

Military Applications for Digital Audio Radio Service (DARS)¹

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Abstract—This paper will discuss the three commercial Digital Audio Radio Service (DARS) systems that are currently, or soon to be, available, and the potential military applications of the different systems. XM Satellite Radio Inc., Sirius Satellite Inc., WorldSpace Corp, and potential future systems from Mobile Broadcasting Corp. and the European Space Agency system are DARS systems that each will provide approximately one hundred channels of radio content to different areas of the world to mobile and static receivers. The paper will be organized as follows. A technical background on the systems will be given, including an analysis of each system's orbits, ground coverage, and system architectures. The systems will be analyzed for potential military applications. Military applications for commercial DARS include moral enhancement for personnel, weather data broadcast to aircraft, propaganda dissemination, and testing and experiment support.

quality music and information to a much larger continuous coverage footprint than current radio, both AM and FM transmission, can provide. Through the use of satellites and, for some DARS systems, terrestrial repeater networks, the DARS companies can broadcast up to 100 or more unique channels of content. The three systems discussed in-depth are XM Radio, Sirius Radio and WorldSpace Radio. After system descriptions, including satellite orbits, ground coverage and architectures, the paper will discuss the potential military utility and value of several applications of the different DARS systems and their respective capabilities. Our view is that Moral, Welfare, Recreation (MWR); Satellite Weather Information Service (SWIS), psychological operations and propaganda, and testing and experiment support are four areas where DARS can provide utility and value the military.

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1.0 INTRODUCTION

This paper will address commercial satellite Digital Audio Radio Service (DARS) and the potential military utilities of DARS. DARS is a relatively new service to consumers that uses a constellation of satellites to broadcast digital

2.0 TECHNICAL BACKGROUND OF DARS SYSTEMS

Commercial satellite Digital Audio Radio Service (DARS) systems provide a service that is relatively new to



Figure 1: General DARS system, with broadcast studios, satellite, terrestrial repeaters and mobile receivers

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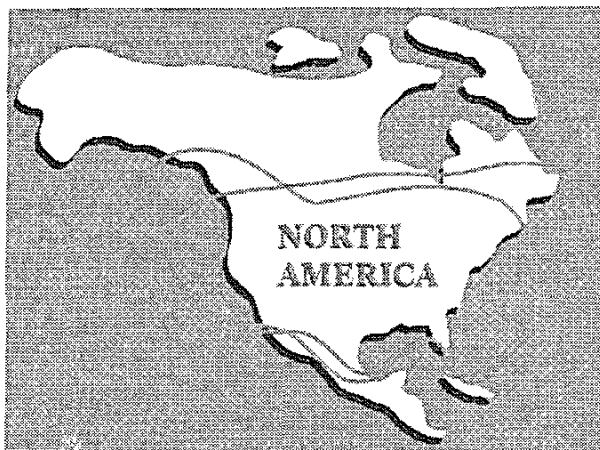


Figure 2: Approximate coverage footprint of XM's satellites, Rock and Roll

consumers throughout the world. For this paper, DARS is defined as a service that broadcasts a digital signal from a satellite to small ground units, providing the user with multiple channels of audio content or digital data. [Figure 1]

The three current DARS systems each broadcast around one hundred different channels of radio content, with each system having different characteristics.

2.1 XM SATELLITE RADIO INC.

XM Satellite Radio Inc. [1], one of two companies that offers DARS services to the continental United States (CONUS), [Figure 2] was incorporated in 1992, received a SDARS (Satellite DARS) license in October 1997, and has been publicly traded on the NASDAQ stock exchange (XMRS) since October 1999. XM began commercial service in limited areas in late 2001. President and CEO Hugh Panero leads XM along with partners General Motors (GM), DIRECTV, Clear Channel (the largest radio station operator in the United States) and American Mobile (a leading provider of integrated terrestrial and satellite digital mobile communications services).

2.1.1 SATELLITE AND GROUND SYSTEMS - XM's service is delivered through two Boeing 702 satellites, named "Rock" & "Roll," positioned in a 35,786 km Geostationary orbit. The Rock satellite is located at 85 degrees west longitude and the Roll satellite at 115 degrees west longitude, providing each satellite with a coverage footprint that includes the continental US and several hundred miles off each coast and into southern Canada and northern Mexico. Each satellite has a design life of roughly 15 years with an initial DC power of 15 kW, twice the power of Digital Broadcast Satellites (e.g. DirectTV). Boeing revealed in October 2001 that several of the 702 series satellite buses have experienced problems with the solar arrays, including XM's two satellites. However there is no need to replace the satellites as operators will closely monitor and manage the health of the satellite. To this end, they will likely

rotate the solar arrays slightly to cool the cells, while maintaining adequate power. [2] Roll was launched on the 8th of May 2001 and Rock on the 18th of March 2001 by Boeing's Sea Launch Limited Partners,. Telesat Canada, who monitors and controls the satellites, also designed Rock & Roll's telemetry, tracking and control system.

The payloads, manufactured by Alcatel Space, broadcast 100 channels of digital music and news to customers with the appropriate receivers (discussed in section 2.1.2). These payloads feature numerous innovations that allow the satellites a transmit power of more than 4 kilowatts to the antenna. XM's SDARS frequency allocation of 12.5 MHz (2332.5 to 2345.0 MHz) is divided into three sections, each satellite uses 5 MHz and the terrestrial repeaters use the remaining 2.5 MHz. From the 5 MHz each satellite transmits a pair of 2.5 MHz carriers. The satellite processor forms each carrier using Time Division Multiplexing (TDM) received from a variety of earth stations. Each carrier signal has components with data rates from 16 kbps to 64 kbps. The composite bit rate of each TDM carrier is 1.536 Mbps providing the capability to multiplex up to 24 music channels per carrier. With each carrier signal able to multiplex 24 channels, each XM satellite can broadcast up to 48 64 kbps channels. And since each satellite's coverage footprint covers all of CONUS, XM can provide over one hundred channels of content. TDM also allows XM signals to be received by terminals moving at speeds up to 500 mph, making it possible to receive data broadcast to a commercial aircraft [3].

