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Survey of COTS-MOTS Lighter than Air Platforms and Communication Relays

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Project Manager: Mark MacDonald
Contract number: W7701-094442/001/QCL
Contract Scientific Authority: Franklin Wong, PhD 418-844-4000 x4200

Defence R&D Canada – Valcartier

Contract Report
DRDC Valcartier CR 2012-076
March 2013

Canada

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Abstract

In the Canada First Defence Strategy, the challenges related to Canada's sovereignty in the Arctic was recognized. It is expected that in the near future, sovereignty and security challenges will become more pressing as the impact of climate change leads to enhanced activity throughout the region thus making protection of territorial integrity in the Arctic a top priority for the government. The Government of Canada plans to enhance the Canadian Force’s (CF's) ability to conduct surveillance in the North through the use of evolving unmanned aerial vehicle technology as one of its options.

The Joint Uninhabited Aerial Vehicle Surveillance and Target Acquisition System (JUSTAS) program has been tasked with the technological and organizational development of unmanned assets that will allow an overland domestic and international C4ISR capability and the definition of a domestic maritime and arctic Communication, Command, Control, and Computers Intelligence Surveillance and Reconnaissance (C4ISR) capability in its first phase of study.

It has been recognized that for the operation of Medium Altitude Long Endurance Uninhabited Aerial Vehicles (MALE UAVs) in the arctic, a variety of methods will be needed to establish reliable communications and data links in the area of operations. Lighter than air platforms carrying a high bandwidth communication and data relays represent one of the possible methods to link Combined Air Operations Center’s (CAOC's) with forward operating forces and MALE assets that are spread over a dispersed area. This survey reviews both Lighter Than Air (LTA) platforms and potential data link payloads.

Résumé

Dans la Stratégie de défense Le Canada d'abord, les défis liés à la souveraineté du Canada dans l'Arctique a été reconnu. Il est prévu que dans un proche avenir, les défis de souveraineté et la sécurité deviendra plus pressante que l'impact du changement climatique conduit à une activité accrue dans toute la région ce qui rend la protection de l'intégrité territoriale dans l'Arctique une priorité absolue pour le gouvernement. Le gouvernement du Canada prévoit améliorer (FC) des Forces canadiennes la capacité d'effectuer une surveillance dans le Nord grâce à l'utilisation de l'évolution des technologies sans pilote véhicule aérien comme l'un de ses options.

Le Comité mixte de surveillance sans pilote véhicule aérien et système d'acquisition de cible (JUSTAS) programme a été chargé de l'évolution technologique et organisationnelle de l'actif sans pilote qui permettra à un terrestre capacité nationale et internationale C4ISR et la définition d'un maritime intérieur et de l'Arctique communication, de commandement, de contrôle , et de l'Intelligence Informatique surveillance et reconnaissance (C4ISR) la capacité dans sa première phase d'étude.

Il a été reconnu que, pour l'opération de moyenne altitude et longue endurance véhicules aériens téléguidés (drones MALE) dans l'Arctique, une variété de méthodes seront nécessaires pour établir des communications fiables et des liaisons de données dans la zone d'opérations. Plus léger que plates-formes aériennes transportant une communication haut débit et les relais de données représentent l'une des méthodes possibles pour relier Combiné Air Operations Center de (CAOC de) avec les forces d'opérations avancées et des actifs MALE qui sont réparties sur une zone de dispersion. Cette enquête examine à la fois plus léger que l'air (LTA) et les plates-formes potentielles de charges utiles de liaison de données.

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1. Introduction

In the Canada First Defence Strategy, the challenges related to Canada's sovereignty in the Arctic was recognized. It is expected that in the near future, sovereignty and security challenges will become more pressing as the impact of climate change leads to enhanced activity throughout the region thus making protection of territorial integrity in the Arctic a top priority for the government. The Government of Canada plans to enhance the Canadian Force's (CF's) ability to conduct surveillance in the North through the use of evolving unmanned aerial vehicle technology as one of its options.

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It has been recognized that for the operation of Medium Altitude Long Endurance Uninhabited Aerial Vehicles (MALE UAVs) in the arctic, a variety of methods will be needed to establish reliable communications and data links in the area of operations. Lighter than air platforms carrying a high bandwidth communication and data relays represent one of the possible methods to link Combined Air Operations Center's (CAOC's) with forward operating forces and MALE assets that are spread over a dispersed area. This survey reviews both Lighter Than Air (LTA) platforms and potential data link payloads.

2. Environmental Conditions

The climate of the Arctic is characterized broadly by long, cold winters and short, cool summers. There is a large amount of variability in climate across the Arctic, but all regions experience extremes of solar radiation in both summer and winter. Some parts of the Arctic are covered by ice (sea ice, glacial ice, or snow) year-round, and nearly all parts of the Arctic experience long periods with some form of ice on the surface. Average January temperatures range from about −40 to 0 °C (−40 to +32 °F), and winter temperatures can drop below −50 °C (−58 °F) over large parts of the Arctic. Average July temperatures range from about −10 to +10 °C (14 to 50 °F), with some land areas occasionally exceeding 30 °C (86 °F) in summer.

The Arctic consists of ocean that is nearly surrounded by land. As such, the climate of much of the Arctic is moderated by the ocean water, which can never have a temperature below −2 °C (28 °F). In winter, this relatively warm water keeps the North Pole from being the coldest place in the Northern Hemisphere, and it is also part of the reason that Antarctica is so much colder than the Arctic. In summer, the presence of the near-by water keeps coastal areas from warming as much as they might otherwise, just as it does in temperate regions with maritime climates.

2.1 Arctic Basin

The Arctic Basin is typically covered by sea ice year round, which strongly influences its summer temperatures. It also experiences the longest period without sunlight of any part of the Arctic, and the longest period of continuous sunlight, though the frequent cloudiness in summer reduces the importance of this solar radiation.

Despite its location centered on the North Pole, and the long period of darkness this brings, this is not the coldest part of the Arctic. In winter, the heat transferred from the −2°C (28 F) water through cracks in the ice and areas of open water helps to moderate the climate some, keeping average winter temperatures around −30 to −35°C (−22 to −31 F). Minimum temperatures in this region in winter are around −50 °C (−58 °F).

In summer, the sea ice keeps the surface from warming above freezing. Sea ice is mostly fresh water since the salt is rejected by the ice as it forms, so the melting ice has a temperature of 0 °C (32 °F), and any extra energy from the sun goes to melting more ice, not to warming the surface. Air temperatures, at the standard measuring height of about 2 meters above the surface, can rise a few degrees above freezing between late May and September, though they tend to be within a degree of freezing, with very little variability during the height of the melt season.

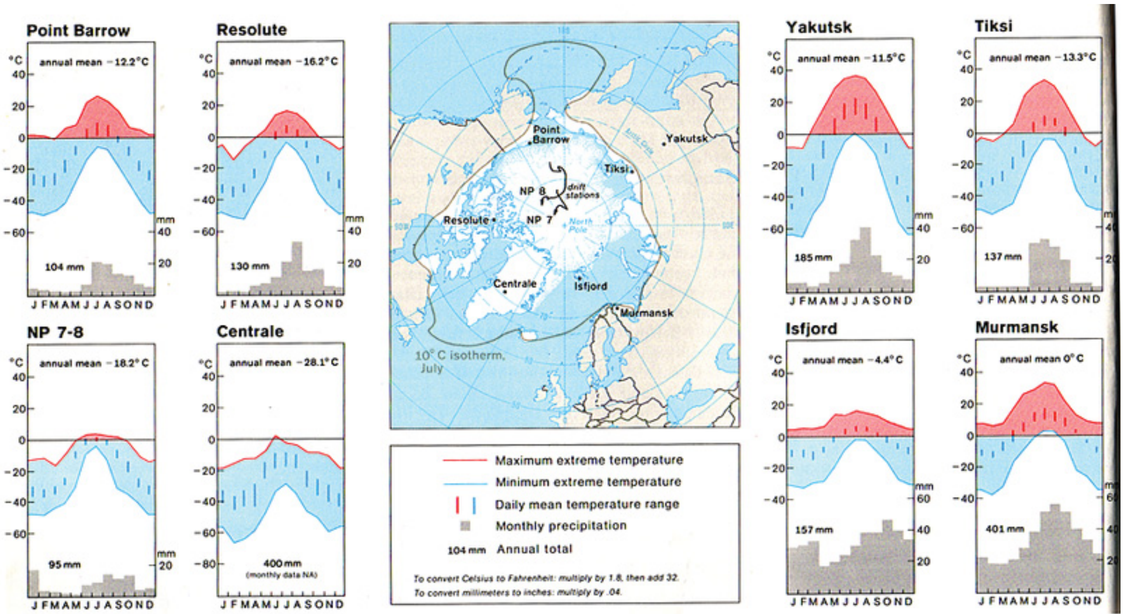


Figure 1. Arctic Climate[1]

In the figure above showing station climatologies, the lower-left plot, for NP 7–8, is representative of conditions over the Arctic Basin. This plot shows data from the Soviet North Pole drifting stations, numbers 7 and 8. It shows the average temperature in the coldest months is in the −30s, and the temperature rises rapidly from April to May; July is the warmest month, and the narrowing of the maximum and minimum temperature lines shows the temperature does not vary far from freezing in the middle of summer; from August through December the temperature drops steadily. The small daily temperature range (the length of the vertical bars) results from the fact that the sun's elevation above the horizon does not change much or at all in this region during one day.

Much of the winter variability in this region is due to clouds. Since there is no sunlight, the thermal radiation emitted by the atmosphere is one of this region's main sources of energy in winter. A cloudy sky can emit much more energy toward the surface than a clear sky, so when it is cloudy in winter, this region tends to be warm, and when it is clear, this region cools quickly (Serreze and Barry, 2005).

2.2 Canadian Archipelago

In winter, the Canadian Archipelago experiences temperatures similar to those in the Arctic Basin, but in the summer months of June to August, the presence of so much land in this region allows it to warm more than the ice-covered Arctic Basin. In the station-climatology figure above, the plot for Resolute is typical of this region. The presence of the islands, most of which lose their snow cover in summer, allows the summer temperatures to rise well above freezing. The average high temperature in summer approaches 10 °C (50 °F), and the average low temperature in July is above freezing, though temperatures below freezing are observed every month of the year.

[1] http://upload.wikimedia.org/wikipedia/commons/a/a6/ArcticStationClimatologies.png

The straits between these islands often remain covered by sea ice throughout the summer. This ice acts to keep the surface temperature at freezing, just as it does over the Arctic Basin, so a location on a strait would likely have a summer climate more like the Arctic Basin, but with higher maximum temperatures because of winds off of the nearby warm islands.

2.3 Precipitation

Precipitation in most of the Arctic falls as both rain and snow. Over most areas snow is the dominant, or only, form of precipitation in winter, while both rain and snow fall in summer (Serreze and Barry 2005). The main exception to this general description is the high part of the Greenland Ice Sheet, which receives all of its precipitation as snow, in all seasons.

Accurate climatologies of precipitation amount are more difficult to compile for the Arctic than climatologies of other variables such as temperature and pressure. All variables are measured at relatively few stations in the Arctic, but precipitation observations are made more uncertain due to the difficulty in catching in a gauge all of the snow that falls. Typically some falling snow is kept from entering precipitation gauges by winds, causing an underreporting of precipitation amounts in regions that receive a large fraction of their precipitation as snowfall. Corrections are made to data to account for this uncaught precipitation, but they are not perfect and introduce some error into the climatologies (Serreze and Barry 2005).

The observations that are available show that precipitation amounts vary by about a factor of 10 across the Arctic, with some parts of the Arctic Basin and Canadian Archipelago receiving less than 150 mm (6 in) of precipitation annually, and parts of southeast Greenland receiving over 1200 mm (47 in) annually. Most regions receive less than 500 mm (20 in) annually (Serreze and Hurst 2000, USSR 1985). For comparison, annual precipitation averaged over the whole planet is about 1000 mm (39 in.). Unless otherwise noted, all precipitation amounts given in this article are liquid-equivalent amounts, meaning that frozen precipitation is melted before it is measured.

2.4 Wind

Wind speeds over the Arctic Basin and the western Canadian Archipelago average between 4 and 6 metres per second (14 and 22 kilometres per hour, 9 and 13 miles per hour) in all seasons. Stronger winds do occur in storms, often causing whiteout conditions, but they rarely exceed 25 m/s (90 km/h, 55 mph) in these areas (Przybylak 2003).

During all seasons, the strongest average winds are found in the North-Atlantic seas, Baffin Bay, and Bering and Chukchi Seas, where cyclone activity is most common. On the Atlantic side, the winds are strongest in winter, averaging 7 to 12 m/s (25 to 43 km/h, 16 to 27 mph), and weakest in summer, averaging 5 to 7 m/s (18 to 25 km/h, 11 to 16 mph). On the Pacific side they average 6 to 9 m/s (22 to 32 km/h, 13 to 20 mph) year round. Maximum wind speeds in the Atlantic region can approach 50 m/s (180 km/h, 110 mph) in winter (Przybylak 2003).

2.5 Terrain

Figure 2 High Arctic Geography[2]

The terrain in Canada's Arctic region is varied with deep fiords and tall flat topped mountains as seen in figure 3.

[2] © 1988-1996 Microsoft and/or its suppliers. All rights reserved.

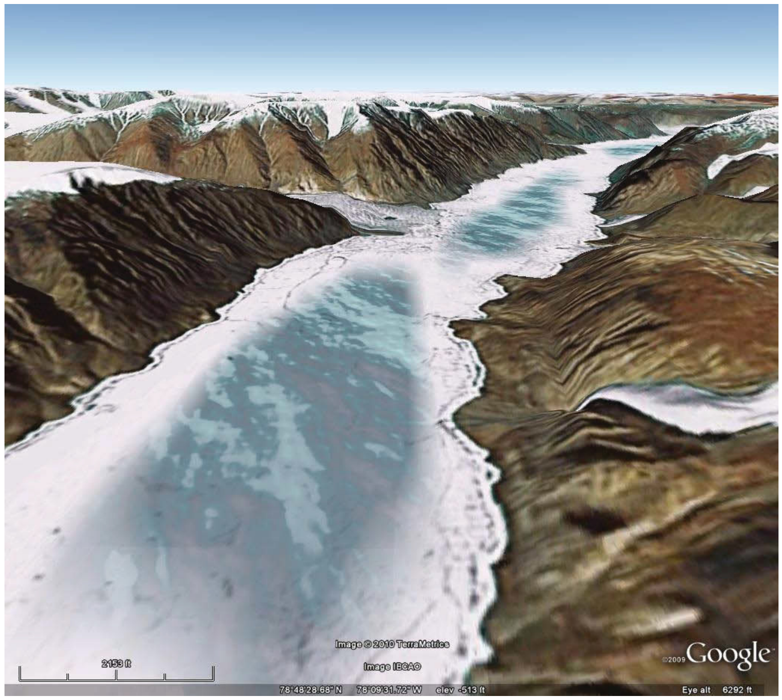
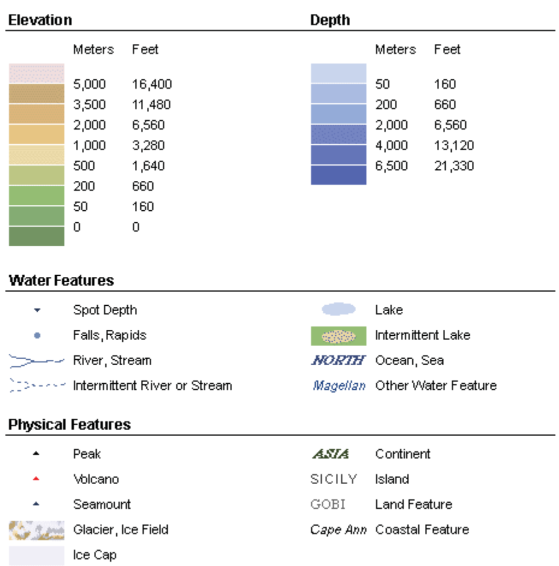


Figure 3. Fiord and Mountianour Terrain Elsmere Island

Figure 4. Eastern Arctic Geography[3]

[3] © 1988-1996 Microsoft and/or its suppliers. All rights reserved.

Figure 5. Western Arctic Geography[4]



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[4]

Figure 6. Resolute NWT

Most Northern community's such as Resolute have very little infrastructure and are dependant upon air and sea borne re-supply for most everything. Deployment of radio relay equipment and the means to keep them airborne will be challenging.

The one of the keys to establishing a persistent airborne surveillance platform is keeping the platform in the air. The following airships all use either helium or hydrogen gas to reduce the weight of the craft. This gives them the advantage of having to expend only a minimum amount of energy on generating lift and can devote much of their energy to station keeping.

3. Lighter Than Air (LTA) Airships

3.1 Stratospheric Airships

Several airships have been designed to occupy the airspace above the jet stream and above commercial jet traffic. At 60,000 only the U2 and Global Hawk platforms, compete for airspace. There are technical challenges for lighter that air airships to meet. For one thing, helium gas expands 16 to 17 times its volume as the airship ascends from the surface to 60,000 or 70,000 feet. For these long duration missions at high altitudes, unmanned airships are planned.

3.1.1 Lockheed Martin High Altitude Airship (HAA)

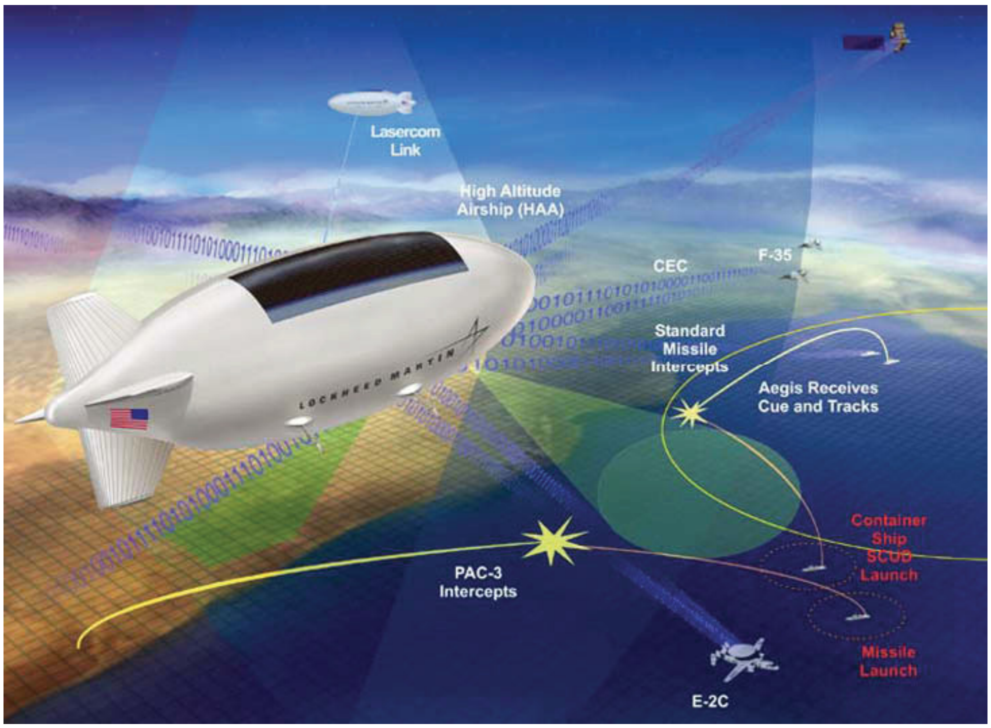

Figure 7: HAA Operational View

Lockheed Martin is developing the High Altitude Airship (HAA^{TM}), an unmanned lighter-than-air vehicle, will operate above the jet stream in a quasi-geostationary position to deliver persistent station keeping as a surveillance platform, telecommunications relay, or a weather observer. The idea is to deliver satellite capabilities from a stratospheric altitude at a fraction of the cost of satellite systems. Once in position, an airship would survey **a 600-mile diameter area** and millions of cubic miles of airspace.

The timing is right now for such an approach as many of the vital technologies have matured to a point that they are ready for system integration. High-strength fabrics to minimize hull weight, thin-film solar arrays for the regenerative power supply, and lightweight propulsion units are available. The combination of photovoltaic and advanced energy storage systems delivers the necessary power to perform the airship functions.

Propulsion units will maintain the airship's geostationary position above the jet stream, propel it aloft and guide its takeoff and landing during ascent and descent. Lighter-than-air vehicles, operating at altitudes above controlled airspace under the control of a manned ground station, give users the flexibility to change payload equipment when the airship returns to its operational base to perform different tasks unlike satellite systems.

Lockheed Martin's has considerable experience certificating commercial airships with the FAA. Lockheed Martin, Akron, received its first production contract for a lighter-than-air vehicle in 1928. Since that time, Lockheed Martin has built more than 300 airships and several thousand aerostats (unmanned ground-tethered balloons). The Lockheed Martin Airdock, which is 1,175 feet long, 325 feet wide and 211 feet high, may serve as a final assembly facility.

Figure 8: High Altitude Airship (HAA)

Under a contract awarded by the Missile Defense Agency, Lockheed Martin is currently in the contract's third phase, which will see a prototype build and flight demonstration. The MDA's performance goals for the prototype HAATM include sustained operations for approximately one month, above 60,000 feet, while providing power to a payload for military use. It will operate unmanned above the jet stream in a quasi-geostationary position to survey an approximately 600-mile diameter area. In this phase of the program, Lockheed Martin will build and fly a HAATM prototype vehicle in order to demonstrate launch and recovery, station-keeping and flight control capabilities.

The airship's utility as a mobile, re-taskable, high-altitude, geostationary, long-endurance platform will span from short and long range missile warning, surveillance and target acquisition to communications and weather/environmental monitoring. Additionally, the HAA™ prototype will demonstrate station-keeping and autonomous flight control capabilities.[5]

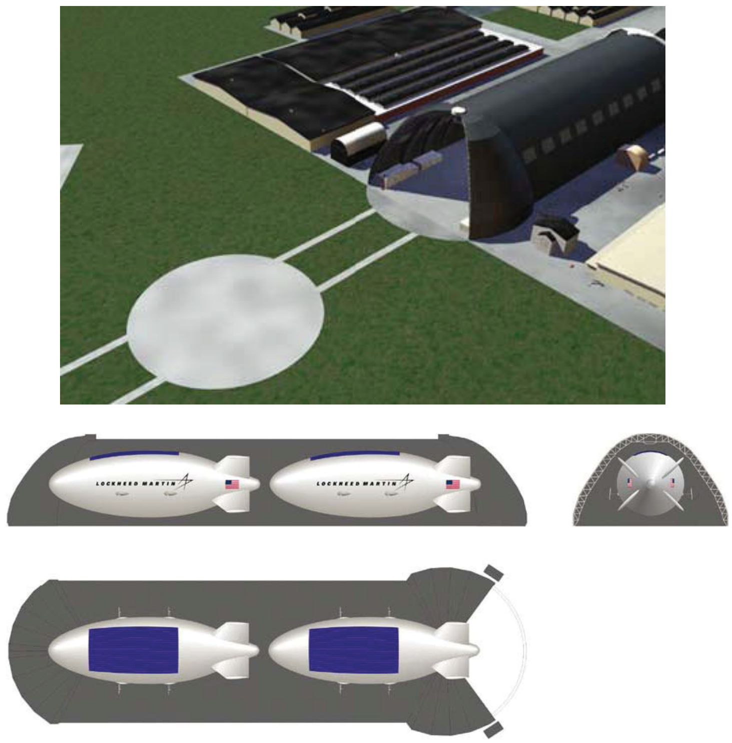

Figure 9: HAA Hanger

Lockheed Martin hopes to keep the unit cost of the operational airship at roughly $50-60 million before its advanced radars, sensors et. al. are installed. If so, its long endurance would give it operating costs in the tens of dollars per payload-pound per hour, as opposed to aircraft or even satellites whose comparable costs are hundreds or thousands of dollars.[6]

Near Space Manoeuvring Vehicle (NSMV)/Ascender/V-Airship[7]

User Service: Air Force
Manufacturer: JP Aerospace
Inventory: 1 Delivered/1 Planned

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[5] "High Altitude Airship," Lockheed Martin, 20 Mar. 2007 <http://www.lockheedmartin.com/wms/findPage.do?dsp=fec&ci=14477&rsbci=7&fti=0&ti=0&sc=400>.
[6] "Lockheed Wins $149.2M Contract for High Altitude Airship." Defense Industry Daily. 16 Jan. 2006. 7 Mar. 2007 <http://www.defenseindustrydaily.com/2006/01/lockheed-wins-1492m-contract-for-high-altitude-airship-updated/index.php>.
[7] US DOD UAV Roadmap 2005-2030 Aug 2005

Figure 10. MSNV

Background:
The Air Force plans to test the V-shaped Ascender, manufactured by JP Aerospace (Sacramento, CA), under contract to Scitor Corporation (Sunnyvale, CA) in 2005. A smaller, 93-ft model has been successfully tested inside its hangar. The Air Force Space Battlelab plans to fly it to 120,000 feet with a 100-lb payload and loiter for 5 days at a distance of 200 nm. Although Ascender uses lightweight carbon-fiber propellers to generate thrust, it also has a unique system that transfers helium between its two chambers to provide additional maneuverability by shifting its center of gravity and adjusting trim. The NMSV is intended to carry ISR, communications relay, and other mission loads for extended periods of time. Canceled in November 2004

Characteristics:
Length 175 ft Tail Span 126.5 ft
Volume 290,000 ft_3 Payload Capacity 100 lb

Performance:
Endurance 5 days Altitude 120,000 ft
Sensor IRS; Communication Relay

3.1.2 21st Century Airships

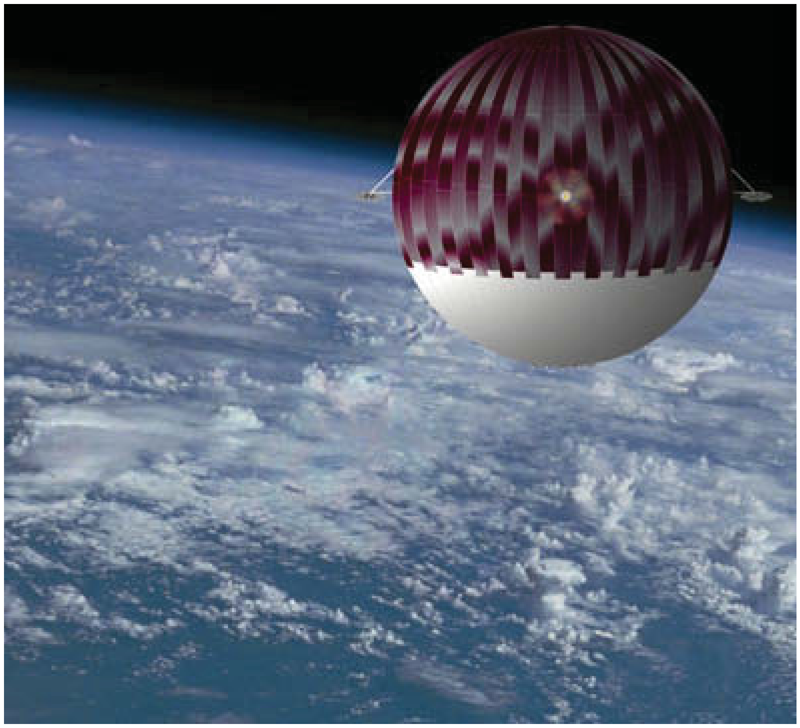


Figure 11: 21st Century Airship High-Altitude Spherical Airship..

A Canadian solution is proposed by Newmarket, Ontario's 21st Century Airships. Their high-altitude spherical airship will provide a stable platform at 20 to 25 km (60,000 to 70,000 ft.) Flying at 20 to 25 km (60,000 to 70,000 ft) above the earth, the high-altitude platforms will stay aloft for up to a year providing a platform for telecommunications and security applications. They offer that their first models will fly for up to one month at a time, but as technology catches up, future models will be capable of multiyear flights, coming down only for maintenance and upgrades to onboard electronic payload. The company states that high-altitude airships could provide wireless service over a very large area up to 118,200 sq km (45,600 sq mi) and that airships are less expensive to deploy than ground-based towers for radio and cell phone use.

21st Century Airships' high-altitude communications platforms will be unmanned and computer controlled, although a pilot on the ground will be able to override the onboard computer and fly the airship or reprogram its course.

21st Century Airships was founded by Hokan Colting in the mid 1990's. After relocating to Canada in the 1980's he began the development of a spherical airship. Forward motion and control are achieved by deflecting the twin engines' thrust with deflector vanes. They have two manned prototypes are currently flying. The SPAS-4 demonstrator (C-FRLM) has a volume of 41,500 cu.ft. (1,180 cu.m.). It is a 43' (13.1 m.) diameter sphere and seats the pilot and one passenger. The SPAS-4 airship is powered by two 50 hp. engines. The newest 21st Century airship is a pre-production model used for type certification. It is of the SPAS-70 type and registered as C-FYOK. It has a volume of 91,000 cu.ft. (2,595 cu.m.). This ship is a 56' (17.05 m.) diameter sphere which seats the pilot and 3 passengers. This airship is powered by four 100 hp. engines. The first test flight with SPAS-70 was made on August 8, 1997.[8]

21st Century Airships sees the following uses for its airships:

- high altitude platform for telecommunications (cellular phone, microwave, broadband) and national security applications
- sightseeing rides
- aerial advertising
- heavy lifting
- flying "yachts"

The company has manufactured ten airships so far, ranging from rudimentary prototypes to sophisticated, record breaking craft. The company claims that the advantages of their patented airship design include:

- most volume efficient shape
- least surface area versus volume, therefore the lowest leakage rate for the lifting gas
- easier to spread the weight of the payload without affecting balance (pitch)
- manoeuvrable at any speed, able to turn quickly without the need for airflow over fins/rudders/elevators like traditional cigar-shaped airships
- uncomplicated and more stable to launch
- able to achieve speeds exceeding 100 knots at 20 km (12.5 mi) altitude where the air density is approximately six per cent that at sea level
- eventually able to stay on station for a year or more providing services ranging from telecommunications to environmental monitoring

Airships are very efficient compared to heavier-than-air aircraft. 21st Century Airships Inc. models are among the most efficient because of their unique design. Because the majority of the airship's lift comes from the lifting gas (the helium), the engines are only required to provide propulsion, and power to onboard systems. They are not required to provide the majority of lift, unlike airplanes and helicopters. This makes airships environmentally friendly, too.

The company claims that the sphere design is good for high altitudes for the following reasons. As the airship ascends, helium expands. By 3,000 feet, it has expanded 10 per cent over sea level. By 20,000 feet, the volume you had at sea level has doubled. When you're coming up to 60,000 to 70,000 feet, you have 16 to 17 times the volume you had. Going the other way around, it means you can only inflate an airship to 6 per cent at ground level for it to fully expand at 60,000 to 70,000 feet. The sphere is the most volume-efficient shape: the helium will naturally occupy the space in the top centre and will act as an upward vertical force along the central vertical axis. That will stabilize the airship in all flight conditions. In a cigar shape, the helium may slosh from side

[8] Escher

to side, creating severe instability. Traditional low-altitude airships don't have this problem because they don't have to allow for 1,700 per cent gas expansion.

21st Century Airships addresses the issue of severe weather performance through powerful engines, modern navigation, radio, and storm detection equipment to help steer clear of severe weather. Snow and ice build up are less an issue with airships than with airplanes and helicopters. If the weather is really bad, takeoff or landing can be delayed.9

21st Century Airships is currently under contract with the Manitoba government to demonstrate the potential of airships in delivering cargo to remote communities in the summer/fall of 2007.

3.2 Classical Airships

The following are examples of classical airship designs – many of which are already carrying surveillance payloads.

3.2.1 American Blimp Corporation SPECTOR™

Figure 12: The American Blimp Corporation SPECTOR™

Airships are an excellent platform for many government surveillance missions:

- Maritime Patrol
- Border Patrol
- VIP Security
- Key Installation Security
- Counter Narcotics
- Anti-Smuggling

[9] "21st Century Airships - the Future of Flight," 21st Century Airships, 11 Mar. 2007 <http://www.21stcenturyairships.com/AirshipFAQ>.

- COMINT/SIGINT

While each of the above missions requires a somewhat different suite of mission equipment, all the missions benefit from the airship's unique capability to remain on station, or cruise on patrol, for extended periods before having to land to refuel.

The American Blimp Corporation SPECTORTM Series of airships are designed to carry payloads for each of the above missions (or multi-mission suites), and cruise at 40 knots, or 74 kph (46 mph), for over 24 hours with reserve fuel remaining. SPECTORTM airships can fly at altitudes up to 1500 m (4921 ft), with more than 1 metric tonne (2200 lb) available for mission crew and payload. Performance is dependent on the mission payload requirements.

