Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Amendment of the Commission's Rules to Provide Spectrum for the Operation of Medical Body Area Networks	)))	ET Docket No. 08-59

To: The Commission

REPLY COMMENTS OF GE HEALTHCARE

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INTRODUCTION AND SUMMARY

GEHC's proposal to allow low-power, short-range Medical Body Area Network ("MBAN)" devices to operate on an opportunistic, non-interference basis in the 2360-2400 MHz band holds tremendous promise for society and is sound both from a technical and regulatory perspective. Objections by incumbent users, including Aeronautical Mobile Telemetry ("AMT") and Amateur Radio, whose higher-power operations now make exceedingly sparse use of the band, are not supported by the facts or science but rather reflect an unfortunate dog-in-the-manger stance that is inconsistent with efficient spectrum policy and the public interest.

I. COMMENTS SUPPORT BENEFITS AND VIABILITY OF MBAN PROPOSAL

The record reflects broad support for the allocation of additional spectrum for MBAN devices and many comments validate key elements of GEHC's specific proposal. Among the

parties in favor of allocating spectrum for MBANs are Philips Healthcare Systems ("Philips")[1], AdvaMed[2], the American Society for Healthcare Engineering ("ASHE")[3], Comsearch[4], the American Telemedicine Association[5], Texas Instruments ("TI")[6], Toumaz[7], Zarlink Semiconductor("Zarlink")[8] and AT&T.[9] ASHE comments that an MBAN allocation "should be of sufficient expanse… to promote competition and permit coexistence"[10] and states that it supports the allocation of 40 MHz of spectrum[11] as proposed by GEHC. Philips, TI, Toumaz and AdvaMed all specifically support the allocation of the 2360-2400 MHz band, as proposed by GEHC.[12]

Philips, AdvaMed and TI all point out that the allocation of 5150-5250 MHz and the disjointed allocation of 2300-2305 MHz and 2395-2400MHz would pose serious implementation

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[1] Comments of Philips Healthcare Systems, ET Docket No. 08-59 (filed October 5, 2009) ("Philips Comments") at 3.

[2] Comments of AdvaMed, ET Docket No. 08-59 (filed October 5, 2009) ("AdvaMed Comments") at 1.

[3] Comments of American Society for Healthcare Engineering of the American Hospital Association, ET Docket No. 08-59 (filed October 5, 2009) ("ASHE Comments") at 3.

[4] Comments of Comsearch, ET Docket No. 08-59 (filed October 5, 2009) ("Comsearch Comments") at 2.

[5] Comments of American Telemedicine Association, ET Docket No. 08-59 (filed October 2, 2009) at 3.

[6] Comments of Texas Instruments, ET Docket No. 08-59 (filed October 5, 2009) ("TI Comments") at 1.

[7] Comments of Toumaz, ET Docket No. 08-59 (filed October 5, 2009) ("Toumaz Comments") at 1.

[8] Comments of Zarlink Semiconductor, ET Docket No. 08-59 (filed October 5, 2009) at 1.

[9] Comments of AT&T, ET Docket No. 08-59 (filed October 5, 2009) ("AT&T Comments") at 7.

[10] *See* ASHE Comments at 3.

[11] *Id*.

[12] *See* Philips Comments at 3-6; TI Comments at 2-3; Toumaz Comments at 1; AdvaMed Comments at 2.

problems hampering MBAN development and performance.[13] In addition, Philips and the Wi-Fi Alliance assert that MBAN operation in either the 2400-2380.5 MHz or 5150-5250 MHz unlicensed bands would pose serious coexistence challenges vis-à-vis the higher-powered 802.11 wireless LAN devices that are broadly deployed in hospital settings.[14]

ASHE, which serves as WMTS frequency coordinator/database manager, and its partner Comsearch both strongly support a license-by-rule/data base coordination regime for MBAN operations under Part 95 of the Commission's rules, as recommended by GEHC.[15] Philips and AdvaMed also support such an approach to licensing MBAN operations.[16]

Philips and AdvaMed both support exclusion zones in the 2360-2390 MHz band as a method of protecting AMT receive sites.[17] Philips submitted an independent detailed coexistence analysis that concurs with a previous analysis of GEHC that modest exclusion zones on the order of 10 km would be sufficient to protect AMT sites from large numbers of MBANS devices.[18]

Finally, even the Aerospace and Flight Test Radio Coordinating Council ("AFTRCC"), which opposes a secondary MBAN allocation in AMT spectrum, acknowledges that "MBAN devices could service a useful purpose as a secondary allocation" so long as the devices do not

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[13] *See* Philips Comments at 11-13; AdvaMed Comments at 4-5; TI Comments at 3-4.

[14] *See* Philips Comments at 11-12; Comments of The Wi-Fi Alliance, ET Docket No. 08-59 (filed October 2, 2009) at 2-3.

[15] *See* ASHE Comments at 3; Comsearch Comments at 2.

[16] *See* Philips Comments at 14; AdvaMed Comments at 6.

[17] *See* Philips Comments at 6-8; AdvaMed Comments at 3 and 6..

[18] Philips recommends 11.5 km exclusion radius based on 41 dBi AMT receive antenna gain, which is in agreement with the value previously determined by GEHC for the same antenna. However because such antennas are quite rare (41 dBi corresponds to a ~30 foot diameter parabolic antenna), GEHC has suggested a 9.7 km exclusion radius, which corresponds to a more common 31 dBi antenna.

cause interference to or otherwise constrain AMT.[19] As GEHC will explain in detail below, AFTRCC's caveats can easily be satisfied.

II. AFTRCC'S CLAIMS REGARDING THE NATURE OF EXISTING AMT OPERATIONS AND THE 2360-2390 MHZ BAND ARE SIMPLY NOT CREDIBLE

In order to argue that it is unfeasible for AMT to share the band with 1-milliwatt MBAN devices that would be confined to known, fixed indoor locations with a minimum of 9.7 km of separation from AMT receivers, AFTRCC resorts to unrealistic, exaggerated and highly selective arguments rooted in faulty engineering analyses performed by a single individual – AFTRCC consultant Daniel Jablonski.

AFTRCC's opposition to the MBAN allocation is fraught with contradictions. On the one hand, it argues that AMT operations, in general, are safety-of-life with an acceptable outage rate of zero (i.e. 100% link availability). At the same time however, AFTRCC would have us believe that AMT users routinely conduct such operations using highly susceptible communications links (e.g. employing zero-margin link budgets and remarkably fragile protocols) in a radio spectrum band that is particularly prone to interference from numerous existing sources including high power amateur radio and WCS devices and highly ubiquitous and uncontrolled Part 15 and 18 devices.

The reality, to which the AMT community itself alludes, is that there are continuums both of AMT link robustness and of flight test risk / AMT criticality.[20] Therefore, while the less risky flight tests, which probably constitute the vast majority of flight tests, may indeed be conducted using less robust AMT links, the flight test community is undoubtedly already – <u>irrespective of</u>

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[19] Comments of Aerospace and Flight Test Radio Coordinating Council, ET Docket No. 08-59 (filed October 5, 2009) ("AFTRCC Comments") at 1-2.

[20] *See* AFTRCC Comments at 6 ("To be sure, not all flight testing involves the highest risk maneuvers").

any incremental interference risk from a new spectrum allocation – taking special precautions with the more risky flight tests, as to do otherwise would be reckless. Indeed, Boeing acknowledges that "[t]hese [most risky] tests are conducted in FAA-approved airspace, have minimum crew on board (generally only a test pilot and co-pilot), and are accompanied by one or more chase airplanes with crew that visually monitor the exterior of the test airplane while maintaining radio contact with the pilot and co-pilot."[21]

However, to the extent that these ancillary mitigations are not sufficient and near-perfect AMT link availability is also required, a host of additional techniques can be employed to make the link substantially more robust. These include:

- Providing more link margin via higher transmit power, larger receive antennas, shorter operating range, and/or error-corrective coding gain.
- Employing more robust protocols, modulation and channel coding schemes.
- Employing receive and/or transmit diversity.
- Operating in the 90 MHz L-band AMT allocation, which has a substantially lower expectation of interference compared to the S-band.

Many of these techniques are actually suggested in the ITU-R M.1459 recommendation[22] as well as a variety of sources in AMT literature,[23] and are relatively simple to implement yet quite powerful in terms of improving link robustness. Safety issues aside, in situations such as

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[21] Comments of The Boeing Company, ET Docket No. 08-59 (filed October 5, 2009) ("Boeing Comments") at 3.

[22] Recommendation ITU-R M.1459, *Protection Criteria for Telemetry Systems in the Aeronautical Mobile Service and Mitigation Techniques to Facilitate Sharing with Geostationary Broadcasting-Satellite and Mobile-Satellite Services in the Frequency Bands 1 452-1 525 MHz and 2 310- 2 360 MHz, 2000* ("ITU-R M.1459 Recommendation") at 13.

[23] *See, e.g.*, Jensen, et al., *Aeronautical Telemetry using Multiple-Antenna Transmitters*, IEEE TRANS AEROSPACE AND ELECTRONIC SYSTEMS, Jan. 2007; Jefferis, *Telemetry Link Reliability Improvement via no Hit Diversity Branch Selection*, PROC ITC 2004; Formeister, *Diversity Branch Selection in Real World Application*, PROC ITC 2007.

those raised by AFTRCC, where telemetry link outages have the potential to cause seven-figure cost overruns, it stands to reason that AMT users would be investing in whatever state of the art wireless technologies that exist.

To be clear, GEHC does not assume the benefit of any such additional mitigations in devising its proposal for protecting AMT receivers. Rather, as will be explained in detail below, GEHC has conservatively considered, and shown that it can protect, the *least* robust AMT links. The, point, however is that AFTRCC's tacit implications that the flight test community is conducting their most safety- and/or economically- sensitive tests using their least robust AMT links (which, if AFTRCC's analysis is to be believed, can be rendered inoperative by the typical out of band emissions from a *single* Part 15 Wi-Fi device at over 8 km, non-line-of-sight[24]) is pure subterfuge and the Commission should not be tricked.

One of the more particularly incredible and demonstrably false claims made by AFTRCC is its repeated assertion that the 2360-2390 MHz band is essentially free from interference so that S-band AMT receivers operate under "noise-limited" conditions and can achieve virtually 100 percent link availability only under such circumstances.[25] As support for this claim, AFTRCC cites two test reports – one by Boeing and one by Textron (Cessna) – that have been submitted into the record.[26] Unfortunately, the Textron test is of virtually no value for at least two reasons: First and foremost, rather than employing actual AMT receive equipment, Textron inexplicably used a much lower gain antenna that, as is shown in Appendix A, was incapable of detecting

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[24] *See* Ex Parte Comments of GE Healthcare, ET Docket No. 08-59 (filed October 30, 2008), at Exhibit A.

[25] Even if the noise-limited condition were accurate, straightforward analysis previously submitted by both GEHC and Philips demonstrates that AMT links with the reported typical parameters and characteristics can be expected to exhibit outage rates of several percent while operating at maximum range.

[26] *See* Boeing Comments at Seattle S-Band Noise Floor Measurements Exhibit; Comments of Textron, ET Docket No. 08-59 (filed October 5, 2009) ("Textron Comments").

ITU-R M.1459 power flux density ("pfd") limit violations less than ~35 dB. Second, even interference strong enough to have been detected by this low-gain antenna could have been masked by strong signals from flight test operations that were reported to have been conducted concurrently at the same location.

Boeing's test, or at least its account of it submitted into the record, also seems to suffer from deficiencies. Nevertheless, as Boeing did employ an actual AMT receive antenna, its results were much more elucidating that those of Textron. Most notably, Boeing's test results are sufficient to disprove AFTRCC's claims of noise-limited operation. A detailed examination of the Boeing test appears in the attached Engineering Statement (Appendix A). However, it should be noted here that in summarizing its test results Boeing acknowledges that the noise floor of it's receivers are routinely observed to rise during the daytime hours due to external "background noise" from "man-made" sources and states that "[t]he measured noise floor… does reflect the industrialized nature of the test area."[27]

The man-made "noise" measured by Boeing is precisely the *interference*[28] that GEHC and others have maintained can be expected to be received well above both the stringent ITU-R M.1459 pfd limit and the actual AMT noise floor (i.e., the floor set by naturally-occurring noise sources both environmental and intrinsic to the receiver). Therefore, AMT receivers are only "noise-limited" insofar as man-made interference is redefined to be "noise", in which case the effective AMT receivers' noise temperatures would actually be on the order of 750 Kelvin versus

[27] Boeing Comments, Seattle S-Band Noise Floor Measurements Exhibit at 17.

[28] That non-naturally occurring electromagnetic radiation – whether it be due to be intentional or unintentional emissions – is referred to as *interference* is widely-accepted convention, as acknowledged in the AFTRCC Comments, Engineering Statement at 2 ("When the source of noise is from man-made sources, such as emissions from other users in the band, it is referred to as interference…").

the 250 Kelvin that has been repeatedly suggested by AFTRCC.[29] If one were to play such a semantic game, then AFTRCC's proposed I/N criterion of –3 dB would become somewhat less draconian, but the ITU-R M.1459 absolute pfd limit of –180 dBW/m^2/4kHz would then correspond to even more ridiculous I/N values of –15 dB or less, proving that, by any account, this absolute limit is far more stringent than actually necessary to protect AMT systems operating in the S-band.

III. AFTRCC'S PREDICTIONS OF INTERFERENCE AND CRITICISM OF GEHC'S COEXISTENCE ANALYSIS ARE ERRONEOUS

Although AFTRCC continues to repeat claims that tests submitted by it and its allies prove that MBAN devices will cause interference, neither AFTRCC nor any of its allies have produced a single test that demonstrates true harmful interference (i.e., outages) to an actual AMT link caused by an MBAN device. Rather, AFTRCC has merely shown that MBAN signals can exceed the ITU-R M.1459 pfd limit, which Boeing's test proves to be a grossly overly-conservative criterion that is already being violated by existing interference and noise sources apparently without any negative impact on actual AMT operations. AFTRCC does continue to cite a 2008 test performed by Learjet.[30] However, as GEHC has pointed out before,[31] this test used a continuous narrowband high power spectral density signal located outdoors at only 0.7 miles from the AMT receiver and suffered from a number of other serious deficiencies (e.g. measured signal levels that imply better than free-space propagation) that neither AFTRCC nor Learjet have ever explained. Finally, in his engineering statement Daniel Jablonski provides a

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[29] Comments of Aerospace and Flight Test Radio Coordinating Council, ET Docket No. 08-59 (filed May 27, 2008) at 15 n.26.

[30] *See id.* at Exhibit G

[31] *See*, e.g., Reply Comments of GE Healthcare, ET Docket No. 08-59 (filed June 11, 2008) at 17-19; Ex Parte Comments of GE Healthcare, ET Docket No. 08-59 (filed September 18, 2008) at 13-15.

sketchy account of a test recently performed in the laboratory where interference from a non-frequency hopping MBAN surrogate device at 60 feet purportedly implies interference out to ten miles. Given the paucity of detail provided, few meaningful conclusions can be drawn regarding this new test except that it obviously would not have included key real-world effects such as long range propagation.

AFTRCC's comments and its attached Engineering Statement by Daniel Jaboloski badly mischaracterize GEHC's coexistence analysis and also misrepresent the ITU-R M.1459 recommendation, which constitutes the centerpiece of their arguments. A detailed rebuttal is contained in the Appendix A, but to summarize:

- AFTRCC mischaracterizes GEHC's C/(I+N) criterion as not accounting for fades[32] when exactly the opposite is true – the "C" in C/(I+N) is the actual received signal power *including the Rayleigh fading behavior that is specified in ITU-R M.1459* while the I/N criterion advocated by AFTRCC completely disregards the actual (faded) received signal power. Since signal fading is an inherently random process (as recognized by ITU-R M.1459), it *must* be accounted for probabilistically, as is done in the GEHC analysis.
- AFTRCC wrongly asserts that C/(I+N) based probabilistic analysis artificially diminishes interference effects and "focus[es] on average . . . performance."[33]
- Mr. Jablonski claims that the ITU-R M.1459 recommendation considers using C/(I+N), but concludes that I/N and pfd are better criteria. In fact, the recommendation never addresses the potential use of C/(I+N) as a protection criterion. ITU-R M.1459 simply sets very stringent pfd and I/N limits in order to preserve maximum performance of *noise limited* AMT links – an approach that is wholly inappropriate for the interference-limited S-band AMT links at issue in this proceeding.[34]
- AFTRCC and Jablonski are very selective in their reading and application of ITU-R M.1459. They minimize or disregard numerous salient aspects of the recommendation, which warn that it may be quite overly-conservative if misapplied.[35]

As described above, there is a continuum of AMT link robustness. Nevertheless, GEHC has conservatively considered the least robust AMT links in its coexistence analysis. It is a key

[32] *See* AFTRCC Comments at 8.

[33] *See* AFTRCC Comments at 7.

[34] *See* AFTRCC Comments, Engineering Statement at 10.

[35] *See* Reply Comments of GE Healthcare, ET Docket No. 08-59 (filed June 11, 2008) at 20-21 (citing numerous qualifiers and cautions from the ITU-R M.1459 Recommendation).

point that, even in the complete absence of interference, such links will exhibit intrinsic baseline outage rates on the order of 10e-2 (*see* Engineering Statement, Appendix A). Therefore, the criterion used in the GEHC analysis is a finite but negligible increase[36] in outage rate relative to the non-zero baseline.

In a remarkably "flat-earth"-like line of argument, AFTRCC also attempts to cast doubt on Monte Carlo analysis, a powerful and versatile technique for analyzing complex systems and interactions that has, for decades, been widely used and accepted throughout numerous and diverse domains of science and engineering, including prominently in both the wireless communications and aviation fields. First, AFTRCC states "the use of the Monte Carlo techniques, in lieu of a deterministic method, is unnecessary. Given the relatively simple mathematical models of the probability distributions assumed . . . direct computation is quite practical."[37] This statement seems to be confusing deterministic analysis with the analytical approach to probabilistic analysis. The latter, which is rarely used except in the simplest cases, simply substitutes analytical methods (i.e., directly solving mathematical equations) for more efficient Monte Carlo techniques but the underlying probabilistic model, and hence the final conclusions, would be the identical. True deterministic analysis, on the other hand, is the application of mathematics to non-probabilistic problems, which AFRTCC acknowledges in referring to probability distributions and by invoking ITU-R M.1459, is not the case at hand.