Along with the Rock & Roll satellites, XM plans to augment the system with a network of approximately 1500 terrestrial repeaters installed in 70 of the nations largest urban markets. Reception of the DARS signal requires line of sight to the satellites, and repeaters will allow users to receive a continuous signal in areas where large buildings and other urban obstructions might otherwise interfere with satellite reception. As stated earlier, the bandwidth for the

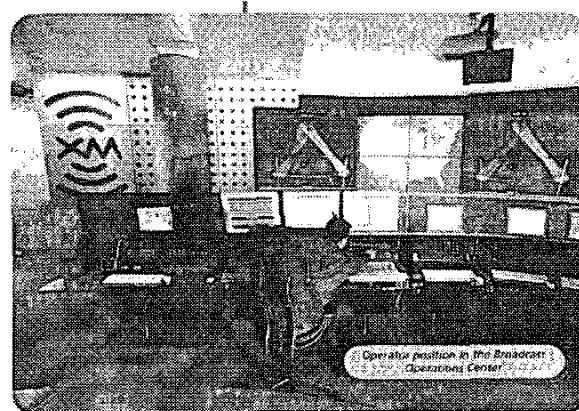


Figure 3: View of XM Satellite's main control center, located in the XM National Broadcast Studios, Washington DC.

terrestrial repeaters is 2.5 MHz, since this bandwidth is half the width of the signal broadcast from the satellite, only half the satellite-transmitted bandwidth undergoes terrestrial repetition [2]

The satellites will be broadcasting close to 100 channels; however, they are not operating at maximum capacity, allowing for the addition of new channels in the future. The XM national broadcasting studios, located in Washington D.C., contain facilities for uplinking data and telemetry, tracking and control of the satellites. [Figure 3]

2.1.2 RECEIVERS - To receive the encrypted signal from satellites and terrestrial repeaters, XM has contracted STMicroelectronics to develop the chipsets that will complete the analog-to-digital conversion and decrypt the signal, and then deliver it to the radio. If customized, receivers could be capable of receiving specially encrypted channels that general consumer receivers couldn't. This would allow a party to lease bandwidth and send an encrypted signal to customized receivers without other receivers recognizing that the signal was being transmitted.

XM has targeted three markets for its receivers, original equipment for vehicles, aftermarket or replacement equipment for vehicles, and, to a much lesser extent, home and portable audio equipment. Six major audio equipment manufacturers have developed receivers capable of receiving DARS signals.

Most people listen to the radio in their vehicles, and as a response to this market, XM has an agreement with GM and several other car manufacturers to offer DARS ready radios as options for the entire line of their vehicles. Agreements have also been reached with two leading companies in the US trucking industry to provide thousands of long-haul tractor-trailers with XM service.

2.1.3 PROGRAMMING - The cost to the consumer for XM service is a subscription fee of \$9.95 USD/month. Service includes close to 100 channels of content ranging from Rock, Country, Urban, Classical, Sports, News, and Talk radio. Of those approximately 100 channels, 70 will offer music, with the remaining channels covering news, sports, comedy, and variety.

Content will originate from the XM national broadcasting studios, located in Washington DC, which houses the service's broadcast studios. These studios are fully wired with fiber optic cable and are designed for the development, production, recording and broadcast of radio content.

2.2 SIRIUS SATELLITE RADIO INC.

Sirius Satellite Radio Inc [4] is the second company planning to deliver DARS services to the continental United States, which gives the system a similar coverage footprint to that of XM. Though similar to XM, there are

several differences between the two systems, including satellite orbits, number of satellites and capacity. Sirius was started in 1989, received a SDARS license in October 1997, and has been publicly traded on the NASDAQ stock exchange (SIRI) since 1994. Sirius was the first US company to develop the idea of satellite broadcast radio. It was their proposal in May of 1990 that led eventually to the FCC creating a separate frequency band for DARS in 1997. The company plans to start the operational role out of its service in 2002. President and CEO Joseph P. Clayton leads Sirius along with major partners DaimlerChrysler Corp., Ford Motor Company, BMW, Loral Satellite (manufacturer of the satellites) and Lucent Technologies (manufacturer of the chipsets).

2.2.1 Satellite and Ground Systems - Sirius' programming is delivered through three Loral FS-1300 satellites in highly elliptical orbits with perigee of 24,469 km and an apogee of 47,102 km centered over the continental US. Initially Sirius planned on using two satellites in Geostationary orbit, but moved to the current configuration in December of 1999. The reason for the change is because the elliptical orbit provides higher-elevation-angle lines of sight in northern CONUS locations (~60°) than are afforded by Geostationary satellites (~30°) [2]. Because of the higher elevation angle, car antennas will have greater minimum gain in the direction of the satellite, thereby reducing the transmit power required for reception. Each satellite has a design of 15 years and produces 3.84 KW of RF power; however, Loral has identified circuit failures in solar arrays on satellites launched since 1997. The circuit failures that have occurred do not limit the power of the broadcast signals, reduce the expected life or otherwise affect operations, but if additional circuits fail the life of the satellites could be reduced [5]. The three satellites were launched from Baikonour Cosmodrome in Kazakhstan on 31 July, 29 September, and 20 December 2000. Each satellite spends 16 hours per day north of the equator, and at any given time two satellites are north of the equator while the third is south of the equator and not broadcasting. The satellites act as "bent pipes," relaying signals directly to the ground, and do not have on-board processing capability.