For example, an airship equipped for providing surveillance of a border might have a mission system comprised of the following:

Qty	Mission Suite Components
1	FLIR system with boresighted color TV camera
1	SAR
1	Workstation integrating data from the sensor suite
1	Searchlight and loudhailer system
1	Data link to provide surface forces with real time sensor data from the airship

Radio relay could be added to this mission suite.

3.2.2 CargoLifter CL160

Boeing and CargoLifter AG are also exploring stratospheric airship concepts. Their contract signed in 2002, provides for a detailed study of lighter-than-air stratospheric platforms.

Figure 13: CargoLifter CL160

CargoLifter AG, based south of Berlin in Germany, is developing lighter-than-air systems for logistics and other applications. The CargoLifter uses helium gas for lift. One cubic meter of helium can carry about one kilogram. The weight of the cargo is compensated for by the lift of the gas. Therefore, energy is only spent on the airship's forward propulsion. CargoLifter AG's CL160 airship is designed to carry outsized and heavy goods over long distances. The CL160 Airship is 260 meters in length and is designed to carry oversized cargo weighing up to 160 metric tons, at a maximum height of 2,000 meters, non-stop over a range of several thousand kilometres. Each airship is powered by eight CT7-8L turboshaft engines. The expected cost of building one CL160 is about USD 60 million, which is roughly half the cost of a Boeing 747.

The CL 160 is being constructed as a semi-rigid keel airship with a working heavy-load crane integrated inside the keel. Helium is used as a non-flammable lifting gas. Due to its unique crane construction, the CargoLifter can load and unload without landing. While the airship hovers approx. 100 meters in midair, the load will be lifted and lowered via anchor winches and four anchoring points. In order for the total weight and flight characteristics of the airship to remain constant, the freight will be exchanged with ballast water.[10]

[10] John Pike, "CargoLifter CL160," GlobalSecurity.Org, 27 Apr. 2005, Global Security, 21 Mar. 2007 <http://www.globalsecurity.org/military/systems/aircraft/cargolifter.htm>.

Dimensions	**Specifications**
Length	260m
Diameter	65m
Total height	82m
Envelope volume	550,000m³
Loading platform	50 x 8 x 8m
Weights	
Basic weight	260t
Payload	Up to 160t
Engines	
Type	8 x GE CT7-8L turboshaft
Performance	
Cruising speed	90km/h
Range	Up to 10,000km
Pressure height	Up to 2,000m
Buoyant gas	Non-flammable helium

Table 1: CargoLifter Specifications

3.2.3 WDL Luftschiffgesellschaft Mbh[11] WDL 1B

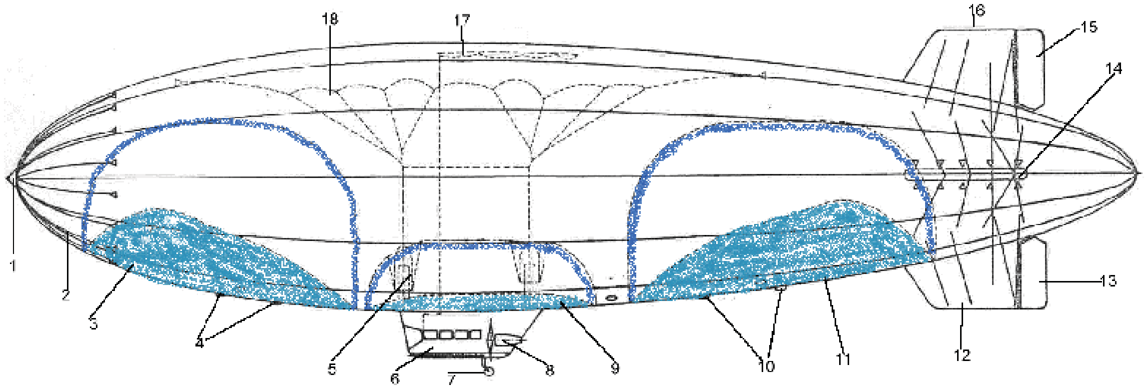
Figure 14: WDL 1B

Another airship in production since 1988 is the WDL 1B. With an envelope volume of 7,200 m³ and a length of 60m it is today's biggest non-rigid airship-type certified for advertising and other commercial purposes.

Length	60 m	197 Feet
Width	16,4 m	54 Feet
Height	19,3 m	63 Feet
Total Volume	7.200 m³	255.000 Feet³
Lifting Gas	Helium	
Seat Capacity	8 (incl. Pilot)	
Pilot	1	
Engines	2 Continental	
Engine Power	210 HP each	
Operation Altitude	300-1800 m	1000-6000 Feet
Air Speed	50-105 km/h	30-58 knots/hr

Table 2: WDL 1B Characteristics

[11] "Luftschiff," WDL Luftschiff, 16 Jan. 2007 <http://www.wdl-luftschiff.com/>.



1 Nose Cone	5 Fuel Tanks	9 Mid. Ballonet	13 Lower Rudder	17 Rip Panel
2 Battens	6 Gondola	10 Rear Valves	14 Horiz. Fins + Elevator	18 Catenary
3 Fwd. Ballonet	7 Landing Gear	11 Rear Ballonet	15 Upper Rudder	
4 Fwd. Valves	8 Engines	12 Lower Fin	16 Upper Fin	

Figure 15: Airship Parts

Figure 16: Wescam Turret on WDL Airship

WDL Airships have seating for 1 pilot and 7 passengers. An important consideration for smaller airships like the WDL 1B is that al though the airship look very large, the usable payload actual available to carry cargo and/or passengers is not that great. It is very similar to the capability of medium-size military helicopters. The typically available gross lift of a WDL 1B sized airships is approximately 2,800 lbs. at sea level.

WDL 1B cruising speed is 32 kts with a range of 200-250 km per day. The typical crew consists of two airship captains, one crew chief, two mechanics and 15 ground crew members who ground-handle the airship during landing and take-off. A total of 14 vehicles (vans and cars with caravans, mast truck and fuel truck) are required to support all ground operations and host the crew at the airfields. Normal hourly charges are about 2.580 USD (2,300 € in 2006). WDL offers chartering for airship tours with a requirement of between 120 and 150 flying hours per month, with a minimum period of three months.

3.2.4 Zeppelin NT[12]

The Zeppelin NT LZ N07 airship has established itself as an efficient and successful scientific and research platform. It has the following characteristics:

- long flight duration (up to 20 hours depending upon payload)
- precise on-the-spot hovering
- flight at very low airspeeds
- flight at low altitudes, possible due to the very low noise levels [69.4 dB(A) on over-flight]
- very low vibrations levels in the cabin (max. 0.02g)
- low noise levels in the cabin [64.5 dB(A)]
- high safety standards due to the rigid internal structure
- low operating costs
- max. payload 1.95 t.

[12] "Zeppelin Lutschifftechnik GmbH/Das Lutschiff," Zeppelin-NT, 22 Mar. 2007 <http://www.zeppelin-nt.com/pages/E/luftsch_u_zepp.htm>.

Figure 17: Zeppelin NT

Figure 18: Zeppelin NT cockpit

Zeppelin states that their NT airship can be used for missions which cannot be easily be undertaken by either an aeroplane or a helicopter In order to perform special missions, extensive equipment including the following mechanical installations is already available in the basic Zeppelin NT airship:

Figure 19: Wescam MX-15 on Zeppelin NT

- special attachments for gyro-stabilised cameras (already certified for Wescam MX-15 and Gyron HD 935, certification of other models in preparation)
- a nose boom and appropriate attachments are available.
- a top platform is available to which sensors and measuring equipment with a total system weight of 450 kg can be attached.
- several attachment points on the envelope
- The electrical installations also meet the requirements of a flying high tech laboratory and include the following:
- interface to the airship avionics (navigation, radio communication, flight data, position information)
- external 5kVA power supply
- additional 8kVA power supply

Figure 20: Zeppelin NT cabin equipment rack

3.2.5 BOSCH Aerospace Small Airship Surveillance System (SSAS)[13]

The SASS LITE (Small Airship Surveillance System, Low Intensity Target Exploitation) is an airship developed by BOSCH Aerospace. The SASS LITE has been used for border surveillance, waterway surveillance, search and rescue, instrumentation for missile data collection, and radio relay operations. It is equipped with a triple redundancy radio control system. Its primary control link is in the "L" band microwave frequencies. An auto track dish antenna is used to provide direct control to 100 kilometres. Video downlink is also accomplished in this frequency range. The "L" band data links are backed-up with a function matched "P" band data link system which is equipped with Yaggi directional antennas. These systems are interfaced to a digital autopilot and GPS navigator which facilitates autonomous navigation beyond radio line of sight. An independent, battery powered, multi-function Flight Termination System (FTS) is carried on the nose ring of the airship. This FTS system allows for engine shutdown, ballast, and helium vent control, and includes a hot wire burn system. The shutdown and vent control features allow for

[13] "Boschaero Military Airships." Military Use Airships. Bosch Aerospace, Inc. 5 Dec. 2006 <http://www.boschaero.com/ship_mil.htm>.

"FREE BALLOON" operations to a desirable landing site, while the burn wire can be activated to destroy the ship in flight if mandated by military necessity. Electronics are jam resistant and the primary system is military hardened.

An advanced digital switching and telemetry system allows the ground operators to control all airship functions, and the payload. Three 9600 baud digital links are embedded in the data link system to facilitate control of the many tens of functions needed in a sophisticated airship. Automated control devices such as pressure control, vents, and auto-navigation can be instantly overridden by the pilot through the digital link structure.

SASS LITE can be carry a variety of sensors, radio relays, scientific instruments, or Electronic Warfare devices. Its payload attaching system facilitates fast change out of payloads, and installation of a wide range of payload shapes, volumes, and weights. The current airship carries loads of approximately 400 lb (190 Kg) and it is capable of greater loads with reduced fuel loads. It has carried multiple IR and visible cameras on independent gimbals on a single mission, as well as a combination multi-spectral payload that included radar, IR, and Visible light sensors interfaced via a software bridge. Power for payloads is provided by two onboard alternators delivering a total of 3250 watts at 24 VDC.

A variety of SASS LITE versions have been built. The ships manufactured to date include the following envelope sizes:

Ship	Volume	Dimensions	Engine
Ship Number 001 & 002:	12,000 ft3	60X20 feet	Single 42 hp
Ship Number 003:	17,000 ft3	72X21 feet	Single 42 hp
Ship Number 004:	22,000 ft3	82X22 feet	Single 42 hp
Ship Number 005:	30,000 ft3	92X25 feet	Dual Engine
Ship Number 006:	34,500 ft3	100X25 feet	Dual Engine

Table 3: SASS LITE versions

The SASS LITE airships operate in speed ranges up to a maximum of 45 mph. Typical mission speeds are on the order of 25 - 35 miles per hour. Endurance of 12 to 24 hours can be obtained, or greater endurance can be achieved by custom designs. The dual engine versions have vectored thrust to enhance launch and recovery with small crews. Maximum crew size is 5 individuals. Ceilings vary from 5000 feet AGL to 6000 AGL on the various designs. Typical mission altitudes are on the order of 2500 to 3500 feet. Higher altitudes can be achieved by installation of larger pressure control ballonets.

BOSCH Aerospace has a new airship design, known as the Advanced Unmanned Reconnaissance Airship (AURA), which will be capable of carrying 1.5 tons of radar and optical payload to 10,000 feet altitudes, for periods of up to 36 hours. AURA will be 160 feet in length, and will have a volume of over 200,000 ft3. Its maximum forward speed will be 55 mph with cruise speed of 40 mph. The digital switching and RF control links discussed above will be installed on AURA, as will be the thrusted vector system and twin engine configuration currently flying on SASS LITE. A direct satellite communications link will be installed to allow constant data link beyond radio line of sight. AURA is expected to be capable of trans-oceanic flight when equipped with auxiliary fuel tanks.

3.2.6 Guardian Airships Polar Series

Figure 21: Guardian Airships Polar 400

Guardian Airships is a division of Aviation Worldwide Services which is a:

- Global provider of logistics and aviation services with $300 million in annual revenue
- Part 125 and 135 carrier for the US DoD
- Operating in over two dozen countries with over 70 aircraft
- Completion center for Sikorsky's Blackhawk
- Part 145 Modification and Repair Station

- The Polar 400 is the smallest of Polar Family of airships and reflects Polar-Family architecture;
- Primary power plant located in gondola for ease of maintenance
- The four hull-mounted propellers driven hydraulically for simplicity
- Two side-mounted vectorable propellers provide vertical thrust for VTOL and horizontal thrust for cruise
- Two stern-mounted propellers provide low-speed yaw and fore/aft control
- Non-rigid design for simplicity, ease of repair, and low cost
- Represents a "scalable" design

- General Specifications
- Take-off power 270 hp

- Maximum continuous power 230 hp
- Speed –max 45 kts
- Speed –cruise 30 kts
- Operating altitude 5,000 ft
- Endurance –max 12 hrs
- Volume 4,000 m3
- Length 49.7 m
- Diameter 12.27 m
- Height overall 14.86 m
- Ballonet total capacity 25%

Test and Evaluation Success under a US OSD-sponsored and contracted launch/recovery/refuelling exercise and technical evaluation of Polar 400 prototype vehicle yielded the following results:

- OSD: "Due to quick turn time (6 to 7 minutes including refuelling) it's clear a single crew could operate at least 2 or 3 different airships…"
- OSD: "The manpower is 5 personnel (including the remote pilot)to attach and release the airship from the mast and 6 personnel… to fuel the vehicle."
- NAVAIR: "The 4 propellers permit vertical takeoff with pitch and lateral control at zero speeds. The impact is:

- No runway needed
- Lower operational costs
- Less people on the ground

Participated in Army RDECOM C4ISR On-the-move, Fort Dix/Lakehurst, July-Sept 09 as central aerial node –multi-payload installation (see below)

- Over 300 total flight test hours and >10 communication/surveillance payloads integrated by end of C4ISR-OTM

"…I get to see a lot of stuff in this class of airship…the [Guardian] engineers have assembled and tested the most mature UAV system of this class." –Senior NAVAIR engineer

There are also the larger Polar 600 and Polar 3000 airships for handling larger cargo missions.

3.3 Hybrid Airships

Hybrid airships derive most of their lift from gases that are lighter than air (i.e. helium) and use standard aerodynamic lift to generate the remaining lift. This makes them very effective for lifting heavy loads while still being able to operate from short runways or even small lakes. They are also capable of higher airspeeds than traditional airships.

3.3.1 SkyCat

The first example of this new breed of airship that this study will explore is the SkyCat-20. The '20' refers to Short Take Off and Landing (STOL) payload capacity. This airship offers a high-endurance, low-cost and versatile airborne platform for missions such as border control, counter-drug operations, coastguard search and rescue, harbour traffic monitoring and police surveillance – as well as civil uses such as surveillance of gas and oil pipeline. The company offers that the SkyCat-20 SkyPatrol offers the following advantages:

i. **Hush and stealth.** Cruising on its rear engines, the SkyCat is extremely quiet, while composite construction materials give an IR and a radar signature as small as that of a light aircraft.

ii. Long endurance. Typically, 7 days on station on a 4,000-mile patrol mission. If required to land and take off vertically (VTOL), the vehicle has a 3-4 day endurance capability. The spacious cabin provides ample operational, accommodation and recreation room for flight and technical crews for the duration of their duty-cycle. As an unmanned airship, this volume can be converted to extra payload/fuel.

iii. **Surveillance payload**. Even in VTOL operation, the SkyCat can carry up to 10 tons of military equipment, sufficient to provide a complete technical surveillance suite, including the large radar antennae necessary for penetrating jungle canopy, advanced "sniffer" and E/M detection devices and the latest infra-red imaging equipment.

iv. **Low vulnerability**. The SkyCat is virtually impervious to automatic rifle and mortar fire: ordnance passes through the envelope without causing critical helium loss. In all instances of light armament fire evaluated under test and live conditions, the vehicle was able to complete its mission and return to base.

v. **Interdiction**. Able to land on water or rough terrain, independent of any support, the SkyCat offers a total patrol vehicle with a direct interdiction capability.14

vi. **Payload**. Like all lighter-than-air vehicles, the payload capability of the SkyCat increases exponentially with size. Unlike airships, however, its aerodynamically-derived lift enables the SkyCat to gain significantly further from the benefits of scale.

vii. **Light/heavy range**. While conventional airships are limited to operating in a narrow band between approx. 5% light and 8% heavy, the SkyCat can operate between 8% light and 40% heavy, thereby greatly increasing its payload capability while eliminating the need for taking on ballast on discharging its load.

viii. **Landing and takeoff distances**. In STOL mode, the SkyCat can land and take off in five hull lengths, while in VTOL mode, by virtue of vectored thrust engines, the vehicles are literally able to set down and lift off in their own length.

ix. **Hull pressure**. The hull is a pressure-stabilised, non-rigid structure, operating at 1%-2% pressure above ambient, with the shape maintained by ballonets (air bags) which automatically deflate and inflate to compensate for changes in outside pressure.

x. **Material construction**. The envelope is constructed of heat-bonded, high-tensile laminated fabric, incorporating a Mylar film that provides the gas barrier. The lift gas is helium and totally inert. The payload module is formed from Kevlar composite material of exceptional strength and can be configured for whatever interior design fit is required.

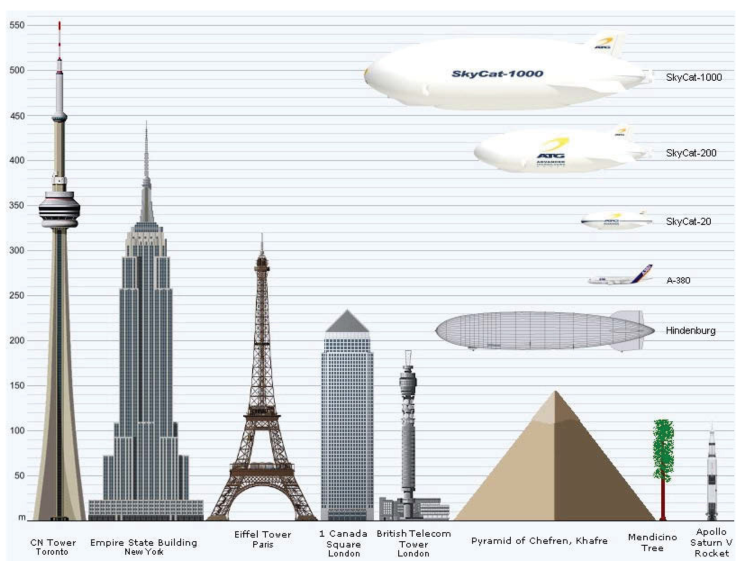


Figure 22: SkyCat size comparisons

14 "Skypatrol: Surveillance Border Control," World SkyCat, 20 Mar. 2007 <http://www.worldskycat.com/markets/skypatrol.html>.

Overall dimensions:	SkyCat-20	SkyCat-220
Length:	81.0m	185.0m
Height:	24.1m	47.0m
Width:	41.0m	77.3m
Payload module:		
Length:	25.5m	64.0m
Height:	2.6m	4.8m
Width:	3.5m	7.8m
Payload:		
Standard STOL mode:	20.0 tons	220.0 tons
Hover/VTOL mode:	14.5 tons	160.0 tons
Range:		
Max payload, at cruise:	2,400 n.miles	3,225 n. miles
Speed:		
Cruise:	75 kts	80 kts
Sprint:	85 kts	95 kts

Table 4: Summary of SkyCat basic data

Safety is a major concern with any new craft – especially with airships with their very memorable Hindenburg history. The company offers the following key points on the SkyCat's safety characteristics:

i. **Lift gas.** The lift gas (helium) is not merely inert but acts as a fire extinguisher.

ii. **Structural safety.** The natural buoyancy and special design features of the SkyCat offer a virtually zero catastrophic failure mode. With the internal hull pressure maintained at only 1%-2% above surrounding air pressure, the vehicle is highly tolerant to physical damage or to attack by small arms fire or missiles.

iii. **Storm and turbulence**. While on long-haul flights weather patterns would be flown to avoid bad weather, the sheer mass of the hull largely dampens out the effect of turbulence – just as a large tanker rides through rough seas.

iv. **Lightning strike.** Constructed mainly from composite materials, the SkyCat offers a poor lightning target and, should it be struck, built-in protection devices ensure that the risk to the vehicle and its cargo is minimal.

v. **Structural vulnerability tests.** A series of tests were carried out by the UK Defence Evaluation and Research Agency (DERA) on a Skyship 600, an earlier airship built by the Munk team to a similar pressure-stabilised design. The picture below shows the airship two hours after several hundred high-velocity bullets were fired through the hull. Even after this intensive assault, the vehicle would have been able to return to base.

The following points the address the differences between the SkyCat-20 and the SkyCat-220 with its larger 220 tons payload capacity along with some of their collective advantages:

i. **Large Payload.** The SkyCat-20 has the flexibility and penetration of a helicopter but with a considerably greater payload capacity, while the SkyCat-220 significantly out-scales and out-performs all existing air freight transport alternatives.

ii. **Long Range and High Endurance.** The standard operating range of the SkyCat-20 with 16 tons payload is 2,400 nautical miles at cruise, enabling the vehicle in a surveillance role (for instance) to remain on station for up to 10 days at a time if required. The standard range for the SkyCat-220 is 3,250 nautical miles, making it ideal for bulk transport – (e.g.of fresh produce direct from grower to market). This is of particular interest to servicing markets in the Canadian North.

iii. **Low Capital and Operating Costs.** The capital cost of the basic SkyCat-20 ranges from $28m-$30m and the direct operating costs are under $1000/hour. The capital cost of the SkyCat-220 is $88m-$95m and the operating cost under $1400/hour. When relative speed is factored in, these costs compare highly favourably with both aircraft and shipping alternatives. In fact, the SkyCat fills the gap in the transportation market between fast, high-cost air transport and the slow, low-cost sea alternative, as below:

iv. **Low Maintenance.** Scheduled maintenance is just 2 weeks per annum and can be conducted in the field without need of hangaring.

v. **High Safety Level.** Natural buoyancy and special design features offer a virtually zero catastrophic failure mode. Low I/R signature and high tolerance to damage and ordnance/missile attack make the SkyCat a uniquely safe flying vehicle.

vi. **High Fuel Efficiency.** With its two stern engines running in the wake of the hull, the SkyCat achieves high fuel efficiencies due to reduced vehicle drag. The fuel burn per ton/km for the SkyCat-20 is well under 50% of that of a C-130J transport aircraft and just 25% that of a 40-ton truck.

vii. **Low Infrastructural Requirement.** Able to land and take off from any reasonably flat terrain, water included, without the need for runways, hangars, ground crews or handling equipment, the SkyCat offers the ideal, environmentally sensitive vehicle for transport over long distances into remote regions.

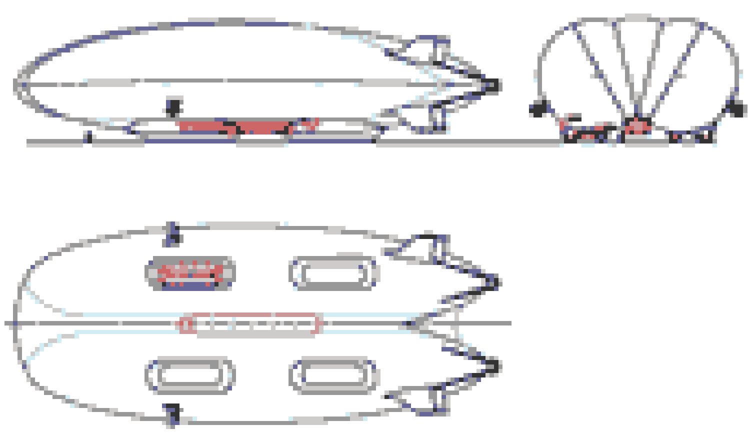


Figure 23: SkyCat additional views

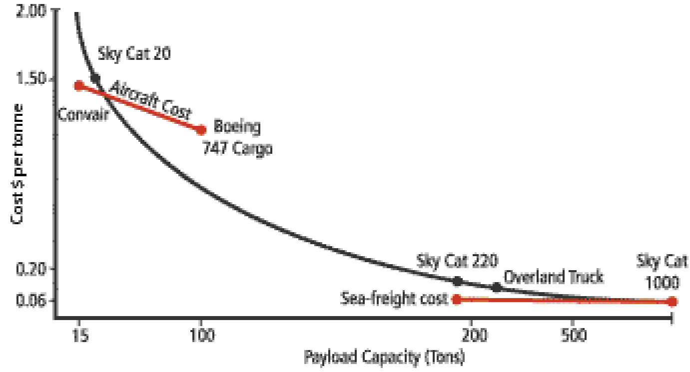


Figure 24: SkyCat Cost per tonne vs Payload Capacity Graph

	SkyCat-20	**SkyCat-220**
Gross Payload:	20,000 Kg	220,000 Kg
Cargo Volume:	140 cu.m.	2,400 cu.m.
Range:	2,000 n. miles	3,225 n.miles
Cruise Speed:	75 knots (140 kph)	85 knots (155 kph)
Vehicle basic price:	$25m - $28m	$80m - $92m
Direct Operating Costs:		
Based on flight hours p.a.:	3,500 hrs	4,500 hrs
- per annum	$3,485,000	$6,200,000
- per flight hour	$995	$1,380
- per ton/km	$0.35	$0.04
Lease costs (long-term basis):		
- per annum	$10m - $11.2m	$22.4 m - $25.7m
- per month	$0.8m - $0.9m	$1.8m -$2.1m
Total Costs:		
- per annum	$13.5m - $14.7m	$28.6m - $31.9m
- per flight hour	$3,850 - $4,195	$6,350 - $7,090
- per ton/km	$1.38 - $1.50	$0.19 - $0.21

Table 5: SkyCat Characteristics

NOTES:

1. All figures subject to confirmation of specific operational role

2. DOC include fuel, consumables, crew, time-dependent maintenance – i.e. everything a user would have to pay over and above the dry lease

3. Lease costs include cost of finance, insurance on the hull and ground equipment, annual maintenance and a nominal figure for overhead and management.

		Cost	
SkyCat-20	**Payload (tons)**	**per hour ($)**	**per ton/hr ($)**
MI8 helicopter	2.5	3,750	1,500
Twin Otter	3	825	275
Shorts 360	4	950	238
Buffalo	7.5	2,350	313
C-130	18	3,950	219
SkyCat-20	**20**	**3,850**	**192**
SkyCat-220			
Il-76	43	3,900	91
Boeing 747-200 (post-1990)	95	7,450	78
Boeing 747-400	110	9,300	85
Antonov 124	120	6,750	56
SkyCat-220 Payload	**220**	**6,350**	**29**

Table 6: Comparative Costs for SkyCat

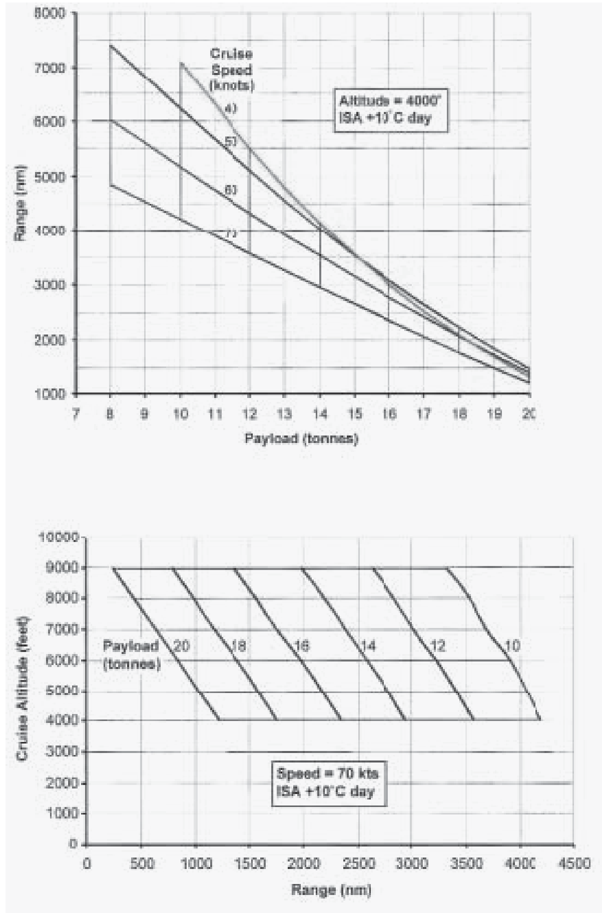


Figure 25: SkyCat Cruise Altitude vs Payload vs Range

3.3.2 Hybrid Aircraft Corp.- SkyFreighter

Figure 26: HAC SkyFreighter™ 50[15]

Imagine a giant, turtle-shaped aircraft, a combo of blimp, plane and hovercraft, filled with freight, quietly floating over the ocean. It sounds like science fiction, but serious experts insist it could someday be a reality in Alaska. Hybrid aircraft, or airships, modern incarnations of the blimp, travel faster than barges and trucks and are cheaper to operate than jets. Promoters hope someday they may haul freight and supplies to remote locations in Alaska.

Alaska is a particularly good market for the airships because of the state's many remote freight needs, like delivering supplies to roadless villages, taking fish to market or hauling oil exploration equipment to the tundra.

The airship is no blimp, Frederick Edworthy, vice president of Aeros, explained to the crowd. "It's a completely different animal." A blimp is a slow-moving, low-flying, difficult-to-manoeuvre, bullet-shaped craft, most commonly used for advertising, famously for the tire company Goodyear.

Airships are designed to carry cargo or passengers. They use a giant bladder, filled with non-flammable helium, and an airplane engine to loft themselves into the air. They fly just low enough to avoid having to pressurize the cabin like an airplane. They are much faster and more manoeuvrable than blimps. They don't require long runways like jets or a large crew on the ground. They also don't need to be stored in a hangar. Aeros is currently building a test craft. [16]

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[15] The image is a computer generated simulation of the 50-ton net payload cargo configured hybrid aircraft, HAC SkyFreighter™ 50, the latest high-tech incarnation of a blimp, filled with helium and powered by airplanes engines. (Photo courtesy Hybrid Aircraft Corp)

[16] Julie O'malley, "Hybrid Aircraft Touted for Future," Adn.Com, 12 Nov. 2006, Archorage Daily News, 13 Nov. 2006 <http://www.adn.com/news/alaska/aviation/story/8402014p-8296833c.html>.

3.3.3 Dynalifter

Another example of the hybrid design is the Dynalifter® hybrid airship. This hybrid airship has the ability to fly on low amounts of power at low speeds, much like airships, but without the operational drawbacks of a traditional airship. This offers long endurance and range. The Dynalifters airships have been designed to land without a mooring crew and do not require a weight transfer system under normal conditions.

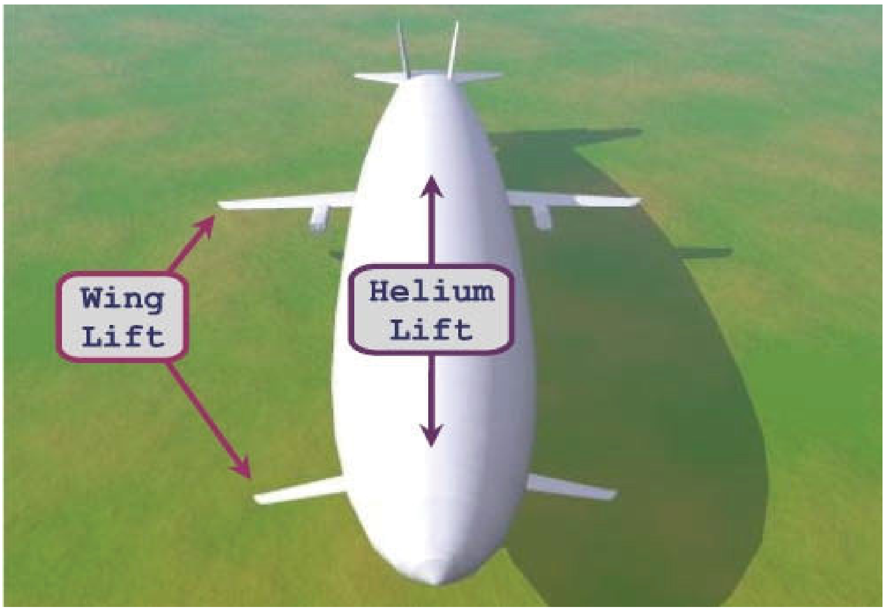

Figure 27: Dynalifter

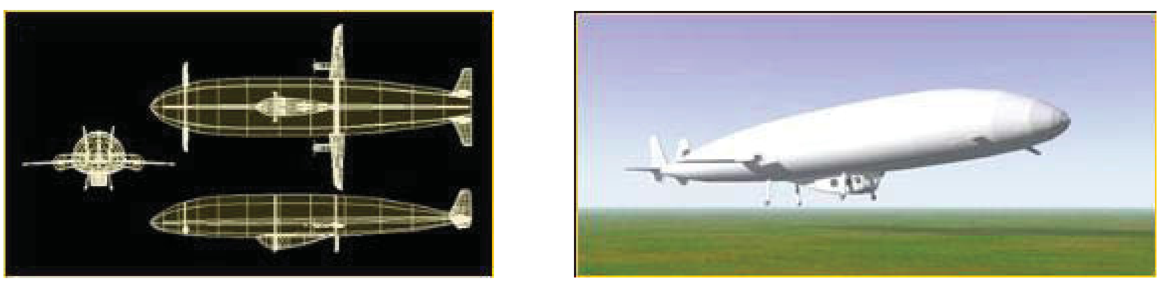

Figure 28: DynaLifter additional views

Because of their large size and slow airspeeds, airships have some challenges in strong winds and rough weather. The company claims that Dynalifters have been designed to withstand up to 30 knot crosswinds after releasing their useful load. In addition to making Dynalifters more operationally robust, this allows for unique capabilities such as precise airdropping and mission-specific, detachable cargo pods. Under extreme conditions (winds in excess of 30 knots), the Dynalifter can remain firmly on the ground either by pointing it into the wind, refuelling before the cargo has been released, not releasing the cargo at all, or tying it down.