AFTRCC then goes on to assert that Monte Carlo analysis has a "well-known tendency… to understate worst-case results" and "obscures the potential for extreme results." To support this claim, AFTRCC cites a single newspaper article[38] positing that Monte Carlo analysis

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[36] An increase factor of 0.6 (e.g. an increase to 4.7% from a baseline outage rate of 2.95%) was derived from the –3 dB I/N criterion given by the ITU-R M.1459 Recommendation.

[37] AFFTRC Comments at 7.

[38] *See* AFFTRC Comments at 7 n.15.

contributed to the recent Wall Street financial crisis. Apart from being radically off-topic to the instant proceeding, this single piece by a newspaper journalist is hardly authoritative on the subject of Monte Carlo analysis. As a counterbalance, Appendix C attached hereto contains a small sampling of respectable scientific and engineering literature featuring the use of Monte Carlo simulation and probabilistic analysis for risk assessment and life safety design application, including, notably, many from aviation and aerospace engineering fields.

GEHC is not the first to apply statistical, probabilistic analysis to assess the probability of harmful interference. Motorola and M2Z Networks ("M2Z") contributed Monte Carlo based statistical analyses to the Advanced Wireless Services ("AWS") proceedings, where M2Z defined the "central question is not whether it is conceivable that interference could occur under an unrealistic scenario, but rather how often and how likely is it that 'harmful interference' will occur."[39]

Yet another example of AFTRCC's misleading advocacy is its continued misrepresentation of the utility of frequency hopping for MBAN systems. In its latest comments, AFTRCC states that "the Nordic application notes for the nRF2401 family of devices specifically recommend against their use for the cognitive, frequency-hopping techniques proposed by GEH and its allies."[40] AFTRCC cites note 17 of its July 28, 2008 ex parte filing where a reference to the Nordic Semiconductor Frequently Asked Questions web site is listed.[41] A review of this FAQ reveals text from Nordic Semiconductor discussing the utility of the carrier-detect function, as specifically implemented in one of its chips, for use in a listen before transmit protocol in the 2.4

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[39] *See* Reply Comments of M2Z Networks, Inc., WT Docket No. 07-195, (filed August 11, 2008), Exhibit at 2.

[40] *See* AFTRCC Comments at 11.

[41] *See* Nordic Semiconductor, "How useful is carrier detect (CD) on the nRF24L01?," http://faq.nordicsemi.no/?q=32 (last visited November 2, 2009).

GHz band given power consumption and other performance trade-offs. This note simply does not "specifically recommend against the use of cognitive, frequency-hopping techniques," as AFTRCC erroneously contends.

Underscoring the fallacious nature of AFTRCCs arguments is the fact that AMT spectrum has been used for years – with AFTRCC's knowledge and coordinated approval – for the wireless video links to televise major outdoor sporting events. As explained by Broadcast Sports, Inc.:

> "RF cameras are essentially mobile… At any given event venue (that is approved and coordinated in advance by AFTRCC), the entirety of that band is utilized for video production operation. The band is used for video production using aeronautical mobile [e.g., blimps] and terrestrial or crane-mounted transmitters with Effective Radiated Power levels in excess of 10 watts." [42]

A review of 29 Special Temporary Authority (STA) experimental licenses granted to Broadcast Sports, Incorporated in 2008 and 2009 reveals transmit power of 250 mW and 1.5 Watts at a variety of locations throughout the Untied States during daytime hours every day of the week[43] using both S- and L-band AMT frequencies. The emission designators for these STA licenses show 8 MHz and 10 MHz bandwidths. Assuming terrestrial propagation with an exponential path loss coefficient of n=2.4,[44] these transmit powers violate ITU-R M.1459's pfd limit at separation distances less than 260 and 550 kilometers, respectively. More than 65% of the Broadcast Sports STA locations that have been coordinated and approved by AFTRCC over

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[42] *See* Comments and Counterproposal of Broadcast Sports, Incorporated, ET Docket No. 08-59 (Mar. 4, 2009) ("*BSI Counterproposal*") at 5.

[43] Events such as Nascar races and PGA golf tournaments often span several days, as reflected in the STA experimental license grants tabulated in Appendix B.

[44] In the case of transmissions from aerial platforms, such as the blimps cited by Broadcast Sports (*See* BSI Counterproposal at 2, n.3), free space (i.e. n=2.0) propagation is more likely and would result in even higher interference levels at the AMT receivers.

the past 18 months reside within 260 km of an AMT site, in violation of the ITU-R M.1459 power flux density limit.

GEHC's 9.7 km AMT site separation distance was based on an analysis of an ensemble of low duty cycle frequency hopping 1 mW MBAN transmitters. Broadcast Sports Incorporated's radiated signal levels are 250 times larger (i.e. 250 mW versus 1 mW) and require much larger separation distance than MBAN transmitters. Applying an exponential path loss coefficient of n = 2.4, the Broadcast Sports Incorporated transmitters would require a separation of at least 97 km. Approximately 40% of the Broadcast Sports STA locations reside within 97 km of an AMT site, affording signals in excess of those predicted by an ensemble of MBAN devices. AFTRCC's history and continued practice of allowing co-channel operation of Broadcast Sports STA transmitters in proximity to AMT sites provides irrefutable evidence of the sparse utilization of the AMT frequency bands, as well as the ability of AMT operations to tolerate in-band signals exceeding the natural noise floor.

Further evidence of the sparse utilization of the AMT frequency bands is obtained from a search of the FCC Universal License database. As outlined in the Engineering Analysis (Appendix A), only 20 active, AMT licenses containing AF service authorization grants within the 2360-2395 MHz band at 29 locations were found. The licensed authorizations for these 29 AMT locations include at most only 62.8% of the available 2360-2395 MHz spectrum. When AMT authorizations for the L-band, (1435-1525 MHz) are examined, only 28.4% of that spectrum is authorized via FCC licenses for use.

The medical telemetry community recently participated in the TV White Spaces ("TVWS") proceeding seeking sensible interference protection for low-power devices operating in the 608-614 MHz WMTS band. Medical telemetry is truly a "safety-of-life" service and its products encompass a continuum of technologies and system designs. Therefore, it would

certainly have been possible to craft similarly unreasonable and selective arguments – touting selected specifications of certain systems, failing to disclose important mitigations (e.g., diversity, redundancy, excess link margin, fail safe technical alarms) or focusing on unrealistic, pathologic scenarios – in order to create the perception that medical telemetry systems are extremely susceptible to interference and unlicensed TVWS devices pose a dire and unacceptable risk to patient safety and should not have been permitted, under any circumstances, to operate in television channels adjacent to the WMTS band. Instead, the medical telemetry community reached agreement with TVWS proponents on a reasonable emissions mask which affords substantial protection under realistic interference scenarios. Regardless of AFTRCC's position, GEHC remains hopeful that the larger AMT community will ultimately see fit to cooperate similarly on the development of reasonable and effective methods for protecting their operations that at the same time permit promising low-power MBAN technologies to make productive use of lightly used spectrum.

IV. EXCLUSION ZONES WOULD BE A PRACTICAL AND EFFECTIVE MEANS OF PROTECTING AMT SITES

Contrary to assertions by AFTRCC, MBAN exclusion zones would be a practical and effective means of protecting AMT sites. In Appendix D, GEHC proposes 97 specific exclusion zones, which would protect all 167 fixed AMT receive sites in the United States. Most of the proposed exclusion zones are defined based on a 9.7 kilometer protection radius, as GEHC's coexistence analysis[45] suggests is conservative, centered on a single AMT receive site. In some cases a single, slightly larger zone is defined to protect a number of AMT sites that are closely clustered together. The reduced number of exclusion zones further simplifies management with no significant reduction in spectrum availability to healthcare facilities.

[45] GEHC September 18, 2008 *Ex Parte*, Appendix A.

In attempting to assert that exclusion zones are unworkable, AFTRCC raises the concern of MBAN devices "straying" inside of the zones. But entire healthcare facilities themselves cannot stray, so this leaves the hypothetical case of an individual MBAN system configured for 2360-2390 MHz straying out of a hospital and into an exclusion zone. And since the 9.7 km exclusion radius is designed to protect an AMT receiver from the *aggregate* interference emitted by all the MBAN devices within a hospital, a single stray MBAN system would have to stray much closer to an AMT receive site than 9.7 km before there could be any interference concern. It is likely that the controlled perimeter of most AMT receive sites would provide separation more than adequate for a single stray MBAN system.

AFTRCC also claims that exclusion zones are not viable for protecting AMT operations because they would not be feasible in the case of mobile AMT receiver vans. This is a red herring since mobile AMT receive sites, by their very nature, do not require exclusion zones. In contrast to fixed installations, mobile receivers inherently afford AMT users great operational flexibility. In choosing locations to park their mobile AMT receive vans, AMT users will be able to check the public database for registered MBAN facilities and identify receive locations that afford sufficient separation, which, given the smaller antennas employed by the mobile vans and the ability to avoid locations that would put nearby MBAN facilities in the main beam, will be substantially less than the 9.7 km exclusion radius proposed for fixed sites. Because the required mobile AMT van to MBAN separation will be quite small relative to the typical AMT operating range (e.g., 320 km), such fine tuning of parking location will not result in any practical constraints on fight test airspace that can be served by mobile receiver vans. In fact, since most flight test airspace is over unpopulated areas, it is likely that there will be large nearby geographic tracts without MBAN facilities available in which receive vans may be parked. Similarly, GEHC also rejects the false dilemma advanced by Boeing that approving exclusion

zones only for fixed receive AMT sites vs. both fixed and mobile receive sites would require that mobile or temporary AMT receive sites be prohibited.[46] There would be no need for such a prohibition.

V. AMT INTERFERENCE TO MBAN DEVICES IS UNLIKELY AND, AT WORST, WOULD BE ISOLATED AND FLEETING

The potential AMT to MBAN interference radius around an airplane is relatively small compared to the 320 km AMT receive radius because, as AFTRCC itself has pointed out,[47] achieving the latter radius requires the extra ~40dB of antenna gain that the MBAN device lacks. Specifically, for free space propagation, this 40 dB difference equates to a 100 times reduction in radius (and a 10,000 times reduction in area), so the AMT->MBAN interference radius around an airplane would be at most only about ~3.2 km and probably significantly less due to:

- MBAN noise figure also being higher than that of the AMT receiver
- Excess MBAN link margin
- Additional non-free space propagation from AMT transmitter to indoor MBAN receiver (e.g. building attenuation)
- Much of the free space distance between the aircraft and the MBAN victim being accounted for by the aircraft's altitude, so that the horizontal radius of the interference "foot print" on the ground would actually be <<3.2km.

Since flight testing is done in remote areas, not over the top of hospitals, it would be very unusual for a hospital to be inside the interference "foot print" under the aircraft. Were that to occur, any such scenario would be likely be very transient since airplanes move so fast relative to the small interference "foot print." Frequency hopping / diversity is a powerful further

[46] Boeing Comments at 33.

[47] See reply comments of the Aerospace and Flight Test Radio Coordinating Council, ET Docket 00-258 (filed December 1, 2003) at 3.

mitigation tool as well, so that any interference to one or a few MBAN *channels* would still not result in harmful interference (i.e., actual *application-level outages* from the perspective of the MBAN user) and that, for this reason, the more spectrum that is allocated, the lower the likelihood of such actual harmful interference.

VI. AMATEUR RADIO CONCERNS ARE UNFOUNDED

GEHC agrees with the honest and sensible assessment provided by the ARRL regarding the practical potential for interference to Amateur Radio caused by low power, duty-cycled MBAN devices. ARRL, the national association for Amateur Radio, comments that it "does not, frankly, expect a significant amount of harmful interference *to* Amateur operations at 2390-2400 MHz from MBANS".[48]

GEHC's coexistence analysis considered the general uses and band plan listed in the ARRL's Repeater Directory.[49] ARRL does not refute this coexistence analysis, commenting instead that "there are no limitations on the type of Amateur operations to be conducted in the 2390-2400 MHz band"[50] and "[i]t is, therefore, inappropriate to use existing activity as a predictor of future Amateur activity in the 2390-2400 MHz band."[51] This is effectively a smoke-screen argument that would, if accepted prevent any honest coexistence analysis between MBAN and Amateur Radio operations.

The ARRL also states that the 2390-2400 MHz band may be used for any Amateur signaling, even weak signal communications.[52] GEHC notes, however, that, while theoretically

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[48] *See* Comments of ARRL, The National Association for Amateur Radio ET Docket 08-59 (filed October 5, 2009) ("ARRL Comments") at 8.

[49] *See* GE Healthcare Reply Comments (June 13, 2008) at B-5.

[50] *See* ARRL Comments at 8.

[51] *Id*. at 9.

[52] *Id*. at 8.

possible, reception of such weak signal Amateur Radio operations is already limited by Part 15 and Part 18 out of band emissions. In addition, such weak signal operations would typically utilize much narrower bandwidths, as compared to the 1 MHz nominal MBAN bandwidths, which would tend to substantially mitigate any potential interference from MBANs.

ARRL cites "[t]he mobile and itinerant nature of Amateur operations in this band, the unpredictability of such operations, the operating parameters, and the fact that the geographic separation between two mobile, terrestrial uses in the band could be very small . . . mak[ing] interference instances completely unpredictable." [53] These specific factors also provide a significant opportunity for MBANs to leverage the sparsely utilized 2390-2400 MHz band along with the 2360-2390 MHz band in an opportunistic manner. GEHC's request for a total MBAN allocation of 40 MHz is based on the approach of time, frequency and incumbent radio service diversity – to adapt within the proposed 2360-2400 MHz band to find and use unused frequencies. GEHC's proposal represents an opportunity to leverage unused spectrum for the benefit of the health care delivery for the entire nation.

ARRL also comments that alternatives to 2390-2400 MHz should be considered including medical telemetry bands.[54] GEHC and ASHE have commented in detail about the "rapid development and increased deployment" of the WMTS spectrum within hospital environments as well as its complimentary use as a long distance backhaul to low-power MBAN networks.[55] GEHC has also commented on the lack of suitability of 400 MHz, MedRadio spectrum for MBANs.[56]

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[53] *Id*. at 11.

[54] *See* ARRL Comments at 12.

[55] *See* ASHE Comments at 2; GE Healthcare Comments (May 27, 2008) at 10.

[56] *Id*. at 9.

ARRL comments that there is "no indication that bands below 5 GHz are necessary or suitable for these systems."[57] The record compiled for this docket includes comments from academic researchers with significant experience in the investigation of body worn sensors and body area radio propagation. Drs. Scanlon [58], Hao and Alomainly[59] attest to the technical suitability of the proposed 2360-2400 MHz frequency band for body area networks, given favorable radio propagation and antenna characteristics. Texas Instruments has also explained why frequencies well below 5 GHz are critical to viability of low power electronics.[60]

CONCLUSION

GE Healthcare's proposal for the creation of the MBAN Service in the 2360-2400 MHz band is a concept offering efficient access to sparsely utilized spectrum for the medical and economic benefit of the nation. The opportunistic, secondary operation within this 40 MHz of spectrum will permit MBAN devices to avoid interference from primary users via advanced protocols and frequency agility techniques.

The record shows support for the benefits, viability and allocation of the 2360-2400 MHz band for MBANs. Objections from the incumbents seeking to protect their allocations, which they utilize sparsely with respect to time, space and frequency, are unfounded or not credible. In fact, AMT has a documented history of permitting and coordinating co-channel use of the 2360-2395 MHz band by televised sporting events using power levels 250 times greater than MBANs and from elevated outdoor platforms. MBAN devices present a very low likelihood of

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[57] *See* ARRL Comments at 12.

[58] *See* Comments of Dr. William G. Scanlon, ET Docket 08-59 (filed April 29, 2008).

[59] *See* Comments of Dr. Yang Hao and Dr. Akram Alomainy, ET Docket 08-59 (filed May 9, 2008).

[60] *See* TI Comments at 3-4.

interference to primary users of the band, and geographic exclusion zones represent practical and effective means of avoiding harmful interference to the incumbent services.

GE appreciates the Commission's continued effort and support of MBAN spectrum allocation and urges the Commission to move expeditiously to final MBAN rules. Such an action would place the United States in a leadership position by fostering the development of advanced wireless medical devices at a time when the aging population could benefit tremendously from enhanced quality, improved access and reduced cost of health care services.

Respectfully submitted,

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November 4, 2009

APPENDIX A

Engineering Statement

1. AMBIENT NOISE MEASUREMENTS FROM BOEING AND TEXTRON (CESSNA) DO NOT SUPPORT CLAIMS OF NOISE-LIMITED AMT RECEIVERS

Despite GEHC reaching out to the AMT incumbents and commenting in the record that it would "welcome the opportunity to cooperate in future tests, [61] Boeing and Textron (Cessna) produced test reports that do not represent an actual AMT receive station or contain confounding calculations.

a. Textron (Cessna) Measurements are not Representative of AMT Antenna and are not Capable of Detecting Interference at the Extremely Low Levels AFTRCC Seeks to Prohibit

Cessna used a 5 dBi, 90 degree beamwidth antenna to measure ambient noise floor levels. This low gain antenna was placed on a tripod and located on the Cessna rooftop, about 33 feet above ground level. Cessna chose to use such an low gain antenna rather than their 8 foot, 31.3 dBi dish telemetry antenna[62] located on top off a 90 foot tower only 100 feet away from their test location. Cessna's measurement equipment was not representative of an actual AMT system, lacking nearly 26 dBi of antenna gain that would be more sensitive at detecting the extremely

[61] GE Healthcare has engaged in a series of telephone conferences with representatives of Boeing and AFTRCC during the course of this proceeding in order to define mutually acceptable tests. However, GEHC has never been informed of these measurement campaigns, nor asked to provide input on the test plan or methodology, despite several long-standing requests to be included. *See e.g.*, GE Healthcare Reply Comments (June 13, 2008) at 19.