The payloads, also manufactured by Space Systems/Loral, broadcast 100 channels of digital music and news to customers with Sirius receivers. Similar to XM, Sirius's SDARS license authorizes 12.5 MHz, which has been divided into three sub-bands. The upper and lower sub-bands are 4.2 MHz and are assigned to the two transmitting satellites that transmit the same material. The middle band of 4.1 MHz is reserved for terrestrial transmission. Again, Time Division Multiplexing (TDM) is used in the downlink signal. The music channels are compressed from 1.44 Mbps to 64 kbps by the application of a Perceptual Audio Coding (PAC) algorithm developed by Lucent Technologies [2]

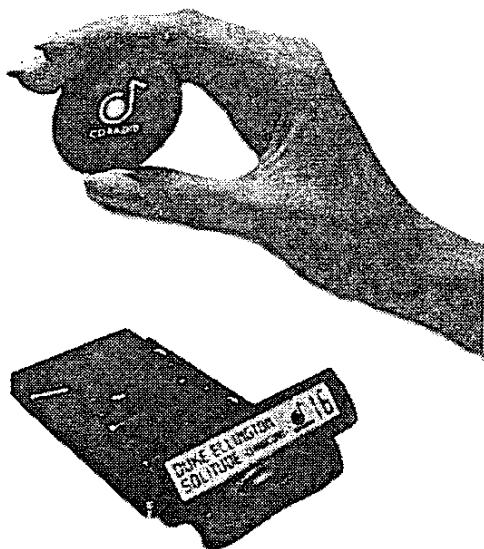


Figure 4: Above Sirius receiver antenna, Below Sirius receiver card for car stereos.

As with XM, signal reception requires line of sight to the satellite, so Sirius has also planned a terrestrial repeater network to augment its satellite broadcast capability. However, Sirius is only planning for roughly 90 repeaters in 45 urban areas. This number is considerably smaller than the number proposed by XM, this is most probably due to the elevation angle benefit mentioned earlier.

Sirius offers a similar number of channels of content to XM, however, the system is operating at close to full capacity and additional channels cannot be added at this time. The Sirius national broadcasting studios, located in New York City, contain facilities for uplinking data to the satellites as well as facilities to perform telemetry, tracking and control.

2.2.2 RECEIVERS - The Sirius receiver is made up of two parts: the antenna module, and the receiver module [Figure 4]. The antenna module is an active system with several elements that "look" along the horizon for the terrestrial signal, and higher for the satellite signal and is about the size of a coaster. This module picks up the available terrestrial and satellite signals simultaneously, amplifies them, filters out the noise and interference, and passes them on to the receiver module.

The chipset down-converts the signals from 2.3GHz to a lower intermediate frequency, and then to the digital base band. On the way down, the signals are converted from analog to digital. Within the digital realm, all available signals are inspected for quality and combined in an optimal way to use the best information from each source. Instead of using just the best signal, it uses the best input from all the signals. The combined digital signal is then processed for a number of things. It's digitally filtered, the

forward error correction is reversed and, the data is decrypted.

Like XM, encryption and customization would also allow selected data to be targeted at certain receivers through a specially encrypted signal that could not be recognized or acknowledged by other receiver units. However, unlike XM, Sirius is targeting only the vehicle markets for its receiver equipment and service, not the home market. Ford, BMW and many other car manufacturers plan to offer DARS ready equipment in their vehicle lines in the future.

2.2.3 PROGRAMMING - The cost to the consumer for Sirius service is a subscription fee of \$12.95 USD/month. Service includes close to 100 channels of content ranging from Rock, Country, Urban, Classical, Sports, News, and Talk radio. Of those approximately 100 channels, 70 will offer music, with the remaining channels covering news, sports, comedy, and variety.

Sirius' programming originates from their national broadcast studios in New York City. As with XM, the studios are 100% digital and contain state-of-the-art development, production, recording and broadcast facilities.

2.3 WORLDSPACE CORPORATION

WorldSpace corp. [7] was the first company worldwide to provide DARS services. Although headquartered in Washington DC, the company's area of coverage footprint does not include the United States, but does cover Central and South America, Africa, Southern Europe, the Middle East, India and Asia. The potential audience for the WorldSpace service is over 5 billion people. [Figure 5]

Audio service to Africa and the Middle East began in October 1999, with the commencement of commercial operations of the AfriStar satellite. Multi-media services became available in selected countries in 2000. AsiaStar, launched in March 2000, provides similar service to Asia. AmeriStar, scheduled for launch in early 2001, will provide service to Latin America and the Caribbean.

Chairman and CEO Noah A. Samara founded WorldSpace

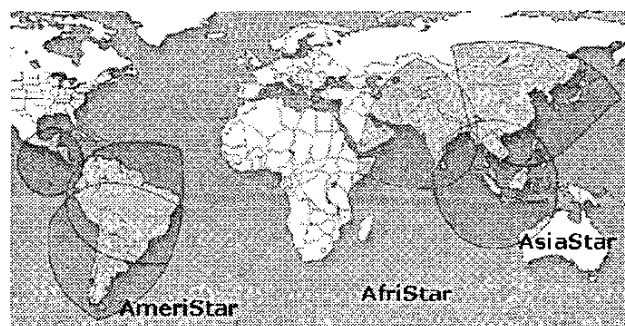


Figure 5: Coverage footprint of WorldSpace System

in 1990 along with partners Alcatel Space, Fraunhofer Institut Integrierte Schaltungen, Micronas Intermetall, Matra Marconi Space and STMicroelectronics.

2.3.1 SATELLITE AND GROUND STATIONS - WorldSpace broadcasts its signal from three satellites, AfriStar, AsiaStar, and AmeriStar, all in Geostationary orbits 35,786 km above the earth. Each WorldSpace satellite has three transmission beams; each beam can carry 50 broadcast channels and covers roughly 14 million square kilometers. The satellites are based on the EUROSTAR 2000+ platform and have a design life of 12 years however the AfriStar satellite has experienced some on-orbit problems. A malfunction occurred in the payload interface unit, which runs the communications electronics and is responsible for four transponders. Alcatel, the satellite contractor, has been unable to switch over to a backup amplifier, which may decrease the mission life of the satellite.

