Torino (Italy), which is involved in several projects, and which was responsible for the HeliPlat design.
- The University of Surrey (UK), which is continuing to carry out research into HAPs and is active in the FP6 NOE SATNEX on the subject. It has recently completed a research project funded by the UK's Engineering and Physical Sciences Research Council has recently completed a study contract to examine 3G from HAAS.

4.8 SHINES

The SHINES project [42], [43] is a consortium of 10 Italian Universities working on a 'research project of relevant national importance', investigating how HAAS should integrate into satellite and terrestrial infrastructure. POLITO is a partner.

4.9 QinetiQ

QinetiQ [44] based in the UK has a number of disparate interests in HAAS, some stemming from the days when it was the UK's Defence Research and Evaluation Agency (DERA). They have the following interests and activities:

- Zephyr 3 unmanned aeroplane and other UAV activity.
- Airships
- Communications
- Surveillance/Remote Sensing

Their activity appears to somewhat un-coordinated across these sectors. However, overall, QinetiQ is a major player in UAV technology, missions and applications. At the present time they are playing a major role in the Pegasus project (see below) with their Mercator UAV craft, a version of Zephyr. Zephyr is a very light-weight UAV which is entirely solar powered.

Zephyr / Mercator is designed to be a simple low-cost UAV which can be hand-launched by only a few men, and which has demonstrated operation to 60,000 ft during trials in Australia. The wingspan is from 12 m to 20 m, and payload mass from 2 kg to >10 kg. The idea is that the craft will engage in slow managed partial descent during the night, and mission duration in excess of 3 months is claimed possible. QinetiQ believe that a number of valuable missions can be supported by Zephyr, despite the limited payload mass and the perhaps not-fully-proven endurance in practical conditions.

Figure 13 QinetiQ Zephyr / Mercator UAV

4.10 The Pegasus Project

PEGASUS (Policy support for European Governments by Acquisition of information from Satellites and UAV borne Sensors) is an initiative led by the Flemish Institute for Technological Research (VITO) for the GMES and INSPIRE programmes [45]. It aims at complementing satellite imagery by high-resolution (10-15 cm) observations made by HALE UAVs at an altitude of 14 to 20 km. A fleet of some fifty UAVs (each covering 100 000 to 1 000 000 km^2) is proposed to be deployed over Europe [46].

In June 2004, the Flemish Government announced its decision to finance the PEGASUS HALE UAV activities. Some 18 MEUR are to be allocated, incl. 11 MEUR for the UAV itself, and 7 MEUR for the creation of a environmental research platform.

The consortium lead by VITO includes :

- Verhaert (Belgium), responsible for the development of the UAV, in cooperation with QinetiQ (UK);

- OIP Sensor Systems (Belgium), responsible for the development of the lightweight remote sensing payload;

- Alcatel Bell Space (Belgium), responsible for the system ground segment.

Named Mercator-1, the first UAV is expected to make its first demonstration flight over Flanders at the end of 2005 (Figure 14). Having a 16 m wingspan and a weight of 18 kg, this first version is based on the Zephyr-4 UAV developed by QinetiQ. The precursor payload is a 2 kg multispectral camera. Subsequent versions of the UAV will be able to embark a thermal camera or a mini SAR in 2007.

Flanders hopes to propose Mercator-1 as an operational stratospheric remote sensing platform in 2008.

Figure 14 Artist's impression of the Mercator-1 UAV in flight

4.11 Lindstrand Technologies Ltd (UK)

Lindstrand Technologies Ltd [47], a UK company led by Per Lindstrand, are based upon a-long established and successful business with airship envelopes and related technology. They were involved in a project funded by the Körber Institute and ESA. Lindstrand has established LBL as a 50/50 partnership with DASA (Daimler Chrysler Aerospace). They have significant expertise in advanced materials required for airship based HAAS, and production facilities capable of manufacturing airship envelopes.

Lindstrand is understood to be actively exploring airships for delivery of communication and surveillance services, and is aiming towards high-altitude long-endurance craft; however there is little evidence of any major funded activity in this area.

4.12 Chinese activities

The Chinese FuTuRE project, which is the major driver for next generation mobile (and other) communications, coordinated by Tsinghua University, China reportedly has HAP elements, although the extent of these is not apparent.

Shanghai JiaoTong University/China Academy of Engineering reportedly have funding for a modest HAP programme.

From time to time other commercial HAAS initiatives have been reported, but progress remains unclear.

4.13 Space Data Corporation

Space Data Corporation [48] is a US company that delivers wireless data services to rural and remote areas. One such example is the provision of telemetry services to the oil and gas industries. It is currently doing this using free flying balloon based technology, their SkySite® network. These balloons are launched every 8 to 12 hours from sites close to the coverage area, with the payload recovered on landing after around 24 hours. They operate up to a height of 80 000 – 100 000 ft and provide at that altitude a coverage area of 350 miles in diameter. Coverage is currently restricted to Texas, Oklahoma, and Louisiana, with limited coverage in neighbouring US states.

They can offer for example [49]:

- SCADA communications
- RTU/EFM/PLC monitoring
- Pump-off controller monitoring
- Utility meter reading
- Compressor/tank alarming
- Pipeline Monitoring

These operate in the 900 MHz band where Space Data hold a 1.7 MHz allocation of spectrum in the US. They additionally offer services to the transportation sector, field communications and location services.

4.14 Bosch Aerospace

Bosch Aerospace have plans for a Rapidly Elevated Aerostat Platform (REAP) [50] as shown in Figure 15. These are deployed for military operations primarily for surveillance operations.