An advantage of the hybrid airship is that is can avoid the operational drawbacks of a traditional airship associated with takeoff, landing, and ground operations. The conventional airship is difficult to handle on the ground. It requires a large number of people to grab lines during landing, or it must use equipment of some sort to "catch" the airship and attach it to a mooring mast. With passengers and fuel removed, the airship experiences excess buoyancy and so must be over-ballasted before unloading. When fuel is burned during flight, it becomes too light to land, requiring either valving off lifting gas or use of an elaborate mechanism to recover water vapour from the engine exhaust.

The company claims that the Dynalifter® avoids many of these problems [with airships] because it isn't "lighter-than-air". With a large fraction of its weight carried by aerodynamic lift on the wings and hull, it has a substantial net download when sitting on the ground allowing it to withstand a gusty side wind. It lands like a normal aircraft, decelerating on a runway as its weight is transferred from the wings to the tires.

The company offers four different sizes Dynalifters ranging from the 120 ft. Dynalifter® Patroller and RV to the 990 ft. Dynalifter® Freighter. The concept has been evaluated by engineering studies that included computational fluid dynamics, initial fabrication selection, and cost analyse.

According to their literature, Dynalifters are capable of releasing detachable cargo pods without the need for a weight transfer system. First, this would allow for rapid loading and off-loading. Loading and off-loading the pods could actually take place without the aircraft's presence, further reducing aircraft vulnerability and deployment time. Second, detachable pods could carry the next mission's fuel and supplies, allowing for in-flight refuelling and quick turnarounds. Third, detachable pods could be uniquely designed for each mission. There would no longer be a need to modify aircraft for special missions; modify the cargo pods instead. Fourth, detachable pods could provide instant infrastructure at the destination point. Like building blocks, Dynalifters could drop off multiple pods, building temporary repair facilities, field hospitals, and barracks. A small base could be assembled remotely with unprecedented speed.[17]

[17] "Welcome to Dynalifter.Com." Dynalifter.Com. 2006. Ohio Airships, Inc. 21 Mar. 2007 <http://www.dynalifter.com/Dynaliftercom/Concept.htm>.

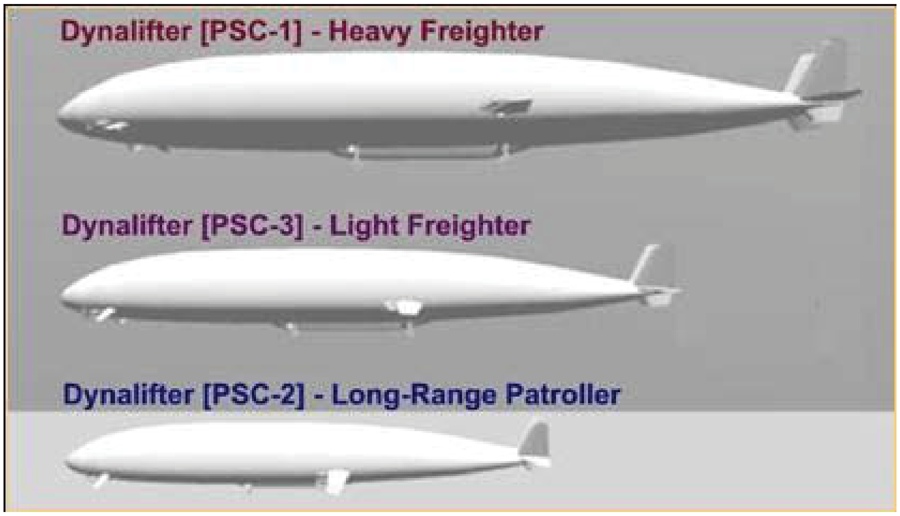

Figure 29: Dynalifter models

Ohio Airships has made considerable technical progress towards realising their Dynalifter design:

i. Awarded a US Patent for the Dynalifter® aircraft's internal structure (2001)
ii. Completed 5 conceptual design studies by highly qualified defense contractors
iii. Phase-1 Dynalifter® Conceptual Design & Feasibility Study (performed by Conceptual Research Corporation, 2002)
iv. Phase-2 Dynalifter® Follow-on Conceptual Design & Feasibility Study (performed by Conceptual Research Corporation, 2003)
v. Dynalifter® Conceptual Structural Design, Fabrication, & Cost Estimation Study (performed by Composite Engineering, Inc., 2003)
vi. Dynalifter® Conceptual Aerodynamic Study using computational fluid dynamics (performed by Analytical Methods, Inc., 2003)
vii. Dynalifter® FAA Certification Process Study (performed by Geoffrey Sommers, FAA expert, 2003)
viii. Secured airport land and built construction hangar for Dynalifter-1 (2003)
ix. Produced a detailed design for Dynalifter-1 manned prototype (2004)
x. Wind tunnel testing – Ohio State University (2004)
xi. Began fabrication of Dynalifter-1 manned prototype (2004)
xii. Completion of Dynalifter-1 (2005)
xiii. Completed no helium, slow-speed runway taxi test (2005)
xiv. Completed 8 full-helium slow-speed taxi tests (2006)
xv. Completed 3 high-speed taxi tests (2006)

xvi. Received FAA Experimental Airworthiness Certificate (2006)

Their prototype test flight progress includes:

i. 11 taxi tests
ii. Structural integrity at high speeds
iii. Controllability at low/high speeds
iv. Engine reliability
v. Takeoff speeds achievable with existing configuration (i.e. horsepower & control)

This work culminated in the Dynalifter hybrid aircraft prototype receiving its Experimental Airworthiness Certificate from the FAA in July 2006, marking the end of ground testing and the beginning of flight testing.

3.4 Tethered Airships (Aerostats)

Aerostats provide the simplest means of putting a payload into the air. The following paragraphs detail some of the current uses of the technology.

Aerostat[18]	
Supported by Lighter-Than-Air Gases (**aerostats**)	
Un-powered	Powered
• Balloon	• Airship
Supported by LTA Gases + Aerodynamic Lift	
Un-powered	Powered
	• Hybrid airship
Supported by Aerodynamic Lift (aerodynes)	
Un-powered	Powered
Unpowered fixed-wing	Powered fixed-wing
• Glider • hang gliders • Paraglider • Kite	• Powered airplane (aeroplane) • powered hang gliders • Powered paraglider • Flettner airplane • Ground-effect vehicle
	Powered hybrid fixed/rotary wing
	• Tiltwing • Tiltrotor • Mono Tiltrotor • Mono-tilt-rotor rotary-ring • Coleopter
Un-powered rotary-wing	Powered rotary-wing
• Rotor kite	• Autogyro • Gyrodyne ("Heliplane") • Helicopter
	Powered aircraft driven by flapping
	• Ornithopter

[18] http://en.wikipedia.org/wiki/Aerostat

3.4.1 TCOM - 71M® Aerostat

Figure 30: TCOM 71M® Aerostat

The TCOM Aerostat is a proven design. A TCOM aerostat is a pressurized, completely flexible structure. Its hull is filled with the inert lighter-than-air, non-burning gas helium. Inside the lower part of the hull is an air compartment called a ballonet. An automatic system of sensors, switches, blowers and valves controls the super-pressure within the hull to maintain the external aerodynamic shape. There is associated power and housekeeping equipment. The hull is an aerodynamically-shaped balloon up to 71 meters in length, fabricated from a high-strength multi-layer fabric and designed for long term use in all types of environments. Thermally bonded together, the completed flexible structure exhibits an exceptionally low helium loss rate. The multi-layer laminate provides significant resistance to ultraviolet radiation, chemicals and oxidation, while offering a field-proven life expectancy of 10 plus years with minimum maintenance.

During the aerostat ascent to altitude, expanding helium forces air from the ballonet chamber to the atmosphere through automatic valves. As the aerostat is retrieved from altitude, the helium contracts, reducing hull pressure. In the TCOM design, this triggers an automatic mechanism that pumps air into the ballonet compartment to compensate. Aerodynamic shape is thereby maintained at all times.

An automatic system continuously monitors all vital aerostat data, including altitude; hull, fin, and windscreen pressures; helium and ambient air temperatures; blower and valve status; and aerostat pitch and roll. This information is relayed to the ground via radio or through fibre optics within the tether.

Although aerostats generally operate in a fully automatic mode, commands can be sent from the ground to control all blowers and valves. Similarly, all aerostat-borne payloads are controlled and monitored by the telemetry and command system.

TCOM offers system integration of all payloads. Using a computer model, TCOM begins payload systems integration by selecting the proper location on the aerostat skin for a given sensor to provide the correct field of view, to minimize interference from other onboard payloads and to correctly balance the aerostat for flight. Once a location is selected, environmental packaging is designed for lightweight weather protection, lightning protection and temperature control – both high and low. The size and weight of the payloads will dictate the load distribution via trusses laced onto the laminated skin. Electric power is provided via cable from the AC or DC distribution module onboard and two-way communications for data and control is provided via a fibre optic combining unit to the optical fibres in the tether. On the ground, the fibre optic communication streams are broken out to the users either on site or at any distant command center.

TCOM's mooring system provides the ground support equipment required to safely and surely control the tether through specially designed winching machinery, over a wide range of tensions, without causing damage or excessive wear to the tether link. The mooring system has been developed to reliably manoeuvre the aerostat during critical launch and recovery cycles and to protect the aerostat while moored in all kinds of unfavourable weather. It is used to store the tether when the aerostat is on the ground, to maintain the tether at the desired length in flight and to outhaul and inhaul the aerostat during launch and retrieval. Furthermore, the mooring system conditions the electrical power for the tether cable as supplied by either commercial power or on-site diesel generators.

A critical component of the aerostat is the tether. A single cable maintains the aerostat in its position above the launch point. The tether not only anchors the aerostat in flight, but through electrical conductors embedded in the cable provides power for the electronics payload and other airborne components. The tether incorporates a metallic braid within the tether jacket in order to safely conduct lightning currents to ground via the mooring system. In addition in the TCOM design, optical fibres are embedded within the tether core in order to provide a secure and reliable communications and control link with the ground support system. A bidirectional serial data link connects the payload with the ground control computer. Radar, TV and narrow and wideband signals may be transmitted between the ground station and the aerostat via secure, dedicated optical fibres. The fibre optic link provides a secure, communications path, free of electromagnetic interference. TCOM claims to be the only successful producer of large, lightning-protected, fibre-optic power tethers capable of delivering from 1kW to 80 kW from reliable ground power to the aerostat and its payloads

Of the TCOM designs, the 71M® aerostat is the largest of their standard aerostats providing excellent performance at 15,000 feet and higher. With an overall length of 71 meters and a hull volume of 16,000 cubic meters the 71M® provides maximum payload capacity, highest operational altitude and longest continuous on-station time. According to the company, 71M® aerostats are providing stable, long endurance high altitude platforms for:

i. Long range radars

ii. Passive surveillance payloads

iii. Communications relay

With its large payload bay and powered tether system, the 71M® accommodates high-power, long-range radars that can provide continuous detection of surface targets and low flying aircraft out to 200 nautical miles. The 71M® can also accommodate future radars that are presently under development. The TCOM 71M® has been selected by the U.S. Government as the official platform of choice for its vital Cruise Missile Defence Program.[19]

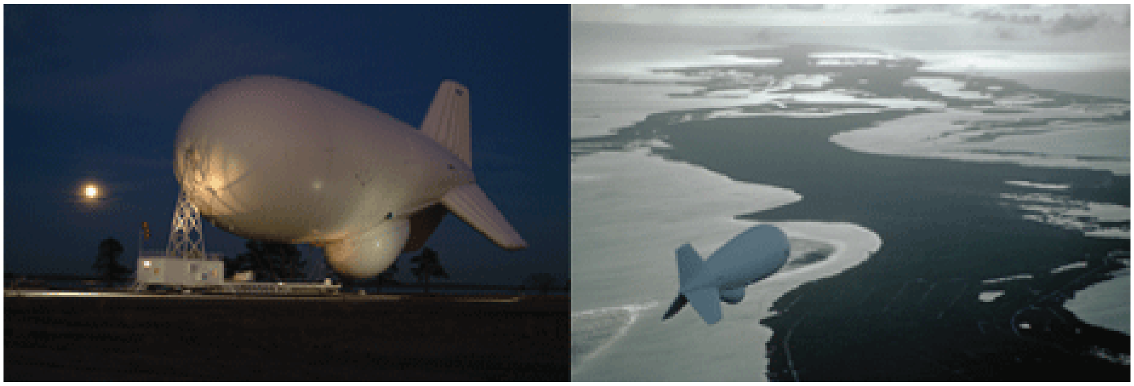

Figure 31: 71M

TCOM details the 71M® Benefits as follows:

i. **Altitude**. Continuous operations above 20,000 ft.

ii. **Endurance.** Mission times of > 30 days uninterrupted.

iii. **Advanced Construction.** Lightest weight, highest strength material.

iv. **Secure Communications.** Fibre optic links to ground facility.

v. **Versatile.** In use for both passive and active surveillance payloads.

vi. **Internationally Proven.** Only aerostat operating in both the United States and other countries

Payload Weight	1,600 kg / 3,500 lbs
Nominal Altitude	4,600 m / 15,000 ft
Available Payload Power	22 kVA
Flight Duration	30 days
Wind Speeds	Operational-70 kts / Survival-90 kts

Table 7: 71M® Specifications

TCOM claims the following innovations in aerostat technology:

i. Broad Spectrum of Communication Systems
   - Television & Radio Broadcast
   - Long-Range Wideband Aerostat Microwave Link
   - COMINT System Surveillance
   - VHF/UHF Radio Links
   - GCI Radio Links

[19] "TCOM 71M - Our Premier Aerostat," TCOM, 26 Feb. 2006, 16 Jan. 2007 <http://www.tcomlp.com/71M.htm>.

ii. Mobility & Transportability
   - Fully Integrated Modular Mooring Systems Support Site Relocation
   - Transportable Land-Based Aerostats for Tactical Deployments
   - Sea-Based Aerostats Provide Maximum Flexibility
   - Truck-mounted Aerostats Provide Surveillance On-the-Move

iii. World's Most Advanced Tether Technology
   - Fiber Optic Powered Tethered System
   - First Lightning-Protected Tether System (Patented)
   - Kevlar, Vectran and Zylon Tether Technology

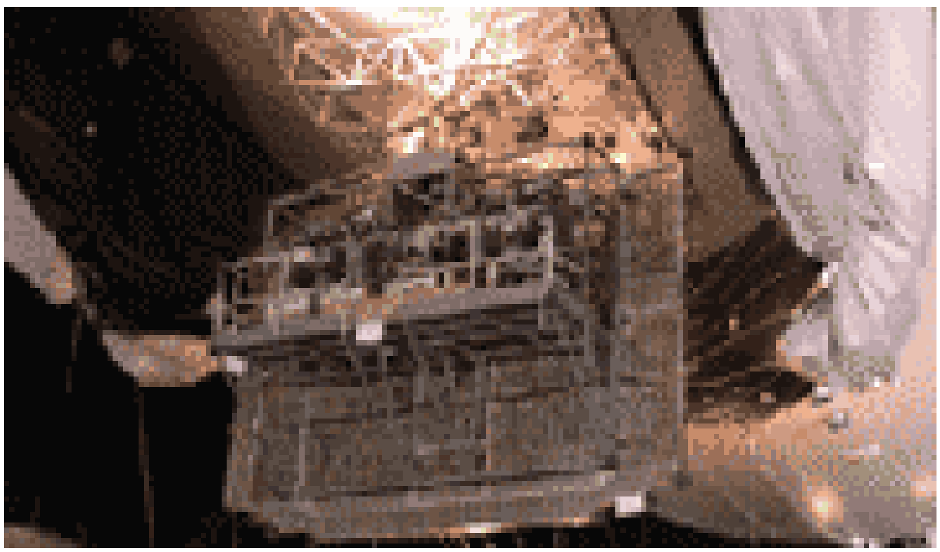

Figure 32: Aerostat-Borne Long Range 3-D Active Aperture Radar

iv. Advanced Payload Systems
   - Fully Coherent Solid State L-Band Aerostat-Borne Radar
   - World's Only Aerostat-Borne Long Range 3-D Active Aperture Radar
   - Pulse Doppler X-Band Multi-Mode Aerostat-Borne Radar
   - Very Low Frequency Communications
   - COMINT/ELINT
   - EO/IR Camera Systems

v. Highest Operational Altitudes
   - AEW Radar Systems Routinely Operate at 15,000ft
   - SIGINT Systems Routinely Operate Above 20,000ft

vi. Other Aerostat Milestones
- Complete Aerostat Flight Simulator Capability
- First to Operate Aerostat North of the Arctic Circle
- Largest Non-rigid Aerostat
- First to Operate an Aerostat Aloft Continuously for 30 Days

The company offers that the following payloads have been successfully deployed on TCOM aerostats:

i. Surveillance radars of all sizes and capabilities
ii. Signal Intelligence (SIGINT) collection equipment
iii. Gyro-stabilized daylight, low-light level and infra-red video cameras
iv. Direct television broadcast and relay
v. FM radio broadcast and relay
vi. VHF/UHF, Ground Control Intercept (GCI) and microwave communications
vii. Environmental monitoring equipment

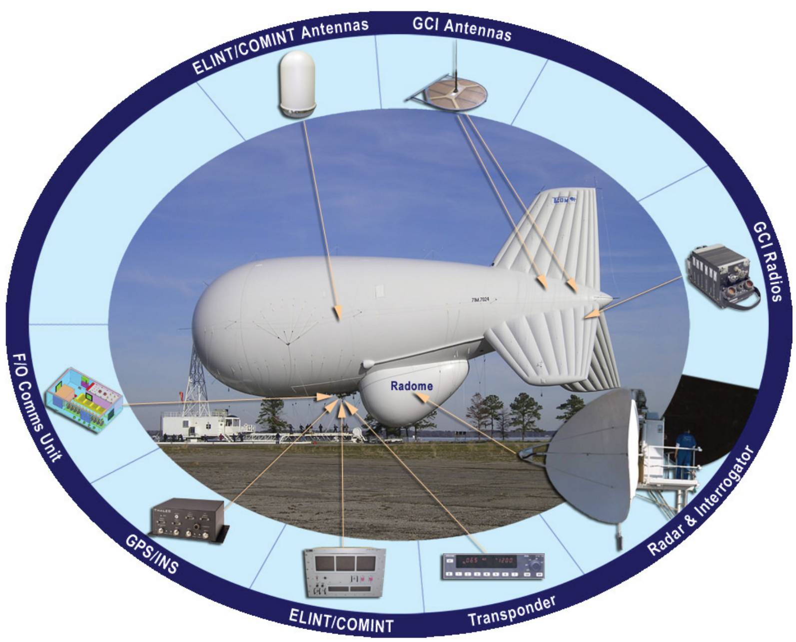

Figure 33: : Typical 71M Multi-Payload System

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Figure 34: TCOM Mooring System

The following articles provide some insight into the resurgence of aerostat technology.

3.4.2 Return of the Navy Blimps?[20]

Figure 35: TCOM 32M aerostat

In the aftermath of World War 2, blimps and airships found themselves gradually phased out of the US military. That didn't begin to change until the 21st century. The heavy-lift WALRUS project may have been cancelled without explanation; but aerostat programs

[20] "Return of the Navy Blimps?" Defense Industry Daily, 02 Mar. 2007, 29 Mar. 2007 <http://www.defenseindustrydaily.com/2007/03/return-of-the-navy-blimps/index.php#more>.

like JLENS cruise missile defence and its smaller RAID local surveillance derivative, and airships like the HAA/ISIS program, remain. The US Navy is also experimenting with aerostats for communications relay, surveillance, and radar over watch functions - and this has become a formal program.

What's driving this interest? Four things. One is persistence, in an era where constant surveillance + rapid precision strike creates a formidable military asset. A second is cost, especially in an era of rising fuel prices. A recent US NAVSEA release offers figures that starkly illustrate the gap in surveillance cost per hour between an aerostat and planes or UAVs:

- *Land-based 71-meter aerostat: about $610/ hour*
- *MQ-1 Predator MALE UAV: about $5,000/ hour*
- *E-2C Hawkeye AWACS aircraft: about $18,000/ hour*
- *RQ-4 Global Hawk HALE UAV: about $26,500/ hour*

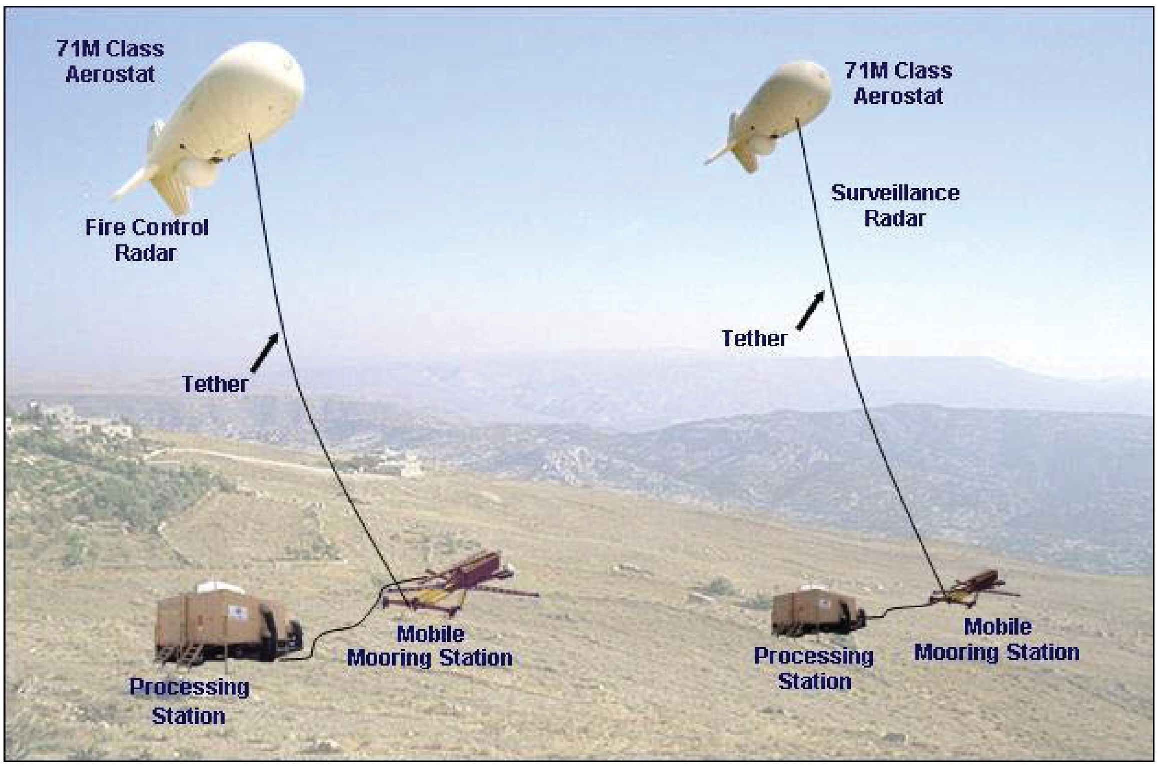


Figure 36: JLENS Concept

The third driver is ballooning bandwidth demands due to increased employment of UAVs and other systems with streaming video. This is a long-term trend that will demand very expensive satellites with long design/launch times - or cheaper patchwork solutions that can remain at altitude for long periods.

The fourth driver is the proliferation and increased lethality of cruise missiles. On land, the concern is the combination of cruise missiles and weapons of mass destruction. At sea, the concern is the increasing lethality of anti-ship cruise missiles, including *supersonic varieties that place a premium on early detection in order to give defensive systems enough time.*

Aerostats are not blimps, and need no pilot. These helium filled, multi-chambered balloons are winched up or down via a combined tether/power line; and can be deployed from trucks, land platforms, or a ship at sea. They can stay at-altitude and on station for weeks at a time, which makes them well-suited for providing over-the-horizon airborne radar, surveillance coverage, and/or communication relays for areas like ports, key sea lanes & straits, coastal areas, main transportation highways, national borders, or demilitarized zones.

Their multiple helium pockets and low differential pressure between the helium and the atmosphere also make them hard to kill, even if shot full of holes. The helium just escapes slowly, and the aerostat will still remain aloft for hours or even days. During one incident in Iraq, a small RAID aerostat came loose from its tether and the US Air Force barely managed to shoot it down before it drifted over the Iranian border.

Aerostats will not replace naval surveillance aircraft. Their tethered nature creates substantial drag when moving at speed, and keeping them aloft at altitude becomes difficult in those circumstances. High winds and thunderstorms can ground them, in situations where aircraft could still fly. They also have rather large radar reflections, which can compromise task force stealth. Their offsetting advantages, however, may make them a critical naval supplement to be deployed over ports or staging areas; or from ships in or near "hot" zones like beachheads, or on picket in and near dangerous areas like the Persian Gulf, Straits of Malacca, Somali coast, et. al.

Accordingly, the USA's NAVSEA and NAVAIR signed a memorandum of understanding on Oct. 28, 2006 to develop a sea-based 38-meter aerostat prototype with a weather hardened design that can carry up to 500 pounds of surveillance equipment. That's NAVAIR's area of expertise, and they will use a 32 meter aerostat they've been experimenting with as a base platform. The Navy also wants to develop this aerostat to accommodate a modular, interchangeable payload system that can offer radar, optronics, communications, or set combinations for maximum flexibility. That's NAVSEA's area of expertise.

The ultimate goal of the program is to develop a sea-based 71-meter, weather-hardened aerostat sensor platform, with larger interchangeable payload modules, capable of operating at an altitude of up to 15,000 feet. This would be conceptually similar to the land-based JLENS aerostats, which will provide cruise missile defence on land.

3.4.3 Joint Land Attack Cruise Missile Defence Elevated Netted Sensor (JLENS)

The Joint Land Attack Cruise Missile Defence Elevated Netted Sensor (JLENS) program takes advantage of the characteristics of aerostats to deliver early detection and warning against the cruise missile threat. The following articles provide an overview of the program.

The proliferation of cruise missiles and associated components, combined with a falling technology curve for biological, chemical, or even nuclear agents, is creating longer-term hazards on a whole new scale. Intelligence agencies and analysts believe the threat of U.S. cities coming under cruise missile attack from ships off the coast is real, *sophisticated and evolving. Meanwhile, the July-August 2005 issue of Air Defence Artillery Magazine discusses experiences in Operation Iraqi Freedom which showed that even conventional cruise missiles could have important tactical uses in the hands of a determined enemy.*

Aerial sensors are preferred against low-flying cruise missiles, because they lack the range/horizon limitations of ground-based systems. The bad news is that keeping planes in the air all the time is very expensive, and the aircraft themselves aren't cheap. The primary challenge for theatre and national cruise missile defence, therefore, is the development of a reliable, affordable, long-flying look-down platform to detect, track and identify incoming missiles and support over-the-horizon engagements in a timely manner[21].

In Air Defence Artillery Magazine, Major Thomas J. Atkins sums up the JLENS system:

"The JLENS system consists of four main components: the aerostats, the radars, the mooring station and the processing station. The aerostats are unmanned, tethered, non-rigid aerodynamic structures filled with a helium/air mix. The aerostats are 77 yards long (three-fourths of a football field) and almost as wide as a football field. The aerostats must be large enough to lift the heavy radars that provide the system's extended range. The radars are optimized for their separate, specific functions, but weigh several tons each. The surveillance radar searches very long distances to find small radar cross-section tracks before they can threaten friendly assets. The fire control radar looks out at shorter ranges than the surveillance radar, but provides highly accurate data to help identify and classify tracks while providing fire control quality data to a variety of interceptors. The two aerostats are connected to the ground via tethers through which power and data is transmitted. The tethers enables the aerostats to operate at altitudes of up to 15,000 feet and contain power lines, fibre-optic data lines and Kevlar-strengthened strands surrounded by an insulated protective sleeve. The tethers connect to mobile mooring stations that anchor the aerostats to the ground and control their deployment and retrieval. The mooring stations are connected to ground-mounted power plants and processing stations. The processing stations are the brains of the whole system. Each processing station contains an operator workstation, a flight-director control station, weather-monitoring equipment and a computer that controls radar functions and processes radar data."

[21] "JLENS: Co-Ordinating Cruise Missile Defense - and More," Defense Industry Daily, 12 Jan. 2007, 29 Mar. 2007 <http://www.defenseindustrydaily.com/2007/01/jlens-coordinating-cruise-missile-defense-and-more/index.php#more>.

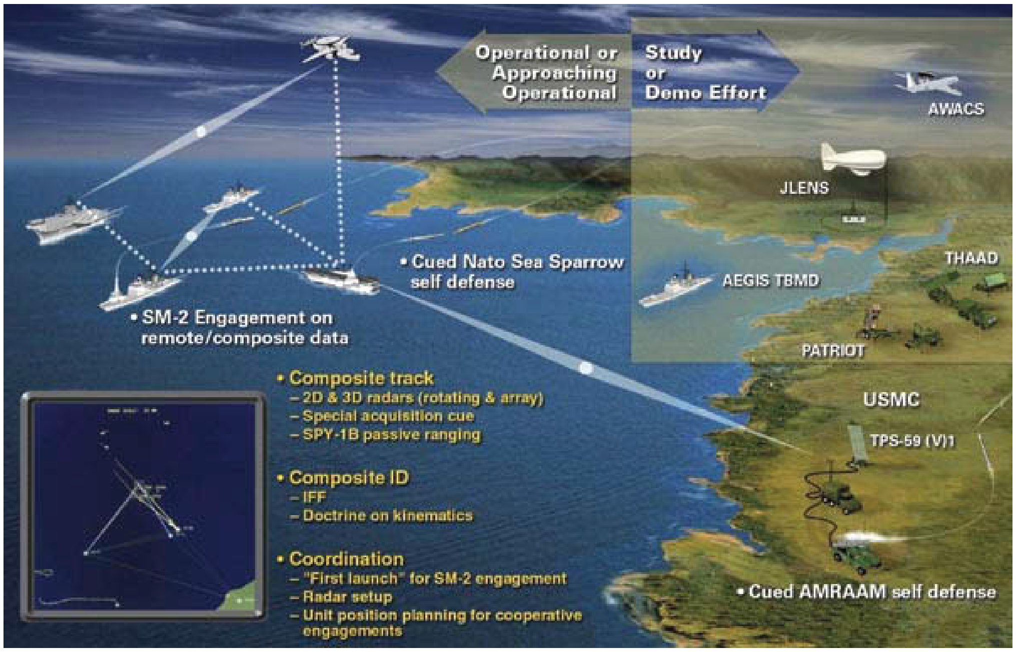


Figure 37: Co-operative Engagement Capability (CEC) Concept

When integrated with Co-operative Engagement Capability (CEC), JLENS can even serve as the linchpin of combined air defense frameworks with significant anti-air and missile defense capabilities. An elevated sensor such as JLENS can support ground based air defense units, such as Patriot, Aegis/Standard Missile and SLAMRAAM (ground-based AIM-120 AMRAAM missiles). In the All Service Combat Identification and Evaluation Team (ASCIET) '99 exercise, a 15m aerostat was deployed with a Cooperative Engagement Capability relay on a mobile mooring station. This relay allowed the Army's Patriot air defense system and the Navy's AEGIS weapon system to exchange radar data. The JLENS is thus a critical enabler of the Joint Theater Air and Missile Defense (JTAMD) system of systems.