Unlike XM and Sirius, WorldSpace satellites have robust on-board processing, allowing content providers to either uplink their own content via the traditional hub method, sending broadcast signals to a central location for transmission to the satellite, or use smaller, more mobile Feeder Link Stations (FLS) for uplink. Globecom Systems will build 14 of FLS, which are small enough to be mounted on a delivery truck-sized vehicle. On-board processing technology converts these multiple signals at the satellite, combining them into a single downlink signal before broadcasting a signal back to earth. Content providers uplink their broadcasts to the satellite on an encrypted digital signal through a small satellite dish on a frequency of 7.025-7.075 GHz. Equipment on the satellites decrypts the broadcaster's signal, amplifies it and then broadcast the signal at data rates from 16-128 kbps on the L-band frequency of 1.452-1.492 GHz. This is a sufficient data rate for a fairly robust, lower bandwidth datacasting capability.

WorldSpace offers a service called Direct Media Service (DMS) that uses datacasting to provide large amounts of data to personal computers. This service is in essence a one-way internet, delivering up to 128 kbps continually to users terminals.

Currently there are no terrestrial repeaters in place to augment the WorldSpace system, as the majority of the system's current operational coverage area contains relatively few urban areas with line of sight obstacles prevalent in many US cities. However, repeaters are being considered for offering service to European countries, many of which contain concentrations of large cities.

Like XM, the WorldSpace system is not operating at full capacity, and could add new channels in the future.

2.3.2 RECEIVERS - WorldSpace currently has 4 different models that can receive the WorldSpace signal; they have

two smaller more portable models that will be available in the near future. A unique flat antenna on each receiver receives the signal; this antenna is detachable and has a generous length of cable to allow for optimum positioning. Another unique feature of the WorldSpace receiver is that it will automatically reconfigure itself to match the specific data rates for programs transmitted from the AfriStar, AsiaStar or AmeriStar satellites, from AM to CD quality. Each receiver has a multimedia capable 64 and 128 kbps data port. Leading consumer electronics manufacturers Hitachi, JVC, Matsushita (Panasonic) and Sanyo developed and are mass-producing receivers.

Current consumer WorldSpace receivers are not designed for use in vehicles. This is because the antenna must be directed towards the satellite and does not accommodate for the direction change of a moving vehicle.

To use the Direct Media Service (DMS) WorldSpace has developed two configurations for users, either through the WorldSpace receiver or a WorldSpace PC card. One can either attach a receiver to a PC via a digital data adaptor, or install a WorldSpace PC card, making the computer itself a receiver. [7]

2.3.3 PROGRAMMING - Currently WorldSpace offers service at no cost, however they are looking into charging a subscription fee in certain areas. WorldSpace is considering the subscription fee for India, but plans on keeping the service free for Africa. Profits for WorldSpace come from the sale of receivers, hardware and the leasing of channels to local content providers. Unlike Sirius and XM, the nine different beams broadcasted on the WorldSpace service (three beams per satellite), can offer 50 channels unique to the area of each beam's broadcast. They do, however, have several channels that are broadcast on all beams.

As mentioned earlier, the Direct Media Service delivers a one-way internet capability to personal computers. While the computer is on, the receiver downloads the contents of multiple webpages, allowing the user to view information at speeds only limited by the computers cache speed. WorldSpace offers a total of 44 websites, ranging from region specific news, worldwide news, sports, health, research material, entertainment news and children oriented material. Unlike the current audio component of WorldSpace, DMS requires a monthly subscription fee that will vary from region to region. DMS is currently only available in parts of East Africa, though the service will be available in India and South Africa in 2002. [7]

2.4 FUTURE DARS SYSTEMS

Though there are only three DARS providers currently, there are plans for at least two more systems. Mobile Broadcasting Corp, a Japanese targeted system, and the European Space Agency have plans to provide DARS to