[62] AFTRCC filed ex parte comments and a DVD video which provided specifics of their 31.3 dBi, 8 foot dish antenna at the Wichita, Kansas facility. *See* AFTRCC Ex Parte Comment, ET Docket No. 08-59 (filed August 1, 2008).

low levels of interference AFTRCC seeks to prohibit. As a result of Cessna's use of a non-representative measurement system, their contribution is of very limited value.

Cessna also performed their measurements during periods of AMT activity. The simultaneous AMT flight activity was strong enough to mask any other man-made signals that may have been present.

Cessna also states that "[t]here are many 2.4 GHz RF devices in this building, including radio controlled cranes. Wi-Fi enabled laptops and access points operating in the 2.4 GHz band are common across the campus, including inside the monitoring building under the horn antenna." [63] Unfortunately, Cessna failed to include a spectrum analyzer sweep of the 2.4 GHz band to substantiate this claim. Assuming these signals were present, the higher gain, 31.3 dBi AMT antenna would be much more likely to detect OOBE radiations from these sources.

Despite their inexplicable choice of a non-representative antenna, Cessna provided valuable details regarding their system configuration, performance specifications, and equations for appropriately calculating the noise floor at the spectrum analyzer or the antenna input.

b. Boeing Test Results Clearly Contradict AFTRCC's Noise-Limited Claims

To their credit, Boeing performed its test using the actual AMT antenna, feeds and LNA at their Seattle, Washington facility to assess the ambient noise floor. Unfortunately there are some deficiencies in Boeing's test as well.

First, Boeing presents only the ***averaged*** spectrum analyzer level over a 20 MHz measurement span. Such averaging may completely eliminate the presence of interference such as out of band emissions ("OOBE") from Part 15 or Part 18 devices. Inspection of Boeing's

[63] *See* Textron Comments at 15.

Figure 9 shows numerous signal components that are 5 dB or more above the average level. As a result, the average results presented by Boeing likely underestimate the actual noise / interference sources captured by their AMT antenna.

Second, Boeings tabulated measurements are impossible in that they are *below* the theoretical level, which Boeing calculates to be –156.86 dBm / 30 Hz at the LNA input equating to –137 dBm / 30 Hz at the spectrum analyzer. This may be an artifact of the averaging of the spectrum analyzer trace samples as discussed above, but could also indicate a problem (e.g. a loose cable, etc) with the test setup.

In any event, the measured noise floor of –148 dBm / Hz as shown in Boeing's Figure 8 equates to –133.2 dBm / 30Hz which *exceeds* the theoretical level by about 4 dB. Boeing explains that "[t]he measured noise floor [in a 1 Hz bandwidth] was -148 dBm which, while low, does reflect the industrialized nature of the test area." Also, although the averaging may have created an inaccurate absolute baseline level, Boeing's tabulated results nevertheless show an increase over the baseline of 2-3 dB or more at certain azimuth angles (note that a 3dB increase corresponds to I/N = 0dB even if the baseline were pure noise). Boeing explains that "there is an indication that background noise increases during work hours. This is to be expected due to the industrial nature of the test location."[64] Boeing goes on to conclude, "[s]pillover interference from signals above 2400 MHz increases the noise in the upper part of the spectrum slightly . . . The measured noise floor is higher than calculated showing the effects of man-made noise in the industrial area that was tested."[65]

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[64] See Boeing Comments, Exhibit, at 11.

[65] *See* Boeing Comments, Exhibit, at 17.

2. JABLONSKI ENGINEERING STATEMENT ANALYSIS SERIOUSLY MISCHARACTERIZES AMT LINK AND GEHC COEXISTANCE ANALYSIS

a. Mr. Jablonski's account of AMT link is inaccurate in several key respects

In his Engineering Statement submitted by AFTRCC, Mr. Jablonski correctly points out that most fades occur during portions of the flight (e.g. certain maneuvers) that cause the worst multipath propagation but that account for the minority of time during a test flight. However Mr. Jablonski then incorrectly suggests that the ITU-R M.1459 fading statistics are long-term statistics that hold only on average over the entire flight and that therefore understate the probability of deep fades during short-term flight maneuvers. In actuality, the Rayleigh-like ITU-R M.1459 fading statistics clearly correspond to the worst-case and thus hold over the short term (e.g. certain flight maneuvers) for the worst fading that can be expected during a flight.

Mr. Jablonski also states "In the case of AMT systems, [the link] margin needs to be much larger, on the order of 30 dB, due to the extreme fading environment encountered during flight testing of rapidly maneuvering aircraft traveling at high speed…" Simple examination of the AMT link, which AFTRCC has consistently neglected or avoided shows that the actual margin of a typical link is substantially less than that.

The AMT link budget can be generalized as follows:

$$P_{RX} - P_{N+I} \geq SINR_{\min} \tag{1}$$

or alternately as

$$Margin = P_{RX} - P_{N+I} - SINR_{\min} \geq 0 \tag{2}$$

where P_{RX} is the received desired AMT signal power in dBm, $SINR_{\min}$ is the minimum permissible signal-to-noise-plus-interference ratio in dB, which according to ITU-R M.1459 may

be in the range 9-15 dB, and P_{N+I} is the combined power of noise and interference at the AMT receiver in dBm given by

$$P_{N+I} = 10\log_{10}\left[10^{P_N/10} + 10^{P_I/10}\right] \quad (3)$$

In equation 3 P_I is the received interference power in dBm, which is a random variable that is a function of several (many also random) factors, such as the emission power spectrum, path loss and AMT antenna gain associated with each interference source, AMT receiver selectivity mask, etc. and P_N is the AMT receiver's intrinsic thermal noise in dBm, which is given by

$$P_N = 10\log_{10}(kTB) + 30 \quad (4)$$

where k is the Boltzmann constant, 1.38 x 10^{-23} Joules/Kelvin, and where T and B respectively are system noise temperature in Kelvin and bandwidth in Hertz of the AMT receiver.

When the inequalities in equations (1) and (2) are satisfied, the AMT symbol or packet error rate will be below the maximum acceptable level and, by definition, the AMT link is "closed" or "available". When these inequalities are not satisfied the symbol or packet error rates will exceed the maximum acceptable level and this by definition will constitute an "outage" event.

The received desired signal power P_{RX} may be expressed as:

$$P_{RX} = P_{in} + G_{TXant} - L_{path} + G_{RXant} \quad (5)$$

Where P_{in} is the conducted input power to the AMT transmit antenna in dBm which according to M.1459 may be in the range 33-44 dBm, G_{TXant} is the effective gain of the AMT transmit antenna in dBi, L_{path} is the path loss in dB, and G_{RXant} is the main beam gain of the tracking directional AMT receive antenna in dBi.

According to ITU-R M.1459, G_{RXant} may be in the range of 20 to 41.2 dBi. Because the AMT link is line-of-sight, the path loss L_{path} is simply the free space loss given by:

$$L_{path} = 20\log_{10}(d) + 20\log_{10}(f) + 32.44 \qquad (6)$$

Where f is frequency in MHz, nominally 2380 MHz for the center of the proposed band, and d is the line-of-sight distance in km, which according to ITU-R M.1459 may be as far as 320 km.

Finally, the effective transmit antenna gain G_{TXant} is a random variable that takes into account fading effects due to reflections and blockages from the aircraft with its potentially rapidly-varying physical orientation. According to ITU-R M.1459, the effective gain of the AMT transmit antenna in linear units, $g_{TXant} = 10^{G_{TXant}/10}$, has the following empirical cumulative distribution function[66] :

$$P[g_{TXant} \le x] = \left(1 - e^{-3.46x}\right)^{1.25} \qquad (7)$$

Within the framework above, we can consider a couple of conservative baseline cases of the AMT link in a purely noise-limited scenario (*i.e.*, in the absence of any interference) where $P_{N+I} = P_N$. First, we shall consider the nature of the AMT link for the case cited by AFTRCC of an aircraft operating at the maximum specified distance of d=320 km, using $P_{in} = 40$ dBm (10W) with a bandwidth of 5 MHz and with receiver noise temp of 200K and receive antenna gain G_{RXant} of 31 dBi, which corresponds to a typical 2.4 meter diameter parabolic dish. Monte Carlo simulation of this scenario, in which the only random variable is G_{TXant}, yields the result in Figure 1.

[66] The M.1459 empirical CDF was found to be very closely approximated by the Gamma distribution with parameters a=1.2446 and b=0.268111.

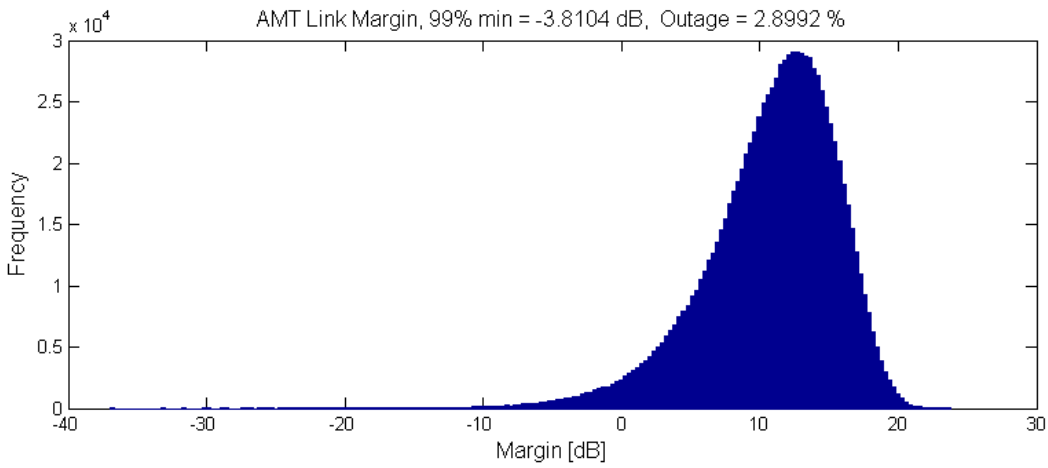

Figure 1: Simulated AMT link margin for G_{RXant} = 31 dBi

It is clear from Figure 1 that the AMT link is generally quite robust because, at most instants in time, it has copious excess margin. Nevertheless, <u>even in the absence of interference, the AMT link is imperfect in that some outages will occur.</u> For this first conservative noise limited baseline case the outage probability is approximately 3%. Furthermore, since the AMT outages are driven by long "tail" of the G_{TXant} fading distribution, they cannot be eliminated simply by modest increases in transmit power or antenna gain. For example, consider the limiting case of G_{RXant} = 41.2 dBi, which corresponds to a huge 10-meter diameter receive antenna, simulation results for which are shown in Figure 2. Even the addition of over 10 dB of link margin has not eliminated outages – they will still occur with 0.17% frequency.

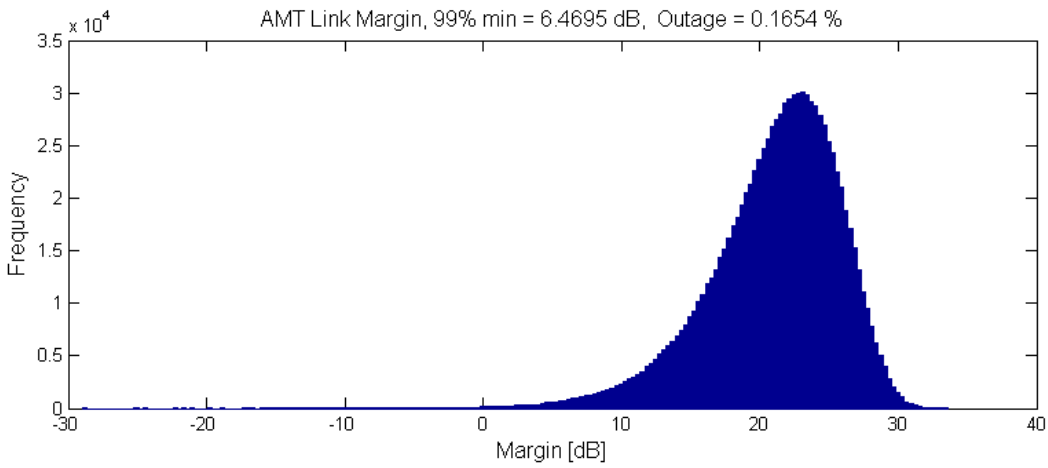

Figure 2: Margin result for G_{RXant} = 41.2 dBi

Clearly, for any case where a perfectly reliable AMT link really is required, it would best be achieved through techniques like coding or diversity, which can exploit the (on average) considerable excess link margin and not by striving to preserve fractional dBs of link margin by imposing overly-stringent interference limits such as the –8.13 dB I/N recommendation in ITU-R M.1459.

The most important conclusion from these baseline AMT link simulations is that AMT outage rates on the order of several percent are apparently being tolerated already and must therefore be acceptable – at least for the typical link parameters offered by AFTRCC.[67] Having established this fact, it is now possible to define a reasonable quantitative harmful interference threshold for the allowable increase in outage rate due to interference. If we consider the effect of the –3 dB I/N ratio provided by ITU-R M.1459 as the "maximum practical value" on outage rate for both of the previous AMT link examples with link distances ranging from 0-320 km, we calculate the results shown in the following Figure 3 and Figure 4.

[67] If this is in fact not the case, then clearly there are other mitigating factors that have not been disclosed by AFTRCC such as AMT employing substantially higher transmit power than the claimed 2-25 W, not operating nearly out to the full 320 km stated radius or incorporating other beneficial techniques (*e.g.*, TX/RX diversity, coding gain).

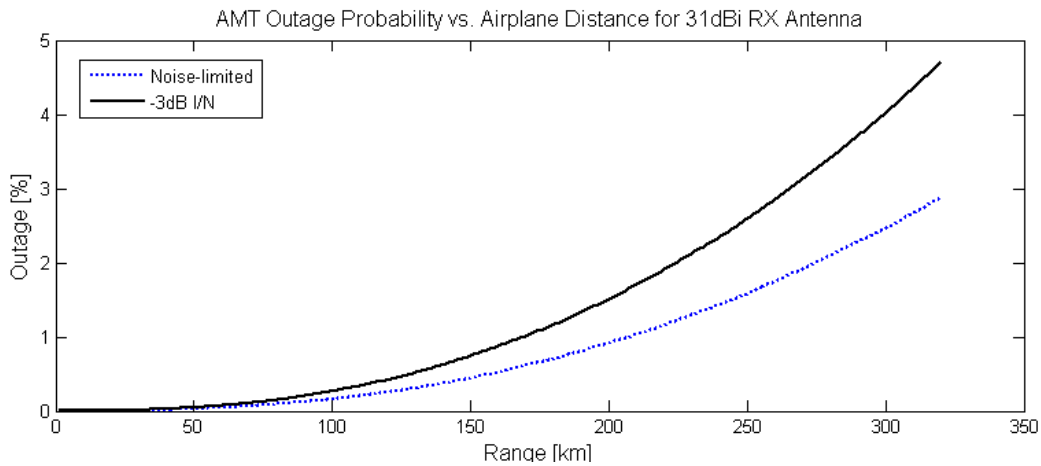

Figure 3: AMT Outage Probability vs. Airplane Distance for G_{RXant} = 31 dBi

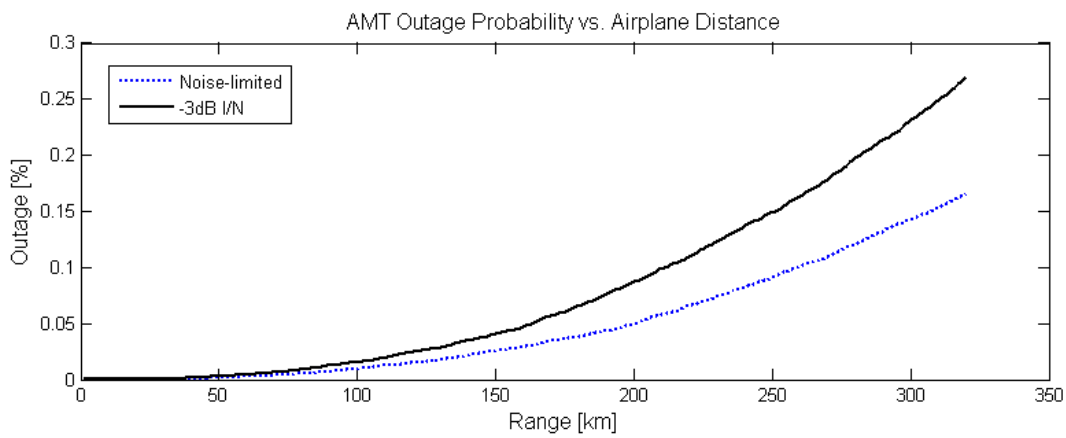

Figure 4: AMT Outage Probability vs. Airplane Distance for G_{RXant} = 41.2 dBi

From these results we can relate the –3 dB I/N limit from ITU-R M.1459 to a factor of 1.6 in outage rate from the baseline noise-limited outage rate. Based on this, we can consider an increase factor greater of 1.6 or less to be non-harmful to AMT operations. This threshold is certainly reasonable from the common-sense perspective as well, since the existing, naturally occurring outage rate of AMT operations cannot be too near the limit of acceptability. Otherwise, it would be expected to frequently violate the limit due to unavoidable small perturbations in system parameters.

b. Mr. Jablonski's mischaracterizes GEHC coexistence analysis

Mr. Jablonski also states "GEH's C/(I+N) criteria … are violated 1.7% of the time even for an exclusion zone with the GEH-suggested radius of 9.7 km. Outages like this, for a safety service for which the target bit error rate is 10-6 are the very definition of "harmful."" However, as explained above, the 1.7% Mr. Jablonski cites actually represents the predicted *increase* (i.e., by a factor 0.6 times) the baseline outage rate of the same AMT link, which was shown to be 2.95%.

3. AMT LICENSES REFLECT LOW UTILIZATION OF SPECTRUM RESOURCES

Review of licensed, AMT operations within S-band (2360-2390 MHz) and L-band (1435-1525 MHz) affords revealing insight as to the low utilization of these spectrum resources by non-government entities within the continental United States.