Additional equipment could offer commanders' extensive communications relay capabilities, or even area surveillance of the ground. The JLENS program reportedly deployed a smaller 15 meter aerostat to Afghanistan in support of Operation Enduring Freedom. In late November 2003, the Army announced its intention to redeploy the Rapid Aerostat Initial Deployment (RAID) force protection aerostat from Afghanistan to Iraq. RAID, adapted out of JLENS via the Army Rapid Equipping Force, is now its own program.

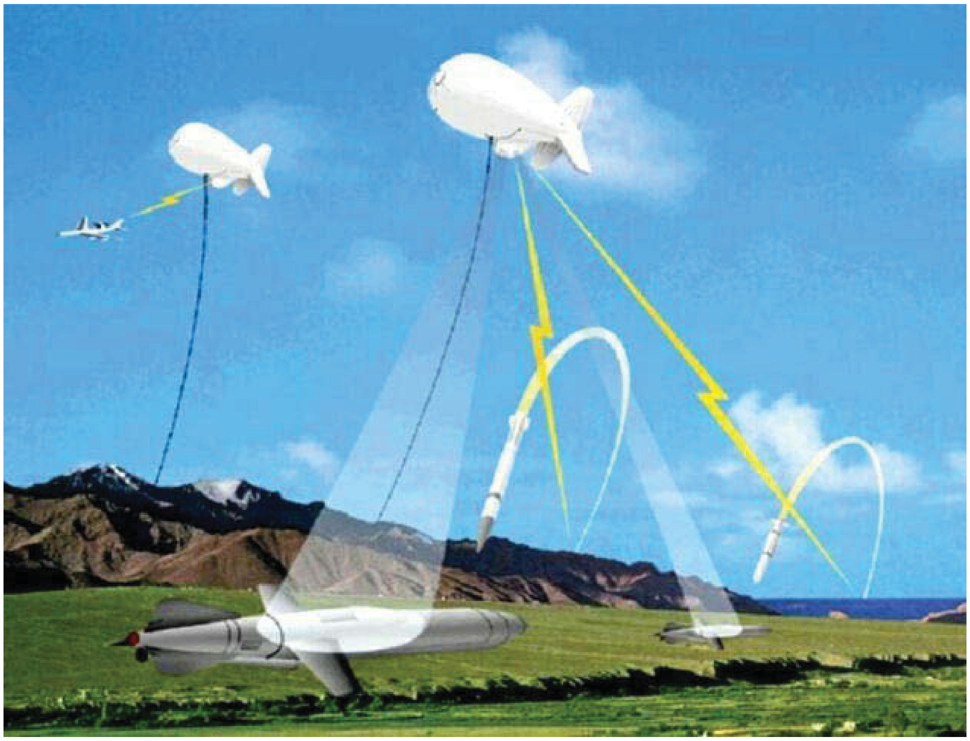


Figure 38: JLENS attack scenario

As of January 2007, Raytheon Company had defined and finalized a $1.4 billion contract modification from the U.S. Army for full-scale JLENS system development and demonstration. Raytheon's Integrated Defense Systems will develop the fire control radar and processing station, and TCOM will develop the 71M aerostat and associated ground equipment. System testing is now scheduled to begin in 2010 (originally 2009), with program completion slated for 2012 (originally 2011).

The US Army's initial System Acquisition Report submission in 2005, following approval to proceed into System Development and Demonstration (Milestone B), placed the JLENS program's total value over its lifetime at $7.15 billion.

3.4.4 Marine Airborne Re-Transmission System (MARTS)[22]

User Service: Marine Corps
Manufacturer: SAIC/TCOM LP
Inventory: 1 Delivered/6 Planned

Figure 39. MARTS

Background:

The DARPA/Marine Airborne Re-Transmitter System (MARTS) program developed a tethered aerostat communications relay in response to an USMC Urgent Need Statement for a secure, reliable, over-the-horizon relay of USMC VHF/UHF PRC 117 (SINCGARS/HAVE QUICK), 119 and 113 radio links, as well as EPLRS. MARTS will provide 24/7 connectivity within a radius of 68 nm. It is designed to continue operations despite punctures created by small arms fire, as well as in windy conditions up to 50+kts and be able to survive lightening strikes. MARTS is easily maintained because all complex radios and power supplies are located on the ground; the aerostat payload contains only simple, highly reliable transponders with a fiber optic cable to the ground equipment. The aerostat only needs a gas boost every fifteen days (15), minimizing its exposure to hostile forces.

Characteristics:

- Length 105 ft Trail Span 75 ft
- Volume 63,000 ft3 Payload Capacity 500 lb

Performance:

- Endurance 15 Days Altitude 3,000 ft
- Sensors VHF/UHF Radios Sensor Make PRC 113, 117, 119, EPLRS

[22] US DOD UAV Roadmap 2005-2030 Aug 2005

3.4.5 US Army's Rapid Aerostat Initial Deployment (RAID) [23]

Figure 40: TCOM 17M RAID Aerostat

Another program using aerostat's is the US Army's Rapid Aerostat Initial Deployment (RAID) program. This is a combination of cameras and surveillance equipment positioned on high towers and aerostats. Because the aerostats are not highly pressurized, bullets won't burst them and they can actually remain buoyant for hours after suffering multiple punctures. The RAID concept uses a smaller TCOM 17M instead of the TCOM 71M JLENS aerostats used for cruise missile and air defence, and sensors optimized for battlefield surveillance rather than powerful air defence radars. The result is a form of survivable and permanent surveillance over key battlefield areas that have been deployed to Afghanistan & Iraq. In May 2007 Raytheon was awarded a US$10.1 million U.S. Army contract option to provide 16 RAID Tower Systems with Base Defense Operation Centers and remote operation capability. Deliveries will begin in June 2007 and end in September 2007.

[23] "The USA's RAID Program: Small Aerostats, Big Surveillance Time," Defense Industry Daily, 08 Nov. 2007, 29 Mar. 2007 <http://www.defenseindustrydaily.com/2006/11/the-usas-raid-program-small-aerostats-big-surveillance-time/index.php#more>.

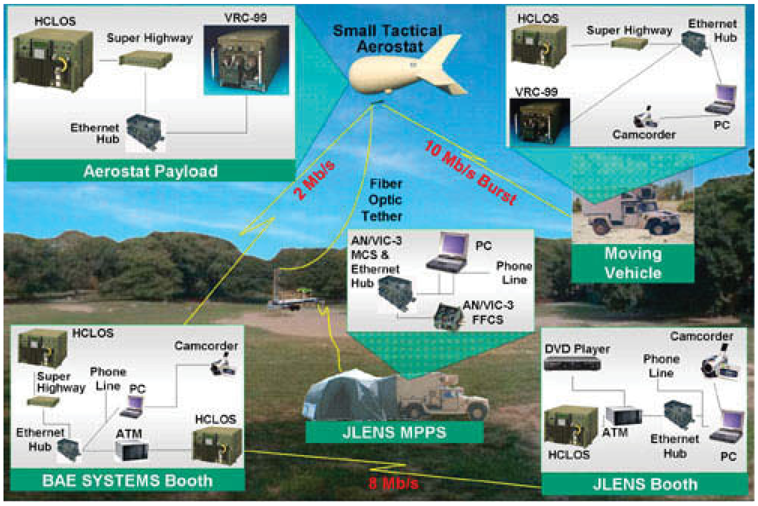


Figure 41: RAID Data Capabilities

3.4.6 Rapidly Elevated Aerostat Platform (REAP)[24]

User Service: Army
Manufacturer: Lockheed Martin/ISL-Bosch Aerospace
Inventory: 2 Delivered/2 Planned

Figure 42. REAP System

Background: REAP was jointly developed by the Navy's Office of Naval Research and the Army's Material Command for use in Iraq. This 31-feet long aerostat is much smaller than the TARS, and operates at only 300 feet above the battlefield. It is designed for rapid deployment (approximately 5 minutes) from the back of a HMMWV and carries daytime and night vision cameras. Its sensors can see out to 18 nm from 300 feet. REAP deployed to Iraq in December 2003.

Characteristics:

- Length 31 ft, Tail Span 17 ft
- Volume 2,600 ft^3
- Payload Capacity 35 lb

Performance:

- Endurance 10 days, Altitude 300 ft
- Sensor EO Sensor Make ISL Mark 1
- IR Raytheon IR 250

[24] US DOD UAV Roadmap 2005-2030 Aug 2005

3.4.6 Skydoc Aerostat System

Figure 43. SKYDOC(tm) Aerostat[25]

Figure 44. Skydoc Truck Mounted Carriage

[25] www.floatograph.com

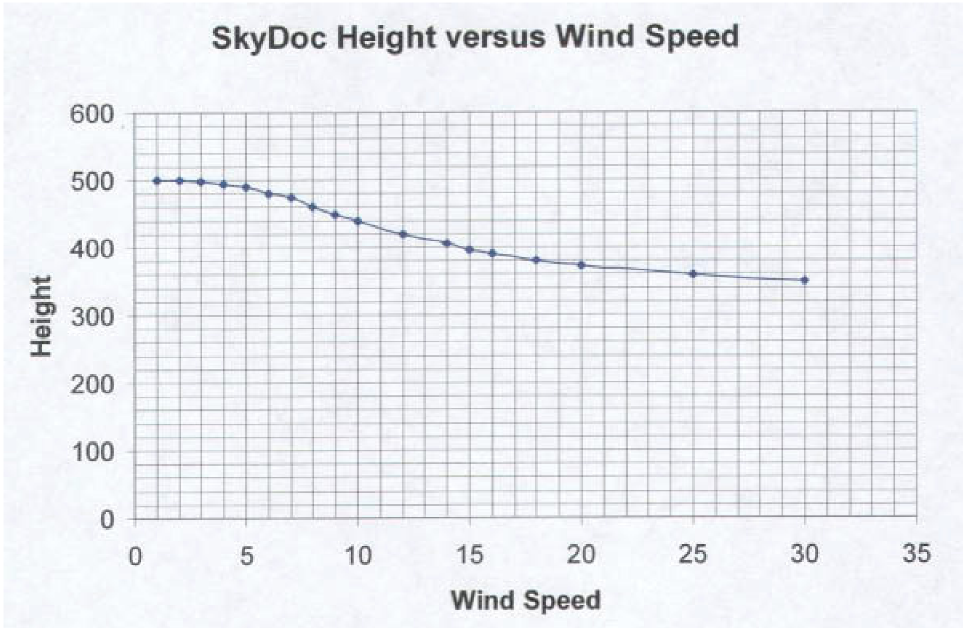
Figure 45. Sky Doc Truck Mounted Carriage Side View

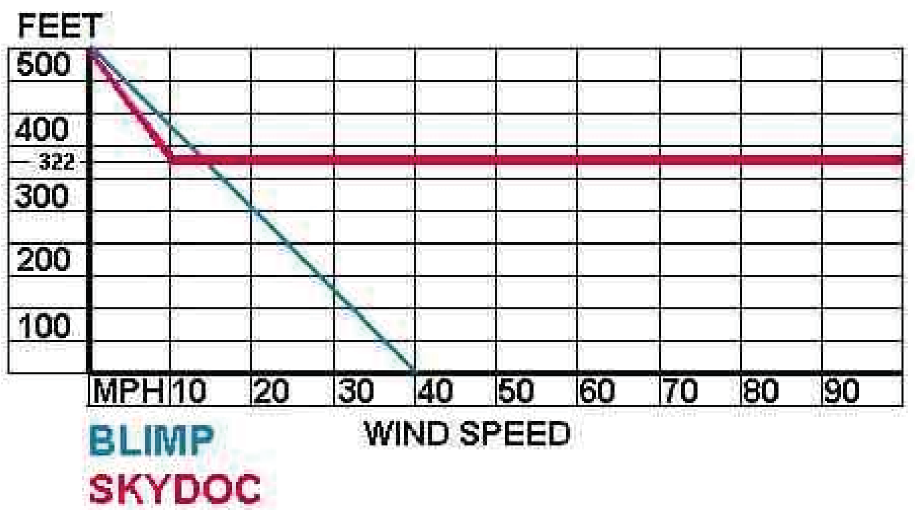
Figure 46. Skydoc Trailer Mounted Carriage

Single-Ply SkyDoc™ Aerostat Payload Carrying Capabilities				
MODEL #	Filled Diameter Filled Height	Cu. Ft.	Net Lift no wind	Maximum Lift at 90 mph
9	7.11' - 4.62'	121	6.1 lbs	500 lbs
10	7.5' - 5.13'	166	7.5 lbs	575 lbs
11	8.69' - 5.65'	221	11 lbs	650 lbs
12	9.48' - 6.16'	287	14 lbs	725 lbs
13	10.27' - 6.67'	365	18 lbs	800 lbs
14	11.06' - 7.19'	456	23 lbs	900 lbs
15	11.85' - 7.70'	560	28 lbs	1,000 lbs
16	12.64' - 8.21'	680	34 lbs	1,125 lbs
17	13.43' - 8.73'	816	41 lbs	1,275 lbs
18	14.22' - 9.24'	969	34 lbs	1,400 lbs
19	15.01' - 9.75'	1139	57 lbs	[26]1,750 lbs
20	15.80' - 10.27'	1329	66 lbs	2,000 lbs
25	19.75' - 12.83'	2593	130 lbs	3,000 lbs

3-Ply SkyDoc™ Aerostat Payload Carrying Capabilities				
MODEL #	Filled Diameter Filled Height	Cu. Ft.	Net Lift no wind	Maximum Lift at 90 mph
13	10.27' - 6.67'	365	12 lbs	800 lbs
14	11.06' - 7.19'	456	15 lbs	900 lbs
15	11.85' - 7.70'	560	19 lbs	1,000 lbs
16	12.64' - 8.21'	680	23 lbs	1,350 lbs
17	13.43' - 8.73'	816	27 lbs	1,725 lbs
18	14.22' - 9.24'	969	32 lbs	2,000 lbs
19	15.01' - 9.75'	1139	38 lbs	2,500 lbs
20	15.8' - 10.27'	1329	44 lbs	3,000 lbs
25	19.75' - 12.83'	2593	86 lbs	4,900 lbs
30	23.70' - 15.40'	4482	149 lbs	5,400 lbs
35	27.65' - 17.97'	7118	237 lbs	6,500 lbs

[26] http://www.floatograph.com/skydoc/





The Aerostat is made of Urethane. The Aerostat expands with temperature rise. Helium loss is 1 to 5 percent per day, depending on temperature swings and aerostat pressure. Net lift is at zero wind speed. Maximum lift is at 90 mph wind speed. Net lift is at Sea Level. Subtract 15 per cent at 5000 feet. [27]

[27] http://www.floatograph.com/skydoc/

3.4.7 Overhead Communications Aerostat (Communications Network - Bluestream™ [28]

The next generation in aerostat and airship communications and remote sensing solutions is here. By integrating the most technologically advanced commercial solutions available today, Overhead Communications brings high-tech capability to an age-old solution.

The idea to use aerostats and blimps for reconnaissance and communications is not a new one. These types of systems have been used since WWII. However, until now, no one has integrated the next generation of aerostats with an IP based, interoperable communication system and remote sensing equipment.

The result of these efforts is the Bluestream™ Communications Network, a network solution that can provide long-range, interoperable communications and remote sensing capabilities in areas with little or no infrastructure, or as a complement to existing communications systems to add further capability.

In addition, because we offer a wide variety of the most technologically advanced aerostats and launch systems, we can provide an unparalleled ability to meet your exact

[28] http://www.overheadcomm.com/communications-network.html

requirements, whether your need is long duration, persistent location coverage or tactical, wide area communications restoration.

Our integrated "High Performance" aerostat systems can carry up to 250 pounds and sustain operations for several weeks at a time.

AS 6200HW

- Class: High Performance Plus
- Person(s): 4-6
- Max. Weight: 200 lbs
- Max. Altitude: 2,000 ft
- Wind: 75 mph
- Duration: 30 days
- Deployment: 1-2 hours

AS 6200

- Class: High Performance
- Person(s): 6
- Max. Weight: 250 lbs
- Max. Altitude: 3,000 ft
- Wind: 40 mph
- Duration: 30 days
- Deployment: 2-3 hours

Overhead Communications "Tactical" series of integrated aerostat systems provide quick response and an extremely light logistics footprint. From two person operations to self inflating aerostat systems we can have you operational within minutes of arrival on station.

AS 2150HW

- Class: Tactical
- Person(s): 2
- Max. Weight: 140 lbs
- Max. Altitude: 2,000 ft
- Wind: 90 mph
- Duration: 3-5 days
- Deployment: 30 minutes

AS 3100SL

- Class: Tactical Plus
- Person(s): 3
- Max. Weight: 100 lbs
- Max. Altitude: 1,000 ft
- Wind: 35 mph
- Duration: 7-10 days
- Deployment: 7 minutes

3.4.8 ALLSOPP HELIKITES Ltd

Figure 47 Helikite with camera payload

Designed by Sandy Allsopp in 1993, **Helikites** are a patented combination of a **balloon** and **kite** that overcomes the shortfalls of normal tethered balloons, blimps and kites. Normal balloons are pushed down by wind, whereas Helikites are actually pushed up by it. Normal kites fall down in no wind whereas helium filled Helikites are lighter-than-air and fly in still airs. Normal tethered blimps have to be brought down in bad weather, whereas Helikites love flying to thousands of feet in high winds. This means that compact, easily handled Helikites have the performance of normal blimps that are many times larger and can work in almost all weathers.

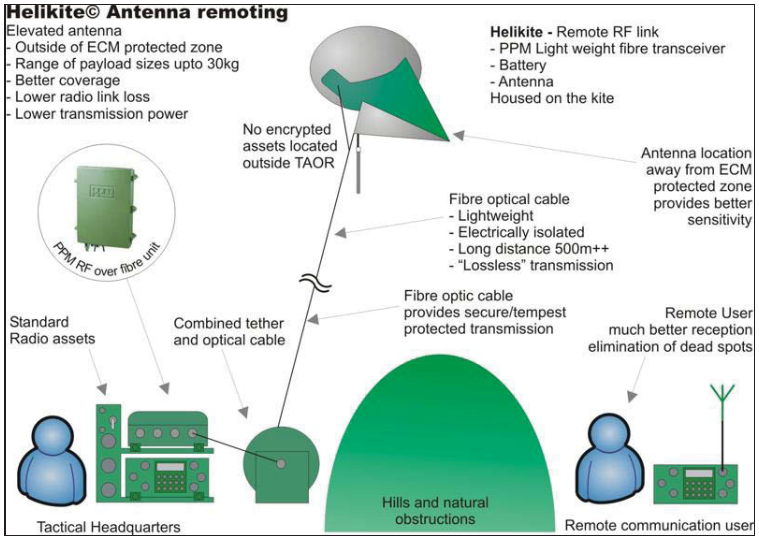


Figure 48. Helikite Radio Relay Configuration

3.4.8.1 Helikites Create Airborne Mobile Ad-Hoc Radio Network (MANET)

On Friday 19th October 2007, a small three cubic metre Low Visibility Skyhook Helikite lifted an ITT Spearnet Radio to 200ft above Allsopp Helikites flight testing grounds. Each Spearnet radio acts as a relay to every other radio, to automatically create a mobile, ad-hoc, internet-protocol network. Good line of sight reception was reached out to six miles between hills. This was an area about 100 X greater than the radio would perform alone. These radio waves can carry a lot of information including real-time video. However the high band width, high frequency radio waves required for this cannot bend around terrain. So without a high altitude relay they are normally restricted in range to less than 0.6 miles.

With a Skyhook Helikite a single soldier can create a large, reliable and widespread radio network in just a couple of minutes, from one position. Compare this to the present method, of using hundreds of soldiers to fight and capture every hill in the district for radio-relay purposes and then providing hundreds more soldiers to constantly defend them from attack.

This test was carried out with the Helikite flying at only 200ft which is the legal altitude limit. However, there was enough spare lift to have flown the 700g radio to 1,500ft if allowed. This correlates with previous unconnected radio-relay tests in the USA using similar Helikites flown to 1,500ft that sent packet video data 61 miles in flat terrain and provided excellent coverage in hilly areas.

Helikites are inexpensive, all-weather and permanent. Everything needed, including Helikite, helium cylinder, line and reel only comes to a weight of 15Kg and can easily be fitted into a small rucksack. Therefore this is a significant event, because for the first time there is an easy and practical way to spread the full power of the internet over the full surface of the land or sea without the need for expensive infrastructure.

3.4.8.2 Classes of Allsopp Helikites

HELIKITE TYPE	HELIUM CAPACITY	BALLOON MATERIAL THICKNESS (THOU' INCH)	LIFT IN NO WIND	LIFT IN 15 MPH WIND (APPROX.)	MAX WIND SPEED (APPROX.)	MAX UNLOADED ALTITUDE (APPROX.)	HELIKITE LENGTH	PRICE
VIGILANTE	0.15cu m	1	0.03Kg	0.15Kg	25mph	1,000ft	3ft	**£119**
LIGHTWEIGHT	0.15cu m	1	0.06Kg	0.18Kg	25mph	1,300ft	3ft	**£98**
SKYSHOT	1.0cu m		Camera of 200g		25mph	2,000ft	5ft	**£450**
SKYSHOT	1.6cu m	2	Camera of 250g		30mph	2,500ft	6ft	**£820**
SKYSHOT	2.0cu m		Camera of 550g		30mph	3,000ft	7ft	**£920**
SKYHOOK	1.0cu m	2	0.3Kg	1.5Kg	28mph	2,000ft	5ft	**£400**
SKYHOOK	1.6cu m	2	0.5Kg	2.5Kg	30mph	2,500ft	6ft	**£750**
SKYHOOK	2.0cu m	2	1.0Kg	4.8Kg	32mph	3,000ft	7ft	**£850**
SKYHOOK	3.3cu m	3	1.2Kg	6.5Kg	35mph	4,000ft	9ft	**£1,100**
SKYHOOK	6.0cu m	3	3.0Kg	9.0Kg	40mph	6,000ft *	11ft	**£1,900**
SKYHOOK	7.0cu m		3.5Kg	10.0Kg	42mph	6,300ft *		**£2,100**
SKYHOOK	11cu m	3	5.5Kg	12.0Kg	45mph	7,000ft *	12ft	**£2,600**
SKYHOOK	16cu m	3	8.0Kg	16.0Kg	46mph	8,000ft *	13ft	**£POA**
SKYHOOK	24cu m	6.0	9.0Kg	20.0Kg	50mph	8,000ft *	16ft	**£POA**
SKYHOOK	34cu m	6.0	14.0Kg	30.0Kg	60mph*	9,000ft *	22ft	**£POA**
SKYHOOK	64cu m	6.0	30.0Kg	70.0Kg	70mph*	10,000ft *	26ft	**£POA**

3.4.8.3 Tactical Aerostat Size

Much has been written about tactical aerostats for military or police use. The blimp aerostat always has the problem of it needing to be big (30 cubic metres+) in order to fly well in even moderate winds. Blimps under 100 cubic metres are seldom able to go above 1000ft and most blimp aerostats cannot fly reliably in high winds however big they are. This is because they are only able to exploit weak helium lift for flight and so are blown down by wind.

Helikites, are not blimps. Helikites are semi-rigid and exploit powerful wind lift as well as helium, so a Helikites of only 11 cubic metres can fly thousands of feet high in no wind, or in in gale force winds and can stay at high altitude unattended for weeks

Launched within 20 minutes, a 14ft long, 11 cubic metre (385cu feet), Skyhook Helikite carrying gyro-stabilised pan/tilt/zoom video camera can provide continuous, long-term aerial surveillance over many miles. Manpower needed is just one. Running costs are minimal.

3.4.8.4 **Personnel Requirement**

Ground handling normal large blimps can be a nightmare in winds over 30 mph, especially at night. This major problem is seldom addressed beforehand in the vain hope that it might somehow magically not occur. So the troops or police end up with serious trouble and risk ground handling huge blimps being whipped around by strong, unpredictable ground winds. In high winds these blimps and handling lines can easily break a mans arm or haul him off his feet and throw him against a wall if he is not careful. Serious injury can be caused and damage to the blimp envelope or the payload is likely. We have even heard rumours that troops in theatre have deliberately ripped open the blimp envelopes with their bayonets to quickly deflate them in high winds. We cannot know for sure if these accounts are true, but it would be understandable if there were not the recommended number of ground-handling personnel available at a critical time.

The blimp aerostats long shape and its sensitivity to ground winds will always make it a ground-handling problem. So however light the payload may be, normal blimp aerostats will still need excessive helium, personnel and ground equipment to function successfully in the military environment. We do not consider this truly tactical. These blimps may also have little in the way of long-term mooring facilities or protective hangers which is essential for military use.

Helikites are different. Even tiny Helikites can fly in higher winds and to higher altitudes than normal blimps, so Helikites do not need to be large to be all-weather. Therefore as payloads become smaller and lighter due to advances in technology, it makes sense to use Helikites to lift them instead of unwieldy blimp aerostats.

Ground handling Helikites is very easy. Helikites under 20 cubic metres can easily be man-handled by one or two people in high or low winds. Helikites of 20 cubic metres upwards are used with an inflatable Helibase which enables their inflation, deflation, launch, flight, and recovery to happen in almost any weather conditions, by only one trained operator - although two is slightly quicker.

Helikites can even be launched and recovered remotely - with no people present at all. They are simply winched off or onto the Helibase. This is possible because Helikites derive much of their stability from gravity which is always constant even when the Helikite is in difficult ground winds. As the Helikite approaches the ground, the buoyant balloon at the front of the Helikite and the aerodynamic lift caused by the speed of winching, keeps the front up - thus keeping it out of danger. The back end of the spar is the only thing that may touch the ground and it is protected for this purpose. All the recovery is done via remotely operated winches. Nobody need to go near the Helikite until it is safely pulled firmly onto the Helibase. Then a few extra safety lines can be attached if so wished, or a tarpaulin can be thrown over the Helikite to camouflage it or protect it from the elements.

In tactical situations, especially overseas, the number of personnel available is severely limited. Normal tactical blimp aerostats will require a personnel ground-handling requirement from 1 to 10, depending upon the size of the blimp and the wind speed. But nobody can predict the future likely wind speed. So a commander may have to keep 10 personnel on stand-by in case the wind gets up. Considering that the cost of sending one US soldier to Iraq has been estimated to cost US$1 million those troops on blimp handling stand-by are pretty expensive.

Compare the Helikite with its Helibase. The commander knows that he only ever has to have one or two people on stand-by, and as these will be needed to monitor the output of the payload anyway, there is no practical increase in personnel required. This saves huge amounts of money that can be spent on other resources.

3.4.8.5 **Speed Of Deployment**

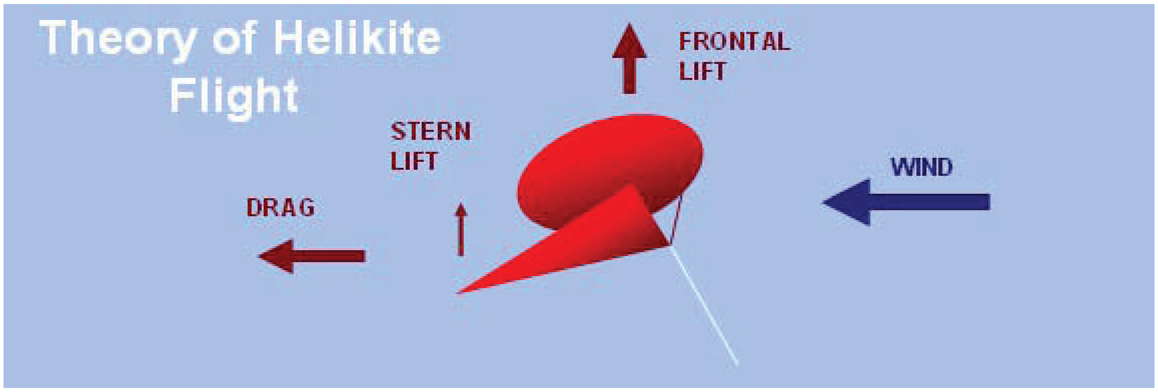
Instant deployment is the ideal. This can never be achieved by a normal blimp aerostat that needs to be inflated prior to use. It always takes a few minutes to inflate a blimp and often some hours for the larger ones. The size of normal blimps precludes them being transported fully inflated. A blimp small enough to fit inflated in a road trailer is not generally able to cope with more than light winds.

However, unlike normal blimps, Skyhook Helikites of 5 cubic metres or less are small enough to allow them to be kept fully inflated in a small road trailer allowing instant deployment (See products section). These small Helikites are able to fly steadily to altitudes of thousands of feet in winds up to 45 mph. This size of Helikite has enough lift to carry video cameras, radio-relays, sensors etc.

Larger Helikites cannot fit in a road trailer when inflated, but they are still have a far smaller footprint than an equivalently performing blimp and are much faster to deploy. An example is the Mobile Operations Room/Helibase (see products section) created to deploy the 34 cubic metre Skyhook Helikite. The Helikite can be safely deployed within 20 minutes, by two people, from the top of a road trailer capable of being pulled by a SUV. It is designed to provide mobile emergency communication relay.

The new Cased Helikite Aerostat Maintainable Platform (CHAMP) allows the deployment of a 10 cubic metre Skyhook Helikite within 30 minutes. The unique part of the CHAMP is that it also includes an excellent Helibase with top cover thus also creating a permanent, safe base for the Helikite - not just a minimal launch platform.

3.4.8.6 Weather Dependency



Normal blimp aerostats are not good in high winds at altitude but they are even worse near the ground. So their practical wind limits are often far lower than is apparent from reading their technical specifications. For example, the huge Meteorological blimp at Cardington, UK is capable of flying in winds up to 50 mph, however, it cannot safely be launched or retrieved in winds over 30 mph. So it tends to be brought down as the wind reaches about 27mph - just in case the wind increases as the blimp is descending.

Other tactical aerostats may seem to have excellent rapid inflation systems, but these can only function when there is very little wind. These systems are designed for nice weather. If there is significant wind the blimp cannot safely be launched at all - never mind quickly.

Helikites are designed for foul weather deployment and foul weather flight. Even the largest Skyhook Helikites can be launched and retrieved in all the winds that they can fly in. So deployment and flight can occur safely in winds up to 50 or 60 mph.

3.4.8.7 Ground Footprint

This means the equipment needed, and the space on the ground, to transport, inflate, launch, recover, deflate and store the aerostat. Large aerostats need large footprints - especially long, thin blimp aerostats. This is because their large surface area to volume ratio, and their need to be big to cope with wind, means they need far more helium than Helikites per kilo of payload. Helium is very heavy to transport because is does not compress to a liquid at room temperature, but only to a compressed gas in relatively heavy high pressure cylinders. So compressed helium cylinders are very large per cubic metre of useable gas compared to cylinders of carbon-dioxide or oxygen that can be compressed to a small volume of liquid. As much military equipment is moved by scarce air transport assets, it is essential to do everything to reduce the volume of a tactical aerostat.

Big aerostats also need big heavy motorised winches and tall, steel towers to moor against that allows them to rotate with the prevailing wind. This rotation requires a large area of flat ground or sea. The winches need inflammable fuel and spare parts. All this equipment needs strong containers to transport it in and trucks to move it as well as numerous personnel to move it - who need housing, food, transport, protection etc, etc. So, creating the ground footprint for a normal blimp aerostat large enough to cope with high winds, is a big and expensive logistical exercise.

The ground footprint of an all-weather Helikite is minimal. The C.H.A.M.P. is a self-contained tactical aerostat system with a 10 cubic metre, Skyhook Helikite, Helibase, hand-winch and enough helium cylinders to give months of flying all contained within one 4ft x 4ft x 4ft palleted container weighing only 190 Kg. One person can easily set it up. The heaviest piece of equipment within the container only weighs 15Kg so the load can easily be split up and back-packed by a few soldiers if required. The resting Helikite is not affected by the wind and so does not need to rotate and thus needs minimal space. The 10 cubic metre Skyhook Helikite is a superb aerostat, able to fly to thousands of feet in winds up to 50 mph lifting a payload of 5kg. It will cope with far higher winds than blimps many times its size and yet is small enough to be quickly winched in or out with a simple, lightweight, robust hand winch - that requires no heavy engine, flammable fuel or expertise.

3.4.8.8 Mountain Use

Tactical aerostats are often required to be used in mountainous areas where the starting altitude is 5000ft or higher. Air is thinner at high altitudes and so helium lift is reduced and cannot support such payloads for a given volume. This affects all aerostats but the problem is far less with Helikites because Helikites are rounded compared to normal long-thin blimps and so Helikites have a better surface area / volume ratio. Also the wind lift that Helikites can exploit is vital to cope with catabatic winds, thermals and other difficult airs around mountains. Helikites perform far better than normal blimps at high altitude.