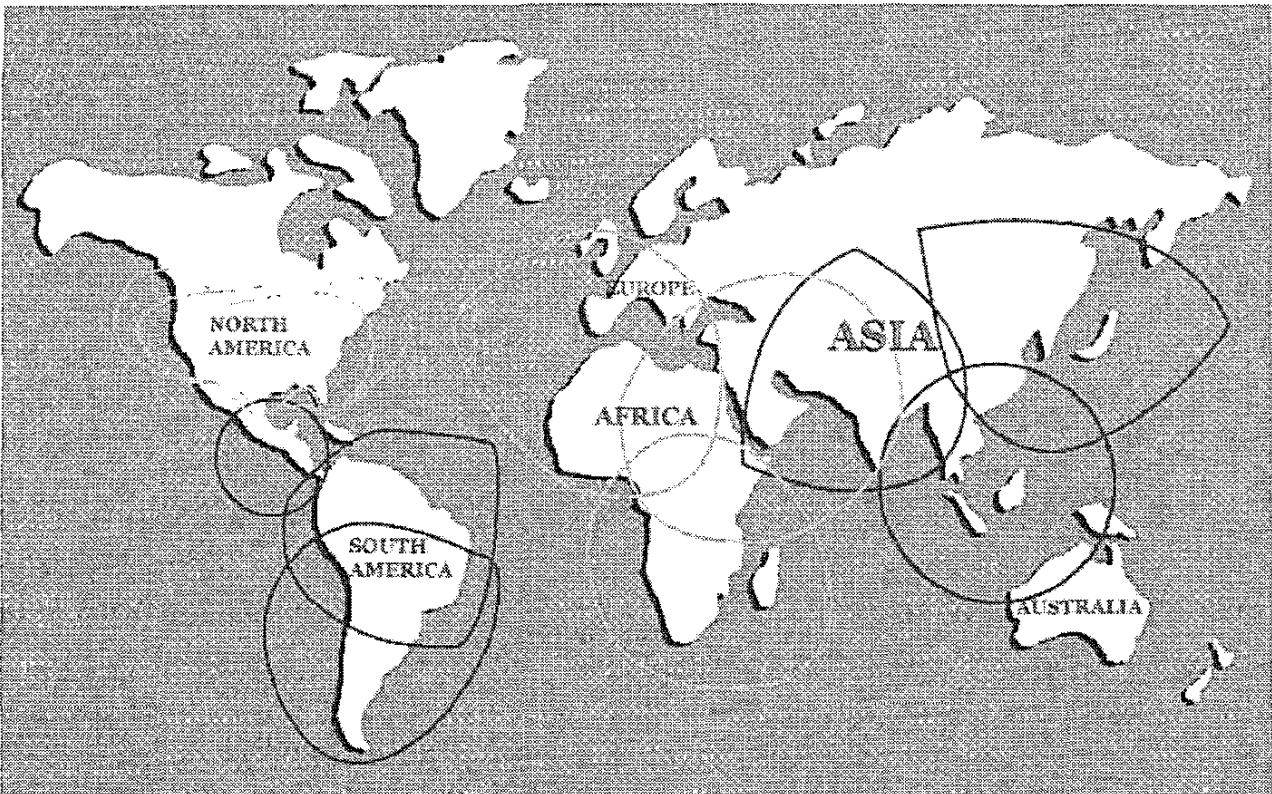


Figure 6: Combined coverage of The WorldSpace Corp. and XM Satellite Radio

their respective areas. These systems will most likely be similar to the general DARS architecture.

3.0 POTENTIAL MILITARY APPLICATIONS

There are several areas of military utility for the use of DARS systems, however, all potential applications are limited by the capabilities and coverage of the various systems. The first limiting factor is the service coverage footprint of the systems, with each system covering a relatively small area of the earth compared to the worldwide scope of US military operations. The coverage footprint of all the current commercial systems combined, however, would cover over 75% of the earth's landmasses, as well as moderate ocean coverage including North and South America, Africa, the Middle East, India, portions of Europe, and Asia. [Figure 6] Military use will be limited to applications specific to each individual system's capabilities and coverage footprint.

Encryption and counterintelligence concerns are also limiting factors. All DARS systems have fairly robust encryption schemes for secure communications, however, military requirements for certain kinds of sensitive information transmission may not be met by the available encryption capabilities of the commercial systems. System requirements for counterintelligence measures such as LPI/LPD (Low Probability of Intercept/Low Probability of Detection) and anti-jamming capabilities may additionally

limit the use of DARS systems for sensitive information transmission.

Another limiting factor is the lack of survivability of commercial satellites. DARS system satellites are not hardened or built to military satellite survivability standards, and the military does not like to rely on satellites that it perceives as too vulnerable. Due to this, it is highly unlikely that the government or military would use commercial systems for critical or mission essential information.

Cost is also a factor. The military needs and requirements that can be met with the capabilities of the multiple DARS systems must be weighed against the costs of exploiting those capabilities.

In light of these limiting factors, there are, however, several potential applications for military use of DARS systems: MWR (Morale, Welfare, and Recreation) for military personnel, psychological operations (PSYOPS) and propaganda dissemination, SWIS (Satellite Weather Information Service), and testing and experiment support. These concepts are all based on the leasing or using of DARS capabilities and services by the military.

3.1 MORALE, WELFARE AND RECREATION (MWR)

The most obvious potential military utilities of DARS are the primary DARS markets: audio entertainment, and to a

lesser extent, datacasting of information. For the military, providing entertainment and information helps to improve quality of life for personnel, which supports MWR. It is Department of Defense (DoD) policy that DoD components provide a well-rounded MWR program that promotes fitness, esprit de corps, and quality of life. MWR programs are vital to mission accomplishment and form an integral part of the non-pay compensation system, which aids in recruitment and retention of personnel. [9]

3.1.1 AUDIO ENTERTAINMENT - For audio entertainment within the US, DARS can provide diverse content that is largely unavailable in the large, urban radio markets, and even less so in smaller markets where many military bases are located. A program to offer troops the opportunity to purchase discounted DARS equipment and service would benefit the military's diverse member's quality of life by increasing access to otherwise unavailable choices of audio entertainment.

A similar agreement with foreign DARS companies to provide discounted equipment and service to troops abroad would be even more beneficial for quality of life of military personnel, as access to English language radio content is severely limited in most of the areas outside the US. To increase English language options on foreign DARS systems, bandwidth could also be purchased in order to program additional English language content.

Negotiating an arrangement with DARS companies to provide military personnel with discounted equipment and service would give value at little or no cost to the military, and at much lower cost than an option of the military itself purchasing equipment and service to be issued to troops. The three currently operating DARS systems all provide coverage to locations where the US military has personnel stationed, and could all support such an arrangement.

3.1.2 DATACASTING - Another capability of commercial DARS systems with potential military utility, which would fall into the category of MWR, is the broadcast of information and data. All three commercial DARS systems have a data broadcast capability, and WorldSpace has already developed and deployed what is in essence a limited, one-way internet service (refer to Section 2.3). This type service would provide a valuable MWR benefit to troops deployed to locations where PCs are available, but the necessary infrastructure for accessing internet service is not. Although it would not be two-way internet, access to this type of service would give such military personnel current news and information which would be otherwise unavailable in as timely a manner.

An arrangement similar to the one proposed for audio service could be negotiated, allowing personnel to purchase data receiving equipment and service at reduced prices. Or, due to the relatively small number of troops that would normally be in such a situation at any given time, it may be

reasonable to procure and issue a limited number of receiving units to deployed locations.

3.2 SATELLITE WEATHER INFORMATION SERVICE (SWIS)

One area of datacasting based on DARS technology, and using the WorldSpace system, that is currently being developed in an experiment with NASA and several other companies, is the broadcast of weather data in-flight to commercial aircraft.

For the civil and commercial aviation system, weather has been identified as a causal factor in 30% of all aviation accidents, and is responsible for up to 65% of domestic US airline schedule delays. These accidents and delays result in significant loss of life and increases in operating costs. A substantial inadequacy in the current aviation system is the lack of timely and accurate weather information delivered to crews of operating aircraft.

