A New Opportunity for Unmanned Aerial Systems (UAS) via Commercial Ka-band Satellites.

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ABSTRACT

In the 1990s, the U.S. Department of Defense investigated a number of initiatives related to using Ka-band satellite systems as an integral part of the DoD commercial satellite backbone. The subsequent dotcom bubble burst effectively destroyed the Ka-band satellite initiatives that were either being designed or implemented at the time. Ka-band has now re-emerged at the same time the need for UAS transmission paths are dramatically increasing. Several systems have been launched. Others are planned to be launched. The projected environments and expectations are smaller and more realistic than the original concepts of Teledesic, Astrolink and Spaceway in the 1990s. What is the utility, if commercial Ka-band is available, of using those systems as a transmission medium to be used by American military forces and coalition partners? If this use is viable, what is the best strategy for employment and, as a corollary, what operations concept would ensure maximum benefit of that strategy? This paper examines the current environment and addresses these questions. It concludes that UAS transmissions via Ka-band satellite could be of substantial benefit, if used appropriately by the American military and its partners in the international community.

INTRODUCTION

In the mid 1990s, the United States was in the midst of a dot-com investment bubble that expanded Information Technology to Ka-band satellites. Lockheed Martin was developing Astrolink. Loral was developing Cyberstar. Hughes was developing Spaceway and Bill Gates and Craig McCaw were proving Ka-band investment wisdom by investing in Teledesic. It is a common and well told story that the Ka-band satellite bubble burst along with many other bubbles associated with dot-com investment strategies. Some have suggested that the reason for the failure of Ka-band systems to capture sufficient market share was they were primarily processed systems and were competing with fiber optic cable enterprises[1]. However, the fiber initiatives were also disadvantaged by the bubble burst which caused an across the board reduction of communications capabilities. The satellites were complicated, expensive and behind schedule. Consequently the systems were never orbited. It is an interesting irony, as illustrated in Figure 1, that the Ka-band satellite programs began disintegrating just as the unmanned aerial systems programs were transitioning from theory to reality. Initial projections of hundreds of satellites in the 1980s were focused downward by development efforts in the 1990s. Spaceway provides a good example. By the mid 1990s articles were addressing a much more limited capability.[2] Spaceway ended up manufacturing three satellites but the first two were used by DirecTV for high definition TV broadcasts. Spaceway 3 was finally launched as a Ka-band communications satellite in 2007. Now the UAS are flying and the American military has insufficient spectrum and insufficient bandwidth to satisfy the requirements that have been generated for Global Hawk and Sentinel.

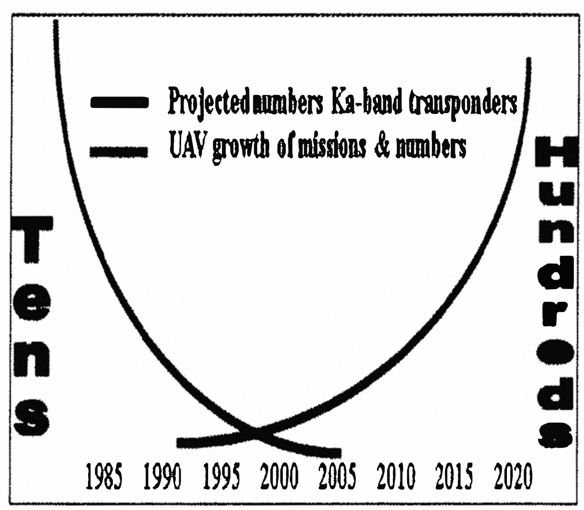

Figure 1. Demise of Ka-band programs vs. growth of UAS.

MILSATCOM REQUIREMENTS

The United States Department of Defense (DoD), through the Defense Information Systems Agency (DISA), maintains a SATCOM Requirements Database (SDB) that documents each current military satellite communications requirement. The Final Report of the Defense Science Board and the Intelligence Science Board Joint Task Force on Integrating Sensor Collected Intelligence[3] documents (from DISA) that the unconstrained demand for SATCOM capacity has reached approximately 30 Gbps in 2011. In order to accommodate some of these requirements the DoD has launched the Wideband Global SATCOM (WGS) system. With the cancelation of the Transformational Communications Satellite Program, additional burdens will be placed on WGS. The total number of satellites in the constellation may grow to seven or eight. DoD is replacing the Defense Satellite Communications System and the Global Broadcast System with X-band and Military Ka-band transponders. These satellites will satisfy military requirements assuming the X-band portions feed large and medium fixed terminals and take advantage of polarization reuse and bandwidth efficient modulation capabilities. However, the capacity available on WGS is significantly less than the documented requirements. From the warfighter perspective, there are, in addition to capacity, real operational requirements for timeliness (low latency), reliability, and throughput. Timeliness is at the top of the priority structure and is an area where the community hasn't sufficiently pushed the state of practice in support of the men and women in harms way.