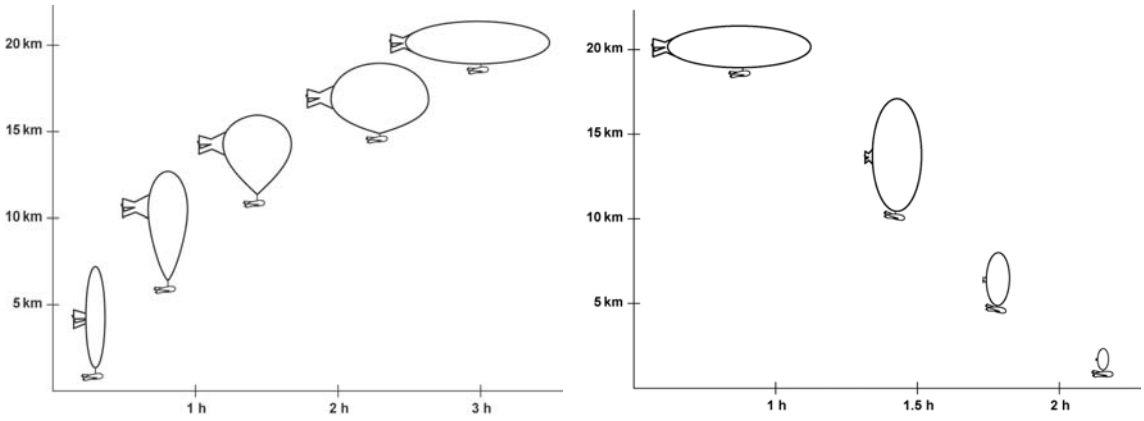
Figure 15 Bosch Aerospace's REAP Aerostats [50]

4.15 StratXX Holding AG: 'X-Station'

The StratXX organisation has quite recently (Spring 2006) become prominent with their 'X Station project'. Their aim is quite specific: to deliver WiMAX applications from a stratospheric platform over Switzerland, although recent promotional material alludes also to navigation, localisation, tracking, security/emergency and monitoring services. The project comprises a Swiss-centric consortium including aerospace manufacturer Ruag, and additional expertise within technical universities EPFL (Lausanne) and ETH (Zurich).

The StratXX roadmap foresees a proof of concept phase and prototype test phase with platform test launches from mid 2006 until end 2007. First commercial sales are scheduled as of 2008.

At a presentation to USE-HAAS in May 2006, StratXX Holding AG announced a funding of some 30 Million Euros, and an aspiration to establish a market within 3–4 years, promising returns to its financial backers.



(a) Ascent phase (b) Descent phase

Figure 16 X-Station launch concept

4.16 Geoscan

Geoscan (UK) plc is a British-Russian Technology Partnership who seek to deliver solutions for Broadband Fixed Wireless Services, 3rd & 4th Generation Mobile Communications, and Earth Observation. Their 'M55' platform is a conventional high altitude, piloted, jet powered aeroplane. Some properties of this platform include:

- Payload mass up to 2,000kg
- Payload volume up to 9 m^3
- Available payload power ~ 40 kW
- Non-pressurized dust and moisture-proof bays
- Flight duration up to 8 hours
- Optimum fuel saving altitude is 18.5 km

The parent organisation, GEOSCAN International Agency (GIA), was established in 2000 by a consortium of academic institutions and research and production enterprises specializing in aerospace technologies and services, Earth and Space sciences and hydrometeorology. GIA has complete access to the Russian Academy of Sciences and the Russian Aerospace Enterprises and has support from the Ministry of Industry, Science & Technology of the Russian Federation (MIST).

Figure 17 M55 High Altitude Aircraft

4.17 Platforms Wireless International

This project is based on tethered platform technology [51] and is aimed at delivering mobile communications access to developing countries, e.g. Brazil. One of their most recent press releases claim (March 2004) they have been awarded a contract to deliver their ARC system to Indonesia [52]. It would appear that the Brazilian venture did not proceed.

4.18 Creative Technologies Israel (CTI)

CTI Israel is a high technology company with expertise including aeronautics and microwave systems and hardware, including high-power systems. They have been responsible for a number of Proposals relating to HAAS, and are leaders of the USE-HAAS project.

One particular technology they are promoting is the use of high-power microwave beams from the ground to provide 24-hour power source for HAAS operation. This is not entirely a novel idea, but they appear to be the only company promoting it. It would involve very high power transmitters on the ground and 'rectennas' on the aerial platform converting the power into a DC voltage.

Another concept which they have developed concerns the use of hydrogen fuel as propellant for power an airship for period of up to 1 week.

CTI's strength appears to lie in their wide range of connections, including a background with UAVs and military systems, and in their varied technology base. Among their significant Proposals has been 'Telaship', which is a high altitude long endurance craft utilising some of the above technologies and providing a range of surveillance and communications applications; and 'FLAMES' which is an application of such craft specifically for identification and management of forest fires.

5. UAVs

UAVs ('Unmanned Aerial Vehicles') are by no means a recent phenomenon. As early as the beginning of 1974, Israel Aircraft industries (IAI) launched the development of a tactical surveillance UAV code-named "Scout". The term UAV has generally been taken to mean vehicles of relatively short mission duration, and (in practice) relatively low altitude. However more recent developments now permit UAVs to fly at altitudes of 50,000 ft or more with mission times of several days. The term is now often used loosely, and in some quarters UAVs are considered to encompass virtually all types of aerial platform including high altitude craft. The term UAS ('Unmanned Aerial System') is also achieving more common usage.

Most UAV projects are military in basis. However there is considerable opportunity for UAVs in civil applications. Currently the main obstacles to operating UAVs for civilian purposes are economic viability and safety of flight. However, the accelerated development of UAVs for military missions acts as a catalyst for civilian applications and the experience gained and the maturity of technologies act as a driving force for producing rules for operation and safety. In addition, technological developments in the field of aerospace facilitate the improvement of reliability and affordability.

Major expansion is expected in activities in the field of UAVs in the coming years in which currently new technologies will mature. This broadening activity and use of new technologies will considerably advance UAV improvements. Emphasis during the coming years will be in the sphere of affordability, performance, safety and readiness. These efforts will be supported and fed by other activities occurring in the world such as manned aircraft technology, automobile technology, communications technology and miniaturisation.