Some aircraft fly routes with flight legs up to 15 hours in length, and weather can change significantly during such an extended period of time. Current methods of transmitting data to the aircraft flight deck are primarily terrestrial VHF transmissions over 25kHz channels, which suffer from low bandwidth, frequency channel congestion, and significant geographical coverage gaps. Updated graphical weather information cannot be provided throughout the entire duration of these extended flights.

Although the military has a more robust capability than civil and commercial aviation to transmit data, including weather information, to its aircraft, that capability is not always employed for routine transportation and training missions. Therefore, a fairly sizeable percentage of military flight is subject to the same delays and accidents caused by weather as civil and commercial aviation.

In an effort to improve aviation safety and accident

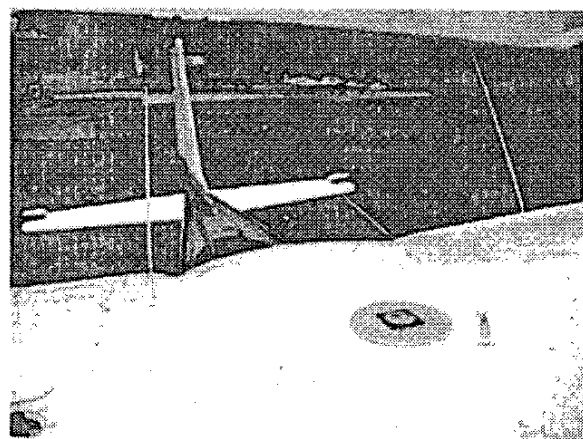


Figure 7: WorldSpace antenna, used to receive weather information from Satellite Weather Information Service (SWIS)

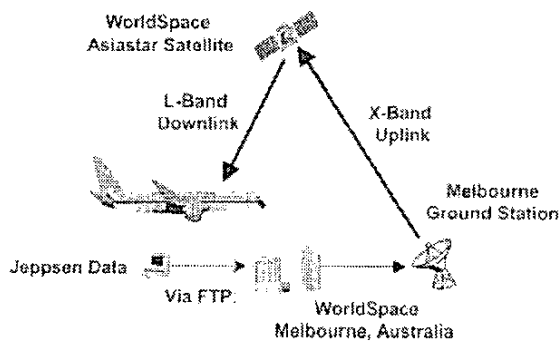


Figure 8: SWIS Phase II system diagram

prevention, DARS capabilities are being utilized to develop a very low cost aviation weather solution. There are three significant factors in the low cost of a DARS based system: 1) The low cost of a receive-only system relative to current methods of weather data communications, 2) DARS satellites broadcast a sufficiently strong signal, up to a 128kbps channel, allowing very small passive microstrip patch antennas to be employed, which are 10 cm in diameter and easily installed on aircraft, and 3) A mass consumer market for DARS receivers allows the exploitation of economies of scale to provide inexpensive receiving equipment.

To date there have been two phases of testing for the SWIS concept. Phase I testing was to determine the feasibility of using DARS capabilities to transmit complex graphical weather data to and aircraft in flight. Weather graphics were successfully broadcast at 64kbps to a Cessna 172 by the WorldSpace AfriStar satellite, and received and viewed on a laptop computer. Continuous error free data was received during normal aircraft maneuvers during takeoff, cruise and landing operations, and during bank angles up to 45 degrees. [Figure 7]

Phase II testing evaluated a prototype system capable of delivering real, up-to-date weather information to a transport class aircraft. During testing, an X-band transmission was uplinked from a Melbourne, Australia ground station to WorldSpace's AisaStar satellite, broadcasted on an L-band downlink [10], and successfully received by two Boeing 727 aircraft. [Figure 8] [11]

The civil and commercial aviation industry is funding the development of the low cost SWIS system. The capabilities of the SWIS system can provide the same utility and value to certain segments of military aviation operations, as it can to civil and commercial aviation. This presents a valuable opportunity for the military to acquire this utility at a very low cost, as development is already funded and equipment is inexpensive. However, the cost and effort required for integrating new systems into military aircraft can be high, and must also be considered.

3.3 PSYCHOLOGICAL OPERATIONS AND PROPAGANDA

DARS can also provide utility in the area of psychological operations (PSYOPS) and propaganda. The US government and Department of Defense (DoD) engage in PSYOPS efforts.

PSYOPS is planned operations to convey selected information and indicators to foreign audiences to influence their emotions, motives, objective reasoning, and ultimately the behavior of foreign governments, organizations, groups, and individuals. The purpose is to induce or reinforce foreign attitudes and behavior favorable to the achievement of national objectives [12]. Propaganda is any form of communication that is designed to accomplish these goals [13].

One highly visible method by which the government seeks to achieve objectives which fall under the auspices of PSYOPS, is the operation of Voice of America (VOA). Drafted in 1960 and signed into law on by President Gerald Ford in 1976, the VOA charter reads, in part, "The long-range interests of the United States are served by communicating directly with the peoples of the world by radio." [14] Today, VOA is an international multimedia broadcast service, with a 2001 budget over \$131 million USD, that broadcasts various types of content worldwide in 53 different languages, serving as a source of news and an outlet to present the policies of the United States to foreign audiences [15].

There are many other methods by which PSYOPS objectives are currently accomplished, however, the use of DARS provides an additional avenue for dissemination of information that can be designed to accomplish these objectives.

The WorldSpace system has the capability to reach 80% of the world's population. This represents a fairly large potential audience in Latin America, Africa, the Middle East, Asia, India, and parts of Europe that can be targeted for reception of DoD and US government designed and developed information. By leasing bandwidth on the three WorldSpace satellites, a number of channels in multiple languages could be utilized to broadcast content designed to accomplish PSYOPS and propaganda objectives, and targeted at the audiences within the coverage areas of each satellite.