During October 2009, queries were made of the FCC Universal License System. Search criteria included active, regular license authorizations within the aeronautical and fixed radio service (AF). Separate searches were conducted for AMT licenses within L-band and S-band frequency ranges. Figure 2 shows the 35 AMT licenses containing authorization grants within the 1435-1525 MHz, L-band spectrum, at a total of 85 locations. Figure 3 shows the 20 AMT licenses containing authorization grants within the 2360-2395 MHz, S-band spectrum, at a total of 29 locations

Each license was reviewed and the frequencies and emission designator (i.e. bandwidth) authorized at each individual location was tabulated. Figure 1 illustrates a map of the L-band and S-band spectrum allocated to AMT operations. Each horizontal row of this figure corresponds to a location listed in an AMT license. The horizontal axis is divided into 1 MHz intervals with 0.5 MHz offset (i.e. 2360.5, 2361.5, etc.). For each location, the specific frequencies and emission bandwidths were used to mark successive, 1 MHz frequency bins as either allocated or not allocated. Allocated bins are shown with black shading in Figure 1. No

modulation spectral shaping was considered. For example, 1440.5 MHz, 3M00FXD would result in marking of 1439.5, 1440.5 and 1441.5 MHz cells as allocated. All emission designators were considered such that the largest emission bandwidth was reflected in the allocation map. Each unique license call sign was identified and its locations evaluated. Hence, there are no duplications in the 100 locations appearing in Figure 1.

If only the L-band licenses are considered, a mere 28.4% of the 1435-1525 MHz spectrum is licensed for non-governmental use. Figure 4 shows the licensed L-band spectrum. As noted above, actual transmit signal spectral envelopes and roll-off are not considered in this map. If only the S-band licenses are considered, 62.8% of the 2360-2395 MHz spectrum is licensed. Figure 5 shows the licensed S-band spectrum. When the combination of L-band and S-band is considered, FCC licenses authorize utilization of only 22.9% of the allocated spectrum.

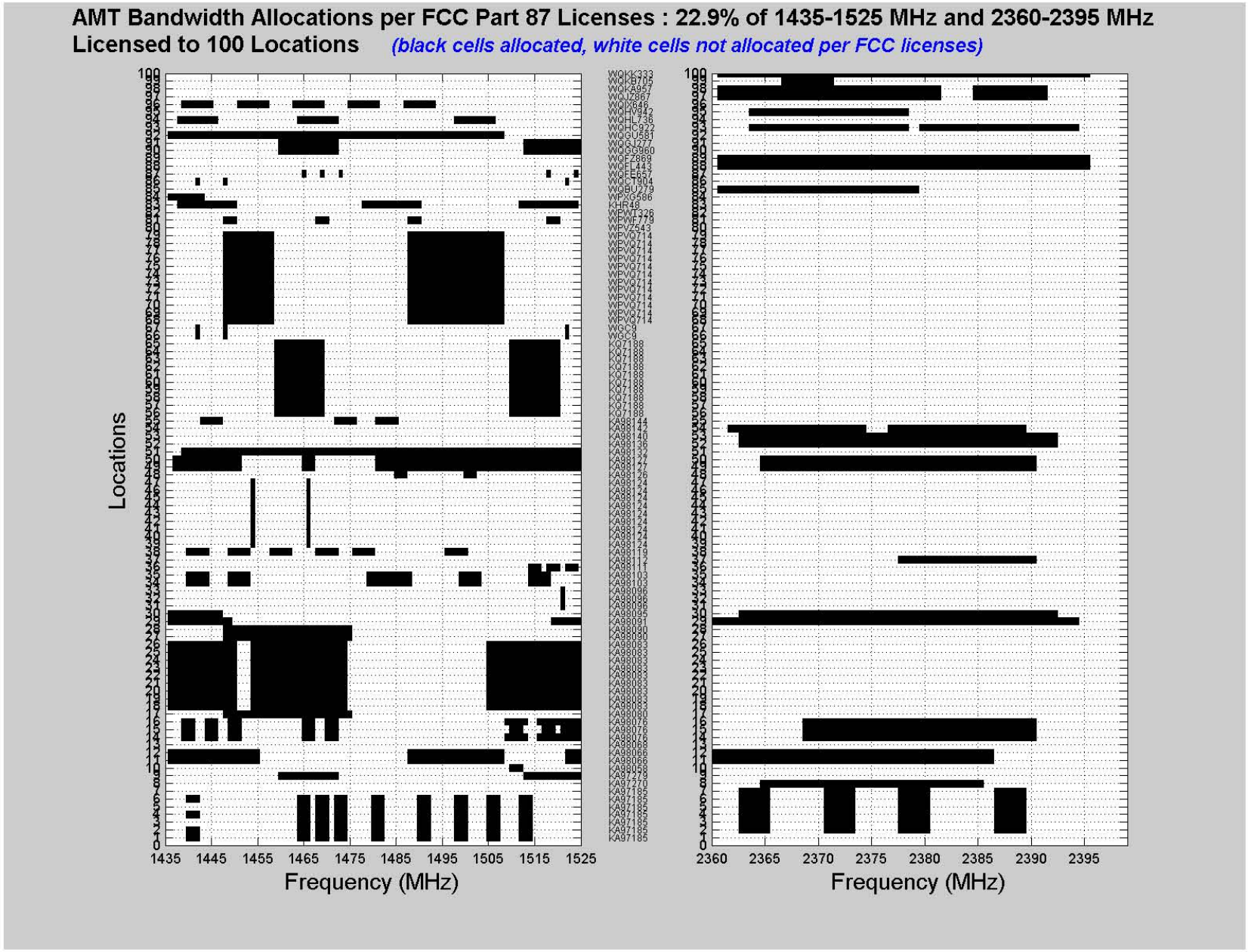

Figure 1 - AMT Bandwidth Authorizations Per FCC Part 87 Licenses

License Search - Search Results - Microsoft Internet Explorer

License Search

Search Results

Specified Search

Radio Service = **AF**
Authorization Type = **Regular**
Status = **Active**
Frequency Upper Band >= **1435**
Frequency Assigned <= **1525**

Matches **1- 35** (of **35**)

PA = Pending Application(s)
TP = Termination Pending
L = Lease

	Call Sign/Lease ID	Name	FRN	Radio Service	Status	Expiration Date
1	KA97105	BELL HELICOPTER TEXTRON INC	0003596020	AF	Active	07/20/2014
2	KA97279	CESSNA AIRCRAFT COMPANY	0002529923	AF	Active	01/24/2011
3	KA98058	FLIGHT RESEARCH INC	0000504342	AF	Active	02/25/2013
4	KA98066	THE BOEING COMPANY	0001583483	AF	Active	03/15/2014
5	KA98068	CESSNA AIRCRAFT COMPANY	0002529923	AF	Active	02/14/2012
6	KA98076	SIKORSKY AIRCRAFT CORPORATION	0003573821	AF	Active	08/08/2012
7	KA98080	THE BOEING COMPANY	0001583483	AF	Active	09/19/2012
8	KA98083	THE BOEING COMPANY	0001583483	AF	Active	09/01/2013
9	KA98090	THE BOEING COMPANY	0001583483	AF	Active	03/15/2014
10	KA98091	Learjet Inc.	0003467586	AF	Active	04/10/2011
11	KA98095	Learjet Inc.	0003467586	AF	Active	04/01/2011
12	KA98096	THE BOEING COMPANY	0001583483	AF	Active	11/16/2012
13	KA98103	LOCKHEED MARTIN CORPORATION	0002149359	AF	Active	06/01/2010
14	KA98111	THE BOEING COMPANY	0001583483	AF	Active	09/16/2011
15	KA98119	GULFSTREAM AEROSPACE CORP	0004417218	AF	Active	02/27/2011
16	KA98124	THE BOEING COMPANY	0001583483	AF	Active	08/01/2012
17	KA98126	Lockheed Martin Corporation	0002149359	AF	Active	01/01/2012
18 PA	KA98127	THE BOEING COMPANY	0001583483	AF	Active	01/01/2012
19	KA98132	THE BOEING COMPANY	0001583483	AF	Active	08/21/2013
20	KA98144	Honeywell International Inc.	0004452231	AF	Active	08/25/2013
21	KHR48	Eclipse Aviation Corporation, Debtor-in-Possession	0018333005	AF	Active	01/29/2013
22	KQ7188	THE BOEING COMPANY	0001583483	AF	Active	04/26/2011
23	WGC9	Calspan Corporation	0012350187	AF	Active	05/24/2011
24	WPVQ714	The Boeing Company	0001583483	AF	Active	08/01/2012
25	WPVZ543	Learjet Inc.	0003467586	AF	Active	09/19/2012
26	WPWF779	THE BOEING COMPANY	0001583483	AF	Active	11/06/2012
27	WPWT326	Hawker Beechcraft Corporation	0002341915	AF	Active	01/16/2013
28	WPXG586	The Boeing Company	0001583483	AF	Active	03/31/2013
29	WQCT904	Calspan Corporation	0012350187	AF	Active	05/24/2011
30	WQFE657	Universal Propulsion Company	0001600816	AF	Active	12/15/2010
31	WQGG960	CESSNA AIRCRAFT COMPANY	0002529923	AF	Active	08/01/2011
32	WQGJ277	CESSNA AIRCRAFT COMPANY	0002529923	AF	Active	08/01/2011
33	WQGU581	Lockheed Martin Corporation	0002149359	AF	Active	01/16/2012
34	WQHL736	L-3 Communications	0001674407	AF	Active	03/01/2012
35	WQIX646	Scaled Composites LLC	0008715286	AF	Active	02/11/2013
	Call Sign/Lease ID	Name	FRN	Radio Service	Status	Expiration Date

Figure 2 - AMT L-Band License Search Results, October 29, 2009

FCC Federal Communications Commission

FCC Home | Search | Updates | E-Filing | Initiatives | For Consumers | Find People

Universal Licensing System

FCC > WTB > ULS > Online Systems > License Search

FCC Site Map

License Search

Search Results

HELP

New Search | Refine Search | Printable Page | Query Download | Map License

Specified Search

Radio Service = **AF**
Authorization Type = **Regular**
Status = **Active**
Frequency Upper Band >= **2360**
Frequency Assigned <= **2400**

Matches **1- 20** (of **20**)

PA = Pending Application(s)
TP = Termination Pending
L = Lease

Page 1

	Call Sign/Lease ID	Name	FRN	Radio Service	Status	Expiration Date
1 PA	KA97105	BELL HELICOPTER TEXTRON INC	0003596020	AF	Active	08/03/2009
2	KA97270	THE BOEING COMPANY	0001583483	AF	Active	12/14/2009
3	KA98066	THE BOEING COMPANY	0001583483	AF	Active	03/15/2014
4	KA98076	SIKORSKY AIRCRAFT CORPORATION	0003573821	AF	Active	08/08/2012
5	KA98091	Learjet Inc.	0003467586	AF	Active	04/10/2011
6	KA98095	Learjet Inc.	0003467586	AF	Active	04/01/2011
7	KA98112	ORBITAL SCIENCE CORP	0014578496	AF	Active	05/01/2011
8 PA	KA98127	THE BOEING COMPANY	0001583483	AF	Active	01/01/2012
9	KA98136	Learjet Inc.	0003467586	AF	Active	09/19/2012
10	KA98140	Learjet Inc.	0003467586	AF	Active	08/19/2013
11	KA98142	THE BOEING COMPANY	0001583483	AF	Active	07/07/2014
12	WQBU279	Learjet Inc.	0003467586	AF	Active	12/14/2009
13	WQFL443	Learjet Inc.	0003467586	AF	Active	04/01/2011
14	WQFZ869	THE BOEING COMPANY	0001583483	AF	Active	11/21/2011
15	WQHC922	Aviation Technology Group, INC.	0014363139	AF	Active	01/09/2012
16	WQHV942	Cirrus Design Corporation	0016855041	AF	Active	08/20/2012
17	WQJZ867	Learjet Inc.	0003467586	AF	Active	01/29/2014
18	WQKA957	Learjet Inc.	0003467586	AF	Active	01/29/2014
19	WQKB705	Diamond Aircraft Industries, Inc.	0010356535	AF	Active	02/05/2011
20	WQKK333	CESSNA AIRCRAFT COMPANY	0002529923	AF	Active	05/21/2014
	Call Sign/Lease ID	Name	FRN	Radio Service	Status	Expiration Date

Page 1

Figure 3 - AMT S-Band License Search Results, October 1, 2009

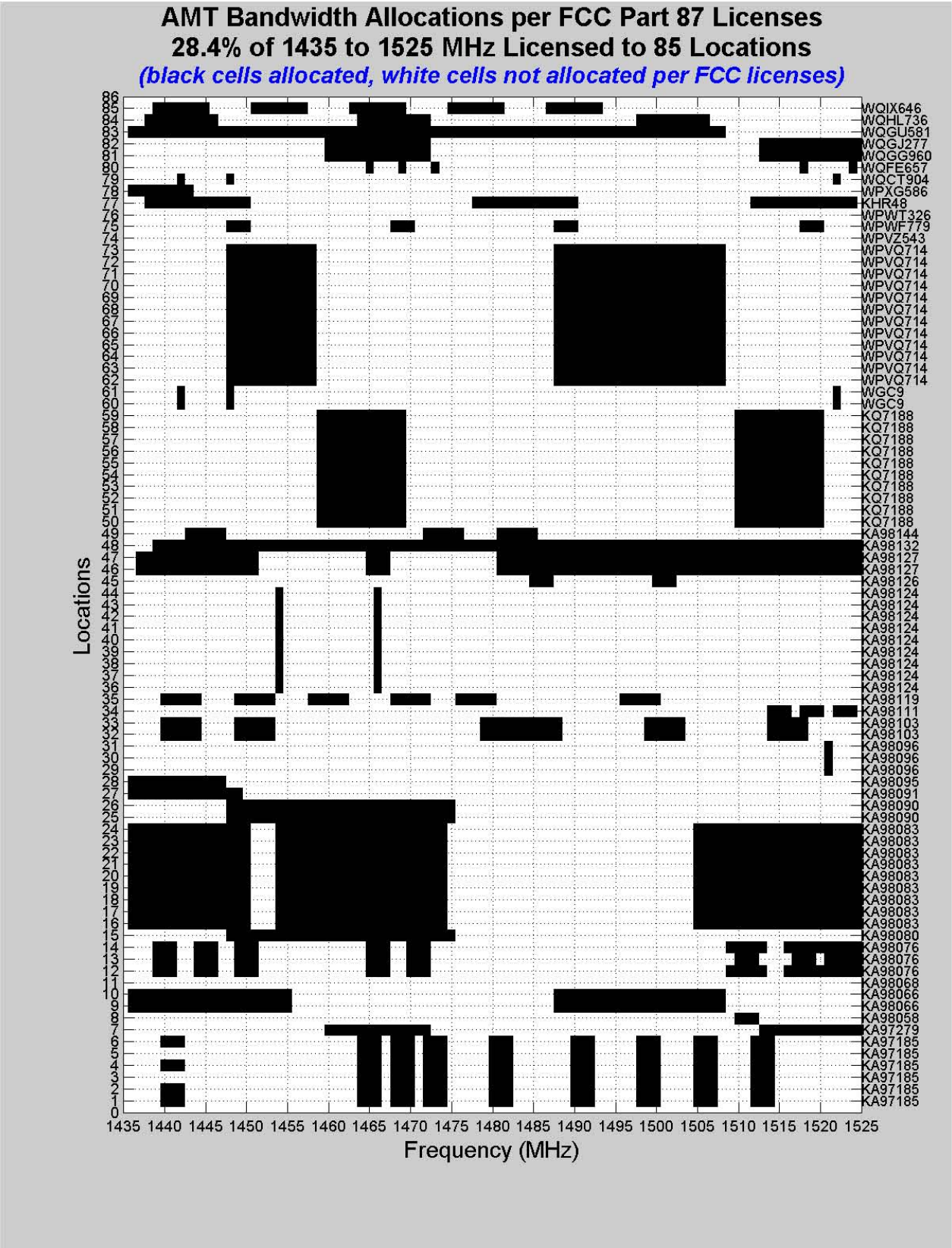

Figure 4 - Licensed AMT L-band Spectrum

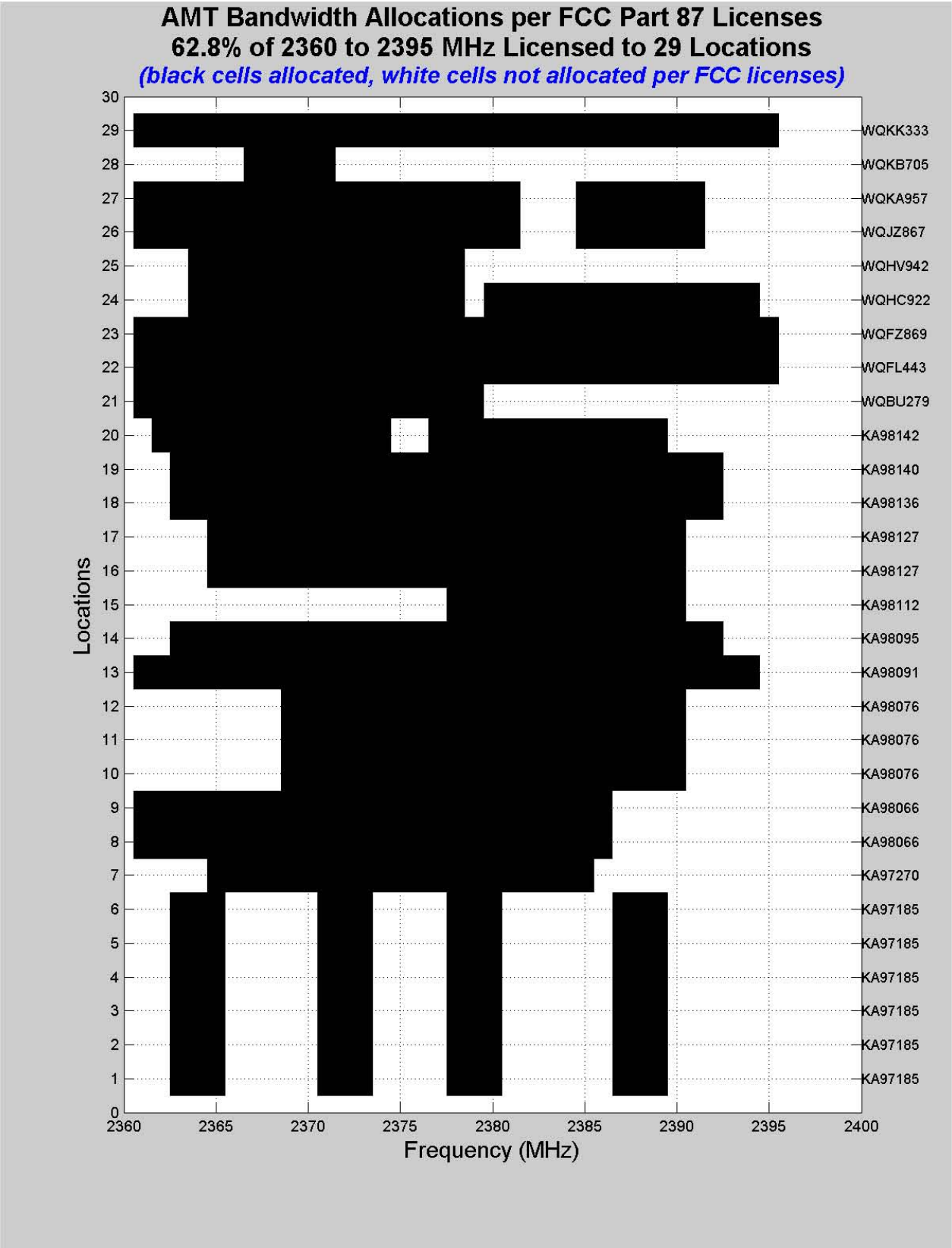

Figure 5 - Licensed AMT S-band Spectrum

APPENDIX B

Comparison of Broadcast Sports' Operations and AMT locations

On October 27, 2009 a search was performed using the OET's Experimental Licensing System (**https://fjallfoss.fcc.gov/oetcf/els/**). A generic search using "Broadcast Sports" applicant name and 2360 MHz lower frequency yielded a total of 60 pending, granted or expired applications for Special Temporary Authority. Of these 60 applications, the 29 most recent STAs grants were examined. These most recent STAs contained grants over the time period beginning September 2008 and ending December 2009.