UAV technology also helps pave the way for long endurance and higher-altitude craft. Operating HALE (High Altitude Long Endurance) UAVs at an altitude of around 60,000 ft has considerable advantages. Flight is above all the normal air traffic and strong winds. The line of sight to the horizon is greater, enabling a wider field of coverage, and there is a potential for more efficient performance capability and longer endurance.

In addition to fundamental technology developments, UAVs serve to demonstrate concepts, break down barriers of perception and credibility, and also help develop a regulatory environment which will benefit all kinds of aerial platform.

UAV activity in the USA is accelerating, with more than $B1 per year budgeted for the DoD's main programs. The budget for all DoD UAV programs doubled between 2001 and 2002, will double again between 2002 and 2005, and is expected to triple between 2002 and 2007.

It is not possible to list all UAV activities here. Some specific developments worthy of note however are outlined below.

5.1 The Heron UAV

The preliminary design of the Heron UAV started as early as 1993 and a "go ahead" for manufacturing was given in January 1994, with the first flight taking place in October that year. The Heron with a 17 m span, is in the weight class of 1100 kg. Developed by IAI, it can fly today at altitudes up to 10 km for more than 52 hours while carrying a payload of 250 kg (including SAR and FLIR radars, EO/IR observation equipment and secured communications). EADS in France plan to manufacture this UAV under its new name “Eagle I” and a much improved version “Eagle II” will have considerably higher performance in altitude and payloads.

Figure 18 HERON UAV

The Eagle is a single system with two platforms (Eagle I and Eagle II) based on the twin booms concept. These platforms employ the same ground segment, the same operation, the same data-link systems, the same safety equipment and the same automatic take off & landing system, but with very different performance characteristics.

The Eagle configuration with its “Payload Oriented” design is ideal for antenna installation above and under fuselage as well as on the booms and wings. It comprises a wet wing to free fuselage volume; two large spaces for modular implementation of payloads; an un-obscured field of view and a broad CG range which facilitates stability for all payload configurations. The retractable landing gear in the booms frees the fuselage for payload antennae installation.

In order to enhance future integration of the UAV into civil airspace, the airframe design conforms with the guidelines of FAR23/JAR23 civil regulations. The UAV system is suitable for adaptation of civil ATC transponders and UHF communication relay to allow the communications between UAV operators and air traffic controllers. The standard equipment will enable to use the "see and avoid" operational concept

in VFR conditions. Optional TCAS II and other modern collision warning systems can be readily integrated into the flight management system.

Special operational procedures have been designed, in order to recover the UAV safely to pre-designated landing sites, in case of emergency engine shut-down (an extremely rare incidence, since this engine's statistical shut-down frequency is $5x10^{-6}$/flight-hr). The high glide rate of the UAV and the back-up emergency batteries installed provide for a controlled un-powered glide to a range of at least 80 km.

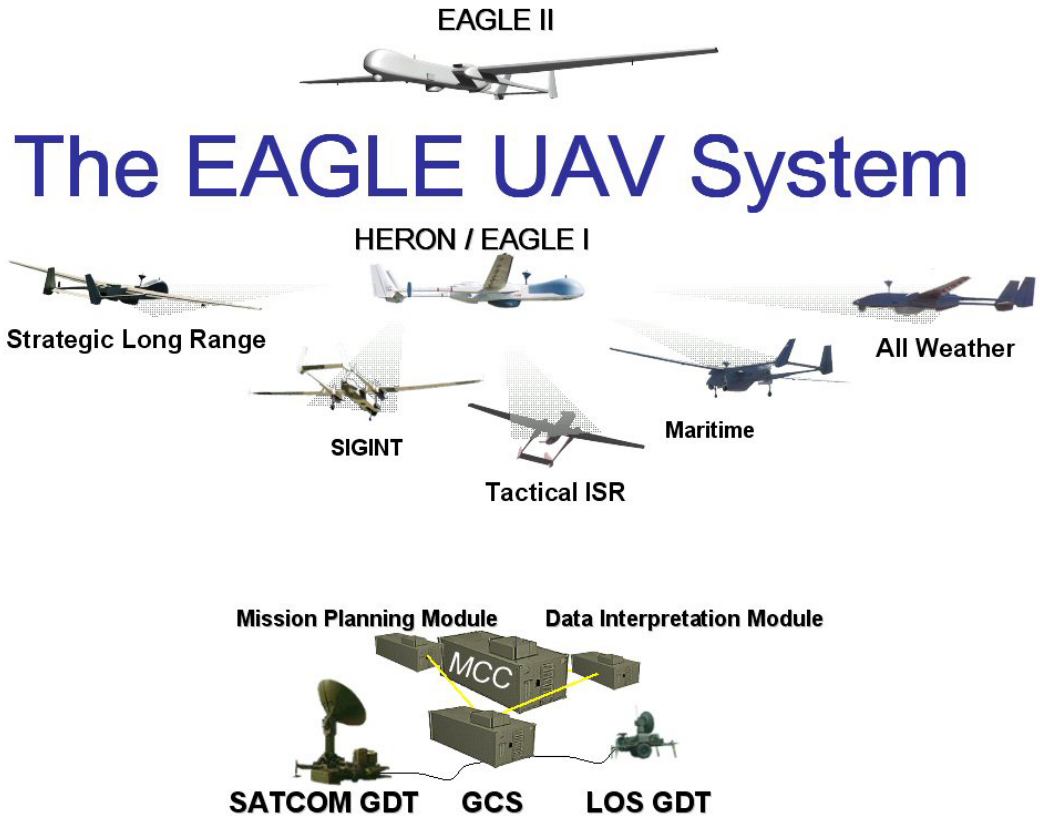


Figure 19 EAGLE I & EAGLE II UAVs

Table 1 Eagle UAV Basic Parameters

	EAGLE I	EAGLE II
Engine	Internal combustion	Turbo-Prop
Power	165 hp	1200 hp
Max Take-off weight	1200 kg	3,900 kg
Max. Payload capacity	>250 kg	>450 kg
Max. Fuel capacity	<400 kg	1,750 kg
Total length	9.3 m	13 m
Wing span	16.6 m	26 m
Total height	2.3 m	3.3 m
TO Distance	<1000 m	<1000 m