3.4.8.9 Tactical Uses For Helikites Aerostats

Helikites are truly tactical aerostats. Deployable within seconds and capable of long-duration, all-weather flight to thousands of feet. They are lightweight to transport, easy to understand and fly. They are very steady platforms in foul weather, have a tiny footprint and only ever need one or two people in any weather.

Helikites make mobile, low cost, persistent aerial surveillance possible. They can lift cameras way above the range of small arms fire and often out out of sight of the naked eye for truly covert surveillance.

Tactical Helikites enable the instant creation of long-term, reliable, high bandwidth, over-the-horizon communications between personnel and vehicles. This allows internet protocol ad-hoc radio networks to be extended from headquarters out to personnel and unmanned vehicles situated far away. Thus enabling control of unmanned ground vehicles, security cameras, sensors etc. to occur via the internet. So operators situated thousands of miles away can take over the work of local security personnel.

Carolina Unmanned Vehicles[29]

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3.4.9 Lightweight Aerostat System (LAS)

3.4.9.1 Background

There is a pressing domestic security, law enforcement and emergency response need for a low cost, responsive, and mobile equipment for resilient and durable communications after an event responsible for the loss or serious degradation of existing communications systems (e.g., due to a natural disaster, major incident, or terrorist act). Local, state and federal law enforcement agencies, the US Coast Guard and Border Patrol also need overhead EO/IR surveillance of outdoor venues, VIP events, border crossings, seaports, airports, etc. that is both less costly and intrusive than helicopters, while providing around the clock coverage. The most efficient means of meeting both these requirement is a low cost, mobile aerostat system. However, traditional aerostats are large, manpower intensive and cannot operate in adverse weather conditions. This has limited their use to a few fixed sites flying large aerostats. Carolina Unmanned Vehicles (CUV) has developed the **Lightweight Aerostat System (LAS)**, a solution that removes these limitations, resulting in a small, mobile and very cost effective system.

3.4.9.2 LAS Concept

The Lightweight Aerostat System (LAS) consists of a small specially designed tethered blimp, called a Helikite, mounted on a trailer Carrier (Fig. 1). The LAS blimp can be flown at several hundred to thousand feet altitude to provide coverage 24 hours a day for a week or more without maintenance or downtime. Operating and maintenance cost is a fraction of the cost of using aircraft or Unmanned Air Vehicles (UAVs) to lift the surveillance or relay payloads. LAS can elevate a communications relay payload up to 4000 feet, providing extended communication coverage out to 40 or more miles from its location, or a circle 80 miles in diameter. Surveillance versions at 500 feet can cover a radius of 15 to 20 miles, depending upon terrain. LAS consist of several unique components that, taken together, comprise a system far smaller and more versatile than any comparable unit. The patented Helikite combines aspects of kites and blimps to operate in much higher winds than traditional aerostat designs, improving system utility and capability in adverse weather. LAS is very mobile and cost-effective through use of unique designs to reduce the need for ground crews to handle the blimp during launch and recovery. It is carried by a single trailer and operated by a two person crew. A small truck can tow the complete system. Prototype military systems with communications and camera payloads have been delivered. The Technology Readiness Level (TRL) would be 8 or 9 for the basic LAS, with the law enforcement communications payloads at TRL of 5 or 6.

Figure 49 Carolina Unmanned Vehicle (CUV) Lightweight Aerostat System

3.4.9.3 CUV Lightweight Aerostat System

- Helikite Lifting Aerostat
- Helirest Protective Mount
- Gyro –Stabilized Camera Payload
- Networked Communications Payload
- Acoustic Gunfire Detectors / Other Payloads

3.4.9.4 LAS Advantages

There are significant operational advantages to using LAS as a platform for surveillance and communications relay payloads:

i. Long Mission Duration, of a week or more;

ii. Low Acquisition Cost, starting at $150,000 for the Carrier and Helikite, total cost depends on the payload;

iii. Very Low Manpower, requiring only two persons to launch and retrieve the system;

iv. Very Low Deployment Requirements (Road and off-road mobile, and only a partial C-130 load for air transport);

v. Ability to cover a very large area, of 40 miles radius;

vi. Ability to function as a translator node for interoperability; and

vii. Ability to act as a network bridge in-the-sky, providing seamless connection of computer and network resources across a wide area.

3.4.9.5 LAS System Description

A complete LAS system of Helikite and Carrier can be towed by a HMMWV, pickup or SUV. It can be readily deployed by National Guard transport aircraft, or helicopters. On deployment location the blimp would be inflated and raised to its operating altitude on the tether. The blimp can be easily retrieved and stored in its Carrier for movement to another location. The entire deployment can be accomplished in under thirty minutes. An onboard generator powers the payload and winch. The helium tanks are standard commercial items.

3.4.9.6 Helikite

The key to making LAS a very compact but versatile system is the Helikite. Developed and patented by Allsopp Helikites Ltd. of Great Britain, Helikites combine a kite and a balloon, employing the advantages of both without incurring their disadvantages. The Helikite employs small flexible fabric wings and keel attached to the body of a helium balloon, combining helium and wind lift to operate easily in high wind speeds and at a fraction of the cost and trouble compared to normal lighter-than-air designs. Why does this Helikite design make a difference? An ordinary blimp in zero wind floats straight up from its tether location, with the helium exerting an upward force and the tether an equal downward force. However, the tether cannot exert a sideward force to counteract wind forces, so traditional blimp shaped aerostats are driven into the ground by only moderate wind. The normal method to counteract wind drag and keep aerostats stable is to increase the buoyancy significantly beyond that required to lift the payload.

However, greater buoyancy requires a significantly larger blimp, resulting in greater cost, difficulty in ground handling and additional personnel. It is a limited solution in any event. Wind drag increases with the square of the wind speed, so very large forces can be created at medium winds. The Helikite is lighter-than-air like a balloon but is not knocked down by the wind like a normal balloon. In fact, the opposite occurs - wind actually forces a Helikite up! Wind forces on the wings and the airfoil shaped balloon generate a force that maintains both the blimp body and

Helikite wings at an angle of attack that generates additional lift to counteract the wind side force. The Helikite is also far more intrinsically stable than traditional blimp designs. With this force to counteract the wind drag the Helikite does not need a large buoyancy margin and we can design the LAS to use modern lightweight electronics. The LAS Helikites will be able to fly in winds up to 70 mph. Other aerostats must be considerably larger to withstand wind forces, typically with buoyant lift of 200 to 300 pounds just for wind stability. This prevents them from being designed to small payloads, and makes them large, clumsy and expensive. Helikite performance is the key that allows LAS to be very compact, use minimum helium and be operable by only two people.

Compared to other traditional tethered blimp systems currently in use, the typical LAS aerostat is very small. Payloads vary according to the size of the aerostat, but generally a Helikite has approximately one kilogram of lift per cubic meter of helium. For example, a 60 cubic meters (2100 ft3) Helikite has a lift of approximately 30 kg (66 lb.) but a diameter of only 5.5 meters (18 feet) and total length of 9 meters (29 feet). For normal operations the aerostat is equipped with FAA compatible lights and banners for visibility. On the other hand, LAS can employ a low signature Helikite design developed for Army tactical use for covert operations such as anti-drug surveillance. The tactical Helikite is constructed from radar transparent material, its Infra-Red signature is very small, and use of transparent materials makes it almost invisible at few hundred feet altitude.

3.4.9.7 Carrier

Until launch the uninflated LAS Helikite is contained in a mobile Carrier with helium tanks, an electric generator, a tether and a winch to raise and lower the tether. Many comparable aerostat handling systems are five to ten times as large, and require multiple trucks for carriage. The standard Carrier body is based on a modified commercial utility truck body mounted on a standard military trailer, which keeps the cost low. In operation the Carrier is towed by a HMMWV or other standard small truck. The tow vehicle would move LAS to a suitable launch point away from tall trees, overhead power lines or other obstructions. During launch and recovery in wind traditional blimps require several people to avoid ground handling problems, which can easily damage the blimp, particularly when half-inflated. LAS inflates the Helikite inside an air inflated unit, called a Helirest, that protects and restrains the Helikite, minimizing wind effects and allows two person operation.

The current military Carrier designs, as shown in figure 1, launches the Helikite from the Helirest placed on the ground behind the Carrier trailer. We have developed a modification to the military Carrier that can launch the aerostat directly from the trailer back, reducing launch times and avoiding any issues with muddy or flooded soil. A smaller palletized unit mounted on the back of a Pickup or HMMWV , can deploy smaller Helikites, up to 25 lb. payloads, directly from the back of the Carrier. The pallet unit can be used on small ships or in fixed locations. These designs also allows the Helikites to be moved about on the Carrier while inflated and elevated within a minute or so of stopping the trailer, for “quick look” missions such as border surveillance.

A Carrier mounted on a commercial trailer is also available .These are more spacious and provide better work environments for the sensor operators than the military trailers. But they have low ground clearance, so they are not off road capable. The military based units are off road capable, air transportable and can respond to any location accessible by a HMMWV. .

Figure 50. Carolina Unmanned Vehicle Launch Trailer

3.4.9.8 Applications

LAS will provide a unique and cost effective overhead capability for many electronic payloads. The main usage categories are communications, law enforcement surveillance and security, and atmospheric research. LAS basic simplicity and the modular design allows it to be manufactured at relatively low cost with minimum capital investment.

3.4.9.9 Relay Platform for Emergency Voice Communications

In this role, the LAS payload could relay voice communications over a wide coverage area. The LAS would act as a transponder, and convert voice communications between frequency bands. In this manner, emergency responders would have seamless communications with remote emergency management personnel at extended ranges, with no dependence on (potentially) inoperative wired, cellular or point-to-point communications links.

3.4.9.10 Network Bridge

Access to computer communications and emergency networks is critical for responders and emergency management. LAS can act as a network bridge in-the-sky, providing seamless connection of computer and network resources. Ground networks or individual computers would communicate to the bridge using inexpensive wireless network interface cards, bi-directional amplifier and antenna. A dedicated frequency band could be employed to ensure non-interference with any other ground assets. Field users would have complete access, as authorized, to all required emergency computer networks, with encryption and authorization techniques as required.

3.4.9.11 Translation For Interoperability

Communication interoperability between local, state and federal agencies has been a major problem in all natural disasters and terrorist incidents. In the translator role LAS would receive multiple signals from various agencies, translate them in a ground terminal on the Carrier and then rebroadcast the signals to users equipped with different equipment. Translator hardware is expensive compared to other equipment, so LAS's broad area coverage would maximize the utility of the translator system. It would eliminate the need for multiple vehicle mounted translator nodes, maximizing communications interoperability with minimum investment. This would greatly enhance interoperability between local, state and federal units.

3.4.9.12 Surveillance and Security

A surveillance version of LAS can be equipped with Video or IR sensors. The current camera payload is a stabilized turret system currently being used on Boeing's **ScanEagle** UAV deployed to Iraq (Its gyro stabilized mounting allows detailed surveillance of people and vehicles out 3 miles or more). Other cameras, including IR units, are being studied for adaptation to LAS. LAS with surveillance cameras and gunfire locator payloads could be utilized by law enforcement agencies and commercial security companies for surveillance of outdoor concerts, fairs, races, VIP events, etc. LAS could also support anti-terrorism surveillance at critical target facilities such as nuclear power plants, or enhance VIP protection for the Secret Service. It would be both less costly and intrusive than helicopters, while providing complete 24/7 coverage. LAS can provide feedback directly to on scene officers and to a central dispatcher / monitoring point, enhancing police coverage of such events, and allow concentrating officers at key points. LAS could assist fire and emergency rescue personnel in control and assessment of activities at major fires and similar emergencies. The Border Patrol could maintain 24/7 overhead wide area surveillance coverage of border crossings, airports, docks etc.

Figure 51. LAS Trailer [30]

3.4.9.13 LAS Commercial Trailer Version Testing

The LAS commercial trailer version shown launches the Helikite directly form the trailer roof, to speed the deployment process. The Helikite shown is a 35 meter cubed unit with a 35 lb. lift at standard sea level atmospheric conditions. The unit is self-contained with Helium tanks, power and winch internally mounted. Internal workspace is also provided. A variant of LAS could provide a platform for rapid assessment of hurricane or other storm damage across a large area. The lightweight Hood Technology camera only requires a Helikite approximately 9 feet in diameter, so it can be transported fully inflated in the back of a truck or on a small utility trailer. In typical operations an assessment team would drive to neighbourhood carrying the inflated Helikite in the back of a truck or on a small trailer. The team would raise the LAS to several hundred feet and do a video survey of all affected areas. It would be able to survey several blocks at on time, not only the areas visible from the street but also backyards, alleys, etc. After completing the survey the Helikite would be brought down to the truck and quickly moved to another neighbourhood while still inflated. This process could be repeated to survey an entire community in a few hours.

3.4.9.14 Technology Maturity

Prototype LAS, consisting of Carrier, Helikite and payloads, have been delivered to several customers. Therefore the Technology Readiness Level (TRL) of the basic system is 7 or 8. We can deliver basic LAS versions in 5 to 6 months from contract start.

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[30] http://carolinaunmanned.com/node/88

CUV as the prime developer of LAS has teamed with several different companies to develop and integrate various payloads into LAS. Hood Technologies of Oregon have developed the lightweight but very capable Alticam stabilized camera system that is the basic sensor for the LAS-SS surveillance version. Other cameras can be adapted to the system, and we are discussing gyro-stabilized turrets with both Electro Optic and Infra-Red capability in one turret. Companies experienced in communications systems for law enforcement and emergency management organizations can be team members for the communications relay applications. Specific payloads will have to be developed from existing components so the TRL for these are 6 or 7, depending upon the exact specifications of the payload.

3.4.9.15 Cost And Procurement

Typical cost for a LAS ranges from $150,000 to $450,000, exclusive of the payload. Obviously the payload cost can vary widely, depending upon the mission. Cost depends upon the payload weight and the operating altitude, which affect the size of the Helikite and Carrier. Also, cost can vary due to factors such as the degree of payload integration or the deployment timelines. For example, a system requiring payload power or data to be transmitted up the tether will require more integration than one carrying a battery powered payload. Likewise, a version requiring rapid deployment and retrieval may require more powerful, and more expensive, winches than a system that can accept somewhat longer timelines. These variables make it impossible to provide across performance and cost estimates for specific versions.

3.4.9.16 Summary

LAS have great potential to as a platform for various communications relay concepts, local area security / surveillance and other missions. It can provide low cost, highly mobile platform with mission duration of a week or more. It can operate in weather conditions too severe for many UAVs or aircraft, or other aerostats, and does so without endangering an aircrew. It is a cost effective solution to many Homeland Security missions. By integrating off the shelf subsystems, specific versions can be quickly developed in concert with the customer. In a typical system payload integration would be the pacing item, but most versions the LAS platform can be developed and produced in three to six months.

3.5 Ground Handling Considerations

3.5.1 Hangarage

The Aerostats mentioned in this document are small enough that a standard garage could provide suitable hangerage for the system. Most have a requirement for a truck and trailer combination.

3.5.2 Mooring

Aerostats are moored to their carrying system through the winch system employed with the unit. Additional ground stakes are recommended as a method of grounding the system.

3.6 Airship Manufacturer Database[31]

3.6.1 Active Manufacturers with Flying Airships/Aerostats

- Guardian Airships
- 21st Century Airships
- Advanced Technologies Group (formerly Airship Technologies)
- Allsopp Helikites
- American Blimp Corporation
- Boland Balloon
- Cameron Balloons
- CargoLifter AG
- Carolina Unmanned Vehicles
- GasKites Aerostats
- GEFA-FLUG GmbH
- Global Skyship Industries Inc.
- Goodyear / Lockheed-Martin
- Hamilton Airship Company
- ILC Dover
- Interface Airships Inc.
- Jump'Air
- Kubicek Balloons s.r.o.
- Prospective Concepts AG
- Raven Industries
- TCOM LP
- Thermoplan
- Thunder & Colt
- US-LTA Corp.
- Voliris
- Westdeutsche Luftwerbung GmbH (WDL)
- Worldwide Aeros
- Zeppelin Luftschifftechnik GmbH

3.6.2 Companies in the Design and Construction Phase

- Advanced Hybrid Aircraft (AHA)
- Airtrain Flugschiffbau AG
- Arctic Antarctic Static Airship Company
- Dirigeables Bride
- LTAS/Cambot LLC
- Ohio Airships, Inc.
- Quantum Aerostatics
- Rigid Airship Design N.V.

[31] http://www.myairship.com/database/index.html Copyright © 1995-2003 by Roland Escher - All Rights Reserved.

- RosAeroSystems s.r.a.
- SkyMedia Airships
- SkyStation, Inc.
- UPship Corporation

3.6.3 Inactive Airship Manufacturers

- Airship Industries
- Barnes
- Memphis
- Pan Atlantic/Nord-Am/Magnus
- Sblimp
- SkyRider Airships
- Thermoplane
- Thompson
- Ulita Industries
- Westinghouse Airships Inc.
- White Dwarf
- World Balloon Corporation
- SkyBoat (AeroTube)

4. COTS/MOTS Communication Relays

4.1 Platform External Communications

The following section provides an overview of COTS and MOTS communication systems that could be payloads of any of the platforms detailed above. CDL links provide for uni- and bi-directional links at 10.71, 137 and 274 MBps. Command and control functions typically can be handled within about 300 kbps. It is in transmitting or relaying sensor data that the demands come. As higher resolution electro-optical sensors are realized and move from transmitting NTSC or PAL signals to MPEG 2 streams (complete with metadata) of 720p and 1020p High Definition sensor imagery the demand jumps dramatically. In order to keep this demand manageable, new compression techniques have been pioneered and agreed to. The H.264 compression algorithm is making transmission of two simultaneous 720p video streams possible in a single TCDL 10.71 MBps link possible. Sensor resolutions and compressions standards for UAV systems are covered fully in STANAG 4609. There are also allowances for new hyperspectral sensors that produce even more raw data per second.

The off-platform bandwidth requirements for radar sensors vary. If all of the processing is done onboard the aircraft and only track information is forwarded, very little bandwidth is required. However if SAR imagery or raw sensor data is forwarded to the ground only the very large capacity sensor data links such as the Common Data Link can accommodate the bandwidth demand.

This section looks first at frequency spectrum allocated for military communications and then the details of STANAG 7085 – CDL, STANAG 4660 – IC2DL, and, finally, Tactical Data Links.

4.2 Frequency Spectrum

The overarching C4ISR system is completely dependant on having the bandwidth available to move sensor data off of the platform. For domestic operations, Industry Canada is responsible for the radio spectrum. One issue that has come to the forefront in recent years is the conflict between the NATO STANAG 7085 CDL frequencies and the satellite upload/download frequencies. The current allocation of frequencies to industry precludes use of CDL and TCDL data links in Canada. The following gives an overview of the frequency allocation process including US military plans for frequency migration.

> *On a global scale, the International Telecommunication Union establishes frequency allocations and regulations for the use of the spectrum and the processes for the coordination of frequency assignments. On a regional scale, the principal body to address spectrum use is the Inter-American Telecommunication Commission, which deals with spectrum and standards issues in the Americas and advocates these views at the global level.*
>
> *Within the Canadian communications environment, use of the radio frequency spectrum is contingent on a balanced set of spectrum and licensing policies, radio regulations, radio system standards, rules, procedures, and practices designed to maximize the economical usage of the spectrum while minimizing the impact of one use on another. The Ministry of Industry, through the Department of Industry Act, the*

Radiocommunication Act and with due regard to the Telecommunications Act, is responsible for developing national policies and goals for spectrum resource use, facilitating efficient development of radiocommunication in the public interest, ensuring effective management of the radio frequency spectrum and fostering the orderly development and operation of communications in domestic and international spheres.

Within the CF, Director Information Management Technologies, Products and Services 5 (DIMTPP 5) ensures that Army, Navy and Air Force commanders have sufficient spectrum to conduct operations and training in peace and war (Doyle 31).

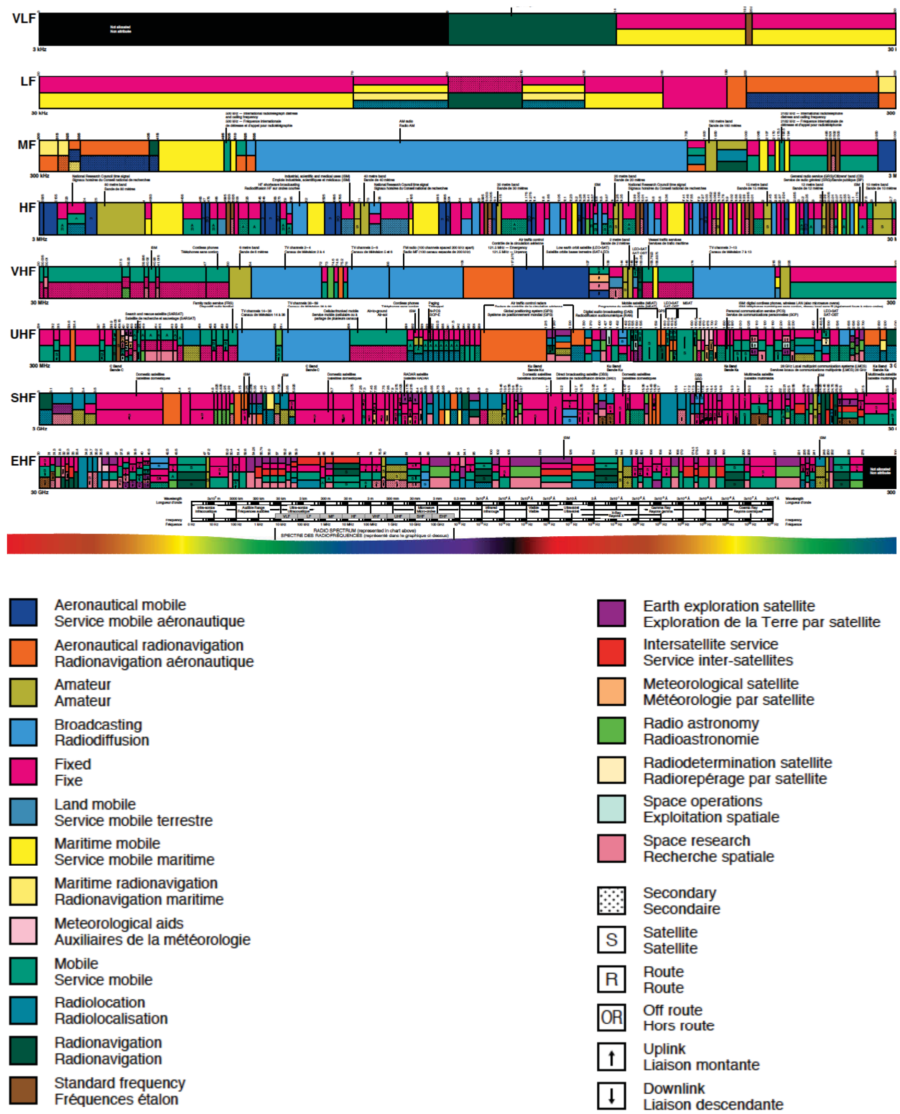


Figure 52: Radio Spectrum Allocations In Canada[32]

The above chart, Figure 45, gives a pictorial representation of the exceptionally crowded spectrum here in Canada. Much of the spectrum in the higher bands which can provide the military with higher bandwidths have been allocated to satellite communications. Figure 53and Figure 54 are expansions on the above graphic to show the current allocations in Ku/Ka and to point out that there are currently issues with obtaining frequencies to operate NATO STANAG 7085 compliant CDL and TCDL equipment in Canada because of competing interests. The 14.5 – 15.35 GHz frequency range is allocated to fixed sites with secondary use allocated to Mobile transceivers.

[32] http://strategis.ic.gc.ca/epic/internet/insmt-gst.nsf/vwapj/spectallocation.pdf/$FILE/spectallocation.pdf

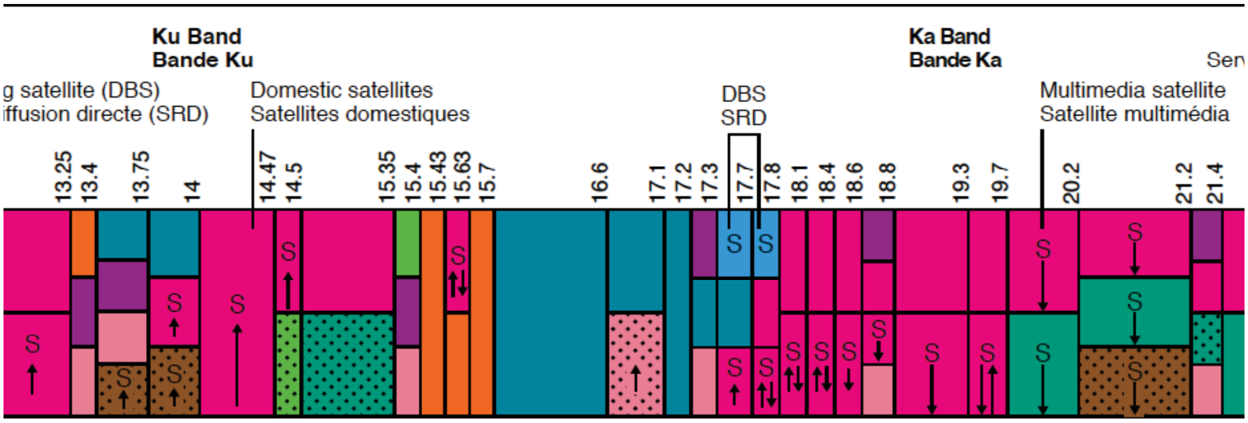


Figure 53: Ku and Ka Band in Canada – Note: TCDL 14,500-15,350 MHz, UAV Satcom Downlink 20200-21200 MHz, Satcom Uplink 30,000-31,000 MHz,

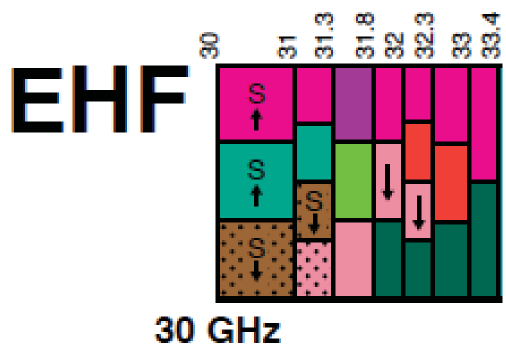


Figure 54: Ka Band - Note: US UAV uplink Frequencies 30,000 -31,000 MHz

4.2.1 US DoD UAV System Radio Frequency Spectrum Plan

The following table, details the current draft of the US DoD UAS Radio Frequency Spectrum Plan as recommended by Marvin H. Hammond Jr., MITRE Corporation. The requirement to maintain interoperability with US forces makes this a critical document. The following text accompanied the table as a Memorandum for:

i. Assistant Secretary Of The Air Force (Acquisition)

ii. Assistant Secretary Of The Army (Acquisition, Logistics And Technology)

iii. Assistant Secretary Of The Navy (Research, Development And Acquisition)

iv. Director, Defense Advanced Research Projects Agency

v. Special Operations Acquisition And Logistics (Special Operations Command).

SUBJECT: Unmanned Aircraft Systems (UAS) Spectrum Regulatory Policy Guidance

With increased reliance on UAS in the Global War on Terrorism and for other missions, the need for spectrum regulatory compliance is essential to ensure successful deployment within CONUS and OCONUS. Recognizing the importance of regulatory compliance and its role in reducing radio frequency interference (RFI), the Office of the Assistant Secretary of Defense for Networks and Information Integration (ASD(NII)) and the Office of the Secretary of Defense UAS Planning Task Force initiated studies to provide a sound technical basis for recommending frequency band allocations for UAS data links.

The attached UAS Radio Frequency Spectrum Plan (Table 8) *assigns threshold frequency bands with implementation dates for large and medium sized UAS programs. Additional objective frequency bands for each system will be reviewed on a case-by-case basis. Guidance for small UAS will be provided in 3rd Qtr FY 06 following the completion of on going studies. The Services will also be given additional direction regarding data link framing and transport standards so as to be compatible with current Global Information Grid plans.*

The Services must continue to adhere to Department Policy outlined in DD 4650.1, "Policy for Management and Use of the Electromagnetic Spectrum". This includes consulting the Service Frequency Management Offices when completing their DoD Form 1494 for spectrum authorization. A waiver from the policy will only be granted at the discretion of the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)) and the ASD(NII). This guidance should further minimize the potential for RFI, increase the effectiveness of UAS operationally, and enhance the UAS acquisition processes. [33]

[33] pdf document: 050510_USA_UAVSpecrumUseRecommendations_draft.pdf obtained from UVS International ICB.