A manual review of the FCC grant documents as well as STA application exhibits and correspondence was conducted to extract the specific locations and operating durations approved for Broadcast Sports Incorporated transmitters and to confirm that AFTRCC coordination was performed for each and every STA application and listed in each STA grant. From these 29 STAs, a total of 109 locations residing within the continental United States were extracted and tabulated including emission designators, latitude and longitude coordinates and transmit power levels (ERP). These details are shown in Table 1. Note that this table shows 250 mW and 1.5 Watt ERP levels for the Broadcast Sports Incorporated transmitters.

The separation distance was calculated between each of the 109 Broadcast Sports Incorporated STA experimental license grant locations and the 157 AMT sites provided to GE Healthcare by AFTRCC during January 2008. This separation distance was computed using the Haversine formula on a spherical earth of radius 6378.137 km. The separation from each STA location to the closest AMT site was stored. Figure 6 contains a map showing the 109 STA locations coordinated by AFTRCC for 250 mW transmission, S-band, co-channel transmission by Broadcast Sports, Incorporated. Figure 7 shows a map with the 157 AMT sites overlaid. In addition, a range ring of 97 km radius is drawn about each AMT site. Figure 8 shows the

cumulative distribution of minimum separation distance for the 109 STA locations to any of the 157 AMT sites.

Assuming terrestrial propagation of the Broadcast Sports transmissions from a shoulder-mounted video camera or elevated crane or blimp, the Broadcast Sports Incorporated's **250 mW and 1.5 Watt radiated power levels** violate the ITU-R M.1459 power flux density limit (-180 $dBW/m^2/4$ kHz) at a separation distances less than range of 260.4 and 549.5 kilometers, respectively. These separation distances are calculated as minimum separation distance = $[(\alpha*\beta*ERP)/(4\pi*pfd\ limit)]^{(1/2.4)}$. Factor α represents wall and building structure attenuation. A value of $\alpha = 1$ representing no structure loss is considered for this comparison. Factor β represents the bandwidth ratio between the M.1459 reference 4 kHz and the Broadcast Sports Incorporated radiated signal. The emission designators for these STA licenses show 8 MHz and 10 MHz bandwidths. Here a value of β = 4kHz/8MHz = 0.0005 is considered. More than 65% of the Broadcast Sports STA locations that have been coordinated and approved by AFTRCC over the past 18 months reside within 260 km of an AMT site.

Consider the 9.7 km exclusion zone separation distanced obtained from GEHC's analysis, which includes an ensemble of 1 mW, low duty cycle, frequency hopping MBAN systems with building structure attenuation. Broadcast Sports Incorporated's radiated signal levels are 250 times larger (i.e. 250 mW versus 1 mW) and require a larger separation distance. Considering an exponential path loss coefficient of n = 2.4, the Broadcast Sports Incorporated transmitters would require a separation of (9.7 km) * $(250\ mW/1mW)^{\wedge(1/2.4)}$ = 97 km. The 97 km range rings shown in Figure 7 allow visual comparison of spatial separation between Broadcast Sports STA locations and AMT sites. Approximately 40% of the Broadcast Sports STA locations reside within 97 km of an AMT site, affording signals in excess of those predicted by an ensemble of MBAN devices.

This analysis shows that AFTRCC has history and continues to coordinate and permit Broadcast Sports transmitters to operate at signal levels and at physical separations that would introduce interference beyond the levels possible from MBAN systems.

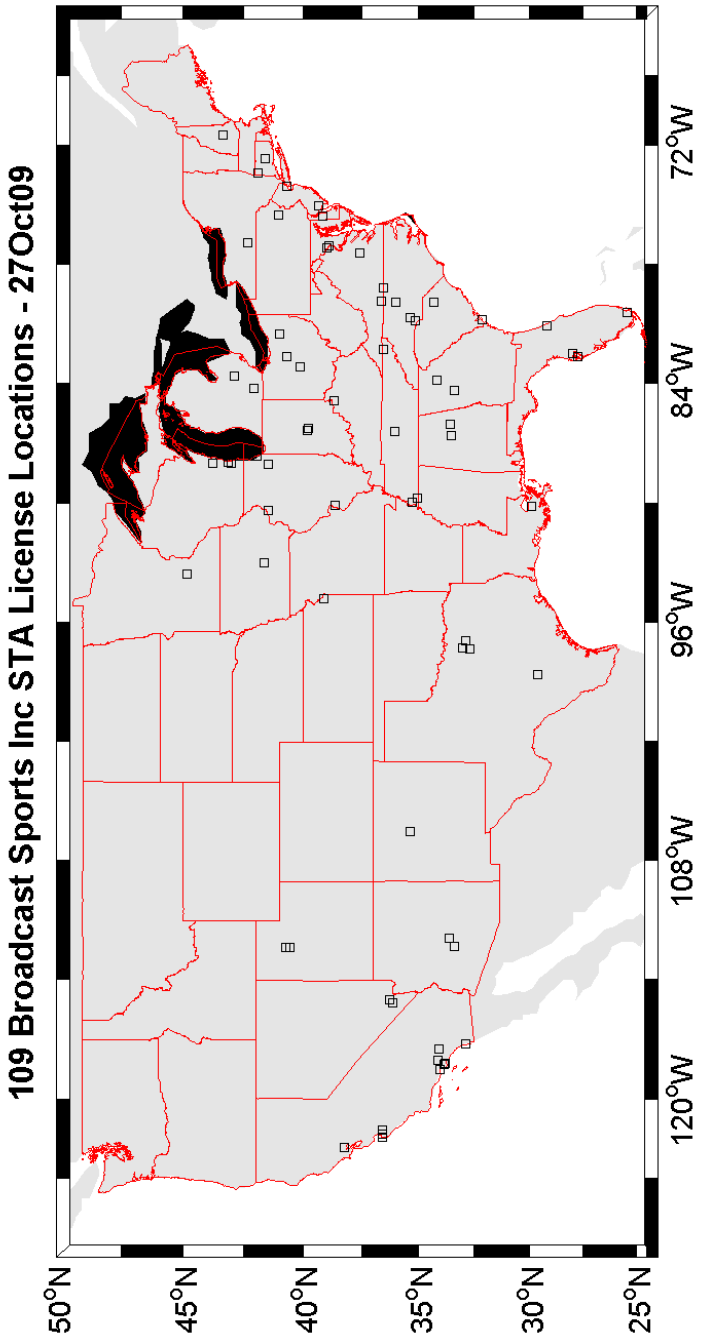

Figure 6 - Map of Broadcast Sports Incorporated Transmit Locations Listed in STA Experimental License Grants Coordinated by AFTRCC

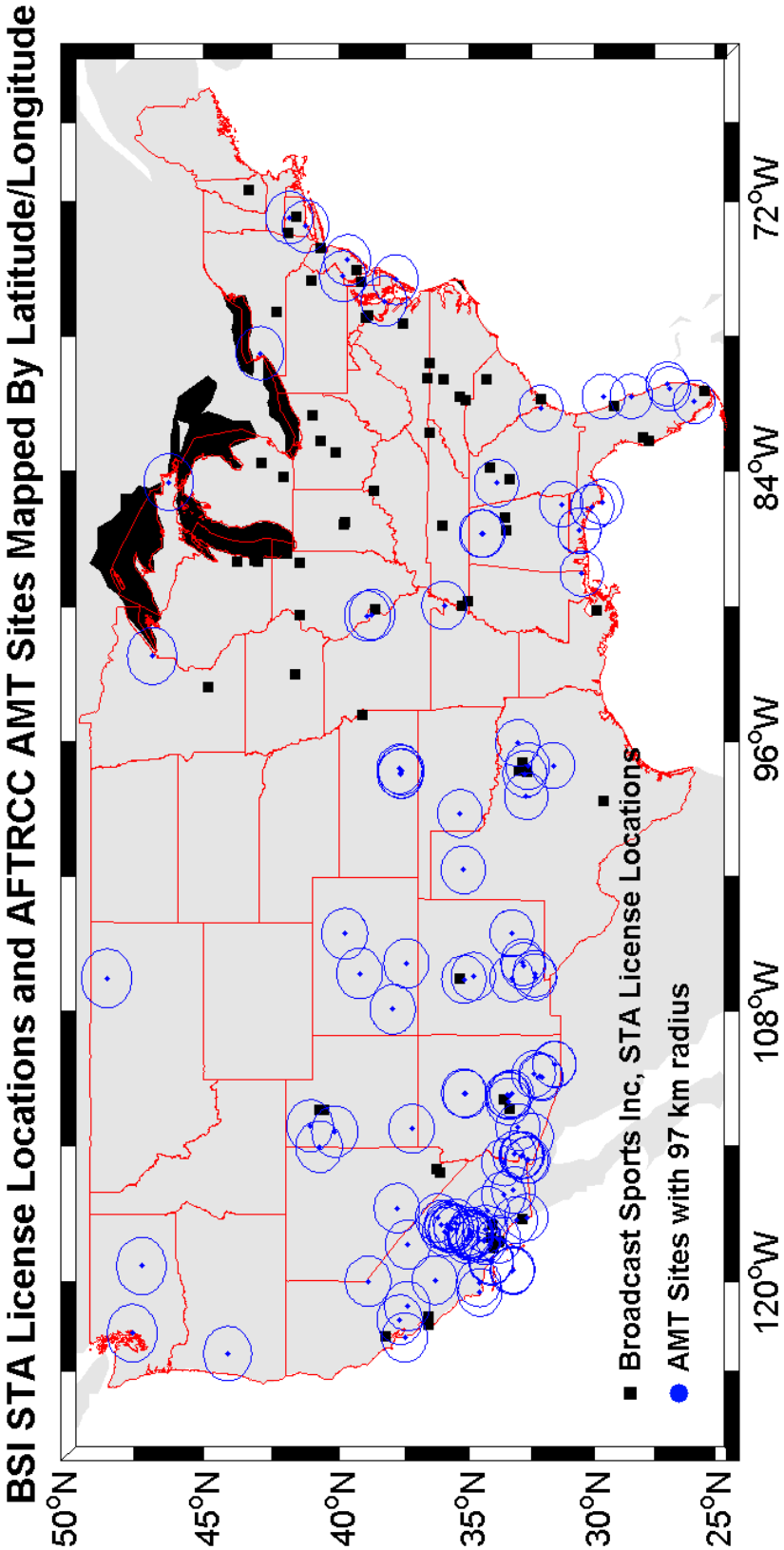

Figure 7 - Map of Broadcast Sports Incorporated Transmitter Locations and AMT Sites Provided by AFTRCC. Range rings of 97 km radius drawn about AMT sites.

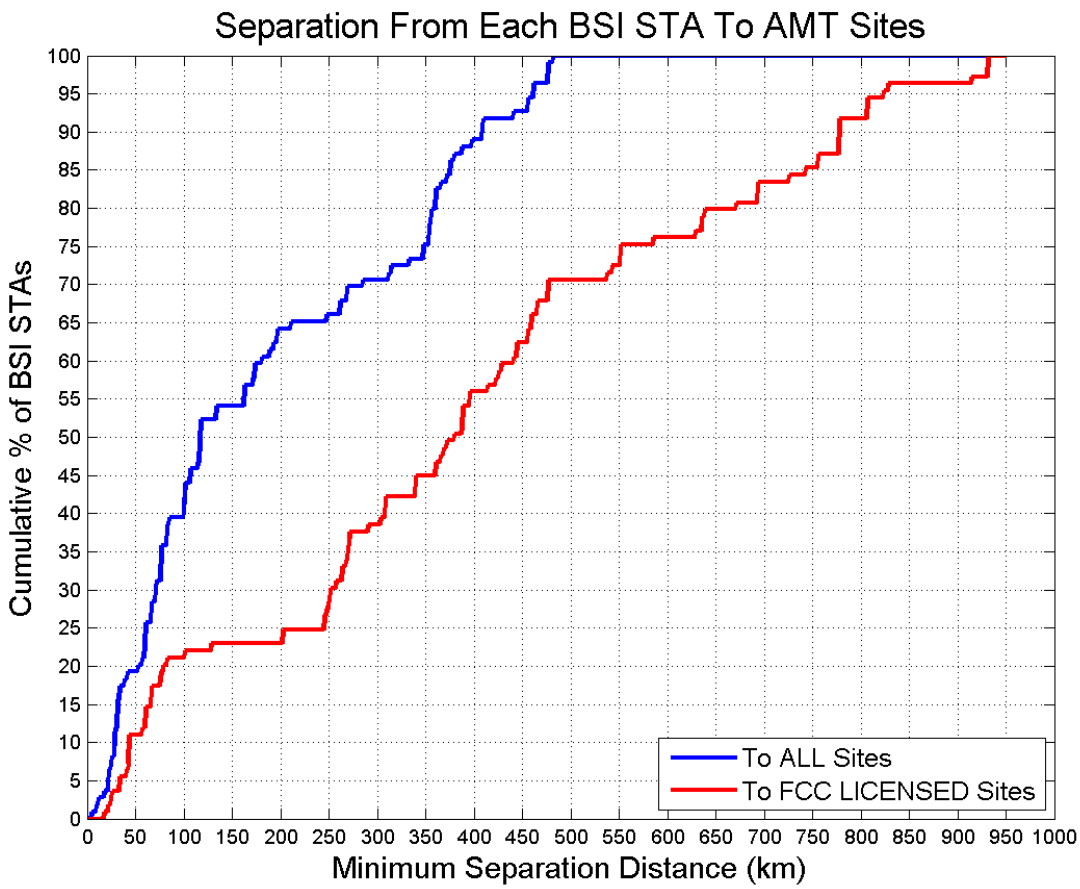

Figure 8 - Cumulative Distribution of Calculated Separation Distance Between Broadcast Sports Incorporated Transmit Locations from AFTRCC Coordinated STA Experimental License Grants

Table 1 - Broadcast Sports Incorporated STA Experimental License Search Results of 27 October 2009

Loc #	Grant Start	STA File Number	Call Sign	Details	Latitude (d-m-s)	Longitude (d-m-s)	Location Start Date	Location Stop Date	Specific Frequencies Listed and Coordinated	Emission Designator
1	11/8/2009	0456-EX-ST-2009	WE9XBH	2360-2390 MHz MO 0.25 W (ERP)	33-22-34	112-18-17	11/9/2009	11/15/2009	2364, 2372 and 2380	8M00D7N
2	11/8/2009	0456-EX-ST-2009	WE9XBH	2360-2390 MHz MO 0.25 W (ERP)	25-27-07	80-24-39	11/16/2009	11/22/2009	2364, 2372 and 2380	8M00D7N
3	9/17/2009	0422-EX-ST-2009	WE9XAN	2360-2390 MHz MO 0.25 W (ERP)	35-16-32	89-56-34	9/30/2009	10/24/2009	2364, 2372 and 2380	8M00D7N
4	9/17/2009	0422-EX-ST-2009	WE9XAN	2360-2384 MHz MO 0.25 W (ERP)	33-02-08	97-16-45	11/2/2009	11/8/2009	2364, 2372 and 2380	8M00D7N
5	9/17/2009	0422-EX-ST-2009	WE9XAN	2360-2384 MHz MO 0.25 W (ERP)	36-38-08	79-51-07	10/20/2009	10/25/2009	2364, 2372 and 2380	8M00D7N
6	9/17/2009	0421-EX-ST-2009	WE9XAK	2360-2384 MHz MO 0.25 W (ERP)	39-06-57	94-49-51	9/29/2009	10/4/2009	2364, 2372 and 2380	8M00D7N
7	9/17/2009	0421-EX-ST-2009	WE9XAK	2360-2384 MHz MO 0.25 W (ERP)	35-21-19	80-41-07	10/12/2009	11/8/2009	2364, 2372 and 2380.5	8M00D7N
8	9/17/2009	0420-EX-ST-2009	WE9XAJ	2360-2390 MHz MO 0.25 W (ERP)	33-34-04	86-04-00	10/27/2009	11/1/2009	2364, 2372, and 2380	8M00D7N
9	9/17/2009	0420-EX-ST-2009	WE9XAJ	2360-2390 MHz MO 0.25 W (ERP)	36-35-27	121-45-19	10/6/2009	10/10/2009	2364, 2372 and 2380 MHz	8M00D7N
10	9/17/2009	0420-EX-ST-2009	WE9XAJ	2360-2390 MHz MO 0.25 W (ERP)	34-05-16	117-29-57	10/6/2009	10/11/2009	2364, 2372 and 2380	8M00D7N
11	9/17/2009	0420-EX-ST-2009	WE9XAJ	2360-2390 MHz MO 0.25 W (ERP)	34-08-25	118-02-42	11/4/2009	11/7/2009	2364, 2372 and 2380	8M00D7N
12	9/17/2009	0420-EX-ST-2009	WE9XAJ	2360-2390 MHz MO 0.25 W (ERP)	25-27-07	80-24-39	10/6/2009	10/11/2009	2364, 2372 and 2380	8M00D7N
13	8/31/2009	0352-EX-ST-2009	WD9XZC	2360-2390 MHz MO 0.25 W (ERP)	43-22-45	71-28-29	9/15/2009	9/20/2009	2364, 2372, and 2380	8M00D7N
14	8/31/2009	0352-EX-ST-2009	WD9XZC	2360-2390 MHz MO 0.25 W (ERP)	40-34-53	112-22-12	9/16/2009	9/20/2009	2364, 2372, and 2380	8M00D7N
15	8/31/2009	0352-EX-ST-2009	WD9XZC	2360-2390 MHz MO 0.25 W (ERP)	37-35-07	77-25-24	9/7/2009	9/12/2009	2364, 2372 and 2380 MHz	8M00D7N
16	8/31/2009	0351-EX-ST-2009	WD9XZB	2360-2390 MHz MO 0.25 W (ERP)	39-11-07	75-32-06	9/22/2009	9/27/2009	2364, 2372 and 2380 MHz	8M00D7N
17	8/31/2009	0351-EX-ST-2009	WD9XZB	2360-2390 MHz MO 0.25 W (ERP)	34-09-13	83-48-22	9/22/2009	9/26/2009	2364, 2372, and 2380	8M00D7N
18	8/31/2009	0351-EX-ST-2009	WD9XZB	2360-2390 MHz MO 0.25 W (ERP)	33-23-01	84-19-07	9/1/2009	9/6/2009	2364, 2372 and 2380	8M00D7N