Table 2 Eagle UAV Performance

	EAGLE I	EAGLE II
Maximum altitude	> 25,000 ft	> 45,000 ft
Operational Altitude	> 20,000 ft	> 41,000 ft
Time of climb to OA	< 50 min.	< 40 min.
Max. payload weight	250 kg	> 450 kg
Max. speed	120 ktas at 25 Kft	220 ktas at 45 Kft
Cruise speed at OA	80 to 110 ktas	180 to 200 ktas
Total mission time	> 30 h	> 24 h
Loiter time at 550 NM	> 12 h	> 16 h
Loiter time at 800 NM	> 7 h	> 12 h

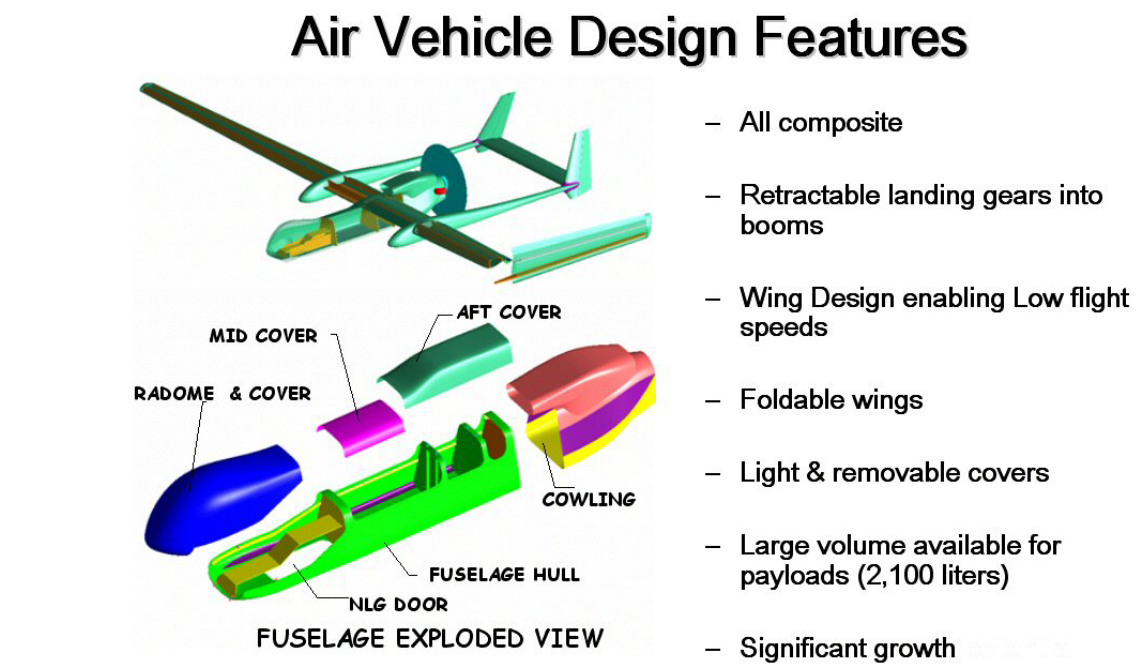


Figure 20 EAGLE Air Vehicle Design Features

5.2 Modular HALE UAV

New potential directions for civil applications are being explored today by IAI in studies taking place in Europe within Framework 5 projects such as CAPECON & USICO. The goal of these projects is to show that there is an economic viability (CAPECON), and a way of determining safety standards and flight rules (USICO). New UAV systems are being defined as part of this activity, such as the Modular UAV defined by IAI, shown above.

The Modular UAV is designed for high altitude and long endurance, having a take-off weight of about 6,000 kg and a payload capability of 500 kg, 36 hours endurance at an altitude of 60,000 ft. The UAV is designed for basic modularity, providing a large volume for installation of payloads and the required electrical supply and cooling. The target operational cost of this UAV is planned to be an order of magnitude lower than that of an equivalent military UAV.

5.3 Global Hawk

The RQ-4A Global Hawk is a high-altitude, long-endurance unmanned aerial reconnaissance system designed to provide high resolution, near-real-time imagery of large geographic areas. Advanced technology sensors, a range greater than half-way around the world, and the ability to remain in flight for long periods of time, enable the Global Hawk to provide surveillance and intelligence data. The Global Hawk has flown over 6,500 flight hours.

The aircraft's 12,000 nautical mile range and 35 hours of endurance, combined with satellite and line-of-sight communication links to the ground segment, permit worldwide operation of the system. High-resolution sensors, which can look through adverse weather (day or night), from an altitude of 65,000 feet, can conduct surveillance over an area of 40,000 square miles.

Once mission parameters are programmed into Global Hawk, the UAV can autonomously taxi, take off, fly, remain on station capturing imagery, return and land. Ground-based operators monitor UAV health and status, and can change navigation and sensor plans during flight as necessary.

When fully-fuelled for flight, Global Hawk weighs approximately 25,600 pounds (11,612 kilograms). More than half the UAV's components are constructed of lightweight, high-strength composite materials, including its wings, wing fairings, empennage, engine cover, engine intake and three radomes. Its main fuselage is standard aluminium, semi-monocoque construction.

Figure 21 GLOBAL HAWK

5.4 Predator B

The Predator B aircraft was developed in 2000 with first flight commencing in February 2001. Powered by a turboprop engine, the Predator B series was designed as a long-endurance, high-altitude unmanned aircraft for use as a multi-mission system by a variety of customers. From reconnaissance, surveillance, targeting, and weapons delivery to scientific research and other civilian applications, Predator B has the capacity to conduct multiple missions simultaneously due to its large internal and external payload capacity.