UAS SYNOPSIS

The military use of UAV/UAS is actually more traditional than it is new or revolutionary and goes back to 1917[4]. UAVs also had active roles in Vietnam and in the Persian Gulf; later in the Balkans and Afghan operations, providing critical reconnaissance in each of those conflicts. During the 1990s, the DoD invested $3 Billion in UAS development. The 2010 planned expenditure for unmanned systems is just over $4 Billion.[5] Also, the highest DOD priority for UAS is reconnaissance. To quote from the Unmanned Systems Roadmap, " ...all classes of unmanned systems listed some form of reconnaissance (electronic & visual) as their number one priority.[6]

The operational and planned systems have a wide variety of payload capabilities, endurance times and altitudes. Some which use, or can use satellite communications are shown in Table 1, taken from the Unmanned Systems Roadmap referenced above. They verify that the requirement for and the work being done on UAS is expansive.

UAS	Endurance Hrs	Altitude Ft	Frequency Band
MQ-1B Predator	24	25,000	Ku-band
MQ-1C Sky Warrior	40	25,000	Ku-band
MQ-9A Reaper	24	50,000	Ku-band
RQ-4A Global Hawk	32	65,000	Ku-band Inmarsat
RQ-4B Global Hawk	28	60,000	Ku-band Inmarsat
Global Observer	168	65,000	Ku-band Ka-band
X47-B	9	40,000	Ku-band Ka-band
RQ-170 Sentinel	TBD	TBD	TBD
Improved Gnat Extended Range/Warrior Alpha	30	25,000	C-band
XPV-2	8.5	10,000	UHF

Table 1. Examples of UAV Payload, Radius and Endurance

The DoD is attempting to satisfy the requirements for these reconnaissance systems with DoD satellite programs such as WGS. However, the DoD procurement system has several constraints. First, satellite systems are designed to provide for a multiplicity of missions and reconnaissance is but one of many. Second, the requirements baseline is kept in a SATCOM database (SDB), which must be rigorously scrubbed to avoid overspending on military procurements. And while the reconnaissance community can point to a requirement for and a capability to generate links with a data rate of over a gigabit per second, the SDB limits link requirements to less than half that capacity. So the DoD is left, in this area, as it is in many others, with a capability shortfall. It just cannot provide sufficient capacity on military satellites to satisfy all military requirements. With UAS reconnaissance, however, there is a compounding issue, namely how to acquire commercial transponders with sufficient bandwidth to actually satisfy the UAS transmission requirements, given the stop, start again history of Ka-band systems.

KA-BAND SYNOPSIS

As noted in the Introduction, a number of Ka-band satellite systems were under development in the 1990s, targeting every government, business and personal user from large corporations to the small office, home office user. Table 2 illustrates the breadth of this proposed investment.

System	Satellites Planned
Astrolink	Four to nine geosynchronous processed satellites providing, high speed, global, flexible bandwidth-on-demand services with data rates up to 8 Mbps
Cyberstar	Three to six geosynchronous satellites with services including teleconferencing, medical and technical tele-imaging, CAD/CAM data and private Vsat networks with data rates below 10 Mbps
Spaceway	Six to seventeen satellites providing video and interactive multimedia communications services with data rates up to 16 Mbps
Teledesic	126 low earth orbit satellites providing residential and business services including Common Data Link and other military services up 64 Mbps on some downlinks

Table 2. Major Ka-band Systems Planned During the 1990s

It could be argued that an additional impact of the original Ka-band business segment failure is that UAS flying today and UAS that will be flying through 2020 will be inadequately matched to satellite repeaters that carry their data to command centers and decision makers. From the UAS planners' perspective, these requirements exist. There is also an assumption in MILSATCOM planning that requirements above 50 Mbps must be satisfied by military satellites. Table 1, shows how new systems are projected to include some Ka-band capability, albeit one that assumes an uncontested environment.. Additionally, the new Roadmap specifically notes the need for the kind of increased bandwidth that Ka-band can provide.[7]

KA-BAND SATELLITE SYSTEMS: In recent years Ka-band constellations did not materialize, Ka-band satellite development has been rejuvenated and a number of satellites have been or are being developed. This leads to the possibility that the Ka-band community and the UAS community may be able to match critical current need with existing capabilities.

Some Ka-band satellites that have been or are soon to be launched are shown in Table 3.