Loc #	Grant Start	STA File Number	Call Sign	Details	Latitude (d-m-s)	Longitude (d-m-s)	Location Start Date	Location Stop Date	Specific Frequencies Listed and Coordinated	Emission Designator
19	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	33-51-46	118-15-26	7/28/2009	8/3/2009	2364, 2372, and 2380 MHz	8M00D7N
20	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	38-14-36	122-27-42	8/18/2009	8/23/2009	2364, 2372, and 2380 MHz	8M00D7N
21	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	41-40-10	93-01-02	7/28/2009	8/1/2009	2364, 2372 and 2380	8M00D7N
22	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	41-28-25	88-03-01	8/24/2009	8/29/2009	2364, 2372 and 2380	8M00D7N
23	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	38-41-25	84-51-54	7/28/2009	8/1/2009	2364, 2372 and 2380	8M00D7N
24	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	42-04-02	84-14-26	8/11/2009	8/16/2009	2364, 2372 and 2380	8M00D7N
25	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	42-53-45	83-35-42	7/28/2009	8/2/2009	2365, 2375 and 2385 MHz	10M0D7W
26	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	44-49-46	93-35-06	8/11/2009	8/16/2009	2365, 2375 and 2385 MHz	8M00D7N
27	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	36-00-38	79-53-01	8/18/2009	8/23/2009	2365, 2375, and 2385 MHz	8M00D7N
28	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	40-42-02	74-04-08	8/25/2009	8/30/2009	2365, 2375, and 2385 MHz	8M00D7N
29	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	42-20-19	76-55-34	8/3/2009	8/9/2009	2364, 2372 and 2380	8M00D7N
30	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	41-00-28	81-30-19	8/4/2009	8/9/2009	2365, 2375 and 2385 MHz	8M00D7N
31	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	40-41-30	82-38-07	8/4/2009	8/9/2009	2364, 2372 and 2380	8M00D7N
32	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	41-03-13	75-30-39	7/29/2009	8/2/2009	2364, 2372 and 2380	8M00D7N
33	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	36-30-57	82-15-27	8/15/2009	8/22/2009	2364, 2372, and 2380 MHz	8M00D7N
34	7/28/2009	0304-EX-ST-2009	WD9XYY	2360-2390 MHz MO 0.25 W (ERP)	43-48-34	87-59-47	8/12/2009	8/16/2009	2364, 2372 and 2380	8M00D7N
35	6/26/2009	0274-EX-ST-2009	WD9XXQ	2360-2390 MHz MO 0.25 W (ERP)	35-21-17	106-33-04	6/26/2009	7/1/2009	2364, 2372, and 2380 MHz	8M00D7N
36	7/20/2009	0262-EX-ST-2009	WD9XXI	2360-2390 MHz MO 0.25 W (ERP)	39-48-48	86-19-51	7/20/2009	7/26/2009	2364, 2372 and 2380	8M00D7N
37	7/14/2009	0261-EX-ST-2009	WD9XXH	2360-2390 MHz MO 0.25 W (ERP)	43-09-29	87-57-07	7/14/2009	7/19/2009	2365, 2375, and 2385 MHz	8M00D7N
38	7/15/2009	0260-EX-ST-2009	WD9XXG	2360-2390 MHz MO 0.25 W (ERP)	33-32-07	86-37-18	7/15/2009	7/19/2009	2364, 2372 and 2380	8M00D7N

Loc #	Grant Start	STA File Number	Call Sign	Details	Latitude (d-m-s)	Longitude (d-m-s)	Location Start Date	Location Stop Date	Specific Frequencies Listed and Coordinated	Emission Designator
39	7/14/2009	0258-EX-ST-2009	WD9XXE	2360-2390 MHz MO 0.25 W (ERP)	38-39-10	90-08-19	7/14/2009	7/18/2009	2364, 2372 and 2380	8M00D7N
40	7/14/2009	0257-EX-ST-2009	WD9XXD	2360-2390 MHz MO 0.25 W (ERP)	41-55-51	73-22-49	7/14/2009	7/18/2009	2364, 2372 and 2380	8M00D7N
41	7/7/2009	0249-EX-ST-2009	WD9XXA	2360-2390 MHz MO 0.25 W (ERP)	41-29-03	90-23-58	7/7/2009	7/12/2009	2365, 2375, and 2385 MHz	10M0D7W
42	7/6/2009	0247-EX-ST-2009	WD9XWZ	2360-2390 MHz MO 0.25 W (ERP)	41-28-25	88-03-01	7/6/2009	7/11/2009	2364, 2372, and 2380	8M00D7W
43	7/1/2009	0245-EX-ST-2009	WD9XWY	2360-2390 MHz MO 0.25 W (ERP)	42-20-19	76-55-34	7/1/2009	7/5/2009	2364, 2372 and 2380	8M00D7W
44	6/28/2009	0244-EX-ST-2009	WD9XWX	2360-2390 MHz MO 0.25 W (ERP)	29-11-02	81-04-04	6/28/2009	7/4/2009	2364, 2372 and 2380 MHz	8M00D7W
45	6/30/2009	0237-EX-ST-2009	WD9XWW	2360-2390 MHz MO 0.25 W (ERP)	38-59-29	77-10-39	6/30/2009	7/5/2009	2365, 2375, and 2385 MHz	8M00D7W
46	7/15/2009	0235-EX-ST-2009	WD9XWO	2360-2390 MHz MO 0.25 W (ERP)	38-41-25	84-51-54	7/14/2009	7/18/2009	2364, 2372 and 2380	8M00D7W
47	6/18/2009	0203-EX-ST-2009	WD9XVV	2360-2384 MHz MO 0.25 W (ERP)	38-53-21	77-01-59	6/18/2009	6/21/2009	2364, 2372, and 2380 MHz	8M00D7W
48	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	38-14-36	122-27-42	6/17/2009	6/22/2009	2364, 2372, and 2380 MHz	8M00D7W
49	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2390 MHz MO 0.25 W (ERP)	41-37-56	72-38-34	6/23/2009	6/29/2009	2365, 2375, and 2385	10M0D7W
50	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	39-11-07	75-32-06	5/25/2009	6/1/2009	2364, 2372 and 2380 MHz	8M00D7W
51	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	41-40-10	93-01-02	6/17/2009	6/22/2009	2364, 2372, and 2380 MHz	8M00D7W
52	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	38-41-25	84-51-54	6/9/2009	6/14/2009	2364, 2372, and 2380 MHz	8M00D7W
53	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	42-04-02	84-14-26	6/9/2009	6/15/2009	2364, 2372, and 2380 MHz	8M00D7W
54	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	43-22-45	71-28-29	6/23/2009	6/29/2009	2364, 2372, and 2380 MHz	8M00D7W
55	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	42-20-19	76-55-34	6/2/2009	6/7/2009	2364, 2372, and 2380 MHz	8M00D7W
56	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2390 MHz MO 0.25 W (ERP)	40-08-14	83-08-32	6/2/2009	6/8/2009	2364, 2372, and 2380 MHz	10M0D7W
57	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	40-41-30	82-38-07	6/16/2009	6/21/2009	2364, 2372, and 2380 MHz	8M00D7W
58	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	41-03-13	75-30-39	6/3/2009	6/8/2009	2364, 2372, and 2380 MHz	8M00D7W

Loc #	Grant Start	STA File Number	Call Sign	Details	Latitude (d-m-s)	Longitude (d-m-s)	Location Start Date	Location Stop Date	Specific Frequencies Listed and Coordinated	Emission Designator
59	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	36-02-57	86-25-03	6/2/2009	6/7/2009	2364, 2372, and 2380 MHz	8M00D7W
60	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	35-03-32	89-46-43	6/9/2009	6/15/2009	2365, 2375, and 2385	10M0D7W
61	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	35-16-32	89-56-34	6/23/2009	6/28/2009	2364, 2372, and 2380 MHz	8M00D7W
62	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2390 MHz MO 0.25 W (ERP)	32-43-01	97-22-19	6/9/2009	6/15/2009	2365, 2375, and 2385	10M0D7W
63	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	33-02-08	97-16-45	6/1/2009	6/7/2009	2364, 2372, and 2380 MHz	8M00D7W
64	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	37-35-07	77-25-24	6/23/2009	6/28/2009	2364, 2372, and 2380 MHz	8M00D7W
65	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	43-01-00	88-00-30	5/26/2009	6/1/2009	2364, 2372, and 2380 MHz	8M00D7W
66	5/25/2009	0168-EX-ST-2009	WD9XVB	2360-2384 MHz MO 0.25 W (ERP)	43-01-00	88-00-30	6/15/2009	6/21/2009	2364, 2372, and 2380 MHz	8M00D7W
67	4/27/2009	0147-EX-ST-2009	WD9XUR	2360-2384 MHz MO 0.25 W (ERP)	36-35-27	121-35-19	5/13/2009	5/18/2009	2364, 2372, and 2380 MHz	8M00D7W
68	4/27/2009	0147-EX-ST-2009	WD9XUR	2360-2384 MHz MO 0.25 W (ERP)	39-47-24	86-14-11	5/18/2009	5/25/2009	2364, 2372, and 2380 MHz	8M00D7W
69	4/27/2009	0147-EX-ST-2009	WD9XUR	2360-2390 MHz MO 0.25 W (ERP)	35-06-57	80-50-22	4/28/2009	5/4/2009	2365, 2375, and 2385	10M0D7W
70	4/27/2009	0147-EX-ST-2009	WD9XUR	2360-2384 MHz MO 0.25 W (ERP)	35-21-19	80-41-07	5/11/2009	5/17/2009	2364, 2372, and 2380 MHz	8M00D7W
71	4/27/2009	0147-EX-ST-2009	WD9XUR	2360-2384 MHz MO 0.25 W (ERP)	39-21-50	75-03-21	4/29/2009	5/4/2009	2364, 2372, and 2380 MHz	8M00D7W
72	4/27/2009	0147-EX-ST-2009	WD9XUR	2360-2384 MHz MO 0.25 W (ERP)	34-17-45	79-54-19	5/4/2009	5/10/2009	2364, 2372, and 2380 MHz	8M00D7W
73	4/27/2009	0147-EX-ST-2009	WD9XUR	2360-2390 MHz MO 0.25 W (ERP)	32-51-46	96-57-36	5/19/2009	5/25/2009	2365, 2375, and 2385	10M0D7W
74	4/27/2009	0147-EX-ST-2009	WD9XUR	2360-2390 MHz MO 0.25 W (ERP)	29-37-30	98-37-47	5/12/2009	5/18/2009	2365, 2375, and 2385	10M0D7W
75	4/27/2009	0147-EX-ST-2009	WD9XUR	2360-2384 MHz MO 0.25 W (ERP)	40-43-53	112-22-12	5/13/2009	5/18/2009	2364, 2372, and 2380 MHz	8M00D7W
76	4/27/2009	0147-EX-ST-2009	WD9XUR	2360-2390 MHz MO 0.25 W (ERP)	37-35-07	77-25-24	4/27/2009	5/23/2009	2364, 2372, and 2380 MHz	8M00D7W
77	3/31/2009	0070-EX-ST-2009	WD9XTR	2360-2384 MHz MO 0.25 W (ERP)	33-34-04	86-04-00	4/21/2009	4/27/2009	2364, 2372, and 2380 MHz	8M00D7W
78	3/31/2009	0070-EX-ST-2009	WD9XTR	2360-2384 MHz MO 0.25 W (ERP)	33-22-34	112-18-17	4/13/2009	4/19/2009	2364, 2372, and 2380 MHz	8M00D7W

Loc #	Grant Start	STA File Number	Call Sign	Details	Latitude (d-m-s)	Longitude (d-m-s)	Location Start Date	Location Stop Date	Specific Frequencies Listed and Coordinated	Emission Designator
79	3/31/2009	0070-EX-ST-2009	WD9XTR	2360-2384 MHz MO 0.25 W (ERP)	33-48-42	118-11-38	4/14/2009	4/20/2009	2364, 2372, and 2380 MHz	8M00D7W
80	3/31/2009	0070-EX-ST-2009	WD9XTR	2360-2384 MHz MO 0.25 W (ERP)	27-46-28	82-39-21	3/31/2009	4/6/2009	2364, 2372, and 2380 MHz	8M00D7W
81	3/31/2009	0070-EX-ST-2009	WD9XTR	2360-2384 MHz MO 0.25 W (ERP)	39-06-57	94-49-51	4/21/2009	4/27/2009	2364, 2372, and 2380 MHz	8M00D7W
82	3/31/2009	0070-EX-ST-2009	WD9XTR	2360-2390 MHz MO 0.25 W (ERP)	29-53-56	90-11-29	4/21/2009	4/27/2009	2365, 2375, and 2385	10M0D7W
83	3/31/2009	0070-EX-ST-2009	WD9XTR	2360-2390 MHz MO 0.25 W (ERP)	32-09-20	80-46-38	4/14/2009	4/20/2009	2365, 2375, and 2385	10M0D7W
84	3/31/2009	0070-EX-ST-2009	WD9XTR	2360-2384 MHz MO 0.25 W (ERP)	36-02-57	86-25-03	4/7/2009	4/12/2009	2364, 2372, and 2380 MHz	8M00D7W
85	3/31/2009	0070-EX-ST-2009	WD9XTR	2360-2384 MHz MO 0.25 W (ERP)	33-02-08	97-16-45	3/31/2009	4/6/2009	2364, 2372, and 2380 MHz	8M00D7W
86	3/31/2009	0070-EX-ST-2009	WD9XTR	2360-2384 MHz MO 0.25 W (ERP)	36-33-11	79-11-33	4/22/2009	4/27/2009	2364, 2372, and 2380 MHz	8M00D7W
87	3/1/2009	0036-EX-ST-2009	WD9XSK	2360-2384 MHz MO 0.25 W (ERP)	33-23-01	84-19-07	3/3/2009	3/9/2009	2364, 2372, and 2380 MHz	8M00D7W
88	3/1/2009	0036-EX-ST-2009	WD9XSK	2360-2384 MHz MO 0.25 W (ERP)	36-14-58	115-02-18	2/24/2009	3/2/2009	2364, 2372, and 2380 MHz	8M00D7W
89	3/1/2009	0036-EX-ST-2009	WD9XSK	2360-2384 MHz MO 0.25 W (ERP)	36-30-57	82-15-27	3/17/2009	3/23/2009	2364, 2372, and 2380 MHz	8M00D7W
90	3/1/2009	0036-EX-ST-2009	WD9XSK	2360-2384 MHz MO 0.25 W (ERP)	36-38-08	79-51-07	3/24/2009	3/30/2009	2364, 2372, and 2380 MHz	8M00D7W
91	1/27/2009	0008-EX-ST-2009	WD9XSA	2360-2390 MHz MO 0.25 W (ERP)	33-38-07	111-54-11	1/27/2009	2/2/2009	2365, 2375, and 2385	10M0D7W
92	1/27/2009	0008-EX-ST-2009	WD9XSA	2360-2384 MHz MO 0.25 W (ERP)	34-05-16	117-29-57	2/17/2009	2/23/2009	2364, 2372, and 2380 MHz	8M00D7W
93	1/27/2009	0008-EX-ST-2009	WD9XSA	2360-2390 MHz MO 0.25 W (ERP)	32-54-14	117-14-45	2/3/2009	2/9/2009	2365, 2375, and 2385	10M0D7W
94	1/27/2009	0008-EX-ST-2009	WD9XSA	2360-2390 MHz MO 0.25 W (ERP)	34-02-52	118-29-59	2/17/2009	2/23/2009	2365, 2375, and 2385	10M0D7W
95	1/27/2009	0008-EX-ST-2009	WD9XSA	2360-2390 MHz MO 0.25 W (ERP)	36-33-56	121-56-22	2/10/2009	2/16/2009	2365, 2375, and 2385	10M0D7W
96	1/27/2009	0008-EX-ST-2009	WD9XSA	2360-2384 MHz MO 0.25 W (ERP)	29-11-02	81-04-04	2/3/2009	2/8/2009	2364, 2372, and 2380 MHz	8M00D7W
97	1/27/2009	0008-EX-ST-2009	WD9XSA	2360-2390 MHz MO 0.25 W (ERP)	27-58-33	82-30-12	1/28/2009	2/2/2009	2365, 2375, and 2385	10M0D7W
98	12/28/2008	0643-EX-ST-2008	WD9XQZ	2385 MHz MO 250 mW (ERP)	41-56-54	87-39-19	12/29/2008	1/1/2009	2385 MHz	10M0D7W