The radar system on the Predator B also represents an upgrade over the Predator A. A superior targeting radar was developed by General Atomics in conjunction with Sandia National Laboratories. The new radar system is known as Lynx synthetic aperture radar. Not only does the new radar have 4-inch imagery resolution, it can also zoom. It allows the Predator B to accomplish its ground-imaging role even in poor conditions.

PREDATOR B	
Military Multi-Mission ISR	
Wingspan:	66 ft (20.1168m)
Fuselage:	36 ft (10.9728m)
Weight:	10,000 lb (4536 kg)
Altitude:	50,000 ft
Endurance:	30+ hr
Payload:	Internal - 800 lb (363 kg)
	External - 3,000 lb (1361 kg)
Power plant:	Honeywell TPE 331-10T
Air Speed:	Over 220 knots

Figure 22 PREDATOR B

5.5 Watchkeeper Tactical UAV

'Watchkeeper' is a United Kingdom tactical UAV system being developed for the British Army. The system will provide the UK armed forces with Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) capability [53]

5.5.1 Genesis

Invitations by the UK MOD to bid were initially placed in 2002. In August 2005, Thales UK was awarded the contract. The number of Watchkeeper systems has not yet been announced.

Thales UK's Watchkeeper proposal included a large UAV and a smaller UAV, support equipment and ground stations. The MoD decided that a single UAV solution offered the more cost-effective and only the larger WK450 UAV from Elbit will be developed. The air vehicle will be capable of carrying a range of sensors including day and night cameras and surveillance radars. Two WK450 air vehicles will be able to operate in tandem, with the second acting as a communications relay. The ground control station will be network-enabled to ensure comprehensive communications links, for example to airborne stand-off radar, attack aircraft and battlegroup headquarters.

The Watchkeeper system will enter service in the British armed forces in 2010. A full Watchkeeper system can be deployed to theatre in a single C-130 Hercules transport aircraft.

5.5.2 Programme

The industrial Watchkeeper consortium, led by Thales UK, includes Boeing; Cobham, Wimborne (major sub-assemblies and components); Cubic Corporation, Greenford (datalinks); Elbit (air vehicles); LogicaCMG, Leatherhead (digital battlespace integration); Marshall SV, Cambridge (ground station shelters and vehicles); Praxis, Bath (programme safety); QinetiQ (airworthiness consultancy and image data management); UAV Engines Ltd, Lichfield (UAV engine); and Vega (training).

A joint venture company, UAV Tactical Systems Ltd (U-TacS) has been set up by Thales UK and Elbit to produce the Watchkeeper system in the UK. The air vehicle development and manufacturing joint venture will be based on Elbit's capability in unmanned air vehicles and Thales UK's capability in detection, identification, electro-optics, imaging and signal processing and system integration. Flight tests of the Watchkeeper air vehicles are to be carried out at the ParcAberporth facility in Cardigan Bay in Wales.

Boeing was selected as a team member to support UK and US interoperability and to play a role in technology and upgrades during the life of the Watchkeeper programme. Watchkeeper will be capable of being deployed with partners in NATO, Europe and USA.

Watchkeeper will be capable of full integration with both the US Network Centric Warfare (US NCW) and the UK Network Enabled Capability (UK NEC). The use of NATO standard data links and international standards for image data transfer will contribute to system interoperability.

5.5.3 WK450 Air vehicle

The Watchkeeper air vehicle, designated WK450, will be based on the Elbit 450 Hermes tactical UAV. The Hermes 450 is a proven system with 20,000 flying hours in service. In 2003, the Elbit Hermes 450 system was accepted by the US Naval Air Station Fallon Joint UAV Test and Evaluation Centre in Nevada for joint interoperability trials.

Figure 23 Watch Keeper UAV (HERMES 450)

The air vehicle can be pre-programmed to carry out fully autonomous missions and can be redirected in flight by the operator on the ground. Take-off and landing can be piloted or automatic. The air vehicle is equipped with global positioning systems, dual computers and dual datalinks. The electrical and avionics systems have built in redundancy for increased reliability.

The air vehicle is powered by rotary engines from UAV Engines Ltd (UEL), based in Lichfield, UK, and uses a two-bladed pusher propeller. For long endurance missions the air vehicle can be fitted with two 50L underwing auxiliary fuel tanks. The air vehicle has an endurance of typically 17 hours.

5.5.4 Payload

WK450 has a maximum payload capacity of 150 kg. The payload will include day/night sensors, a laser designator and a synthetic aperture radar/ground moving target indicator (SAR/GMTI). The CoMPASS electro-optic observation system, supplied by El-op, and the I-Master SAR/GMTI radar were chosen as the mission payloads for Watchkeeper. CoMPASS (Compact Multi-Purpose Advanced Stabilized System) sensors can include: 3rd generation, 3-5 micron focal plane array FLIR, 8-12 micron FLIR, colour TV camera with zoom, eyesafe laser rangefinder, diode-pumped laser designator, laser target illuminator, autotracker.

A wide-band satellite link can be installed on the air vehicle. The on board satellite link can be used to give extended range operation without deploying a separate radio relay aircraft.

5.5.5 Ground Control Station

The Watchkeeper UAV will be connected by satellite datalink to a network of containerised Ground Control Stations, where the imagery will be analysed and disseminated.