The cost of implementing such a concept would be reasonable. Each 16Kbps increment of bandwidth (the smallest increment of bandwidth that WorldSpace leases) would cost \$190,000 USD/year to lease, and would provide one channel of FM quality voice broadcast. The price for WorldSpace to uplink 16Kbps of content is \$30,000 USD/year. However, because of the on-board processing capability of the WorldSpace satellites, a customer could purchase his own uplink hardware and perform the uplink

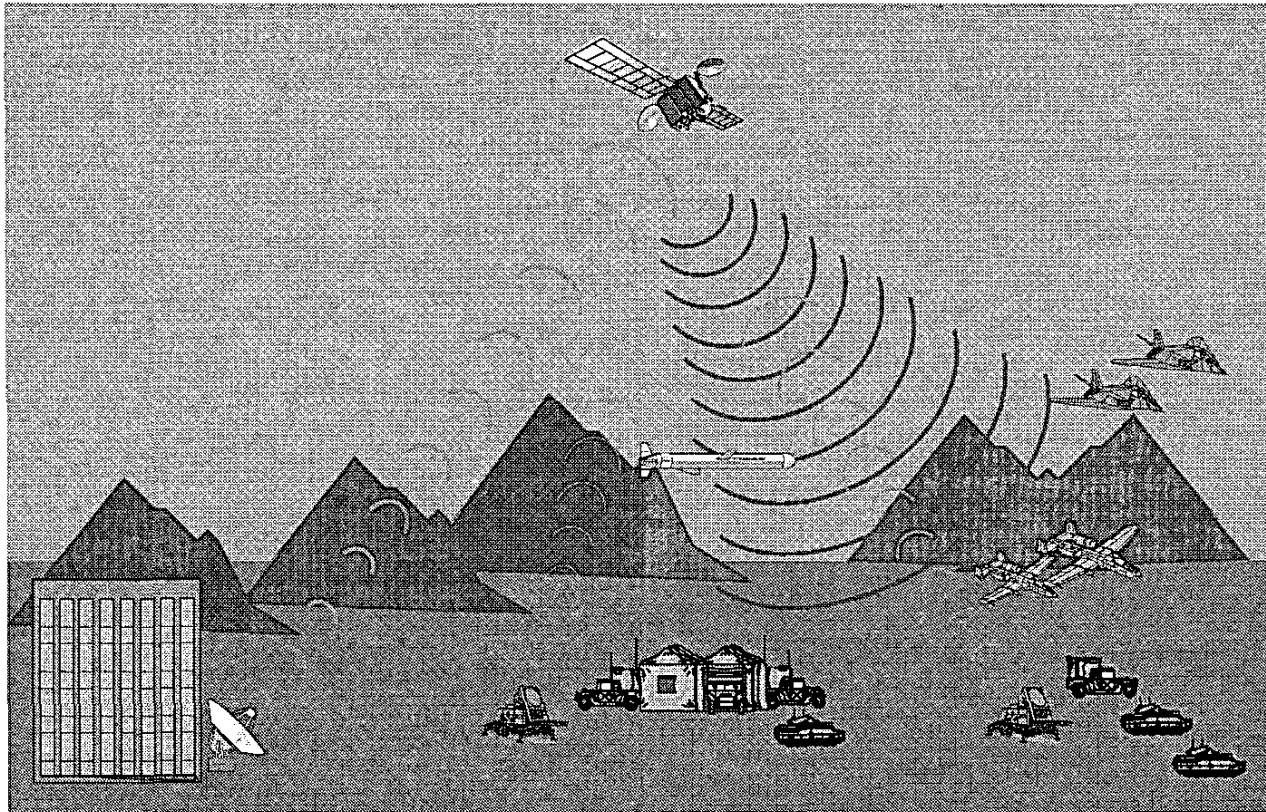


Figure 9: Concept of how military could use a DARS system to validate concepts and new technologies for experiments and demonstrations

himself. Uplink terminals can be purchased for approximately \$350,000-\$400,000 USD.

This presents an opportunity for the US government or military to acquire, at relatively low cost, a very robust coverage footprint for an additional avenue for dissemination of information which can further the accomplishment of PSYOPS and propaganda objectives. For example, two channels of information on each of the three beams of the three WorldSpace satellites, or 18 channels placed in different concentrations on the system, uplinking through WorldSpace uplink service or a self-owned terminal, could be leased and operated for approximately \$5 million USD/year [10].

In contrast, this \$5 million USD/year figure represents less than 4% of just the 2001 fiscal year budget of VOA alone, not including transmission or other support activity costs for VOA. This would also be a much smaller percentage of the total budget for accomplishing all government and military objectives in the PSYOPS arena [15].

3.4 TESTING AND EXPERIMENT SUPPORT

All four military services conduct tests and experiments to validate new concepts and technologies. The ability to do this in areas that utilize or rely on space-based capabilities, without incurring the large cost of building a new satellite

system, holds great utility to the military. Exploitation of a commercial solution to this end would be not be inappropriate, as the DoD currently projects the need to use commercial satellite systems to fulfill a portion of its bandwidth requirements. [Figure 10]

By utilizing DARS systems, the military could acquire the use of a working, space-based digital broadcast prototype at a very low relative cost. This prototype could be used to demonstrate and test several different space-centric concepts that require a digital broadcast capability.