Loc #	Grant Start	STA File Number	Call Sign	Details	Latitude (d-m-s)	Longitude (d-m-s)	Location Start Date	Location Stop Date	Specific Frequencies Listed and Coordinated	Emission Designator
99	12/28/2008	0643-EX-ST-2008	WD9XQZ	2360-2390 MHz MO 0.25 W (ERP)	36-06-41	115-10-17	12/28/2008	12/31/2008	2365, 2375, and 2385	10M0D7W
100	10/27/2008	0499-EX-ST-200	WD9XOJ	2360-2384 MHz MO 0.25 W (ERP)	33-22-34	112-18-17	11/3/2008	11/9/2008	2364, 2372, and 2380 MHz	8M00D7W
101	10/27/2008	0499-EX-ST-200	WD9XOJ	2360-2384 MHz MO 0.25 W (ERP)	25-27-07	80-24-39	11/10/2008	11/16/2008	2364, 2372, and 2380 MHz	8M00D7W
102	10/27/2008	0499-EX-ST-200	WD9XOJ	2360-2384 MHz MO 0.25 W (ERP)	33-02-08	97-16-45	10/27/2008	11/2/2008	2364, 2372, and 2380 MHz	8M00D7W
103	10/15/2008	0494-EX-ST-2008	WD9XNP	2360-2394 MHz **MO 1.5 W (ERP)**	36-35-27	121-45-19	10/15/2008	10/20/2008	2368.5 MHz	17M0F3W
104	9/29/2008	0474-EX-ST-2008	WD9XNM	2360-2384 MHz MO 0.25 W (ERP)	33-34-04	86-04-00	9/29/2008	10/5/2008	2364, 2372, and 2380 MHz	8M00D7W
105	9/29/2008	0474-EX-ST-2008	WD9XNM	2360-2394 MHz **MO 1.5 W (ERP)**	34-09-13	83-48-22	9/30/2008	10/5/2008	2368.5 MHz	17M0F3W
106	9/29/2008	0474-EX-ST-2008	WD9XNM	2360-2384 MHz MO 0.25 W (ERP)	33-23-01	84-19-07	10/21/2008	10/26/2008	2364, 2372, and 2380 MHz	8M00D7W
107	9/29/2008	0474-EX-ST-2008	WD9XNM	2360-2384 MHz MO 0.25 W (ERP)	35-21-19	80-41-07	10/7/2008	10/11/2008	2364, 2372, and 2380 MHz	8M00D7W
108	9/29/2008	0474-EX-ST-2008	WD9XNM	2360-2384 MHz MO 0.25 W (ERP)	35-16-32	89-56-34	10/22/2008	10/25/2008	2364, 2372, and 2380 MHz	8M00D7W

APPENDIX C

Bibliography of Selected Literature Featuring Monte Carlo Methods

While examples can be found on the use of Monte Carlo simulation in various industries (nuclear, etc), publications of the technique as applied to aircraft and aviation safety are plentiful. The publications that follow were identified by searching Engineering Village's Compendex and IEEE Xplore databases over the 1989 to 2009 time period. A cursory Internet search using Google also afforded several news articles and documents supporting the use of Monte Carlo simulation techniques as part of probabilistic risk assessment by Boeing and NASA for safety and security related aviation applications. Finally, limited examples are included of the use of Monte Carlo simulation techniques by the nuclear and power industries as an element of reliability and safety analyses.

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
1	"Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment" Document Number: ARP4761 Date Published: December 1996 SAE International	Scope: This standard describes guidelines and methods of performing the safety assessment for certification of civil aircraft. It is primarily associated with showing compliance with FAR/JAR 25.1309. The methods outlined, including Markov Chain Monte Carlo (MCMC) methods, identify a systematic means, but not the only means, to show compliance. A subset of the material may be applicable to non-25.1309 equipment. The concept of Aircraft Level Safety Assessment is introduced and the tools to accomplish this task are outlined. The overall aircraft operating environment is considered.
2	Probabilistic Risk Assessment Procedures Guide for NASA Managers and Practitioners Version 1.1, August 2002 Dr. Michael Stamatelatos, NASA Headquarters Office of Safety and Mission Assurance (OSMA) http://www.hq.nasa.gov/office/codeq/doctree/praguide.pdf Last accessed 10/20/2009.	2.5 PRA SCOPE NASA (NPG.8705.XX) [6] has been drafted to guide the implementation of PRA application to NASA program and projects. Table 2-2, taken from this document, shows the requirements for the types of program/projects that need to perform PRA with a specified scope. A full scope scenario-based PRA process, typically proceeds as follows: … Uncertainty Analysis. As part of the quantification, uncertainty analyses are performed to evaluate the degree of knowledge or confidence in the calculated numerical risk results. Monte Carlo simulation methods are generally used to perform uncertainty analysis, although other methods exist.

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
3	Federal Aviation Administration (FAA) Guide to Reusable Launch and Reentry Vehicle Reliability Analysis Version 1.0, April 2005 http://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/FAA_AST_Guide_to_Reliability_Analysis_v1.pdf Last accessed 10/21/2009.	"The FAA recommends that system and subsystem reliability analyses account for uncertainty through the use of Monte Carlo simulation and sensitivity analyses." – page 13.
4	Federal Aviation Administration (FAA) Flight Systems Laboratory Branch http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs400/afs450/more/ Last accessed 10/20/2009.	FAA Flight Systems Laboratory Branch… Maintains the FSL Tools' server farm for access of FSL Tools via the Internet. Users include the FAA, military, general aviation and/or commercial aviation community. The FSL Tools' server farm also provides Internet access to multiple servers used by AFS-400 personnel to perform Monte Carlo simulations.
5	Federal Aviation Administration (FAA) The Risk Analysis Correspondence Course http://www.faa.gov/aircraft/air_cert/design_approvals/csta/publications/media/risk_analysis_corres_course.pdf Last accessed 10/20/2009.	This information is presented to Federal Aviation Administration (FAA) engineers and other interested individuals for aid in the understanding of the risk assessment process used by the FAA's Engine and Propeller Directorate. It also has applicability to risk analysis in general… Basically, there are two techniques to use in arriving at the risk factor - calculating it directly, or using Monte Carlo techniques.
6	Federal Aviation Administration (FAA) Advisory Circular, "Continued Airworthiness Assessments of Powerplant and Auxiliary Power Unit Installations of Transport Catetgory Airplanes" AC No: 39-8, Date: 9/8/03. http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/list/AC%2039-8/$FILE/AC39-8.pdf Last accessed 10/21/2009.	1. PURPOSE. a. This advisory circular (AC) describes the Continued Airworthiness Assessment Methodologies (CAAM). The Federal Aviation Administration (FAA) Engine and Propeller Directorate (EPD) and the Transport Airplane Directorate (TAD) may use CAAM to identify unsafe conditions and determine when an "unsafe condition is likely to exist or develop in other products of the same type design" before prescribing corrective action in accordance with Title 14 of the Code of Federal Regulations (14 CFR) part 39. CAAM is used for products associated with the Powerplant or Auxiliary Power Unit (APU) Installations on Transport Category Airplanes. 2. RELEVANT STRUCTURED METHODS AND TOOLS. There are a variety of analytical tools that can aid in the process of identifying potential unsafe conditions and resolving those judged to be actually unsafe. These include both qualitative and quantitative techniques. Listed below are categories of methods. These are described in greater detail in Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 4761, "Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment". The tools listed are variously applicable to both the identification and risk estimation steps… c. Statistical and numerical methods. Often, either inductive or deductive analysis methods are used to qualitatively identify the characteristics of either populations or failure conditions, or both, for which quantitative insight is desired. The following tools are used to quantitatively model and evaluate those characteristics: Weibull and other distributional analyses, and Monte Carlo simulation.

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
7	"NTSB Disappointed That A380 Fuel Tanks Will Not Be Inerted" Aviation Today, Monday, July 11, 2005 http://www.aviationtoday.com/regions/usa/NTSB-Disappointed-That-A380-Fuel-Tanks-Will-Not-Be-Inerted_2728.html Last accessed 10/20/2009.	Regarding specific FAA and NTSB objections to its special conditions, EASA was pretty clear in its view: FAA: "Flammable conditions within the [Thai and Philippines jets] would have been reached in flight after these airplanes began to climb, even if the tank had not been heated." EASA: "EASA does not consider any of the A380 fuel tanks as exhibiting high flammability characteristics." FAA: "The Monte Carlo assessment approach ... has been used for the last seven years to assess the impact of design changes on fuel tank flammability." EASA: "The Monte Carlo tool is not the most adequate tool to establish if a tank belongs to either the low or high flammability categories."
8	"TCAS: A Second Set of Eyes for Pilots" The MITRE Corporation, June 2009 http://www.mitre.org/news/digest/aviation/06_09/eyes.html Last accessed 10/20/2009.	The safety of commercial aircraft in the United States is something most travelers take for granted. It's been 23 years since the last aircraft collision over the U.S., thanks to a network of complementary systems that augment pilots' situational awareness of the airspace surrounding them… As a centerpiece of our work on refining TCAS II, MITRE performed Monte Carlo computer simulations that generated numerous variations of collision scenarios, enabling the system logic to be tested thoroughly.
9	"TSA rolls dice on risk model - Boeing to build Monte Carlo simulation to weigh air transportation risks", by Wilson P. Dizard III Jun 02, 2007 http://www.gcn.com/Articles/2007/06/02/TSA-rolls-dice-on-risk-model.aspx. Last accessed 10/20/2009.	TSA said Boeing would use its Monte Carlo simulation model 'to identify U.S. commercial aviation system vulnerabilities against a wide variety of attack scenarios.' The Monte Carlo method refers to several ways of using randomly generated numbers fed into a computer simulation many times to estimate the likelihood of an event, specialists in the field say. The Monte Carlo method plays an important role in many statistical techniques used to characterize risks, such as the probabilistic risk analysis approach used to evaluate possible problems at a nuclear power plant and their consequences. Boeing engineers have pushed the mathematical usefulness of the Monte Carlo method forward largely by applying the technique to evaluating the risks and consequences of aircraft component failures.
10	A Particle System for Safety Verification of Free Flight in Air Traffic Blom, H.A.P. Krystul, J. Bakker, G.J. National Aerosp. Lab., Amsterdam This paper appears in: Decision and Control, 2006 45th IEEE Conference on Publication Date: 13-15 Dec. 2006 On page(s): 1574 - 1579 Location: San Diego, CA	Under free flight, an aircrew has both the freedom to select their trajectory and the responsibility of resolving conflicts with other aircraft. The general belief is that free flight can be made safe under low traffic conditions. Increasing traffic, however, raises safety verification issues. This problem is formulated as one of estimating for a large scale stochastic hybrid system the probability of reaching a small collision set. The huge state space prohibits the use of existing numerical approaches to solve this safety verification problem. As an alternative we study randomization methods, the simplest of which would be to run many Monte Carlo simulations with a stochastic model of free flight operations, and count the number of runs during which a collision between two or more aircraft occurs. The huge state space prohibits such a straightforward MC simulation approach. By exploiting recent particle system theory by Del Moral and co-workers, this paper develops a sequential Monte Carlo simulation approach for the estimation of collision risk in a future air traffic scenario. The working of the resulting particle system is demonstrated for an eight aircraft scenario under free flight air traffic conditions

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
11	A probabilistic approach to aircraft conflict detection Prandini, M. Hu, J. Lygeros, J. Sastry, S. Dept. of Electron. for Autom., Brescia Univ., Italy; This paper appears in: Intelligent Transportation Systems, IEEE Transactions on Publication Date: Dec. 2000 Volume: 1 , Issue: 4 On page(s): 199 - 220	Conflict detection and resolution schemes operating at the mid-range and short-range level of the air traffic management process are discussed. Probabilistic models for predicting the aircraft position in the near-term and mid-term future are developed. Based on the mid-term prediction model, the maximum instantaneous probability of conflict is proposed as a criticality measure for two aircraft encounters. Randomized algorithms are introduced to efficiently estimate this measure of criticality and provide quantitative bounds on the level of approximation introduced. For short-term detection, approximate closed-form analytical expressions for the probability of conflict are obtained, using the short-term prediction model. Based on these expressions, an algorithm for decentralized conflict detection and resolution that generalizes potential fields methods for path planning to a probabilistic dynamic environment is proposed. The algorithms are validated using Monte Carlo simulations
12	A Statistical Method for the Detection of Sensor Abrupt Faults in Aircraft Control Systems Samara, P.A. Fouskitakis, G.N. Sakellariou, J.S. Fassois, S.D. Dept. of Mech. & Aeronaut. Eng., Patras Univ., Patras This paper appears in: Control Systems Technology, IEEE Transactions on Publication Date: July 2008 Volume: 16 , Issue: 4 On page(s): 789 - 798	Aircraft sensors are important for proper operation and safety, and their condition is conventionally monitored based upon the hardware redundancy principle. In this work a statistical method capable of independently monitoring a single sensor, and thus enhancing reliability and overall system safety, is introduced. The method's main advantages are simplicity, applicability to a wide variety of aircraft operating conditions, the handling of uncertainties, no need for additionally monitored signals, and no need for physics based aircraft dynamics models. The method is based on a statistical time series framework accounting for random effects and uncertainties, and exploits the fact that abrupt faults are characterized by time constants smaller than those of the aircraft. It employs monitored signal nonstationarity removal, signal whitening via novel pooled autoregressive modeling, statistical decision making, as well as electronic spike/glitch removal logic. The method effectiveness is demonstrated within the simulation environment of a small commercial aircraft via test cases and Monte Carlo experiments with abrupt faults occurring in an angle-of-attack sensor.
13	Aircraft landing scheduling optimization for single runway noncontrolled airports: Static case Yuanyuan, Ding1, 2, 3; Valasek, John1, 2, 3 Source: Journal of Guidance, Control, and Dynamics, v 30, n 1, p 252-255, January/February 2007	A static optimization scheduling algorithm using linear programming was developed for automated aircraft landing scheduling at single runaway non controlled airports. There are two basic functionalities in the air traffic control automation; trajectory analysis to provide flight-path predictions and aircraft scheduling to take advantage of accurate aircraft trajectories to produce efficient landing sequences. A scheduling model using Real Time Monte Carlo flight simulation for noncontrolled airports is developed using objective functions and the performance matrics of total cost of deviation, total holding time, and total delay time of the feeder route. The model is implemented in the automated safety and training avionics (ASTRA) that is a real time computerized airborne expert system and simulation environment that uses multiple intelligent aircraft agents. Each agent is equipped with simulated automatic dependent surveillance-broadcast devices, providing traffic information. (9 refs.)
14	Aircraft safety modeling for time-limited dispatch Prescott, D.R. Andrews, J.D. Dept. Aeronaut. & Automotive Eng., Loughborough Univ., UK This paper appears in: Reliability and Maintainability Symposium, 2005. Proceedings. Annual Publication Date: Jan. 24-27, 2005 On page(s): 139 - 145	SUMMARY & CONCLUSIONS This paper offers an alternative method of modeling the Time-Limited Dispatch (TLD) of aircraft. Existing methods involve the use of fault tree analysis and Markov analysis with various simplifying assumptions. Monte Carlo simulation (MCS) is the suggested alternative, which overcomes the problems associated with the other techniques, such as dependencies between basic events (fault tree analysis) or huge number of system states (Markov analysis). The results obtained from the analysis of a simple example are compared for the existing modeling approaches and MCS. MCS is seen to have potential advantages, especially when modeling TLD for large, full scale systems.