Table 3 Watchkeeper WK450 tactical UAV Specifications

UAV Dimensions	
Wing span	10.5 m
Length	6.10 m
Weights	
Take-off weight	450 kg
Payload	150 kg
Performance	
Endurance	20 to 30 hours
Altitude	5,500 m
Loiter speed	100 km/hr
Maximum speed	175 km/hr
Propulsion	
UEL AR 801 engine	38.8 kW

6. Other HAAS-related Projects, or those completed or inactive

6.1 HeliNet

One completed European HAP project is HeliNet (IST-1999-11214) [54], which ran between January 2000 - March 2003 funded by the European FP5 programme. The project examined aeronautical issues and three prototype applications: broadband telecommunications; environmental monitoring; and vehicle localisation. A scale size prototype stratospheric aircraft, 'Heliplat', was designed and built (but not flown) as illustrated in Figure 24.

The University of York (UK) undertook the majority of the work in the broadband application, with input from Politecnico di Torino (Italy - also overall coordinator), Josef Stefan Institute (Slovenia), the Budapest University of Technology and Economics (Hungary), and the Technical University of Catalonia (Spain). Barclay Associates provided input on regulatory matters. Other members of the consortium were: CASA (Spain); Enigma Technology (UK); Carlo Gavazzi Space (Italy); Fastcom (Switzerland); and Ecole Polytechnique Fédérale de Lausanne (Switzerland).

Several of these consortium members continued to work on the CAPANINA project (described above).

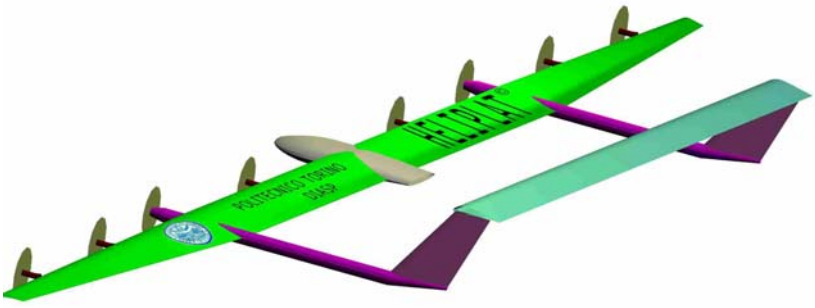


Figure 24 Artist's Impression of the Heliplat

6.2 Angel Technologies - HALO

Angel Technologies [55] developed a manned stratospheric plane, Proteus, in the late 1990s as shown in Figure 25. Test flights were understood to have taken place in 2000. They were planning to deliver continuous services to users using a fleet of these craft that would have a mission duration of 8 hours, where they would circle above the coverage area. They produced several good quality publications

describing their system, e.g. [56,57], but the project did not appear to follow through to commercial applications.

However, the Proteus craft is now owned and operated by Scaled Composites, a company with a range of manned aircraft. It is understood that it is being used by the US military; they also claim that it is suitable for "telecommunications, reconnaissance, atmospheric research, commercial imaging, and space launch" [58].

Figure 25 HALO Manned Stratospheric Aircraft [55]

6.3 Sky Station

This US-based project was responsible for much of the initial work on the radio regulations within ITU-R. It is understood to be no longer active.

6.4 General Atomics

General Atomics [59] is the maker of numerous UAVs such as the Predator. It has in the past proposed a Aerial Vehicle Communications System (AVCS), but there seems no evidence that this is currently active.

6.5 British National Space Centre

British National Space Centre (BNSC) funded a modest study contract in 2003 to BTexact, UOY, and SkyLARC Technologies Ltd to examine the implications of V-band for HAPs and satellite application. At the present time, it is not known whether they have a specific interest in HAP developments.

6.6 Indonesia Posts and Telecommunications

Indonesia Posts and Telecommunications have been reported as having plans to develop HAPs for Indonesia [60]. Little is known about the current status of their project.

6.7 International Telecommunications Union (ITU) Activity

The International Telecommunications Union Radiocommunications Sector (ITU-R) has wide ranging activities concerning spectrum regulation for HAPs. Although these scarcely count as 'major players' in HAPs, their activities are of some interest.

Their activities take place in working parties (e.g. WP9B, WP4-9S, and to a lesser extent WP8F). A list of recent ITU Recommendations relevant to HAPs is included in Table 4.

Number	Title	Status
F.1500 (05/00)	Preferred characteristics of systems in the fixed service using high altitude platforms operating in the bands 47.2-47.5 GHz and 47.9-48.2 GHz In force	In force
F.1569 (05/02)	Technical and operational characteristics for the fixed service using high altitude platform stations in the bands 27.5-28.35 GHz and 31-31.3 GHz	In force
F.1570-1 (02/03)	Impact of uplink transmission in the fixed service using high altitude platform stations in the Earth exploration-satellite service (passive) in the 31.3-31.8 GHz band	In force
F.1570 (05/02)	Impact of uplink transmission in the fixed service using high altitude platform stations on the Earth exploration-satellite service (passive) in the 31.3-31.8 GHz band	Super-seded
F.1607 (02/03)	Interference mitigation techniques for use by high altitude platform stations in the 27.5-28.35 GHz and 31.0-31.3 GHz bands	In force
F.1608 (02/03)	Frequency sharing between systems in the fixed service using high altitude platform stations and conventional systems in the fixed service in the bands 47.2-47.5 and 47.9-48.2 GHz	In force
F.1609 (02/03)	Interference evaluation from fixed service systems using high altitude platform stations to conventional fixed service systems in the bands 27.5-28.35 GHz and 31.0-31.3 GHz	In force
F.1612 (02/03)	Interference evaluation of the fixed service using high altitude platform stations to protect the radio astronomy service from uplink transmission in high altitude platform station systems in the 31.3-31.8 GHz band	In force
M.1456 (05/00)	Minimum performance characteristics and operational conditions for high altitude platform stations providing IMT-2000 in the bands 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz in Regions 1 and 3 and 1 885-1 980 MHz and 2 110-2 160 MHz in Region 2	In force
P.1409 (10/99)	Propagation data and prediction methods required for the design of systems using high altitude platform stations at about 47 GHz	In force
SF.1601 (02/03)	A methodology for interference evaluation from the downlink of the fixed service using high altitude platform stations to the uplink of the fixed-satellite service using the geostationary satellites within the band 27.5-28.35 GHz	Super-seded
SF.4/33-9/42 (Rev.1) (04/05)	Draft revision of Recommendation ITU-R SF.1601 - Methodologies for interference evaluation from the downlink of the fixed service using high altitude platform stations to the uplink of the fixed-satellite service using the geostationary satellites within the band 27.5-28.35 GHz	Pre-published