In addition, future DoD organic SATCOM resources are projected to fall short of future bandwidth needs and requirements. By using commercial DARS capabilities to

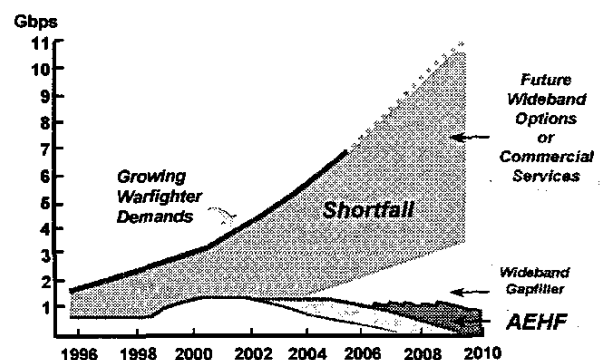


Figure 10: Current and projected DoD SATCOM bandwidth requirements

support tests and experiments, the military could reallocate needed bandwidth by allowing current military systems to focus on operational mission requirements. [Figure 10]

The basic architecture of such a prototype system would be very similar to the Satellite Weather Information Service (SWIS) prototype already discussed (refer to Section 3.2). Encrypted data would be uplinked to a commercial DARS satellite and then broadcasted to various types of devices customized to receive the encrypted signals that would otherwise be invisible to normal consumer receiver units. Depending on the experiment or the concept or technology being tested, the receivers could be anything from slightly modified consumer receiver units to integrated modules that provide data to software. [Figure 9]

A sample concept that could be tested and demonstrated with this capability is instant information dissemination to personnel, from front line troops through decision makers at various levels in the chain-of-command. Location and timing information on impending strikes, broadcasted over a very large coverage footprint to handheld smart terminal receivers, may result in a reduced number of casualties, from both enemy attacks and friendly fire. Enemy locations and movements can be relayed to battlefield commanders faster than current methods allow, resulting in improved decision making. A sample technology that could be tested is in-flight retargeting of munitions. Cruise missiles or smart bombs could be fitted with a module capable of receiving DARS signals containing retargeting instruction, and then relaying that instruction to guidance systems. Last minute intelligence indicating a benefit in re-targeting munitions already en-route, could be instantly relayed to those weapon.

The cost of the uplink and broadcast piece of this prototype architecture would be similar to that of the radio broadcast capability already discussed (refer to Section 3.3). Around 300 kbps of bandwidth could be leased and operated for less than \$5 million USD/year [8]. The cost of the receiving piece would vary widely, depending on the complexity and function of the concept or technology being tested.

4.0 CONCLUSIONS

At the beginning of our investigations into DARS, our initial perception was that the only military value to be gained from DARS systems was in the area of Moral, Welfare, and Recreation (MWR). We have found this not to be the case, as MWR is only one of several valuable applications DARS systems can potentially provide to the military. The datacasting capability, though miniscule in comparison to high bandwidth systems that broadcast in higher bands (e.g. Ka, Ku), can provide utility in several areas where a lower data rate is all that is required.

The Satellite Weather Information Service (SWIS) concept, which has been proven technically valid, is one application

of DARS capabilities that could provide great utility. The ability to broadcast detailed weather data to the cockpit of aircraft would not only decrease delays and increase safety, but could be acquired by the military as a relatively low cost solution and at very little to no cost for development.

Using DARS for psychological operations (PYSOPS) and propaganda dissemination is a great example of operational use. Though the military has capabilities to accomplish these objectives through various means, additional avenues of delivery are always valuable.

The final use of DARS covered in this paper is military experiment and test support. This concept is a great example of leveraging off of commercial space capabilities and using commercial systems to meet military needs with a low-cost commercial solution. Millions are spent each year proving technologies and conducting experiments, savings in this mission area will provide more money for developing the systems that the concepts have proven.

5.0 RECOMMENDATIONS

A commercial DARS system is a relatively new service to users worldwide. The marketing departments for each of the respective companies do a good job at informing their targeted audience, the consumer. However they don't have the time, resources or basic knowledge of the military mission to be able to properly sell the idea of using their system to meet military needs. Our office, the Commercial Planning Office (CPO), was stood up for that purpose; to analyze commercial space capabilities and determine the potential military utility of these capabilities. The next step is to go to the warfighter and inform him of the utilities DARS holds for meeting his goals and objectives, and to work towards making these potential benefits a reality for the warfighter.

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6.1 IMAGES

[Figure 1] SMC/XRR image created to demonstrate basic DARS system; 2 Lt Dustin Ballinger; Sep 01

[Figure 2] Created using information provided from John Archer. Originals not used due to XM proprietary information

[Figure 3] XM Satellite Radio, Facility Focus; April 11, 2001; pg 6

[Figure 4] Investing in Digital Audio Radio Satellites (DARS), Oct 01; Dr. Michael Horstein, Roger Rusch, Charles Emmert, Steven Mather; pg. 16

[Figure 5] The WorldSpace Corp.; <http://www.worldspace.com>

[Figure 6] Combined graphic, developed from The WorldSpace Corp. and XM Satellite Radio Inc. data.

[Figure 7] Satellite Delivery of Aviation Weather Data, Sep 1999; Robert J. Kerczewski, NASA Glenn Research Center, Cleveland, Ohio 44135; Richard Haendel, Rockwell Collins, Cedar Rapids, Iowa, 52498.

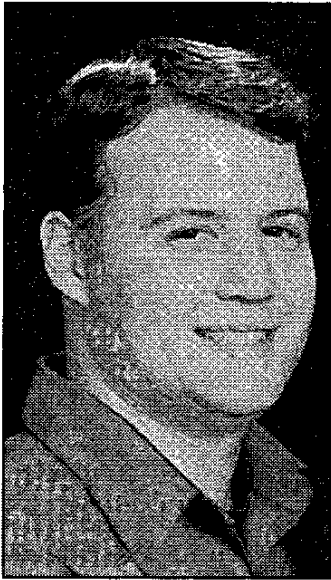
[Figure 8] Satellite Delivery of Aviation Weather Data, Sep 1999; Robert J. Kerczewski, NASA Glenn Research Center, Cleveland, Ohio 44135; Richard Haendel, Rockwell Collins, Cedar Rapids, Iowa, 52498.

[Figure 9] Concept generated by authors

[Figure 10] Taken from the Developmental Planning Directorate's Commercial Planning Office "Commercial Space" briefing presented at the Space and Missile System Center's Business of Space Course.

7.0 BIOGRAPHY

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