Satellite	Location	Transponders
Spaceway III	95 degrees West	72 Ka-band
Wild Blue	73/109.2 degrees West	35 Spotbeams
Telstar 8	89 degrees West	24 Ka-band
Hylas 1	33.5 degrees West	8 Ka-band
Eutelsat Ka-Sat	9 degrees East	Over 80 spot beams
Yahsat 1A	52.5 degrees East	21 Ka-band
ViaSat 1	115 degrees West	72 spot beams
HNS Jupiter	107.1 degrees West	60 spot beams
Express AM4	80 degrees West	2 Ka-band
Eutelsat W3C	16 degrees East	3 Ka-band

Table 3. Launched Or Soon To Be Launched Ka-band Satellites

NOTIONAL LINK CALCULATION

The striking difference between a UAS satellite link and most other commercial channels is that this system will be uplink limited. Accordingly, a notional uplink calculation from a UAS to a satellite follows. The important parameters are:

G/T = 10 dB/K (Terminal figure of merit)
FSL = 214 dB (Free space loss)
Eb/No = 6 (Bit energy per noise spectral density)
DR = 256 Mbps (Data rate)

The power required from the UAS will be a function of the data rate, the bit energy per noise spectral density, the free space loss, Boltzman's constant, the link margin and the satellite receive figure of merit. Stated mathematically:

$$
\begin{aligned}
P_{UAS} &= 10 \log R + Eb/No + FSL + K + M - G/T \\
&= 10 \log 256 \times 10^6 + 6 + 214 - 228.6 + 3 - 10 \\
&= 84 + 6 + 214 - 228.6 + 3 - 10 \\
&= 68.4 \text{ dBW}
\end{aligned}
$$

The power required from the UAS is therefore 68.4 dBW. With a 3-foot conformal antenna we get 46.5 dB of gain, leaving 22 dBW or a little less than 200 watts for the amplifier. With a 5-foot antenna we get 51 dB of gain, leaving 17 dBW or a little less than 100 watts for the amplifier. A more striking example can be made with HNS Jupiter, scheduled be launched in 2012. Jupiter has a G/T of 18 dB and a possible bandwidth of 375 MHz.

That brings the P_{UAS} down to 60.4 dBW so that with the same 46.5 dB antenna gain the same performance can be achieved with a 20 watt amplifier. Alternatively, the same 100 watt amplifier could provide a comfortable power margin.

POSSIBLE COMBINATION PROGRAMS

The notional satellite solution above is one that requires a less capable system than those now being orbited. The two primary system constraints are the antenna size and the power amplifier capability. The communications package on the Global Hawk already supports a 42 inch antenna vs. the 36 inch one postulated in the example. The package supports a 400 watt amplifier or three dB of surplus power.[8] With this capability, one could imagine entering into a contract with INTELSAT, SS/Loral or another satellite provider for a 10-year lease of a transponder that could be tailored for the Ka-band UAS traffic. Other transponders could then be leased as part of the normal offering. One variation on this theme might be to enter into a relationship with a Direct-to-Home TV system to share use of a satellite covering Europe with Ka-band High Definition Television coverage. Another could be to place a Ka-band transponder on one of the Inmarsat next generation satellites so that Inmarsat could provide both L-band and Ka-band services to the American military, just as an earlier generation of Gapfiller satellites provided UHF along with L-band. Satellite location to support the Central Command area could probably be arranged without too much difficulty.

CONCLUSION

The United States military and the Ka-band satellite community have reached a point where a symbiotic relationship could develop that might serve both groups well for a long period. Although investment risks and commitment risks exist, the technology risks have long since been mitigated. The previous generation of Ka-band satellite systems failed because the scope was too broad. Current wideband Ka-band development has progressed to the point where DoD investment could take advantage with minimal risk. Should the DoD use these systems? Modern Ka-band systems could satisfy most UAS requirements. What is the best strategy for employing these systems? A cooperative arrangement with a satellite operator could mitigate risk and reduce expense. The time is right to carefully consider merging current operational requirements with proven commercial wideband technology.

References:

1. Mazzei, Ka-band Satellite Payload Considerations, 7th Ka-band Utilization Conference, 2001.
2. "Hughes Satellite gives telcos, TV companies needed 'net competition," InfoWorld, October 28, 1996.
3. Memorandum for Under Secretary of Defense for Acquisition, Technology & Logistics, Subject: Final Report of the Defense Science Board (DSB) and the Intelligence Science Board (ISB) Joint Task Force on Integrating Sensor Collected Intelligence, dated 28 October 2008.
4. Office of Secretary of Defense, Unmanned Aerial Vehicles Roadmap, December 2002, p iii.
5. Office of Secretary of Defense, Unmanned Systems Roadmap (2007-2032), December 10, 2007, Table 2.1, p. 10.
6. Ibid, p. 23
7. Ibid, p. 50
8. L-3 Communications Global Hawk Integrated Communications System fact sheet.