	Platform (See Note 1)	Sub systems	Type	Current Frequency Used (MHz)	Transition Freq to be Used (MHz) (See Note 2)	Implementation Date (See Note 3)
Army	**Hunter**	Data Link	Uplink (LOS) (See Note 4)	4415-4478; 4922-4985; 5215-5278; 5720-5785	4400-4825, 4835-4940, 14500-15350	FY08
			Downlink (LOS) (See Note 4)	4480-4645; 4755-4920; 5245-5420; 5555-5720		FY08
	I-GNAT	Data Link	Uplink (LOS) (See Note 4)	5625-5850	14500-15350	FY08
			Downlink (LOS) (See Note 4)	5250-5475		FY08
	Shadow	Data Link	Uplink (LOS) (See Note 4)	340-400; 2400-2483.5	4400-4825, 4835-4940, 14500-15350 (225 -380 MHz)	FY08
			Downlink (LOS) (See Note 4)	340-400; 2400 - 2483.5; 4400 -4940; 5250 - 5850		FY08
	ER/MP	Data Link	Uplink (LOS) (See Note 4)	15150-15350	14500-15350	FY08
			Downlink (LOS) (See Note 4)	14400-14830		FY08
		Ku SATCOM	Uplink	14000-14500	30000-31000	FY08
			Downlink	10950-12750	20200-21200	FY08
Army/ Navy	**Fire Scout**	Data Link	Uplink (LOS) (See Note 4)	225-400; 15150-15350	14500-15350 (225 -380 MHz)	FY08
			Downlink (LOS) (See Note 4)	225-400; 14410-14830		FY08
USMC	**Pioneer**	Data Link	Uplink (LOS) (See Note 4)	420-450; 4450-4570	4400-4825, 4835-4940, 14500-15350 (225 -380 MHz)	FY08
			Downlink (LOS) (See Note 4)	4750-4950		FY08
Navy	**BAMS**	Data Link	Uplink (LOS) (See Note 4)		14500-15350	FY08
			Downlink (LOS) (See Note 4)			FY08
		Ku SATCOM	Uplink		30000-31000	FY08
			Downlink		20200-21200	FY08

	Platform (See Note 1)	Sub systems	Type	Current Frequency Used (MHz)	Transition Freq to be Used (MHz) (See Note 2)	Implementation Date (See Note 3)
Air Force	**Global Hawk**	Data Link	CDL up (See Note 4)	9750-9950	14500-15350	FY07
			CDL down (See Note 4)	10150-10425		FY07
			KU SATCOM up	14000-14500	30000-31000	FY 08
			Ku SATCOM down	10950-12750	20200-21200	FY 08
	Predator	Data Link	Up-link (see Note 4)	5625-5850		FY 08
			Down-link Control (See Note 4)	5250-5475	14500-15350	FY08
		Ku SATCOM	Uplink	14000-14500	30000-31000	FY08
			Downlink	10950-12750	20200-21200	FY08
	Predator B	Data Link	Up-link (See Note 4)	5625-5850	14500-15350	FY08
			Down-link Control (See Note 4)	5250-5475		FY08
		Ku SATCOM	Uplink	14000-14500	30000-31000	FY08
			Downlink	10950-12750	20200-21200	FY08
DARPA	**J-UCAS**	Data Link	Up and Down Link (LOS)	225-400	14500-15350 (225 -380 MHz)	FY06
		SATCOM	Up Link	291-318	30000-31000	FY06
			Down Link	243-270	20200-21200	FY06
	A-160	Data Link	Uplink (LOS) (See Note 4)	225-400; 15150-15350	14500-15350 (225 -380 MHz)	FY08
			Downlink (LOS) (See Note 4)	225-400; 14410-14830		FY08
	Note 1: Future and unnamed UAS shall utilize the same spectrum bands as recommended for UAS that are within the same class (e.g., same general size, weight, and performance) Note 2: To enhance optimal frequency effectiveness, for use outside the United States and Possessions, all systems should incorporate the capability of tuning within the entire range of the bands indicated. Bands within ( ) are included for increased operational flexibility and greater probability of host nation approval for use. Note 3: Implementation date: After the beginning of the indicated FY, no funds should be expended to procure any UAS communication system that does not meet this guidance Note 4: Tactical Common Data Link or Common Data Link Waveform Required via OASD NII (formerly ASD(C3I) CDL Policy Memo dated 19 June 2001					

Table 8: DoD UAS Radio Frequency Spectrum Plan

4.3 Common Data Link (CDL) – STANAG 7085

The Common Data Link (CDL) (STANAG 7085) system is a family of full duplex, jam-resistant, point-to-point microwave communication links developed by the United States Government and used in imagery and signals intelligence collection systems.[34]

i. STANAG 7085 - Edition 2 (effective 15 January 2004) contains three annexes:
   - Annex A - Analog
   - Annex B[35] - Digital point-to-point
   - Annex C - Digital Broadcast

ii. STANAG 7085 – Edition 3 is in Draft form. It contains no annexes but defines two implementations:
   - Implementation #1: CDL Specification Rev F
   - Implementation #2: Digital Video Broadcast System (DVBS)

It is important to understand what CDL is not:

iii. TADIL (Tactical Data Link) family
   - E.g., Link 16 is established as the primary tactical data link for the dissemination of processed information directly to operators on the battlefield
   - Inherently not interoperable with CDL

iv. SCDL (Surveillance and Control Data Link)
   - Used to transfer Joint STARS targeting and other data to surface terminals
   - Not interoperable with CDL

v. C-band, analog, and other ISR data links

vi. Other tactical data links

The original CDL Standard Waveforms included four waveforms:

i. The Forward Link/Command Link is:
   - Transmitted from the Surface

ii. Uses Direct Sequence Spread Spectrum which is has the characteristics of:

- Anti-jam
- Low Probability of Interception/Detection
- 200 kb/s data rate

[34] Common Data Link Waveform Specification, Specification 7681990, Revision F, November 2002, p.1
[35] CDL Specification Revision E is Implementation #1

iii. The Return Link is
   - Transmitted from Airborne Platform
   - Available at three rates
     - 10.71 Mb/s
     - 137.088 Mb/s
     - 274.176 Mb/s

The standard CDL Waveforms has been expanded to support the following:

i. Forward Link Rates to include: 200 kb/s, 400 kb/s, and 2.0 Mb/s.

ii. Return Link Rates to include: 10.71 Mb/s, 21.42 Mb/s, 44.73 Mb/s, 137.088 Mb/s, and 274.176 Mb/s

iii. The following rates support both Forward and Return Link: 2.0 Mb/s, 10.71 Mb/s, 21.42 Mb/s, and 44.73 Mb/s

The CDL has the following functions:

i. Multiplexer/Demultiplexing to support multiple channels

ii. Randomization/Derandomization to ensure no long sequences of ones or zeros

iii. Differential Encoding/Decoding to resolve phase ambiguities

iv. Encryption/Decryption to protect transmitted data

Typically installations include 9-inch airborne antennas & 6 foot surface antennas. 70-Watt Traveling Wave Tubes (TWT) allow wideband data to be transmitted up to 300 nautical miles

4.3.1 Tactical Common Data Link (TCDL)

TCDL is a subset of the Common Data Link Specification for lower rate applications

i. Return Link Data Rates: 10.71 Mbps (200 kbps, 2 Mbps, and 45 Mbps coming soon)

ii. Forward Link Data Rates: 200 Kbps and 10.71 Mbps (2 Mbps and 45 Mbps coming soon)

iii. Ku-band required (X-band available)

All other parts of the CDL specification must be upheld by TCDL. TCDL is fully compliant to STANAG 7085 for the common rates above. TCDL is fully interoperable with existing CDL systems at common data rates. TCDL adds sensor interfaces connected to the standardized CDL ports

TCDL Air Terminal Equipment (ATE) Requirements

i. CDL compatible, Ku band only

ii. Narrowband 10.71Mb/s return link only

iii. 200 Kb/s forward link

iv. Superchannel return link multiplexer
v. Forward & return link encryption
vi. MPEG-2 coding for video data
vii. 150Km range in weather, over 200Km in clear
viii. -30° to +49° C (non-condensing)
ix. 25,000’ operational altitude
x. 23”x10”x4”, 17.5 lbs, 300W
xi. Flexible, expandable, scalable, modular, affordable

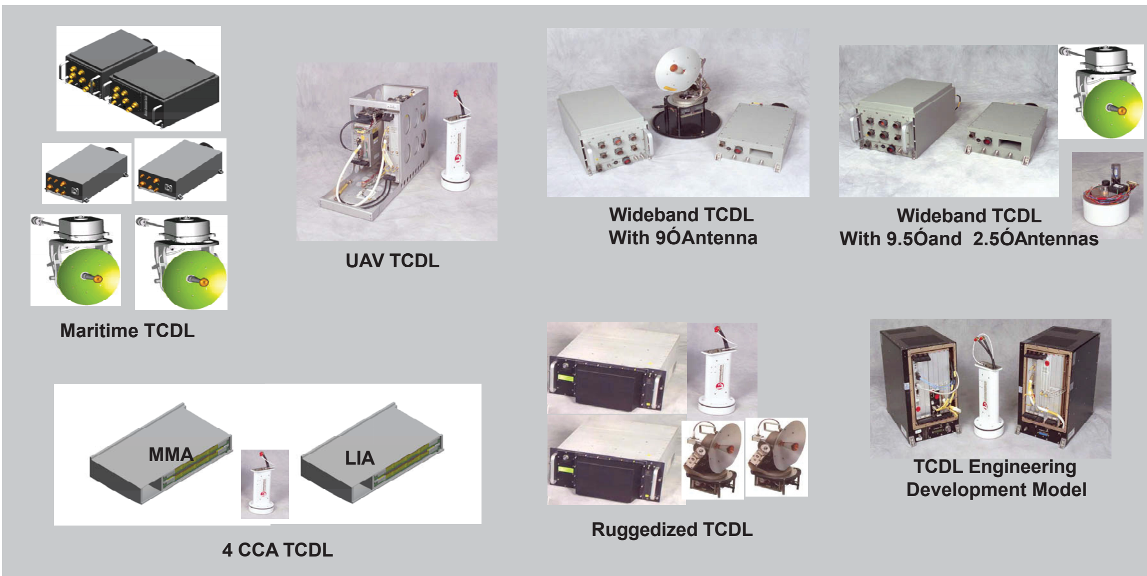


Figure 55: TCDL Configurations

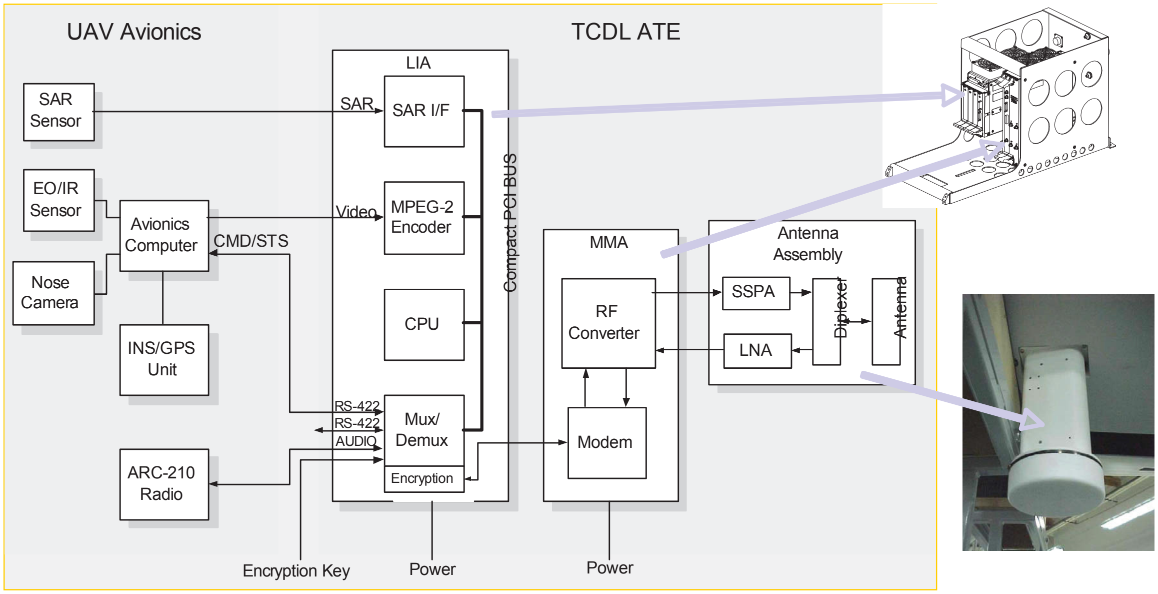
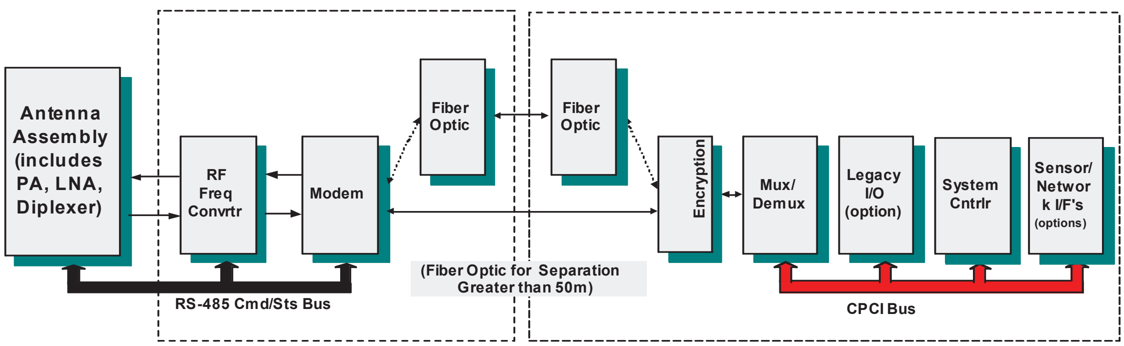


Figure 56: Typical TCDL UAV Installation



- **Eurocard form factor (6U/3U) with CompactPCI bus**
- **CPCI bus used as a "data highway" linking sensor interfaces to CDL Mux**
- **Legacy I/O has direct connect to Mux through CPCI user defined pins**
- **RS-485 Cmd/Sts bus for "black side" module and antenna control**

Figure 57: Example TCDL Implementation

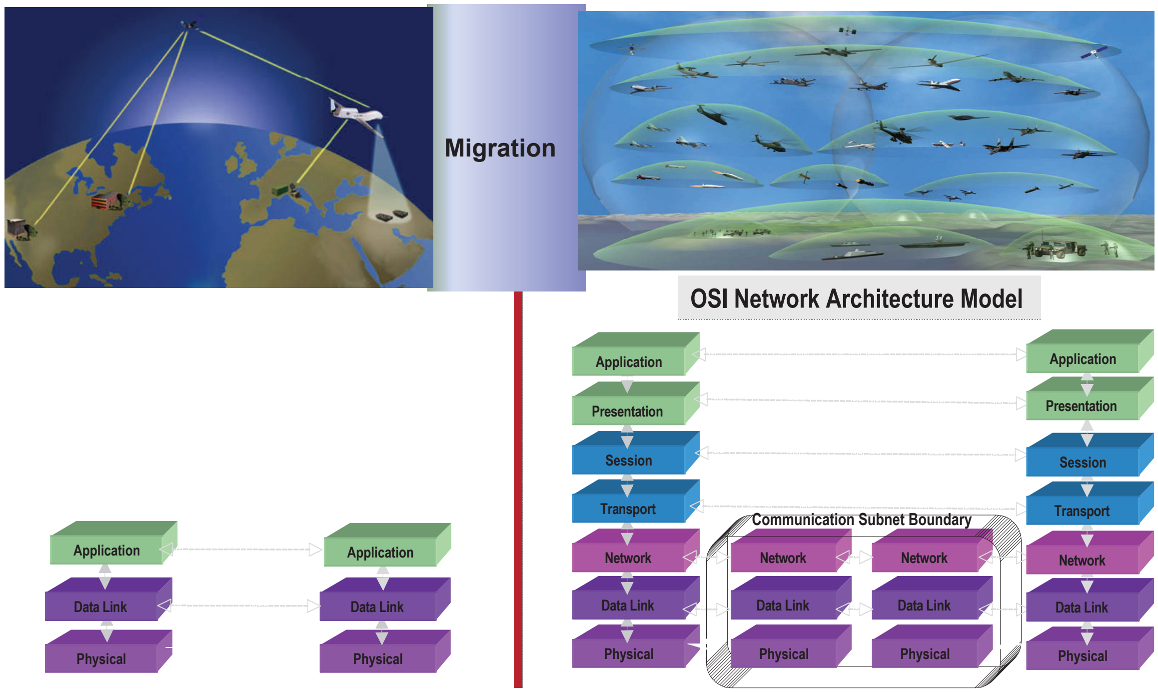


Figure 58: Data Links to Mobile Multi-Tier Networks

4.4 Interoperable Command and Control Data Link (IC2DL) – STANAG 4660

There has been a longstanding requirement for a second C2 link to provide assured communications with UAVs operating in the NATO military environment. This was originally called the High Integrity Data Link (HIDL). Recently it advanced to obtain its own STANAG number, 4660, and a new name – the Interoperable Command and Control Data Link (IC2DL). The UK Watchkeeper Program may be first user/implementer of IC2DL STANAG and will provide STANAG "Validation" and lessons learned.

The intent is to provide a second interoperable line-of-sight command and control link to TCDL. A typical network would consist of five active nodes and an unlimited number of passive nodes. A configuration of one CUCS and 4 aircraft is anticipated but the design will accommodate up to 10 nodes easily. A TDMA implementation there is a trade in data rate versus time. The link will support digital voice, primarily to allow communications with Air Traffic Control. It will allow sending of sensor data but that is not its primary purpose. In addition to a Mode A and Mode B, a Mode C is under consideration for smaller UAVs. The link will support a Relay function. Cubic Corporation and Ultra Electronics are implementing the design under their contract on the UK Watchkeeper program. External configuration of the link will be through a set of STANAG 4586 messages. Because of its spread spectrum nature, it has some inherent anti-jamming characteristics.

STANAG 4660 Development Status[36]:

- May 06 Draft STANAG for Review
- Oct 06 STANAG ratification submission
- Jun 07 Implementation/Test Plan

Status (as of January 2005)

- Initial waveform definition completed. It is a modified UK HIDL Waveform - used in UK WATCHKEEPER Program
- The Desired Frequency Band has been agreed. It will be operate in the S-Band (2.3GHz). The number of 25 kHz channels are not obtainable in the UHF band required the move to S-Band.
- The draft STANAG "Shell" has been completed
- Technical Details (Annex B) outline completed
- Scope, overview, requirements and waveform definition sections completed and agreed
- Initial Link Control Messages have been defined
- Interface and message formats for interface with STANAG 4586 compliant UCS drafted
- Continuing dialogue between 4586 and 4660 teams
- Network management control, timing synchronisation, data header configuration, latency & the mixing of data types still need to be addressed.

[36] PowerPoint Presentation to STANAG 4586 WG: Interoperable Command and Control Data Link (IC2DL) - STANAG 4660 "Status and Way Ahead", Colin Cooke, [dstl], January 2006

Table 9 summarizes the IC2DL requirements:

PARAMETER	Mode A REQUIREMENT	Mode B REQUIREMENT
Bit Error Rate (BER)	10-8	
Availability	System Dependant	
Environment. Conditions	System Dependant	
Frequency – see Note 1	S Band (2.3 GHz)	
Waveform Inter-node Range –see Note 2	0.001-100NM	0.001-200NM
Data rate	10-300 Kbps	
Encryption	External to Data Link	
LPI/LPD	Yes, 10 log (bandwidth ratio)	
Latency Launch and Recovery Sensor	 50-100ms 200ms	
Update rate Launch and Recovery Sensor C2	 20 – 25 Hz 5-10 Hz	
Polarization	Vertical	
Communication protocol Ground Data terminal (GDT) Air Data Terminal (ADT) Digital Voice (ATC)	 IP/UDP TBD TBD	
Multiple Access Communication	TDMA	
Note 1: Primary frequency band. (Operational constraints may require use of other frequency band) - Data link design shall allow use of other frequency bands. Note 2: This range value is for waveform design (time slot)		

Table 9: IC2DL Requirements

4.5 Tactical Data Links

4.5.1 HF UAV Data Link

The HF data link system HRM 7031 provides reliable communications for long distances (up to 500 km and more) "beyond the horizon" for UAVs. HRM 7031 does not depend on any third party providers or infrastructure.

- No constraints from terrain features
- Resistance to Electronic Counter Measures (ECM)
- Airborne equipment and antenna easily adaptable to different airframes

- Low to medium data rates available in both directions

The HRM 7031 consists of:

- Transceiver HRU 7031
- Antenna tuning unit ATU 7031

The HRM 7031 hardware is based on the proven standard equipment series HRM. Packaging of these airborne units may be tailored according to airframe shape. An assigned ground station is available and consists of basic HRM family components such as e.g. transceiver HRU 7000M, PAU 7400, ATU 7400, DPA 7400.

The HRM 7031 is a radio system that has been optimized for UAV communications and that supports several data transmission modes:

- Robust mode (for degraded channel conditions)
- Normal mode (for normal propagation conditions)
- BLoS mode (Beyond Line of Sight)
- LoS mode (Line of Sight)[37]

Transmission Modes

- Standard: For transmission of any command and acknowledge information, status and position information
- High Speed: Especially for transmission of still images (IR, EO and Radar)

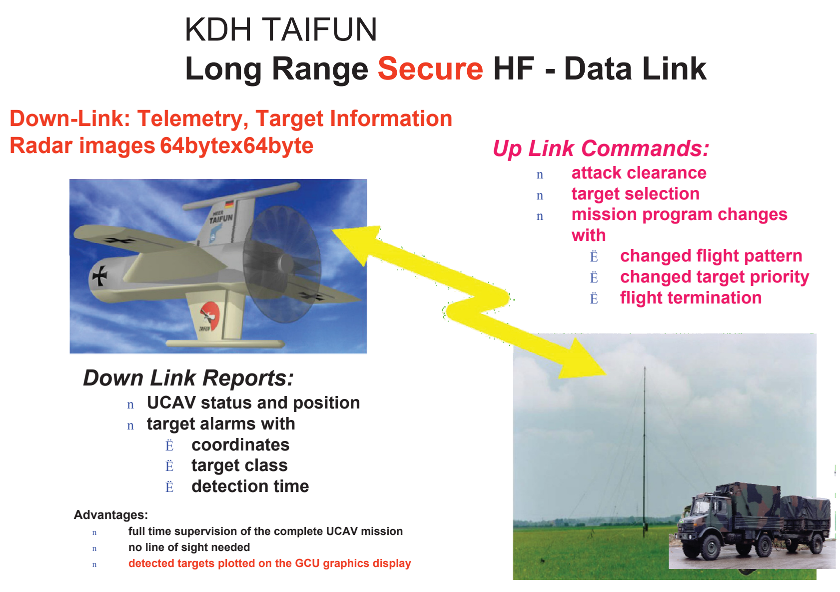


Figure 59: KDH Taifun UAV implementation of HF Data Link[38]

[37]Telefunk Racoms website, http://www.tfk-racoms.com/index.php?id=39

4.5.2 Tactical Digital Information Links (TADIL)

Tactical data links involve transmissions of bit-oriented digital information which are exchanged via data links known as **Tactical Digital Information Links (TADIL)**. The TADIL Program applies to all bit oriented message formats used in support of joint and combined operations for Joint Interoperability of Tactical Command and Control Systems (JINTACCS). The TADIL Program facilitates information exchange between the United States and Allied commands. The Army uses TADIL messages to exchange information with other services and agencies and with other Allied users. A TADIL is a Joint Chiefs of Staff (JCS) approved standardized communication link suitable for transmission of machine-readable, digital information. The United States Navy uses the NATO designation, Link-16, when referring to Tactical Digital Information Link (TADIL).

Link-16 is synonymous with TADIL J. The latter term is employed only by United States Joint Services. Similarly, Link-11 is synonymous with TADIL A and Link-4A with TADIL C.

4.5.3 TADIL A/B [Link-11]

Tactical Digital Information Link (TADIL) A/B [Link-11] employs netted communication techniques and a standard message format for exchanging digital information among airborne [TADIL-A] as well as land-based and shipboard [TADIL-B] tactical data systems. Link-11 data communications must be capable of operation in either the high-frequency (HF) or ultra-high-frequency (UHF) bands. TADIL-A/B is used by a number of intelligence platforms such as RIVET JOINT that conduct signal intelligence (SIGINT) data collection, including communications intelligence (COMINT) and electronic intelligence (ELINT).

Link 11 provides high speed computer-to-computer digital radio communications in the high frequency (HF) and ultra-high frequency (UHF) bands among Tactical Data System (TDS) equipped ships, aircraft and shore sites. Currently the Fleet is using a number of different data terminal sets to provide Link 11 functionality, these include the AN/USQ-74, AN/USQ83, AN/USQ-120, AN/USQ-125 and other Data Terminal Sets. The new Common Shipboard Data Terminal Set (CSDTS) card set provides all of the capabilities of the older Link-11 data terminal sets including Kineplex, Single Tone, and Satellite transmission capabilities. It also incorporates multi-frequency Link 11 enhancements, allowing the operation of up to four parallel channels among participating units. The CSDTS card set will be included in the Common Data Link Management System, described below.

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[38] Tom Walati, "TAIFUN" German Army Lethal UAV Program, IQPC: Suppression of Enemy Air Defences Conference, 26th-28th February 2003, STN ATLAS Elektronik GmbH, Airborne Systems, Bremen, Germany

4.5.4 TADIL C [Link-4A]

Link 4 is a non-secure data link used for providing vector commands to fighters. It is a netted, time division link operating in the UHF band at 5,000 bits per second. There are 2 separate "Link 4s": Link 4A and Link 4C.

Link 4A TADIL C is one of several tactical data links now in operation in the United States Armed Services and forces of the North Atlantic Treaty Organization (NATO). Link-4A plays an important role by providing digital surface-to-air, air-to-surface, and air-to-air tactical communications. Originally designated Link-4, this link was designed to replace voice communications for the control of tactical aircraft. The use of Link-4 has since been expanded to include communication of digital data between surface and airborne platforms. First installed in the late 1950s, Link-4A has achieved a reputation for being reliable. But Link-4A's transmissions are not secure, nor are they jam-resistant. However, Link-4A is easy to operate and maintain without serious or long-term connectivity problems.

Link 4C is a fighter-to-fighter data link which is intended to complement Link 4A although the two links do not communicate directly with each other. Link 4C uses F-series messages and provides some measure of ECM resistance. Link 4C is fitted to the F-14 only and the F-14 cannot communicate on Link 4A and 4C simultaneously. Up to 4 fighters may participate in a single Link 4C net. It is planned that Link 16 will assume Link 4A's role in AIC and ATC operations and Link 4C's role in fighter-to-fighter operations. However Link 16 is not currently capable of replacing Link 4A's ACLS function and it is likely that controlled aircraft will remain equipped with Link 4A to perform carrier landings. Message standards are defined in STANAG 5504 while standard operating procedures are laid down in ADatP 4.

4.5.5 TADIL J [Link-16]

Link-16 is a relatively new tactical data link that is being employed by the United States Navy, the Joint Services, some nations of the North Atlantic Treaty Organization (NATO) and Japan. Link-16 uses the Joint Tactical Information Distribution System (JTIDS) which is the communications component of Link-16. The E-8C Joint Surveillance Target Attack Radar System (Joint STARS) data links such as TADIL-J as well as the Surveillance Control Data Link (SCDL) to pass information to the Ground Station Modules (GSMs), which are the Army component for the Joint STARS. Link-16 does not significantly change the basic concepts of tactical data link information exchange supported for many years by Link-11 and Link-4A. Rather, Link-16 provides certain technical and operational improvements to existing tactical data link capabilities and provides some data exchange elements that the other data links lack. It provides significant improvements as well, such as jam resistance; improved security; increased data rate (throughput); increased amounts/granularity of information exchange; reduced data terminal size, which allows installation in fighter and attack aircraft; digitized, jam-resistant, secure voice capability; relative navigation; precise participant location and identification and increased numbers of participants.

LINK-16 is DoD's primary tactical data link for command, control, and intelligence, providing critical joint interpretability and situation awareness information. Link 16 uses a Time Demand Multiple Access (TMDA) architecture and the "J" message format standard. The "J" series of message standards are designated as the Department of Defense's primary tactical data link, according to the Joint Tactical Data Link Management Plan (JTDLMP).

The JTIDS terminal is one of two terminals providing LINK-16 capability to the soldiers, sailors, and servicemen in the field. The other LINK-16 terminal is the **Multifunctional Information Distribution System (MIDS)** terminal--a joint / international ACAT-1D program.

The Fleet is currently using AN/URC-107 (V) **Joint Tactical Data Link System (JTIDS)** terminals to provide ships, aircraft and shore sites with Link 16 capability. JTIDS is an advanced radio system that provides information distribution, position location, and identification capabilities in an integrated form. JTIDS distributes information at high rates, in an encrypted and jam-resistant format. JTIDS is a multi-service and multi-national system. US participation includes Army, Navy, Air Force and Marine Corps.

The **Multi-functional Information Distribution System Low Volume Terminal (MIDS/LVT)** is a five-nation cooperative program that provide a third generation Link 16 system that satisfies U.S. and Allied requirements. MIDS uses new technology to reduce system size and weight.

The **TADIL J Range Extension (JRE)** program addresses the requirement to pass secure/anti-jam data and voice via a common means in a timely manner beyond line-of-sight (BLOS) without the use of a dedicated airborne relay. This requirement is documented in the Joint Requirement Oversight Council TMD Mission Need Statement 064-91, 18 Nov 91 and Air Force TMD Mission Need Statement MNS-004-91, 1 Oct 91. It has been incorporated into the Link-16 Operational Requirements Document, CAF 315-92 III-D dated 2 Nov 96. Two reasons for this requirement. First, the current method for extending the range of a JTIDS network BLOS is to employ airborne assets as relays between zones. This allows deployment of a very large (geographically), integrated JTIDS network that provides interconnectivity between all the elements in a theater. However, use of airborne relays is wasteful of theater assets and consumes network capacity that could be used for reporting additional information. Second, studies show that JTIDS has the technical capacity to support the TMD communications requirements, but load mitigation strategies should be explored to improve network performance. The concept envisions JRE as a gateway between existing JTIDS and satellite terminals. The gateway’s physical configuration would be determined by individual service requirements. It could either be fully integrated into an existing host system, a separate processor sharing common hardware and software, or a stand-alone system. The JTIDS terminal would be linked to the JRE gateway for transmitting and receiving TADIL J messages from a particular JTIDS zone. Linked at the other end of the gateway will be the satellite terminal whose function is to transmit and receive messages via satellite.

Current studies have focused on two employment applications of the JRE gateway: 1. In-theater Reachback: This application is used to transmit the air surveillance and ballistic missile information from a forward area of a theater to a remote command center located beyond line-of-sight of the forward JTIDS elements. 2. Inter-zone Connectivity: This application is used to transfer air surveillance and ballistic missile information between localized areas of a theater operations.

The Air Force is pursuing a prototype capability using both Ku and SHF bands. Current planning calls for the AF Prototype to be a COTS workstation with the appropriate hooks to allow it to interact with a JTIDS terminal and a satellite terminal. The main prototype development will be the gateway software which will reside in the workstation. The software to be developed includes message forwarding, buffering, prioritization, protocols, etc. that would allow the gateway to perform the JRE functions. Two gateways will be procured so that the system can be tested and demonstrated in a zone-to-zone capability.

The prototype program development was planned for 18 months. The contract was awarded on the 23 December 1997 to Raytheon Corporation with Titan/Eldyne Corporation as its subcontractor.

Air Combat Command (ACC) has expressed a keen interest in the potential capability of JRE to provide TADIL J information to ingressing, egressing, and transiting combat aircraft. For JRE to add this capability to its tool bag, the program office is initiating a study in FY98 to assess the requirements and feasibility for this capability. Also, the joint community has expressed an interest in JRE using not only satellite communications but also UAVs and terrestrial communications to accomplish the long haul link.

4.5.6 Link 1

Link 1 is a duplex digital data link primarily used by **NATO's Air Defence Ground Environment (NADGE)**. It was designed in the late 1950s to cater for point-to-point data communication. Link 1 mainly provides for exchange of air surveillance data between **Control and Reporting Centres (CRCs)** and **Combined Air Operation Centers (CAOCs)/Sector Operation Centers (SOCs)** and has a data rate of 1200/2400 bit per second (bps). It is not crypto secure and has a message set (S-series) limited to air surveillance and link management data. Within NATO, Link 1 is used by NADGE systems (NADGE/GEADGE/UKADGE, etc). Most mobile CRCs are also equipped with Link 1 capabilities. Additionally, most NATO Nations employ receive-only equipment at air bases and SHORAD centers for Early Warning purposes. Message standards are defined in STANAG 5501 while standard operating procedures are laid down in ADatP 31.

4.5.7 Link 14

Link 14 is a broadcast HF teletype link for maritime units designed to transfer surveillance information from ships with a tactical data processing capability to non-tactical data processing ships. The design of the teletype transmission allows reception over very long ranges. Link 14 provides the capability to broadcast picture compilation and status information for use in units unable to receive Link 11 transmissions either direct or via an interface, e.g. non-Tactical Data System (TDS) units. The Link can be either HF, VHF or UHF dependent on unit-communication fits. More than one Link 14 net, with or without separate transmitting units, may be set up if desired, e.g. to split air and surface/sub-surface data. However, some units will be limited by communications fits in their capability to receive two nets. Few units will have the capability to transmit on two separate Link 14 channels at the same time. Selection of the Link 14 transmitting unit will depend on force disposition stationing of non-TDS units, Link 14 frequency, etc. Each nation within NATO has its own Link 14 transmission formats which are promulgated in ADatP-14. Message protocol is defined in STANAG 5514.

4.5.8 Link 22

Link 22 is the next-generation NATO Tactical Data Link, and is also referred to as the NATO Improved Link Eleven (NILE). The NILE collaborative project will design a system consisting of a computer to computer digital data link among Tactical Data Systems (TDS) equipped ships, submarines, aircraft and shore sites which meet the requirements of the NATO Staff Requirement. The goal of the system is to increase the timeliness of the tactical information transfer and transmission of high priority warning and force orders in a dense and hostile communications environment. This program will develop common specifications, which will permit the participants to implement appropriate Link 22 equipment. Link 22 is a multi-national development program that will produce a "J" series message standard in a Time Demand Multiple Access architecture over extended ranges. Link 22 Transmission media will be used to exchange Link 22 messages. Link 22 messages, comprised of F-Series formats, will be used for the exchange of maritime operational data between tactical data systems using line of sight (UHF 225-400 MHz) and beyond line of sight (HF 3-30 MHz) bands. [39]

The following article from Naval Forces III/2005 presents a brief summary of the Tactical Data Link 22, current German Navy engagement, and the new Telefunken RACOMS SPC 1920 providing the Signal Processing Controller (SPC) function for Link 22.