Table 4 List of ITU Recommendations on HAPS in April 2005 [61]

7. Discussion and Conclusions

This document has identified the main research and development programmes in HAAS and their applications across the world. There are a handful of substantive projects, and a number of more modest activities, concerned with both the aerial vehicles themselves and also the application areas,

The major high altitude projects would seem to be: the Japanese National Project; the NASA-funded programme for aerial platforms / UAVs; the related Aerovironment / Skytower programme; the Korean National Project; and the Lockheed Martin US military airship project. These are all large programmes, demanding large budgets, and necessarily extending over a number of years. While all have made steady progress in terms of the engineering research and development, even these projects do seem to be subject to chronic uncertainties regarding their funding.

These large projects are primarily concerned to develop a viable high altitude platform as a necessary basis for provision of services. The Japanese and Korean projects are notably concentrating upon the design of communications services from these HAAS. The other programmes would seem to be targeting a range of services, including remote sensing / earth observation and related applications; however it is not always so clear how far these applications have been investigated or developed.

There are also several smaller projects, e.g. Sanswire. Some of these would appear to be short-term start-up activities, offering promise of large returns from communications, but all too often fading away rapidly leaving little more than artists' impressions of a HAAS. Others are pursuing longer-term goals of viable HAAS, but in all cases these projects are largely uncoordinated, and suffer from serious funding difficulties.

Within Europe, there are several modest research activities, but not on a scale comparable to major programmes elsewhere. The European Commission has been supportive through some modest FP5 and FP6 projects (HeliNet and CAPANINA). These have been very successful, but have been essentially studies, and also concerned more with applications then with the HAAS themselves. It would also seem that there is no direct support for HAAS through the aerospace / aeronautical directives. HAAS, or their applications, are represented across Europe in some NoEs, a COST Action, and other networks; but some of these have already finished, and long-term support of this nature would appear to warrant a firmer and more coherent direction

Nevertheless, Europe does offer considerable potential, and there is a wealth of engineering background and expertise across the sector ranging from airship companies through defence companies to small specialist companies and several academic institutions. Such activity remains largely uncoordinated and undeveloped however. The challenge must be to harness the momentum across Europe of the strong interest and expertise in HAAS and their applications. It will be interesting to

see how Zeppelin and its related German Lighter than Air Institute (GLAI) fare in this regard.

UAVs represent a buoyant area generally, with much of the funding and direction from military requirements. The definition and boundaries of UAVs is widening, with some craft sustaining flight at high altitude, and it is suggested that some current UAV activity may represent a valuable evolutionary step towards high altitude long endurance systems. There is considerable expertise in UAVs, most notably in the US and Israel, with some significant European players also. However, this activity and expertise does again appear to be spread rather widely, and the challenge is to harness it coherently towards the goals of HAAS.

In terms of applications from HAAS, the civil emphasis has so far been largely on communications services. The broad benefits of such services are not in doubt, but implementation is awaiting availability of HAAS which are reliable and economic; there also remains a need for research bridging the gap between the platform and the application.

The other main application area is remote sensing / earth observation, together with related services such as monitoring and security. Despite evident considerable benefits of these applications from HAAS, these areas would appear to be somewhat neglected in the civil sphere.

References

[1] T. Shimizu, *Japanese SPF Airship Project Progress*, 5th Stratospheric Platforms Systems Workshop, Tokyo, Japan, February 2005, In Japanese/English.
Also, JAXA website, www.ista.jaxa.jp/npl/spf/0index.html

[2] R. Miura and M. Suzuki, *R&D Achievements and Future Perspective on Telecomunications and Broadcasting System Using Stratospheric Platform*, 5th Stratospheric Platforms Systems Workshop, Tokyo, Japan, February 2005, In Japanese/English

[3] K. Ohasi, *Promising Features of the Integrated SPF Tracking and Control System*, 5th Stratospheric Platforms Systems Workshop, Tokyo, Japan, February 2005, In Japanese/English

[4] M. Oodo et al., *Experiment of IMT-2000 using stratospheric-flying solar-powered airplane*, GLOBECOM 2003 - IEEE Global Telecommunications Conference, vol. 22, no. 1, Dec 2003, pp. 1152 - 1156

[5] M. Nagatsuka et al., *Testing of Digital Television Broadcasting from the Stratosphere*, IEEE Transactions on Broadcasting, vol. 50, no. 4, Dec. 2004

[6] Y. Arakaki et al., *Preliminary Flight Tests for Stratospheric Platform Systems - mm-Wave Multi-Beam Hone (MBH) Antenna Systems Using Helicopter*, AIAA-2003-2270 21st International Communications Satellite Systems Conference and Exhibit, Yokohama, Japan, Apr. 15-19, 2003

[7] M. Nagatsuka et al. *Experiment for Wide-Area Digital Broadcasting*, 5th Stratospheric Platforms Systems Workshop, Tokyo, Japan, February 2005, In Japanese/English

[8] H. Tsuji et al. *Fundamental Experiment of Real-Time Estimation of Mobile-Terminal Localization*, 5th Stratospheric Platforms Systems Workshop, Tokyo, Japan, February 2005, In Japanese/English

[9] Y. Arimoto et al. *Laser Tracking Trial between the Airship and Ground Station*, 5th Stratospheric Platforms Systems Workshop, Tokyo, Japan, February 2005, In Japanese/English

]10] Skystation www.skystation.com

[11] Article 5, Radio Regulation, ITU, Edition of 2004

[12] D.-S. Ahn, B.-J. Ku, T.C. Hong, J.M. Park, B.-S. Kang, and Y.-S. Kim, *Core Technology Development and Standardization for HAPS in Korea*, 5th Stratospheric platforms Systems Workshop, Tokyo, Japan, February 2005

[13] D.-M. Kim, Y.-G. Lee, S.-J. Lee, C.H. Yeom, *Research Activities for the Development of Stratospheric Airship Platform in Korea*, 5th Stratospheric platforms Systems Workshop, Tokyo, Japan, February 2005

[14] Photo Courtesy of Korean Aerospace Research Institute, Airship Dept, www.kari.re.kr

[15] J.-M. Park, B.-J. Ku, Y.S. Kim, D.-S. Ahn, *Technology Development for Wireless Communications System Using Stratospheric Platform in Korea*, PIMRC 2002, Lisbon, Portugal, pp. 162-170, September 2002

[16] Preliminary Draft New Recommendation ITU-R F.[HAPS-RRS], *Methodology to evaluate interference from fixed service system using high altitude platform stations (HAPS) to radio-relay system in the bands above 3 GHz*, Oct 2004

[17] J. Del Frate, *Developing Technologies for High Altitude Platforms and Long Endurance*, Stratospheric Platforms Systems Workshop, Tokyo, Japan, February 2005

[18] T.E. Noll, J.M. Brown, M.E. Perez-Davis, S.D. Ishmael, G.C. Tiffany, M. Gaier, *Investigation of the Helios Prototype Aircraft Mishap*, Volume I Mishap Report, NASA, January 2004, www.nasa.gov/pdf/64317main_helios.pdf

[19] NASA HALE ROA Programme Website, http://www.nasa.gov/centers/dryden/research/HALE_ROA/index.html

[20] AeroVironment Website, www.aerovironment.com

[21] SkyTower Website, www.skytowerglobal.com

[22] S. Konyavko, *HAA and Lighter than Air Development in the US*, International HAPS Workshop, Seoul, Korea, organized by Korean Institute of Industrial Engineers, and Electronics and Telecommunications Research Institute, November 2004

[23] Lockheed Martin High Altitude Airship, www.lockheedmartin.com/data/assets/7966.pdf

[24] Lockheed Martin High Altitude Airship Website, www.lockheedmartin.com/wms/findPage.do?dsp=fec&ci=14477&rsbci=0&fti=0&ti=0&sc=400

[25] ATG Website: not available (May 2006)

[26] J. Miller, *STRATSAT ATG Progress Update 2005*, 5th Stratospheric Platforms Systems Workshop, February 2005

[27] CAPANINA Website, www.capanina.org

[28] USEHAAS Website, www.usehaas.org

[29] COST297 Website, www.hapcos.org

[30] SATNEX Website, www.satnex,org (found temporarily unavailable, May 2006)

[31] UAVNET website, www.uavnet.org

[32] Stratospheric Platforms - a definition study for an ESA system, European Space Agency, April 2004, telecom.esa.int/telecom/www/object/index.cfm?fobjectid=8188

[33] ESA HALE Study Website, http://www.esa.int/esaCP/Pr_19_2000_p_EN.html

[34] Techsphere International Website, www.techspheresystems.com

[35] CyberAerospace Website, www.proxygen.com/37/

[36] 21st Century Airships, www.21stcenturyairships.com/

[37] RosAeroSystems Website, www.rosaerosystems.pbo.ru/english/products.html

[38] Sanswire Networks LLC Website, www.sanswire.com

[39] Kestral Aerospace Limited Website, www.kestrelaerospace.com/

[40] Höhenplattform, University of Stuttgart Website (in German), www.isd.uni-stuttgart.de/arbeitsgruppen/airship/halp/index.htm

[41] University of York, www.elec.york.ac.uk/comms

[42] E. Cianca and M. Ruggieri, *SHINES: A Research Program for the Efficient Integration of Satellites and HAPs in Future Mobile/Multimedia Systems*, WPMC 2003, Yokosuka, Japan, September 2003

[43] SHINES Project Website, www.irisgroup.it/projects.html

[44] QinetiQ Website, www.qinetiq.com

[45] VITO http://www.vito.be

[46] Pegasus project http://www.pegasus4europe.com

[47] Lindstrand Balloons Website, www.lindstrand.co.uk

[48] Space Data Corporation Website, www.spacedata.net

[49] Space Data Corporation Energy Brochure, www.spacedata.net/docs/Energy_Brochure_2004.pdf

[50] Bosh Aerospace REAP Aerostats, www.boschaero.com/aerostat.htm

[51] Platforms Wireless International Corporation Website, www.plfm.net

[52] Platforms Wireless awarded to Begin Development Of "ARC" System-based National Telecommunication Network For South Asia Nation, www.plfm.net/news/01_07-18-indonesia.html, March 9 2004

[53] http://www.thalesgroup.co.uk/thales_corporate/majorprogrammes/watchkeeper.cfm

[54] HeliNet Project Website, www.helinet.polito.it (maybe obsolete, May 2006)

[55] Angel Technologies Website, www.angeltechnologies.com

[56] G. M. Djuknic, J. Freidenfelds, and Y. Okunev, *Establishing Wireless Communications Services via High-Altitude Aeronautical Platforms: A Concept Whose Time Has Come?*, IEEE Commun. Mag., pp. 128-35, September 1997

[57] N. J. Collela, J. N. Martin and I. F Akyildiz, *The HALO Network*, IEEE Commun. Magazine, June 2000, pp. 142-8

[58] http://www.scaled.com/projects/proteus.html

[59] General Atomics Website, www.uav.com/home/index.html

[60] High Altitude Platforms Systems (HAPS): Wahana Terestrial Masa Depan, ASSI Newsletter, No. 5 Vol. I, May 2000, www.elektroindonesia.com/elektro/assi0500.html

[61] International Telecommunications Union Website, www.itu.int