Background. *Started in 1992, NATO Improved Link 11 (NILE) – known today as Link 22 – has been developed collaboratively by 7 nations with the goal of replacing Link 11 and complementing Link 16. Now Link 22 is finally getting ready to enter the operational world. Under an MOU, Canada, France, Germany, Italy, Spain, UK, and US will carry out the in-service support (ISS) phase until 2007. The NILE steering committee, consisting of national representatives, has tasked the NILE Program Management Office (PMO) with overseeing all required program tasks.*

Link 22 Capabilities. *Both Link 11 and Link 22 operate on HF and UHF frequency bands, whereas Link 16 only uses UHF. Link 22 will overcome Link 11 deficiencies on throughput, robustness, routing, EPM measures and message standard limitations. Network access through a dynamically configurable TDMA architecture provides flexible resource management. The built in relay function extends communication range.*

[39] http://www.globalsecurity.org/intell/systems/tadil.htm

Link 22 Architecture. *A Link 22 net consists of a Super Network (SN) of up to 125 NILE Units (NUs) connected by RF links. One designated NU will act as SN management unit (SNMU). The SN is subdivided into up to 8 NILE Networks (NNs), each composed of a subset of the NUs operating on a common RF channel, and administrated by a network management unit (NMU). NUs are able to simultaneously participate in up to 4 NNs, depending on the availability of RF links. Figure 61 depicts the devices comprised by a NU supporting four channels.*

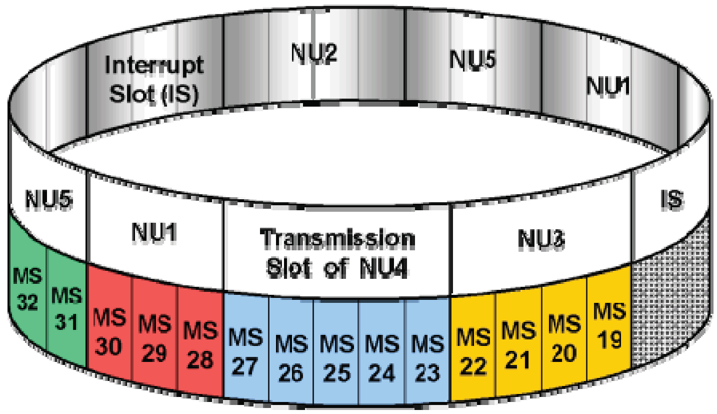

Figure 60: Operational Network Cycle Structure (example)

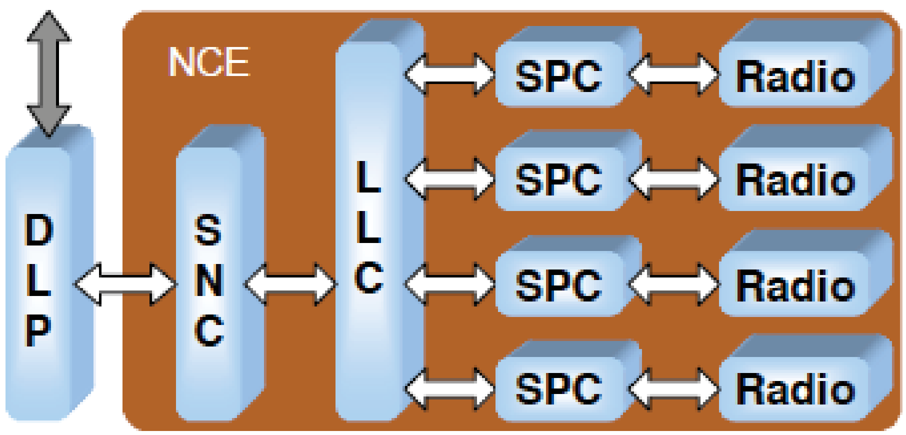

Figure 61: Multi-Network NILE Unit (NU)

*The **Data Link Processor (DLP)** is a functional entity and could be a distinct physical one, depending on national implementation. The DLP provides in interface between the host tactical data system and the NCE. It generates all tactical messages and is heavily involved in message addressing and forwarding to other data links. The **System Network Controller (SNC)** is a functional entity whose present implementation is NILE nations proprietary, based on specifications developed by the NILE PMO. The SNC provides NN management and monitoring, SPC configuration, and message delivery including addressing, timestamping or relaying. The SNC (as NMU) controls the **operational network cycle structure (ONCS),** within which each unit has its own Transmission Slot.*

Transmission Slot lengths can vary and can be tailored to meet individual platform's data requirements. The ***Signal Processing Controller (SPC)*** *is another functional entity whose implementation is a national level responsibility. The SPC provides message fragmentation,* ***forward error correction (FEC)****, modulation, radio configuration, and link quality feedback. Highly precise transmission and reception is mandatory and provided based on an accurate external time-of-day reference. For a dedicated NN RF channel, the SPC will be configured to one of the following Media:*

- *HF Fixed Frequency, according to STANAG 4539 annex D*
- *EPM, according to STANAG 4444*
- *UHF Fixed Frequency, according to STANAG 4205*
- *UHF EPM, according to STANAG 4372 (SATURN)*

For Beyond Line of Sight (BLOS) communication, HF links are optimized for 300 nm while UHF is only intended for LOS. For fixed frequency media, existing Link 11 radios can be used.

GERMAN SITUATION AND INITIATIVE. Link 11 is currently used in the following frigates classes: F122, F123, F124, as well as the support ship EGV702. Link 16 is currently only available in the F123 and F124 classes. The K130 corvette and F125 frigate classes are also scheduled for Link 16. German ships are to begin receiving Link 22 systems in 2008. As a NILE nation, Germany is actively participating the Link 22 ISS phase and subsequent implementation. The German MOD has tasked Telefunken RACOMS to develop a HF fixed frequency SPC to be integrated in the currently setup German NILE reference system (NRS-GE).

TELEFUNKEN RACOMS LINK 22 PRODUCT SCOPE. The new SPC 1920 will provide the Signal Processing Controller function for the NILE Communications Equipment. The Telefunken RACOMS (www.tfk-racoms.com) SPC 1920 is a new tactical data link modem, which will offer all media types of Link 22. For ground and ship borne applications, a 19" 1U standard rack equipment will provide dual link capability, e.g. two SPCs in one housing. Each link, e.g. each single SPC, will be configured selectively as one of the four SPC medias. Setup is either manually via front panel or by remote control interface. By loading SW, functionality can be upgraded to particular radio device drivers as well as future evolutions. Automatically initiated self-test at power-on and a comprehensive built-in-test will ensure faultless operation.[40]

4.5.9 Multi-Platform Common Data Link (MP-CDL)

The following is a description of the evolution of the Common Data Link:

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[40] Andre Kotlowski, Advanced Modem For Link 22: Enhancing Tactical Data Link Capability For Improved Allied Interoperability, NAVAL FORCES, International Forum for Maritime Power, III/2005

The Multi-Platform – Common Data Link (MP-CDL) was initially planned to replace the Joint Surveillance Target Attack Radar System (JSTARS) E-8C Surveillance and Control Data Link (SCDL), which transmitted data to/from the E-8C and its ground station, the Common Ground Station (CGS). The Air Force restructured the MP-CDL program to be the data link for a Network Centric Warfare capability to support Network Centric Collaborative Targeting (NCCT) Advanced Concept Technology Demonstration (ACTD), in addition to its role supporting the Multi-Platform Radar Technology Insertion Program (MP-RTIP) family of systems. Because of difficulties determining the requirements, the Air Force has restructured the program as a technology development and experimentation program. The MP-CDL program will produce a few systems with which to explore concepts and capabilities. If those capabilities meet an operational need, the Air Force may decide to produce them for employment on combat systems.

MP-CDL will provide a network-centric data link between airborne and surface intelligence, surveillance, and reconnaissance (ISR) assets. MP-CDL is currently envisioned to meet the need for a number of network clients (airborne or surface) to interact with a centrally located airborne terminal as well as other clients. The central airborne terminal may function primarily as a source of ISR data, a correlation node of ISR data, or mixed operation of the two modes. All terminals are to support gateway connectivity to other links external to the MP-CDL network in order to extend access into or out of the network to additional ISR collection platforms, exploitation nodes, or other users. These links may be either in-theater line of sight links or beyond line of sight SATCOM links.

The MP-CDL program objective is to provide an affordable, operationally effective line of sight (LOS), wideband, air-to-air and air-to-ground, point-multipoint and point-point connectivity in a networked environment. MP-CDL is planned to meet the needs for a number of airborne and surface platforms to simultaneously distribute sensor data products to multiple supporting airborne and ground stations. MP- CDL shall be scalable (expandable and compressible) and modular (adaptable to new waveforms by software upgrades or hardware module upgrades without requiring redesign of the entire system), and will utilize off-the-shelf components to the greatest extent possible within operational limitations. The MP-CDL system is one part of an overall plan to migrate the Common Data Link family of data links to the network-centric connectivity envisioned in Joint Vision 2010/2020.

The MP-CDL program objective is to conduct an evolutionary acquisition for the MP-CDL system as an integral part of the larger Intelligence, Surveillance, and Reconnaissance (ISR) Network Program which will use a spiral-based development process. The MP-CDL system is planned to satisfy the threshold requirement for a networked multipoint data link capability providing a growth pathway to desired system enhancements. The MP-CDL capability will support sensor product dissemination to multiple primary users in a point-multipoint configuration, both air-to-air and air-to-ground. Additional Objective capabilities are desired in the initial MP-CDL program: Simultaneous data link operations supporting either a point-point link and a networked point-multipoint link, or two networked point-multipoint links.

Other capabilities yet to be fully defined, including different network connectivity architectures (mesh, ad hoc, etc.), increased data rates, Satellite Communication (SATCOM), and enhancements to node compatibility, number of nodes supported, latency, throughput, jitter reduction, data prioritization, and data security. The government envisions that objective capabilities not included in the initial MP-CDL program may be incorporated in spirals under the separate ISR Network Program.

MP-CDL is closely tied to the Multi Platform-Radar Technology Improvement Program (MP-RTIP), Joint Surveillance Target Attack Radar System (JSTARS), Distributed Common Ground Station-Army (DCGS-A), and Global Hawk programs. Additionally, MP-CDL, as an integral part of the ISR Network, is envisioned to be an enabling technology for Network Centric Collaborative Targeting (NCCT), Multi Sensor Command and Control Constellation (MC2C), Deployed Theater Information Grid (DTIG), and Global Information Grid (GIG) concepts. The MP-CDL CTD contract is envisioned to work closely with these communities by performing and supporting study efforts and performing integration work.

Initial application of MP-CDL, to provide Army surface units command/control access to surveillance products from the Multi-Platform Radar Technology Insertion Program (MP- RTIP) platform, necessitates the use of jam-resistant technologies to protect network operations from a specified jamming threat against both surface and airborne assets. Due to limited spectrum availability, as well as other factors which place practical limits on achievable jam resistance at higher data rates, only communications from the surface client terminals to the central airborne terminal and a relatively narrowband component of the MP- RTIP data that is broadcast from the central airborne terminal to the surface client terminals require jam resistance.

The architecture will need to address non-uniform/bursty communications from the surface client terminals to the central airborne terminal and minimize latency in the transfer of time critical data. The size of the network, in terms of number of clients actively communicating with the central airborne terminal, should be scalable in order to address varying mission applications. In addition to network operations, which implies deviation from the conventional CDL point-point waveform, MP-CDL terminals are to support capability for point-point interoperability with CDL surface and/or airborne terminals. The anticipated requirement for the central airborne terminal is to provide a single point-to-point data link operating simultaneously with an independent multi-user network. The terminal's point-to-point data link must be interoperable with existing CDL surface communication equipment (T) and Airborne Information Transmission (ABIT) relay terminals (T) at established standard data rates up to 274 Mb/s.

The objective (O) requirement for the terminal's point-to-point data link is interoperability with both CDL surface and platform communication equipment and ABIT relays and collectors at standard data rates up to 274 Mb/s. The multi-user network will connect up to 32(T)/50+(O) users on a COTS-based network architecture. The broadcast data transmission rate capability from the central airborne terminal to client terminals will be 45(T)/137(O) Mb/s (including a 2.2Mb/s (T) jam resistant channel). The data transmission rate capability from the clients to the central airborne terminal is

0.059(T)/45(O) Mb/s. The aggregate throughput bandwidth to the central airborne terminal will be 0.5(T)/45(O) Mb/s.

The contractors that develop the central airborne terminal and surface client terminals will jointly define the network-mode waveform and frequency plan. The MP-CDL system will have an open/scalable architecture to allow additional linkages, scalable bandwidths, and multiple configurations. Potential future applications include relays that extend the network, central airborne terminal hardware that is reconfigurable to act as a client terminal, airborne client terminals, central surface terminals, and multiple simultaneous links on MP-CDL terminals. Range will be dependent on size, weight and power requirements and mission geometries to be defined later, but is initially estimated to be nominal maximum line-of-sight from an altitude of 40,000 feet. The MP-CDL system will be able to operate in Ku band (T) and should support future growth capability to operate in one or more alternative RF bands (i.e. X, Ku, Ka) to allow multiple simultaneous links (O).

The Air Force restructured the MP-CDL program to support the NCCT ACTD. The NCCT ACTD requires the low data latencies provided by MP-CDL rather than its high throughput. The NCCT ACTD is intended to provide a combat capability by networking Command Control and Intelligence Surveillance and Reconnaissance assets into a collaborative entity. NCCT should dramatically improve target location accuracy, timeliness, and combat identification certainty for the warfighter. Networking optimizes high-speed machine-to-machine interaction between sensors for detection, association, and correlation of high-interest and time-sensitive targets. NCCT is focused on the find, fix, track, and assess elements of the find, fix, track, target, engage, and assess kill chain.[41]

[41] http://www.globalsecurity.org/intell/systems/mp-cdl.htm

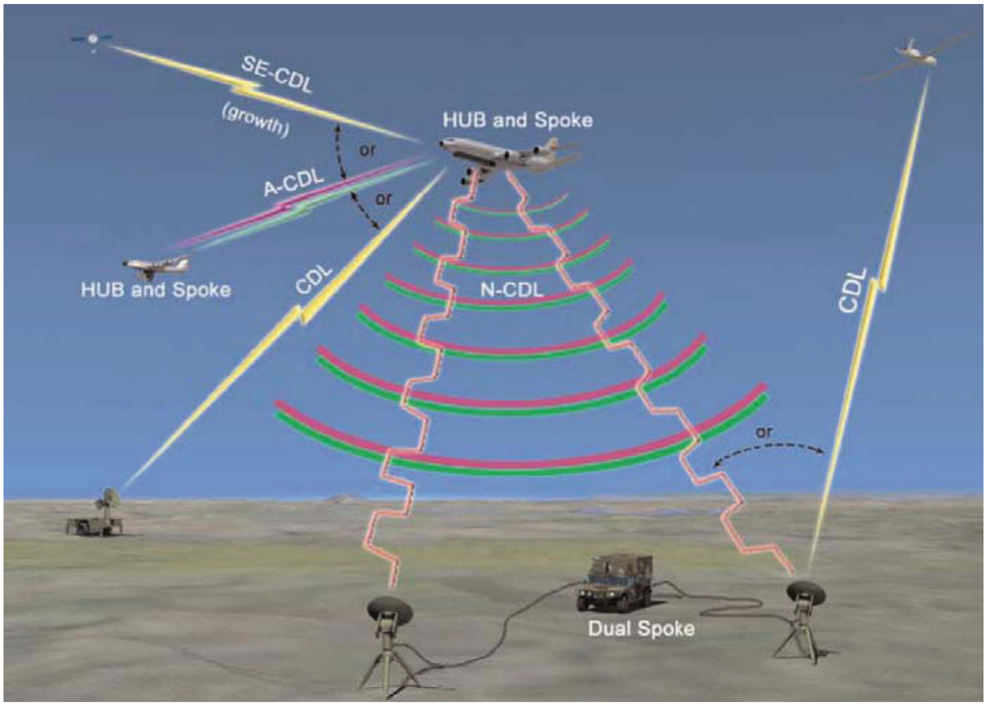

Figure 62: MP-CDL

The following except provides an additional view of the Multi-Platform CDL:

> ***What is it?*** *In today's evolving battlespace environment, nothing is more critical to the precise execution of targets than the rapid exchange of information. At the same time, this information is becoming exponentially larger in file size and is rapidly outpacing the capacity of our current radio frequency or "RF" based data links. The Multi-Platform Common Data Link terminal will address these issues for the warfighter.*
>
> ***Why is it needed?*** *Although Common Data Link terminals contain the word "common," in actuality there's very little in common from one waveform (a unique modulation scheme applied to a signal in free space) to another. Over the years, numerous terminals have been developed using variations of the CDL waveform to meet specific mission demands. This has created a lot of non-interoperable terminals that have been fielded throughout the joint community. Addressing this situation, "the MP-CDL terminal will be the first truly common, Common Data Link terminal in that it will be the first terminal delivered that is backward-compatible with all current CDL waveforms" said Maj. Gen. Tommy Crawford, AFC2ISRC commander.*
>
> ***How does it work?*** *The three primary waveforms in the MP-CDL terminal will be Standard CDL, offering a Line of Sight data rate of up to 274 Mbps; Advanced CDL, allowing an automatic air-to-air connection with improved anti-jam characteristics also up to 274 Mbps, and the newly developed Networked CDL, offering a networking capability with up to 137 Mbps on the outbound link and 40 Mbps inbound to the hub. The N-CDL waveform is the key to bringing the intelligence, surveillance and*

reconnaissance platforms such as Joint STARS, Rivet Joint, and AWACS into the network-centric arena.

What's happening with it now? *The MP-CDL terminal will be transformational; enabling the Command and Control Constellation and aircraft applications such as Network Centric Collaborative Targeting. The MP-CDL terminal should be thought of as the "Internet" path, much like a cable modem you would use at home. An application, such as NCCT, would use that path to obtain its objectives. MP-CDL terminals will have two variants, an airborne and a ground terminal. These will initially be delivered with a two-channel capability with growth potential to a third. To further the terminal's interoperability, the CDD mandates Joint Tactical Radio System Software Communications Architecture (compliance, programmable crypto devices, and implementation of the new Internet Protocol version 6 standards. In addition, the MP-CDL program has several potential upgrades under the spiral development process. These upgrades include the development and implementation of a high capacity waveform to deliver 548Mbps and eventually 1.096Gbps and the development of the Satellite Extension waveform for a Beyond Line Of Sight capability.*[42]

4.6 UHF High Capacity Communication Relays:

4.6.1 Kongsberg Defence & Aerospace AS (Integrated Defence Systems) UHF Radio

In Annex D and E are datasheets of the high capacity UHF radios. A vehicle version (5W output power) and a soldier worn version (1W output power) are available. For integration in an UAV, the soldier version is the most applicable. The radio has been integrated into UAV and small air-planes in Norway. The radio was tested by Canadian DND in Suffield in 2009 where they used this radio as a relay in an aerostat with huge success. The radios have been delivered in a small quantity to Canadian DND (towards DLCSS) two years ago.

4.6.1.1 Voice Communication and Data Communication

The data interface is Ethernet. Up to 2.5 Mbps is supported. The radio performs automatic multihop in a MANET fashion. UDP unicast and multicast is supported (and TCP).

Voice can be transmitted as VoIP (treated as standard data packets) or in a special Soldier waveform. In soldier mode two parallel simultaneous voice channels are relayed in parallel with data. The radio has a dual analogue interface for handling of data towards the user. The remaining data capacity in soldier mode is about 700 kbps gross rate.

4.6.1.2 Equipment Considerations

- Size: 36x97x218 mm (without battery and antenna)
- Weight: 700 g without battery and antenna

[42] Mr. Brian Lewis, Multi-Platform Common Data Link, intercom, The Journal of the Air Force C4 Community, 1 February 2005, http://public.afca.af.mil/Intercom/2005/February/FEBTECHGIZ.html

- Antenna: 80 g (about 25 cm length for the soldier radio)
- Power: 7.5 W during transmission, 4.5 W during reception. External power supply 7-18 VDC.

4.6.1.3 System Operation

- Range: Depends upon UAV height and antenna used on ground, but anything from 50-200 km could be expected. If you can give us input regarding the height and antenna we can give you an estimate.
- Life Cycle: Cost Easy to maintain, easy to load new software
- Manning and Training: Web based and partly SNMP. Very easy to learn how to configure and use. As easy as a wireless router to integrate into any system.

4.6.1.4 Maturity Assessment:

Delivered to a number of countries in smaller volumes (including Canada). The equipment is not fully industrialized, but is available in small volumes. A fully qualified and industrialized version will be available end of 2010.

4.7 Coverage Factors

4.7.1 Weather

Weather is addressed in section 1 of this document

4.7.2 Airspace Restrictions

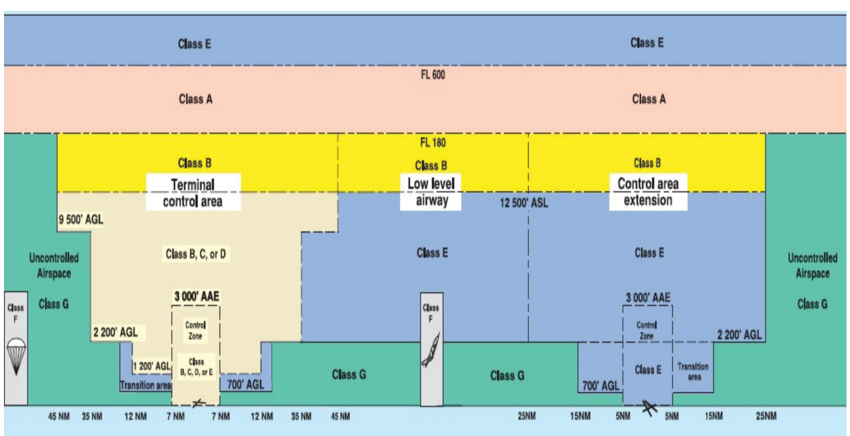

Figure 63: Classes of Airspace[43]

[43] Bob Kirkby, "Sharing the Airspace From a GA Perspective," UVS Canada, UVS Canada National Conference, Fairmont Chateau Montebello, Montebello, 8 Nov. 2006.

Most of the airspace where these platforms would operate would be Class G (i.e. below 18,000 feet) or Class A (i.e. between 18,000 and 60,000 feet) if they are to be in positions to observer the approaches to urban areas. HALE UAVs and stratospheric airships would operate in Class E airspace above FL 600.

4.7.3 Coverage

The coverage provided by a given platform/radar combination is function of height above the ground, gain of the antennas involved, power and processing capability.

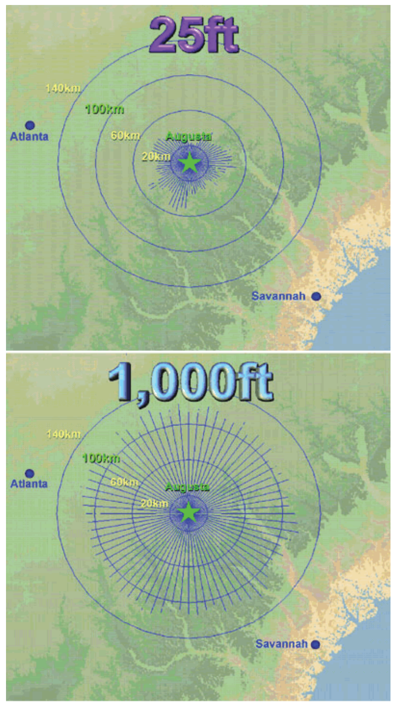

Figure 64: Radar: height matters – example of JLENS Aerostat coverage

There has been some research into novel approaches to combine the UAV with a ground processing capability to extend the sensor reach. This research was applied to electronic surveillance but might be applicable to the radar realm.

> *In addition to placing the sensor/processing capabilities onboard the UAV, it can be treated as a "flying antenna". In this case, the UAV is effectively an electromagnetic "bent pipe" – comprising a receive antenna, a modest amount of processing capacity, some time stamping & signal amplification, and a (directional) transmit antenna. Combined with knowledge of the UAV's location and a high gain antenna on the ground (and considerably more processing power than is available onboard the UAV) we have the capacity for significant horizon extension (See Figure 65).*

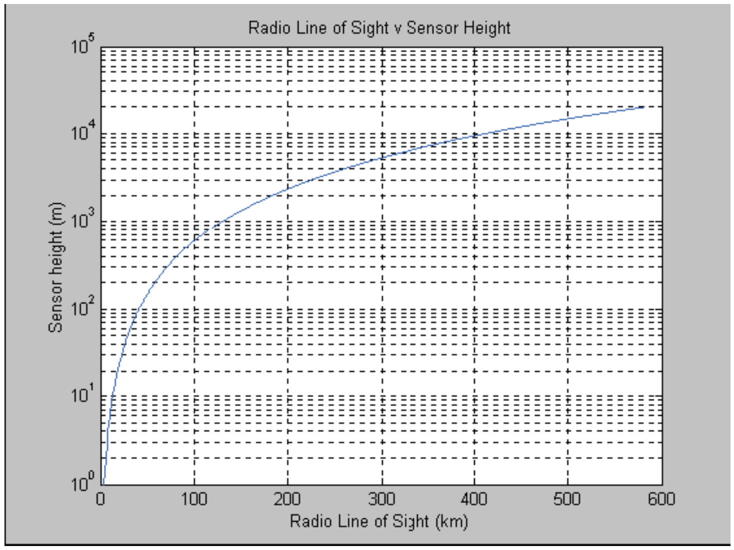

Figure 65: Radio line of sight vs. altitude.

4.7.4 Range

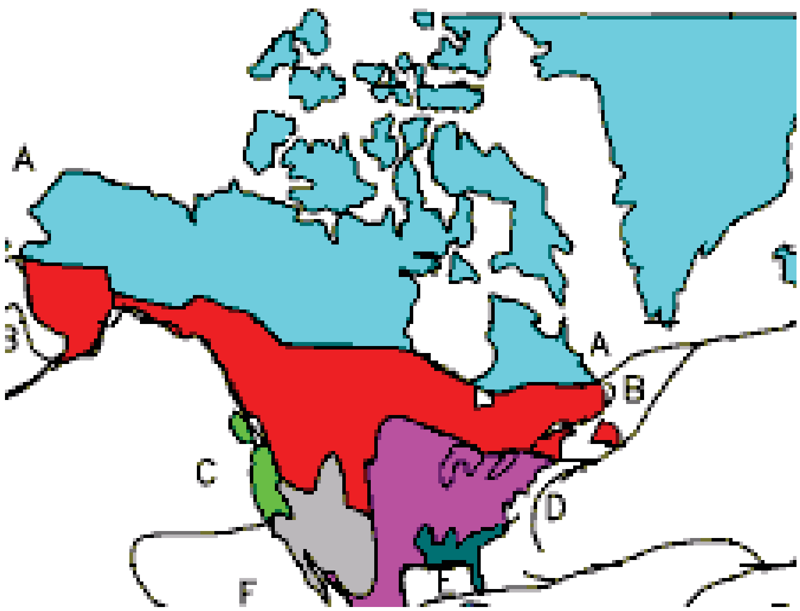

Figure 66: Crane Rain Regions in Canada

For domestic operations, there are four rain regions in Canada to consider from a communications/radar range point of view:

- Northern - Region A

- Central and east/west coastal - Region B
- Southwestern coast, Vancouver island - Region C
- Great lakes area, U.S. Border & extreme eastern coast - Region D

Range calculations, particularly in the Ku Band that CDL employs, need to consider frequency and amount of rain as well as mean temperatures. The following summarizes the four regions:

- Region A: maximum rainfall rate about 30 mm/hr. Characterized as treeless, dry tundra (arctic plains). Permafrost is common, mostly north of the arctic circle
- Region B: maximum rainfall rate about 70 mm/hr. Characterized as moderate, coniferous forests. Long, severe winter. Region south of the arctic circle
- Region C: maximum rainfall rate about 78 mm/hr. Maritime regions in the temperate zone
- Region D: maximum rainfall rate about 108 mm/hr. Continental, temperate climate. Generally experience all four seasons. Forests are deciduous and coniferous

The following are link margin assumptions for a short range (50 km) TCDL implementation calculation[44]:

- Ground Data Terminal (GTE) assumed is using a 9.5" directional antenna instead of the standard GDT 36" antenna and a 2 watt solid state power amplifier (SSPA)
- Air Terminal Equipment (ATE) is using an airborne OMNI antenna and a 2 watt solid state power amplifier (SSPA) with a TCDL data rate of 10.71 Mbps in the RF frequency of the Ku band.
- Clear weather

Results:

- A 0 dB margin @ 3,450 foot (1.05 km) altitude for 1º look up angle from ground station 50 km (164,000 feet) away gives a 5.9 dB link margin at 30 km
- For an ATE at the 25,000 foot (7.6 km) maximum operating altitude where:
    - The look up angle from the ground station is 8.6º.
    - The clear weather margin is 1.8 dB @ 50 km slant range (the link margin would be 6.5 dB @ 30 km).
    - Range at 1º look up angle = 235 km (would need 15 dB more gain)

[44] courtesy of L-3 Communications

Figure 67 provides a comparison of the geometry between the A 3,450 ft and 25,000 ft:

- Slant range & look up angles for 25K feet and 3,450 feet
- The heavy green line represents a weather “ceiling”. The signal for the 25K foot altitude stays above most of the weather for more of the path. Link margin is better at higher altitudes for this reason.

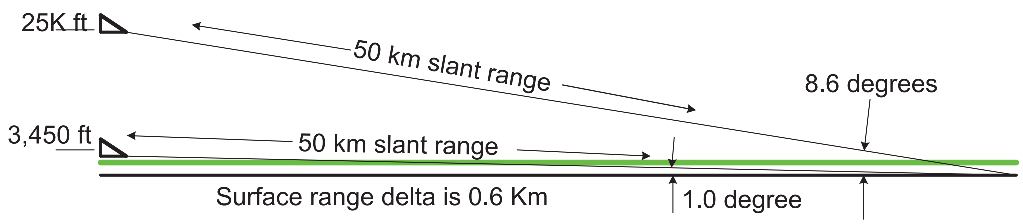

Figure 67: Comparison of 3,450' and 25,000' at 50 km Slant Range

5. Summary

The Canadian Arctic remains a harsh environment for all aviation. Airships of all types are, however, being increasingly seen as viable craft for this environment due to low operation cost and high lift capacity. Tethered systems are even simpler to operate and maintain than full LTA craft. Some new approaches such as the Helikite offer better performance in high wind conditions. All of these systems offer advantages to any high bandwidth radio relay system by moving the relay point high into the air where Line-of-Sight can be maintained with a deployed MALE UAV. They can provide sufficient payload capacity and power to accommodate the Canadian Forces' desired radio systems.

Annex A Airship/Aerostat Manufacturer Addresses[45]

Manufacturer	Address	2nd Address
21st Century Airships www.21stCenturyAirships.com	mailing address: Box 177 180 Main Street Newmarket, Ontario L3Y 4X1 Canada	head office: 110 Pony Drive Newmarket, Ontario L3Y 4W2 Canada Tel: 1-905-898-6274 Fax: 1-905-898-7245
Advanced Hybrid Aircraft www.ahausa.com	3173 Kinsrow Av. Eugene, OR 97401 USA Fax: 1-541-344-5323	Gorse Bank Brookhill Rd Ramsey IM8 2H Isle of Man
Advanced Technologies Group www.airship.com	6th Floor, Town Hall St Pauls Square Bedford, MK40 1SJ UK Tel: 01234 221800 Fax: 01234 221801	
Allsopp Helikites Ltd http://www.allsopp.co.uk/	South End Farm, Damerham, Fordingbridge, Hampshire, SP6 3HW, England Tel: +44(0)1725 518750 Fax: +44(0)1725 518786	
American Blimp Corporation www.americanblimp.com	1900 NE 25th Av. Suite 5 Hillsboro, OR 97124-5983 USA Tel: 1-? Fax: 1-?	
Boland Balloon Boland homepage	Brian Boland Post Mills Airport P.O. Box 51 Post Mills, VT 05058 USA Tel: 1-802-333-9254 Fax: same as above E-mail:	

[45] http://www.myairship.com/reference/address_man.html

	balloons@vermontel.net	
Cameron Balloons www.cameronballoons.co.uk www.cameronballoons.com	Cameron Balloons Ltd. St John's Street Bedminster, Bristol BS3 4NH England Tel: 44 (272) 637216 Fax: 44 (272) 661168	Cameron Balloons US P.O. Box 3672 Ann Arbor, MI 48106 USA Tel: 1-313-426-5525 Fax: 1-313-426-5026
CargoLifter AG www.cargolifter.com	Kreuzberger Ring 21 D-65205 Wiesbaden Germany Tel: +49 611 9748188 Fax: +49 611 9748100	
Carolina Unmanned Vehicles Ltd http://www.carolinaunmanned.com/	4105 Graham-Newton Road, Raleigh, NC 27606 Tel: (919) 851-9898	
GasKites Aerostats http://www.helikites.ca/	5703 Gartrell Road Summerland, BC V0H 1Z7 Canada Tel: 250-583-9875 Fax: 250-404-0308	
GEFA-FLUG GmbH www.gefa-flug.de	Weststrasse 24c D-52074 Aachen Germany Tel: 0241-889040 Fax: 0241-8890420	
Global Skyship Industries Inc. www.globalskyships.com	1001 Armstrong Blvd Unit A Kissimmee, FL 34741 USA Fax: 1-407-932-2916	
Hamilton Airship Company www.hamilton.co.za	P. O. Box 67492 Bryanston 2021 South Africa Phone: +27 11 884 4352 Fax: +27 11 884 3277 Email: webmaster@hamilton.co.za	

Interface Airships Inc. www.ecoblimp.com	PO Box 317 780 Terra Ceia Road Terra Ceia, FL 34250 USA Tel: ? Fax: ?	
Lindstrand Balloons www.lindstrand.co.uk www.lindstrand.com	Lindstrand Balloons Ltd. Maesbury Road Oswestry, Shropshire SY10 8ZZ England Tel: +44 (1691) 671717 Fax: +44 (1691) 671122	Lindstrand Balloons USA 11440 Dandar Street PO Box 6002 Galena, IL 61036 USA Tel: 1-815-777-6006 Fax: 1-815-777-6004 E-mail: info@lindstrand.com
Prospective Concepts AG www.prospective-concepts.ch	Rietstrasse 50 CH-8702 Zollikon/Zurich Switzerland Tel: +41 1 395 4300 Fax: +41 1 391 4323 E-mail: info@prospective-concepts.ch	
Thunder & Colt www.thunderandcolt.co.uk	St John's Street Bedminster, Bristol BS3 4NH England Tel: +44 ? Fax: +44-117-966-3638	Thunder & Colt America P.O. Box 3672 Ann Arbor, MI 48106 Tel: 1-734-426-5525 Fax: 1-734-426-5026
UPship Corporation	Route 2, Box 53-4 Elba, Alabama 36323 USA Tel: 1-334-897-6132 Fax: 1-334-897-3434	
US-LTA Corp. www.us-lta.com	US-LTA Corp. 750 Commercial Street Eugene, Oregon 97402 USA Tel: 1-541-683-4983 Fax: 1-541-342-3806	

	E-mail: info@us-lta.com	
Westdeutsche Luftwerbung (WDL) http://www.wdl-worldwide.de/?getlang=en	WDL Luftschiffgesellschaft mbH Flughafen D-45470 Muelheim/Ruhr Germany Tel: +49-208-3780-80 Fax: +49-208-3780-841	Ormond Beach, Florida
Worldwide Aeros Corp. www.aeros-airships.com	9617 Canoga Ave. Chatsworth, CA 91311 USA Tel: 1-818-993-5533 Fax: 1-818-993-9435	
Zeppelin Luftschifftechnik GmbH www.zeppelin-nt.com	Allmannsweilerstr. 132 D-88046 Friedrichshafen Germany Tel: +49-7541 202-05 Fax: +49-7541 202-516	

Annex B DISTANT EARLY WARNING LINE/NORTH WARNING SYTEM CONSOLIDATED SITE TABLE[46][47]

Note: Click on Site Geographic Place Name to go to Site page

DEW = DEWLINE
DEW AUX = DEWLINE AUXILLIARY SITE
DEW "I" SITE = DEWLINE INTERMEDIATE SITE
DEW MAIN = DEWLINE MAIN SITE
DEW REAR COM = DEWLINE REARWARD COMMUNICATION SITE

NWS = NORTH WARNING SYSTEM
NWS LRR = NORTH WARNING SYSTEM LONG RANGE RADAR SITE
NWS SRR = NORTH WARNING SYSTEM SHORT RANGE RADAR SITE
NWS LSS = NORTH WARNING SYSTEM LOGISTIC SUPPORT SITE

N/A DEW = NOT APPLICABLE TO THE DEWLINE
N/A NWS = NOT APPLICABLE TO THE NORTH WARNING SYSTEM

LAT/LON = LATITUDE AND LONGITUDE)
NOTE: REFS MARKED WITH * ARE APPROXIMATE. OR ARE OF A GEOGRAPHIC PLACE OF THE SAME NAME

AKA = ALSO KNOWN AS

DEW or NWS SITE # and LAT/LON	SITE TYPE	GEOGRAPHICAL PLACE NAME	NWS SITE ESTABLISHED	DEW OPERATION CEASED
*	*	**COB SITES**	*	*
COB 1 52 58 30N 168 51 20W	ALEUTIAN DEW LRR N/A NWS.	NIKOLSKI ALASKA	.	30 SEP 69.
COB 2 53 58 28.81N 166 54 18.516W	ALEUTIAN DEW LRR N/A NWS.	DRIFTWOOD BAY ALASKA	.	30 SEP 69.
COB 3 54 35 32N 164 52 34W	ALEUTIAN DEW LRR N/A NWS.	CAPE SARICHEF	.	30 SEP 69.
COB M 55 15 49N	ALEUTIAN DEW LRR	COLD BAY ALASKA	.	30 SEP 69

[46] Langille, Robert. "117/124 Sites - Site List." E-mail to Patrick Crandell. 22 Mar. 07.
[47] Courtesy of Electronic Warfare Consulting Service

162 53 08W	N/A NWS			
COB 4 55 58 41N 160 30 01W	ALEUTIAN DEW LRR N/A NWS.	PORT MOLLER ALASKA	.	30 SEP 69.
COB 5 56 58 38N 158 39 09W	ALEUTIAN DEW LRR N/A NWS.	PORT HEIDEN ALASKA	.	30 SEP 69
*	*	**REAR COMM SITES**	*	*
AGE-X	DEW REAR COM N/A NWS	ANCHORAGE ALASKA	.	1963
NEL-X	DEW REAR COM N/A NWS	FORT NELSON BC	.	1963
*	*	**LIZ SITES**	*	*
LIZ-1	DEW "UNK" SITE N/A NWS	CAPE LISBURNE ALASKA	.	UNK
LIZ-A 69.01.27N 163.51.26W	DEW "I" SITE N/A NWS	CAPE SABINE ALASKA	.	1963
LIZ-2 69 44 08N 163 00 59W	DEW AUX NWS LRR	POINT LAY ALASKA	89/90 Deactivated 1994	.
LIZ-B 70 17 16.96N 161 54 35.64W	DEW "I" SITE N/A NWS	ICY CAPE ALASKA	.	1963
LIZ-3 70 36 32.65N 159 52 07.93W	DEW AUX NWS SRR	WAINWRIGHT ALASKA	1994	APR 1995
LIZ-C 70 48 32 N 158 15 15W	DEW "I" SITE N/A NWS	PEARD BAY ALASKA	.	1963
*	*	**POW SITES**	*	*
POW-MAIN 71 19 38N 156 38 10W	DEW MAIN NWS LRR	POINT BARROW ALASKA	89/90	.
POW-A 71 03 26N 154 43 28W	DEW "I" SITE N/A NWS	CAPE SIMPSON ALASKA	.	1963
POW-1	DEW AUX	LONELY ALASKA	1994	OCT 1990

70 54 37N 153 14 23W	NWS SRR			
POW-B 70 34 31.22N 152 16 00.87W	DEW "I" SITE N/A NWS	KOGRU ALASKA	.	1963
POW-2 70 29 54N 149 53 22W	DEW AUX NWS LRR	OLIKTOK POINT ALASKA	89/90	.
POW-C 70 24 09N 148 40 38W	DEW "I" SITE N/A NWS	POINT MCINTYRE ALASKA	.	1963
POW-3 70 10 31.23N 146.51.18.03W	DEW AUX NWS SRR	FLAXMAN ISLAND ALASKA AKA BULLEN POINT	1994	APR 1995
POW-D 69 58 27N 144 50 15W	DEW "I" SITE N/A NWS	BROWNLOW POINT ALASKA aka KANGIGIVIK POINT aka AGILGUAGRUK, aka COLLINSON POINT, aka CAMDEN BAY, aka NUVUBAQ in Inupiat	.	1963
*	*	**BAR SITES**	*	*
BAR-MAIN 70 07 49.5N 143 38 21W	DEW MAIN NWS LRR	BARTER ISLAND ALASKA	15 NOV 1990	.
BAR-A 69 53 09N 142 18 28W	DEW "I" SITE N/A NWS	DEMARCATION BAY ALASKA aka NUVAGAPAK POINT	.	1963
BAR-1 69 35 53N 140 11 00W	DEW AUX NWS SRR	KOMAKUK BEACH YUKON	OCT 1990	04 AUG 1993
BAR-B 69 19 49N 138 44 13W	DEW "I" SITE NWS SRR	STOKES POINT YUKON	JUL 1991	.
BAR-2 68 55 23N 137 15 32W	DEW AUX NWS LRR	SHINGLE POINT YUKON	JUN 1989	JUN 1989
BAR-C 69 0010N	DEW "I" SITE	TUNUNUK CAMP YUKON	.	1963

134 40 00W	N/A NWS			
BAR-BA3 68 53 44N 133 56 12W	N/A DEW NWS SRR	STORM HILLS NWT	NOV 1990	.
BAR-3 69 26 35N 132 59 55W	DEW AUX NWS SRR	TUKTOYAKTUK NWT	SEP 1990	13 SEP 1993
BAR-D 69 57 00N* 131 27 00W*	DEW "I" SITE N/A NWS	ATKINSON POINT NWT	.	1963
BAR-DA1 69 36 30N 130 54 00W	N/A DEW NWS SRR	LIVERPOOL BAY NWT	NOV 1990	.
BAR-4 69 55 38N 128 58 13W	DEW AUX NWS SRR	NICHOLSON PENNINSULA NWT	OCT 1990	09 SEP 1993
BAR-E 70 00 59.02N 126 56 35.11W	DEW "I" SITE NWS SRR	HORTON RIVER NWT AKA MALLOCH HILLS	JUN 1991	1963
*	*	**PIN SITES**	*	*
PIN-MAIN 70 10 17N 124 43 30W	DEW MAIN NWS LRR	CAPE PARRY NWT	AUG 1989	AUG 1989
PIN-A 69 49N* 122 44W*	DEW "I" SITE N/A NWS	PEARCE POINT NWT	.	1963
PIN-1 69 35 00N 120 44 46W	DEW AUX N/A NWS	CLINTON POINT NWT	.	03 SEP 1993
PIN-1BD 69 40 18.96N 121 40 14.75W	N/A DEW NWS SRR	KEATS POINT NUNAVUT	JUL 1991	.
PIN 1BG 69 16 00N 119 13 00W	N/A DEW NWS SRR	CROKER RIVER NUNAVUT	AUG 1991	.
PIN-B 69 13 00N* 118 38 00W*	DEW "I" SITE N/A NWS	CLIFTON POINT NUNAVUT	x	1963
PIN-2 68 55 47N 116 55 45W	DEW AUX N/A NWS	CAPE YOUNG NUNAVUT	.	31 AUG 1993

PIN-2A 68 50 23N 116 58 57W	N/A DEW NWS SRR	HARDING RIVER NUNAVUT	SEP 1991	.
PIN-C 68 46 55.00N* 114 50 01.27W	DEW "I" SITE N/A NWS	BERNARD HARBOUR NUNAVUT	1963	.
PIN-CB 68 45 19.16N 114 56 21.58W	N/A DEW NWS SRR	BERNARD HARBOUR NUNAVUT	SEP 1991	.
PIN-3 68 28 45N 113 13 32W	DEW AUX NWS LRR	LADY FRANKLIN POINT NUNAVUT	JUN 1989	JUN 1989
PIN-D 68 31 00N* 111 10 00W*	DEW "I" SITE N/A NWS	ROSS POINT NUNAVUT	.	1963
PIN-4 68 55 00N* 108 30 21W*	DEW AUX N/A NWS	BYRON BAY NUNAVUT	.	21 AUG 1993
PIN-DA 68 29 09.26N 110 51 50.58W	N/A DEW NWS SRR	EDINBURGH ISLAND NUNAVUT	OCT 1991	.
PIN-EB 69 01 30N 107 48 10W	N/A DEW NWS SRR	CAPE PEEL WEST NUNAVUT	OCT 1991	.
*	*	**CAM SITES**	*	*
CAM-MAIN 69 06 58.72N 105 07 08.83W	DEW MAIN NWS LRR/LSS	CAMBRIDGE BAY NUNAVUT	SEP 1989	SEP 1989
CAM-A 68 47 591N 103 19 58W	DEW "I" SITE N/A NWS	STURT POINT NUNAVUT	1963	.
CAM-A3A 68 57 47.39N 103 45 34.33W	N/A DEW NWS SRR	STURT POINT NUNAVUT	OCT 1991	.
CAM-1 68 39 17N 101 45 00W	DEW AUX N/A NWS	JENNY LIND ISLAND NUNAVUT	.	.
CAM-1A 68 44 31N 101 51 17W	N/A DEW NWS SRR	JENNY LIND ISLAND NUNAVUT	OCT 1990	1992
CAM-B 68 19 02.71N	DEW "I" SITE	HAT ISLAND NUNAVUT	SEP 1991	1963

100 04 09.15W	NWS SRR			
CAM-2 68 40 48.35N 97 48 38.84W	DEW AUX NSW SRR	GLADMAN POINT NUNAVUT	OCT 1990	1992
CAM-C 68 52 10N 95 09 25W	DEW "I" SITE N/A NWS	MATHESON POINT NUNAVUT	.	1963
CAM-CB 68 38 10.37N 95 52 11.99W	N/ADEW NWS SRR	GJOA HAVEN NUNAVUT	OCT 1990	.
CAM-3 68 47 34.94N 93 26 25.17W	DEW AUX NWS LRR	SHEPHERD BAY NUNAVUT	JUL 1989	JUL 1989
CAM-D 68 35 41.34N 91 57 24.66W	DEW "I" SITE NWS SRR	SIMPSON LAKE NUNAVUT aka SITE 25	SEP 1991	.
CAM-4 68 26 13.06N 89 43 34.07W	DEW AUX NWS SRR	PELLY BAY NUNAVUT	SEP 1991	1992
CAM-E 68 17 00N* 88 16 00W*	DEW "I" SITE N/A NWS	KEITH BAY NUNAVUT	.	1963
CAM-5 68 18 03N 85 40 29W	DEW AUX N/A NWS	MACKAR INLET NUNAVUT	.	1992
CAM-5A 69 39 21N 85 34 22W	N/A DEW NWS SRR	CAPE MCLOUGHLIN NUNAVUT	JUL 1992	.
CAM-F	DEW "I" SITE N/A NWS	SCARPA LAKE NUNAVUT aka SITE 29	.	1963
CAM-FA 69 06 38.46N 83 32 23.57W	N/A DEW NWS SRR	LAILOR RIVER NUNAVUT	AUG 1992	.
*	*	**FOX SITES**	*	*
FOX.MAIN 68 45 39.30N 81 13 35.20W	DEW MAIN NWS LRR/LSS	HALL BEACH NUNAVUT aka SITE 30	SEP 1989	SEP 1989
FOX-1 69 04 01.79N 79 03 55.15W	DEW AUX NWS SRR	ROWLEY ISLAND NUNAVUT	AUG 1991	.
FOX-A	DEW "I"SITE	BRAY ISLAND	AUG 1991	.

69 13 26.23N 77 13 48.97W	NWS SRR	NUNAVUT aka SITE 32		
FOX-2 68 53 56N 75 08 54W	DEW AUX NWS SRR	LONGSTAFF BLUFF NUNAVUT aka SITE 33	NOV 1990	1991
FOX-B 68 37 14N 73 12 58W	DEW "I" SITE NWS SRR	NUDLUARDJUK LAKE NUNAVUT aka WEST BAFFIN	OCT 1991	.
FOX-3 68 39 02.56N 71 13 58.93W	DEW AUX NWS LRR	DEWAR LAKES NUNAVUT	JUL 1989	JUL 1989
FOX-C 68 46 00N* 68 37 00W*	DEW "I" SITE N/A DEW	EKALUGAD NUNAVUT	.	1963
FOX-CA 68 38 51N 69 07 47W	N/A DEW NWS SRR	KANGOK FJORD NUNAVUT	SEP 1992	.
FOX-4 68 28 21N 66 48 01W	DEW AUX NWS SRR	CAPE HOOPER NUNAVUT aka SITE 37	DEC 1990	1991
FOX-D 67 57 06.70N 64 54 35.70W	DEW "I" SITE N/A NWS	KIVITOO NUNAVUT	.	1963
FOX-5 67 32 07.49N 63 47 11.43W	DEW AUX NWS SRR	BROUGHTON ISLAND NUNAVUT aka QIKIQTARJUAQ aka SITE 39	DEC. 1990	1991
FOX-E 67 05 00.03N 62 12 59.87W	DEW "I" SITE N/A NWS	DURBAN ISLAND NUNAVUT aka PADLOPING	.	1963
*	*	**DYE SITES**	*	*
DYE-MAIN 66 39 52.46N 61 21 21.53W	DEW MAIN NWS LRR	CAPE DYER NUNAVUT aka SITE41	AUG 1989	AUG 1989
*	*	**DYE SITES Greenland)**	*	*
DYE-1 66 38 23N 52 52 22W	DEW AUX N/A NWS	QAQQATOQAQ GREENLAND near Sisimiut	N/A	1990/91
DYE-2 66 29 30N 46 18 19W	DEW AUX N/A NWS	ICE CAP 1	N/A	01 Oct 1988

DYE-3 65 10 57N 43 49 10W	DEW AUX N/A NWS	ICE CAP 2	N/A	1990/91
DYE-4 65 31 32N 37 10 31W	DEW AUX N/A NWS	KULUSUK GREENLAND	N/A	24 Sep 1991 Last American out
*	*	**DYE SITE Iceland)**	*	*
DYE-5	LRR N/A NWS	ROCKVILLE ICELAND aka H1	.	.
*	*	**BAF SITES**	*	*
BAF-2 64 57 28N 63 34 46W	N/A DEW NWS SRR	CAPE MERCY NUNAVUT	JUL 1992	.
BAF-3 (RES-X-1) 63 20 20N 64 09 28W	DEW REAR COM NWS LRR	BREVOORT ISLAND NUNAVUT	OCT 1988	.
BAF-4A 62 30 22.00N 64 31 06.183W	N/A DEW NWS SRR	LOKS LAND NUNAVUT	AUG 1992	.
BAF-5 (RES-X) 61 35 47.95N 64 38 20.40W	DEW REAR COM NWS SRR	RESOLUTION ISLAND NUNAVUT	SEP 1991	1963
*	*	**LAB SITES**	*	*
LAB-1 59 59 15N 64 09 55W	N/A DEW NWS SRR	CAPE KAKIVIAK LABRADOR	JUL 1992	.
LAB-2 58 29 19.35N 62 35 08.00W	N/A DEW NWS LRR	SAGLEK LABRADOR	NOV 1988	.
LAB-3 57 08 07.6N 61 28 32.8W	N/A DEW NWS SRR	CAPE KIGLAPAIT LABRADOR	AUG 1992	.
LAB-4 55 44 30N 60 25 42W	N/A DEW NWS SRR	BIG BAY LABRADOR	SEP 1992	.
LAB-5 54 42 53N 58 21 30W	N/A DEW NWS SRR	TUKIALIK LABRADOR	OCT 1992	.

LAB-6 53 33 08N 56 49 46W	N/A DEW NWS LRR	CARTWRIGHT LABRADOR	NOV 1988	JUN 1968 (Pinetree Ops)
.	.	.	.	.

NOTE: This table should be considered illustrative because of some information gaps.

Annex C NAV CANADA RADAR SITES[48]

C.1 Terminal Surveillance Radars (TSR) - 22

Generally comprise: a short-range PSR (80NM) operating on 1250-1350 MHz and a long range SSR (250NM) transmitting on 1030 and receiving transponder replies on 1090 MHz[49]

Ser	Name	Ident	Latitude	Longitude
1	Gander	RTQX	48 59 10.42884N	54 30 14.50717W
2	St-John's	RTYT	47 39 00.93048N	52 48 25.15440W
3	Halifax	RTHZ	44 54 37.70158N	63 25 45.23390W
4	Moncton	RTQM	45 51 17.64990N	64 47 31.01437W
5	Quebec City	RTQB	46 41 07.2317N	71 23 09.0708W
6	Dorval	RTUL	45 28 00.26870N	73 46 00.08410W
7	Mirabel	RTMX	45 41 41.58503N	73 57 52.69783W
8	Ottawa	RTOW	45 18 20.41607N	75 37 21.94850W
9	Toronto	RTYZ	43 40 18.8124N	79 39 22.3865W
10	Hamilton	RTHM	43 10 09.2011N	79 55 19.1345W
11	London	RTXU	43 01 58.4595N	81 08 30.4442W
12	North Bay	RTYB	46 22 24.94708N	79 24 48.57036W
13	Sault Ste Marie	RTAM	46 28 45.94608N	84 31 18.37638W
14	Thunder Bay	RTQT	48 31 04.53144N	89 23 51.55452W
15	Winnipeg	RTWG	49 55 25.11779N	97 14 55.68611W
16	Regina	RTQR	50 25 58.98986N	104 40 16.67799W
17	Saskatoon	RTXE	52 10 10.96301N	106 42 26.76622W
18	Edmonton	RTEG	53 20 58.73259N	113 16 37.44285W
19	Calgary	RTYC	51 08 38.7845N	113 58 56.3878W
20	Prince George (Baldy Hughes)	RTBH	53 36 46.96650N	122 57 15.71530W
21	Vancouver (Sea Island)	RTSI	49 11 51.92345N	123 12 18.50391W
22	Victoris (Mt Newton)	RTYJ	48 36 44.2745N	123 26 35.9673W

C.2 Independent Secondary Surveillance Radars (24)[50]

Long range 250nm transmitting on 1030 MHz and receiving transponder replies on 1090 MHz.[51]

Ser	Name	Ident	Latitude	Longitude

[48] Valid 11 August 2004. Courtesy of J. Lemire Nav Canada via Electronic Warfare Consulting Service
[49] "AIP CANADA (ICAO) PART 2 EN-ROUTE (ENR) Figure 1.6.1 and 1.6.2." NAV Canada. 13 Apr. 06. 31 Mar. 07 <www.navcanada.ca/.../Publications/AeronauticalInfoProducts/ AIP/Current/PDF/EN/part_2_enr/2enr_eng_3.pdf>.
[50] Langille, Robert. "Re: Info Request - Radar List & Coordinates of All Nav Canada Radars."
[51] AIP CANADA (ICAO), Part 2 Enroute (ENR) Figure 1.6.1 and Figure1.6.2

1	Goose bay	RSYR	53 28 16.9992N	60 17 40.2874W
2	Stephenville	RSJT	48 35 26.87410N	58 39 56.82332W
3	Sydney	RSQY	46 05 35.1924N	60 26 19.0006W
4	Digby	RSQI	44 42 54.82803N	65 15 28.79544W
5	Sept-Iles	RSZV	50 12 19.9788N	66 41 44.9886W
6	Chibougamau	RSMT	49 57 29.3656N	74 12 08.6010W
7	Chisasibi	RSSU	53 48 23.9625N	78 55 42.9645W
8	Brisay	RSAY	54 23 06.24137N	70 34 56.36784W
9	Kuujjuaq	RSVP	58 08 45.772N	68 24 12.500W
10	Iqaluit	RSFB	63 46 50.66695N	68 32 40.91396W
11	Hearst (Formerly Kapuskasing)	RSHF	49 41 56.76097N	83 32 02.58902W
12	Big Trout Lake	RSTL	53 49 00.96752N	89 54 23.49746W
13	Dryden	RSHD	49 53 36.70019N	92 48 07.19498W
14	Langruth	RSLR	50 19 52.67147N	98 40 29.51799W
15	Thompson	RSTH	55 51 54.3921N	97 47 30.0709W
16	La Ronge	RSVC	55 12 39.3169N	105 19 14.3136W
17	Stony Rapids	RSSF	59 10 24.2749N	105 46 52.3412W
18	Ft McMurray	RSMM	56 22 59.88689N	111 14 55.44651W
19	Medicine Hat	RSXH	50 39 45.60975N	111 15 08.31694W
20	Yellowknife	RSZF	62 27 44.351N	114 28 19.133W
21	Grande Prairie	RSQU	55 13 32.0322N	119 17 38.0278W
22	Kamloops (Mt Wallensteen)	RSWA	50 39 22.19344N	119 29 46.80804W
23	Port Hardy (Holberg)	RSKM	50 41 35.11387N	127 41 57.09067W
24	Sandspit (Cumshewa)	RSCU	53 08 38.4538N	131 58 02.5959W

C.3 NAV CANADA

C.3.1 Training, Test and Maintenance Radars[52]

xii. NCTI TSR Training,

xiii. NCTI NCSSR1 (SSR only) 2 Channels,

xiv. Ottawa Transportable TSR, and

xv. Ottawa Transportable NCISSR1 (SSR only) 1 Channel

C.3.2 Under consideration for future (SSR only, Mode S)[53]

xvi. Purvinituq, Que

xvii. Fort Severn, ON

[52] Langille, Robert. "Re: Info Request - Radar List & Coordinates of All Nav Canada Radars."
[53] Ibid

xviii. Arviat, NU

xix. Coral Harbour, NU

C.4 DND RADARS

C.4.1 Coastal Radars (AN/FPS-117)[54]

Ser	Location	Installed	Remarks
1	Gander NL	1990	Unknown whether this is the LRR at the Nav Cda Gander TSR
2	Sydney NS	1991	Unknown whether this is the LRR at the Nav Cda Sydney ISSR
3	Barrington NS	1991	
4	Holberg BC	1991	Unknown whether this is the LRR at the Nav Cda Port Hardy ISSR

NOTE: This table should be considered illustrative because of the confusion over ownership.

Two other coastal radars at Saglak and Cartwright Labrador are actually part of the NWS.

C.4.2 TRACS ATC Radars[55]

Ser	Location	Ident	Latitude	Longitude
1	CFB Bagotville	RMBG	48 19 23.5N	70 59 51.4W
2	CFB Trenton	RMTR	44 07 33.949N	77 31 47.201
3	CFB Cold Lake	RMOD	54 24 32.000N	110 18 24.998W
4	CFB Comox (Planned for Nov 04) RPDS2	RMQQ	49 42 34.76N (Tower)	124 53 32.14W

NOTE: This table should be considered illustrative. Some or all of these may have been upgraded to RPDS2 standards.

[54] Langille, Robert. "117s (Npt on Picture) - Atlanic Region." E-mail to Patrick Crandell. 23 Mar. 07.
[55] Langille, Robert. "Re: Info Request - Radar List & Coordinates of All Nav Canada Radars."

C.5 FAA/DOD RADARS[56]

(The status of these radars is unknown)

i. Lake Side (replacement to Mica Peak (Spokane DOD/FAA Long Range Radar)
ii. Mika Peak (Spokane), soon
iii. Biorka Island, soon
iv. Makah, soon
v. Caribou, Fall 04
vi. Buck's Harbour, Fall 04
vii. St. Albans, Fall 04
viii. Detroit (Canton) LRR, Fall 04
ix. Detroit TRACON for Windsor tower, Fall 04
x. Nashwauk for Toronto and Winnipeg, Fall 04
xi. Empire for Winnipeg, Winter 05

[56] Ibid

List of symbols/abbreviations/acronyms/initialisms

ACC	Area Control Centres
ACC	Air Combat Command
ACO	Airspace Control Order
ADF	Australian Defence Force
ADS-B	Automatic Dependent Surveillance - Broadcast
ADT	Air Data Terminal
AESA	active electronically scanned array ()
AEW&C	airborne early warning and control
AIMP	Aurora Incremental Modernization Program
AIS	Automatic Identification System
AMTI	Air Moving Target Indicator
ASCIET	All Service Combat Identification and Evaluation Team
ASIP	Advanced Signals Intelligence Program
ATE	Air Terminal Equipment
AWACS	airborne warning and control system
BER	Bit Error Rate
BLOS	Beyond Line-of-Sight
CANR	Canadian NORAD Region
CAOCs	Combined Air Operation Centers
CARs	Canadian Aviation Regulations
CBRN	Chemical Biological Radiological Nuclear
CDL	Common Data Link
CEC	Co-operative Engagement Capability
CIP	common imagery processor
CMD	Cruise Missile Defense
CMDS	Countermeasures Dispensing System
COMINT	communications intelligence
CRCs	Control and Reporting Centres
CVFR	Controlled VFR
CW	Chemical Weapons
DCGS-A	Distributed Common Ground Station-Army
DERA	Defence Evaluation and Research Agency now [dstl]
DFO	Department of Fisheries & Oceans
DIRCM	Directional Infrared Countermeasures
DND	Department of National Defence
DSP	Defense Support Program
DSTO	Defence Science and Technology Organization
DTIG	Deployed Theater Information Grid

EA	Electronic Attack
ECCM	electronic counter-counter measures
ELINT	electronic intelligence
EO/IR	Electro-Optic/Infrared
EW	electronic warfare
FAA	Federal Aviation Authority
FEC	forward error correction
FICs	Flight Information Centres
FINAS	Flight in Non-Segregated Air Space
FTS	Flight Termination System
GCS	ground control station
GDT	Ground Data terminal
GIG	Global Information Grid
GMTI	Ground Moving Target Indicator
GWOT	Global War On Terrorism
HAA	High Altitude Airship
HAA	High Altitude Airship
HEU	highly enriched uranium
HF	high frequency
IAF	Israel Air Force
IC2DL	Interoperable Command and Control Data Link
ICAO	International Civil Aviation Organization
IED	Improvised Explosive Device
IFF	Identification Friend or Foe
IOC	Initial Operational Capability
ISAR	Inverse Synthetic Aperture Radar
JCS	Joint Chiefs of Staff
JINTACCS	Joint Interoperability of Tactical Command and Control Systems
JLENS	Joint Land Attack Cruise Missile Defense Elevated Netted Sensor
Joint STARS	Joint Surveillance Target Attack Radar System
JRE	TADIL J Range Extension
JTAMD	Joint Theater Air and Missile Defense
JTDLMP	Joint Tactical Data Link Management Plan
JTIDS	Joint Tactical Data Link System
LALE	Low Altitude Long Endurance
LCC	Land Component Commander
LPAR	L-band large phased array radar
LPI	Low Probability of Intercept
LRE	Launch and Recovery Element
LTAA	Lighter Than Air Airships

MAWS	Missile Approach Warning System
MC2A	Multi-Sensor Command and Control Aircraft
MC2C	Multi Sensor Command and Control Constellation
MCE	Mission Control Element
MESA	Multi-role Electronically Scanned Array
MIDS	Multifunctional Information Distribution System
MIDS/LVT	Multi-functional Information Distribution System Low Volume Terminal
MOSP	Multi-mission Optronic Stabilized Payload
MP	Maritime Patrol
MP-CDL	Multi Platform-Common Data Link
MP-RTIP	Multi-Platform Radar Technology Insertion Program
MTI	Moving Target Indication
NADGE	NATO's Air Defence Ground Environment
NAVSPASUR	Naval Space Surveillance Network
NCCT	Network Centric Collaborative Targeting
NILE	NATO Improved Link Eleven
NNs	NILE Networks
NORAD	North American Aerospace Defense Command
NWS	North Warning System
ONCS	operational network cycle structure
OPI	Office of Primary Interest
OSA	Open Systems Architecture
OTH-B	Over The Horizon Backscatter
PARCS	Precision Acquisition Radar Characterization System
PAWS	Ballistic Missile Early Warning System
PDPC	Pulse Doppler Pulse Compression
PGM	Precision Guided Munitions
PRC	People's Republic of China
R&D	Research & Development
R&M	reliability and maintainability
RAID	Rapid Aerostat Initial Deployment
RCMP	radar control and maintenance panel
RCS	Radar Cross Sections
RSIP	Radar System Improvement Program
SAR	Synthetic aperture radar
SASS LITE	Small Airship Surveillance System, Low Intensity Target Exploitation
SBIRS	Space Based Infrared System
SFOC	Special Flight Operations Certificates
SIM	Surveillance Information Management

SN	Super Network
SNC	System Network Controller
SOCs	Sector Operation Centers
SPC	Signal Processing Controller
SSAS	Small Airship Surveillance System
SSPA	solid state power amplifier
STANAG	Standard NATO Agreement
STOL	Short Take Off and Landing
TADIL	Tactical Digital Information Links
TCAS	Traffic Alert and Collision Avoidance System
TCDL	Tactical Common Data Link
TDS	Tactical Data System
TMDA	Time Demand Multiple Access
UAS	Unmanned Aircraft System
UAVs	Unmanned Aerial Vehicles
UHF	ultra-high frequency
VP	Vital Point
VTOL	Vertical Take Off and Landing
WAS	Wide-Area Surveillance
WMD	Weapons of Mass Destruction
WTC	World Trade Center

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In the Canada First Defence Strategy, the challenges related to Canada's sovereignty in the Arctic was recognized. It is expected that in the near future, sovereignty and security challenges will become more pressing as the impact of climate change leads to enhanced activity throughout the region thus making protection of territorial integrity in the Arctic a top priority for the government. The Government of Canada plans to enhance the Canadian Force's (CF's) ability to conduct surveillance in the North through the use of evolving unmanned aerial vehicle technology as one of its options.

The Joint Uninhabited Aerial Vehicle Surveillance and Target Acquisition System (JUSTAS) program has been tasked with the technological and organizational development of unmanned assets that will allow an overland domestic and international C4ISR capability and the definition of a domestic maritime and arctic Communication, Command, Control, and Computers Intelligence Surveillance and Reconnaissance (C4ISR) capability in its first phase of study.

It has been recognized that for the operation of Medium Altitude Long Endurance Uninhabited Aerial Vehicles (MALE UAVs) in the arctic, a variety of methods will be needed to establish reliable communications and data links in the area of operations. Lighter than air platforms carrying a high bandwidth communication and data relays represent one of the possible methods to link Combined Air Operations Center's (CAOC's) with forward operating forces and MALE assets that are spread over a dispersed area. This survey reviews both Lighter Than Air (LTA) platforms and potential data link payloads.

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UAV, LTA, Airship, Aerostat, Communications Relay, Survey

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