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
15	An object-oriented approach to risk and reliability analysis: Methodology and aviation safety applications Wyss, Gregory D.1; Durán, Felicia A.1; Dandini, Vincent J.1 Source: Simulation, v 80, n 1, p 33-43, January 2004, Air Transportation	This article describes how features of event tree analysis and Monte Carlo-based discrete event simulation can be combined with concepts from object-oriented analysis to develop a new risk assessment methodology, with some of the best features of each. The resultant object-based event scenario tree (OBEST) methodology enables an analyst to rapidly construct realistic models for scenarios for which an a priori discovery of event ordering is either cumbersome or impossible. Each scenario produced by OBEST is automatically associated with a likelihood estimate because probabilistic branching is integral to the object model definition. The OBEST methodology is then applied to an aviation safety problem that considers mechanisms by which an aircraft might become involved in a runway incursion incident. The resulting OBEST model demonstrates how a close link between human reliability analysis and probabilistic risk assessment methods can provide important insights into aviation safety phenomenology. (13 refs.)
16	Autonomous midcourse navigation for lunar return Zanetti, Renato1 Source: Journal of Spacecraft and Rockets, v 46, n 4, p 865-873, July-August 2009 ISSN: 00224650 CODEN: JSCRAG Publisher: American Institute of Aeronautics and Astronautics Inc.	Autonomous navigation systems provide the vehicle with estimates of its states without ground support. This work develops an autonomous navigation architecture for lunar transfer using optical sensors and celestial navigation. Measurement and error models are developed for two classes of celestial measurements, the elevation of known stars from the Earth's or moon's limb, and the apparent radius of the Earth or moon. Monte Carlo methods are used to support the development of measurement error models. The proposed architecture is tested with linear covariance techniques; navigation errors and trajectory dispersions are obtained to confirm the feasibility of the approach. The navigation system is required to provide 0.5 deg flight-path angle accuracy at entry interface for mission safety. The simulation results show that the proposed autonomous navigation system meets the reentry safety requirement. Copyright © 2009 by The Charles Stark Draper Laboratory, Inc. (7 refs.)
17	Conflict probability analysis of automatic air traffic control Cui, Deguang1; Cheng, Peng1; Geng, Rui1 Source: Qinghua Daxue Xuebao/Journal of Tsinghua University, v 40, n 11, p 119-122, November 2000	The safety and efficiency of air traffic control can be improved with a new method to estimate flight conflict probability. A previous conflict probability algorithm designed for 2-D was extended to 3-D. An approximate analytical algorithm was developed which was capable of dealing with the complex situation in the terminal area. A Monte-Carlo simulation experiment verified the precision and effectiveness of the 3-D algorithm. (6 refs.)
18	Conflict probability estimation for free flight Paielli, Russell A.1; Erzberger, Heinz1 Source: Journal of Guidance, Control, and Dynamics, v 20, n 3, p 588-596, May-Jun 1997	The safety and efficiency of free flight will benefit from automated prediction and resolution advisories. Conflict prediction is based on trajectory prediction and is less certain the farther in advance the prediction, however. An estimate is needed, therefore, of the probability that a conflict will occur, given a pair of predicted trajectories and their levels of uncertainly. A method to estimate that conflict probability is presented. The trajectory prediction errors are modeled as normally distributed, and the two error covariances for an aircraft pair are combined into a single, equivalent covariance of the relative position. A coordinate transformation is then used to derive an analytical solution. Numerical examples and a Monte Carlo validation are presented. (10 refs.)
19	Escaping a microburst with turbulence Dogan, A. Kabamba, P.T. Dept. of Aerosp. Eng., Michigan Univ., Ann Arbor, MI, USA; This paper appears in: American Control Conference, 2000. Proceedings of the 2000 Publication Date: 28-30 June 2000 Volume: 2 On page(s): 1349 - 1353 vol.2 Meeting Date: 06/28/2000 - 06/30/2000 Location: Chicago, IL	This paper compares three escape strategies for microburst encounters during final landing approach: altitude guidance, dive guidance, and pitch guidance. In the paper, two different approaches are used for comparison. 1) In a sample analysis approach, typical samples of the time histories of various variables are analyzed. 2) In a statistical approach, the probability distribution of the minimum altitude is estimated by the Monte Carlo method when the statistical properties of the microburst parameters are known. Both approaches suggest that, within the modeling assumptions of this paper, and in the absence of human factors, altitude and dive guidance with low commanded altitude may provide better safety than pitch guidance

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
20	Creating carpet plots that address uncertainty for aircraft sizing Habrel, Christopher R.; Crossley, William A. Source: Collection of Technical Papers - AIAA 5th ATIO and the AIAA 16th Lighter-than-Air Systems Technology Conference and Balloon Systems Conference, v 2, p 1198-1208, 2005, Collection of Technical Papers - AIAA 5th ATIO and the AIAA 16th Lighter-than-Air Systems Technology Conference and Balloon Systems Conference	All designers are aware of the uncertainty inherent in conceptual aircraft design. Most often it is dealt with by the use of a safety factor or a design margin that is added to constraints or limits to account for variability between a predicted result and the actual result. Both safety factors and design margins can be very effective; however, they may result in an "over designed" aircraft and sometimes an "under designed" one. This may require late design changes, which are typically costly to perform. Engineers understand that a large source of uncertainty in initial aircraft sizing comes from the empty weight equations. They generally use an empirically-based equation or a set of such equations that are a function of major aircraft design parameters, like wing area, sweep, and aspect ratio and have been defined during conceptual design. It is possible to characterize the uncertainty in these equations and to use Monte Carlo simulations to combine all of the component weight uncertainties into a distribution of empty weight. Because empty weight affects the overall size and performance of the aircraft, the uncertainty in the weight equations can be propagated to the vehicle level. The end result is a "probabilistic carpet plot" that is much like a traditional carpet plot, only each design point in the sizing matrix is now represented by distributions of weight and performance values. A "minimally invasive" approach to account for uncertainties in aircraft sizing is provided here. Seemingly insignificant scatter about component weight trend lines leads to large uncertainties in the final design point. Copyright © 2005 by the American Institute of Aeronautics and Astronautics, Inc. All rights reserved. (6 refs.)
21	Design of Intelligent Acceleration Schedules for Extending the Life of Aircraft Engines Chen, C.L.P. Ten-Huei Guo Texas Univ. San Antonio, San Antonio This paper appears in: Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on Publication Date: Sept. 2007 Volume: 37 , Issue: 5 On page(s): 1005 - 1015	Aircraft engine controllers are designed and operated to provide desired performance and stability margins. This paper addresses the relationship between acceleration action and engine component life usage. Based upon this relationship, an intelligent approach for designing acceleration schedules that provide proper tradeoffs between performance and engine life usage is proposed. The benefit of this approach is that it is expected to maintain safety while minimizing the overall operating costs. With the advances of computer technology, engine operation models, and damage physics, it is necessary to reevaluate the control strategy for overall operating cost consideration. This paper uses the thermal--mechanical fatigue (TMF) of a critical component to demonstrate how an intelligent acceleration algorithm can drastically reduce the engine life usage with minimum sacrifice in performance. We have modeled and calculated the probability of failure due to TMF damage. A Monte Carlo simulation is also performed to evaluate the likelihood of engine damage accumulation under various operating conditions. By means of genetic search algorithms, optimal acceleration schedules can be obtained with multiple constraints. The simulation results show that a selected best acceleration schedule can provide a significant life saving in selected engine components.
22	Escaping microburst with turbulence: Altitude, dive, and pitch guidance strategies Dogan, Atilla1; Kabamba, Pierre T.1 Source: Journal of Aircraft, v 37, n 3, p 417-426, May/June 2000	Three escape strategies are compared for microburst encounters during final landing approach: altitude guidance, dive guidance, and pitch guidance. The main difference between pitch guidance and the other two strategies is that pitch guidance immediately attempts to increase altitude at the expense of airspeed, whereas dive and altitude guidances initially trade altitude for airspeed. We use a full, six-degree-of-freedom, nonlinear, rigid-body aircraft model, including the effects of windshear and wind vorticity, and a model of microburst with turbulence. We also model the effect of stall prevention on the escape path. Two different approaches are used for comparison: 1) In a sample analysis approach, typical samples of the time histories of various variables are analyzed. 2) In a statistical approach, the probability distribution of the minimum altitude is estimated by the Monte Carlo method when the statistical properties of the microburst parameters are known. In the sample analysis and statistical approaches, the simulations take into account turbulence in addition to windshear. Both approaches suggest that, within the modeling assumptions presented, and in the absence of human factors, altitude and dive guidance with low commanded altitude may provide better safety than pitch guidance. (33 refs.)

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
23	Experimental and computational investigation of ice shedding from aircraft surfaces Papadakis, Michael; Yeong, Hsiung-Wei1; Suares, Ian G; Jacob, Joel Source: Collection of Technical Papers - 44th AIAA Aerospace Sciences Meeting, v 16, p 12108-12132, 2006, Collection of Technical Papers - 44th AIAA Aerospace Sciences Meeting	Ice particles shed from aircraft surfaces are a safety concern because they can damage aft mounted engines and other aircraft components. Current particle trajectory simulation methods have limited capabilities in predicting ice fragment trajectories. This is due to the random characteristics of the shed particles and lack of experimental aerodynamic data for ice fragments. This paper describes a new effort in developing a methodology for computing the trajectories of large ice particles. The methodology combines experimental aerodynamic characteristics of ice fragments, computational fluid dynamics, trajectory analysis and the Monte Carlo method to provide probability maps of shed particle footprints at desired locations. The methodology was applied to compute the trajectories of a square ice fragment and a rectangular plate shed in a three-dimensional uniform flowfield. Monte Carlo simulations were also performed where ice fragment parameters such as length, thickness, lift and drag coefficients, initial orientation, etc. were randomly changed and probability maps were computed. (38 refs.)
24	Flight nuclear safety risk assessment for cassini Hemler, Richard J.[1]; Cook, Beverly[1]; Owings, W.Donald[1]; Bradshaw, C.Thomas[1]; Bartram, Bart[1] Source: *SERA, Safety Engineering and Risk Analysis*, v 2, p 113-121, 1994, *Safety Engineering and Risk Analysis* CODEN: SSEAEA Conference: Proceedings of the 1994 International Mechanical Engineering Congress and Exposition, November 6, 1994 - November 11, 1994 Publisher: ASME Author affiliation: [1] Martin Marietta Astro Space, Philadelphia, United States	This paper presents a description of the safety review and approval process used to obtain flight approval for space missions using nuclear powered devices. It outlines the safety assessment and risk analysis approach, and it presents the details of the analytical tools to be used in the Cassini safety analysis. The Cassini safety assessment will extend the probabilistic risk analysis pioneered by the Department of Energy (DOE) and its contractors for the U.S. space nuclear safety program. An analytical tool to be used is the Launch Accident Scenario Evaluation Program (LASEP), a Monte Carlo computer code for determining the GPHS response in the various launch and early ascent accidents. In another area, a first time industry application of computational fluid dynamics techniques will be used to analyze extremely high speed reentries of a graphite body into an oxidizing atmosphere. Finally, radiological risks will be determined by recently improved techniques and codes for atmospheric dispersal and biological uptake.
25	Intelligent life-extending controls for aircraft engines Guo, Ten-Huei1; Chen, Philip2; Jaw, Link3 Source: Collection of Technical Papers - AIAA 1st Intelligent Systems Technical Conference, v 2, p 910-919, 2004, Collection of Technical Papers - AIAA 1st Intelligent Systems Technical Conference	Aircraft engine controllers are designed and operated to provide desired performance and stability margins. The purpose of life-extending-control (LEC) is to study the relationship between control action and engine component life usage, and to design an intelligent control algorithm to provide proper trade-offs between performance and engine life usage. The benefit of this approach is that it is expected to maintain safety while minimizing the overall operating costs. With the advances of computer technology, engine operation models, and damage physics, it is necessary to reevaluate the control strategy for overall operating cost consideration. This paper uses the thermo-mechanical fatigue (TMF) of a critical component to demonstrate how an intelligent engine control algorithm can drastically reduce the engine life usage with minimum sacrifice in performance. A Monte Carlo simulation is also performed to evaluate the likely engine damage accumulation under various operating conditions. The simulation results show that an optimized acceleration schedule can provide a significant life saving in selected engine components. (13 refs.)

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
26	Microburst escape using altitude guidance Dogan, A. Kabamba, P.T. Dept. of Aerosp. Eng., Michigan Univ., Ann Arbor, MI, USA; This paper appears in: Decision and Control, 1998. Proceedings of the 37th IEEE Conference on Publication Date: 16-18 Dec. 1998 Volume: 4 On page(s): 4228 - 4233 vol.4 Meeting Date: 12/16/1998 - 12/18/1998 Location: Tampa, FL	This paper compares three escape strategies for microburst encounters during final landing approach: altitude guidance, maximum angle-of-attack guidance, and constant pitch guidance. Altitude guidance with the lowest possible commanded altitude appears to be the safest strategy in that it yields the lowest probability of crash. Moreover, the safety of this escape strategy is the most robust against variations in microburst size, strength, and location. In the paper, three different approaches are used for the comparison: Deterministic simulations, a semi-analytic approach, and a statistical approach. All three approaches suggest that altitude guidance with the lowest possible commanded altitude is the safest and most robust strategy
27	Monte Carlo Optimization for Conflict Resolution in Air Traffic Control Visintini, A.L. Glover, W. Lygeros, J. Maciejowski, J. Dept. of Eng., Leicester Univ. This paper appears in: Intelligent Transportation Systems, IEEE Transactions on Publication Date: Dec. 2006 Volume: 7 , Issue: 4 On page(s): 470 - 482 Location: Tokyo, Japan	The safety of flights, and, in particular, separation assurance, is one of the main tasks of air traffic control (ATC). Conflict resolution refers to the process used by ATCs to prevent loss of separation. Conflict resolution involves issuing instructions to aircraft to avoid loss of safe separation between them and, at the same time, direct them to their destinations. Conflict resolution requires decision making in the face of the considerable levels of uncertainty inherent in the motion of aircraft. In this paper, a framework for conflict resolution that allows one to take into account such levels of uncertainty using a stochastic simulator is presented. The conflict resolution task is posed as the problem of optimizing an expected value criterion. It is then shown how the cost criterion can be selected to ensure an upper bound on the probability of conflict for the optimal maneuver. Optimization of the expected value resolution criterion is carried out through an iterative procedure based on Markov chain Monte Carlo. Simulation examples inspired by current ATC practice in terminal maneuvering areas and approach sectors illustrate the proposed conflict resolution strategy
28	Monte Carlo optimization strategies for air-traffic control Lecchini, A.; Giover, W.; Lygeros, J.; Maciejowski, J. Source: *Collection of Technical Papers - AIAA Guidance, Navigation, and Control Conference*, v 1, p 1-8, 2005, *Collection of Technical Papers - AIAA Guidance, Navigation, and Control Conference 2005*	The safety of the flights, and in particular conflict resolution for separation assurance, is one of the main tasks of Air Traffic Control. Conflict resolution requires decision making in the face of the considerable levels of uncertainty inherent in the motion of aircraft. We present a Monte Carlo framework for conflict resolution which allows one to take into account such levels of uncertainty through the use of a stochastic simulator. A simulation example inspired by current air traffic control practice illustrates the proposed conflict resolution strategy. Copyright © 2005 by the American Institute of Aeronautics and Astronautics, Inc. All rights reserved. (21 refs.)
29	Probabilistic reachability analysis for large scale stochastic hybrid systems Blom, H.A.P. Bakker, G.J. Krystul, J. Nat. Aerosp. Lab. NLR, Amsterdam This paper appears in: Decision and Control, 2007 46th IEEE Conference on Publication Date: 12-14 Dec. 2007 On page(s): 3182 - 3189 Location: New Orleans, LA	This paper studies probabilistic reachability analysis for large scale stochastic hybrid systems (SHS) as a problem of rare event estimation. In literature, advanced rare event estimation theory has recently been embedded within a stochastic analysis framework, and this has led to significant novel results in rare event estimation for a diffusion process using sequential MC simulation. This paper presents this rare event estimation theory directly in terms of probabilistic reachability analysis of an SHS, and develops novel theory which allows to extend the novel results for application to a large scale SHS where a very huge number of rare discrete modes may contribute significantly to the reach probability. Essentially, the approach taken is to introduce an aggregation of the discrete modes, and to develop importance sampling relative to the rare switching between the aggregation modes. The practical working of this approach is demonstrated for the safety verification of an advanced air traffic control example.

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
30	Probability of Midair Collision During Ultra Closely Spaced Parallel Approaches Houck, Sharon W.; Powell, J. David Source: Journal of Guidance, Control, and Dynamics, v 26, n 5, p 702-710, September/October 2003	This research considers the technological components required in an aircraft to safely perform simultaneous, instrument approaches into an airport with parallel runways spaced less than 2500 ft apart. Monte Carlo simulations were used in order to assess the probability of collision during an unexpected aircraft blunder, but many of the input parameters such as flight technical error, navigation sensor error, and pilot time delay were based on recently generated experimental data. This analysis shows that with the Federal Aviation Administration's global positioning system-based Local Area Augmentation System operational and a reliable data link transmitting full state information between aircraft, it is technically feasible to reduce runway spacing to 1500 ft or less using the same safety criteria as that used for the recently implemented Precision Runway Monitor program. (24 refs.)
31	Range safety requirements and methods for unguided suborbital rocket launches Wilde, Paul D.1 Source: European Space Agency, (Special Publication) ESA SP, n SP-645, July 2007, Proceedings of the 2nd IAASS Conference: Space Safety in a Global World	This paper describes requirements and methods employed to ensure safety during sounding rocket launches. Sounding rockets are typically rail launched with no active guidance systems; instead fins are used to stabilize the rocket by moving the center of pressure behind the center of gravity. Fins mounted at an angle to induce spin about the roll axis are a particularly effective means to maintain flight along the intended trajectory. This paper reports on the application of high fidelity trajectory and debris impact dispersion analysis methods and launcher setting optimization techniques to prevent debris impacts outside of the pre-determined hazard areas for multi-stage spin-stabilized sounding rockets. Accurate trajectory analyses, for nominal and malfunction conditions, are critical to the safety of sounding rocket launches, whether or not a risk assessment is performed. Therefore, a significant section of this paper addresses requirements and methods for high fidelity trajectory analyses, including lessons learned from recent experiences. Examples are presented to demonstrate that a full six degree-of-freedom trajectory analysis is necessary to compute accurate impact dispersions for sounding rockets with significant angular momentum. The importance of angular momentum to the flight dynamics of a typical spin stabilized rocket highlights the desirability of a nominal impact dispersion analysis that uses the Monte Carlo technique to account for the non-linear effects of various combinations of input parameter perturbations, such as launch elevation and thrust angle, or thrust offset and thrust angle. This paper also describes requirements and methods used for public risk management of unguided suborbital rockets, including risks to people in various transportation modes such as aircraft, ships, and automobiles. This paper assesses generic types of sounding rocket anomalies, such as fin failures, motor case ruptures, or staging anomalies, and illustrates methods to address these types of events from a range safety perspective. (22 refs.)
32	Receding horizon control for aircraft arrival sequencing and scheduling Xiao-Bing Hu Wen-Hua Chen Dept. of Aeronaut. & Automotive Eng., Loughborough Univ., UK This paper appears in: Intelligent Transportation Systems, IEEE Transactions on Publication Date: June 2005 Volume: 6 , Issue: 2 On page(s): 189 - 197	Airports, especially busy hub airports, proved to be the bottleneck resources in the air traffic control system. How to carry out arrival scheduling and sequencing effectively and efficiently is one of main concerns to improve the safety, capacity, and efficiency of the airports. This paper introduces the concept of receding horizon control (RHC) to the problem of arrival scheduling and sequencing in a dynamic environment. The potential benefits RHC could bring in terms of airborne delay and computational burden are investigated by means of Monte Carlo simulations. It is pointed out that while achieving similar performance as existing schemes, the new arrival scheduling and sequencing scheme significantly reduces the computational burden and provides potential for developing new optimization algorithms for further reducing airborne delay.

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
33	Robust Kalman filter design for predictive wind shear detection Stratton, D.A. Stengel, R.F. Dept. of Mech. & Aerospace Eng., Princeton Univ., NJ, USA; This paper appears in: Aerospace and Electronic Systems, IEEE Transactions on Publication Date: Oct. 1993 Volume: 29 , Issue: 4 On page(s): 1185 - 1194	Severe low-altitude wind shear is a threat to aviation safety. Newly developed airborne sensors measure the radial component of wind along a line directly in front of an aircraft. The authors use optimal estimation theory to define a detection algorithm to warn of hazardous wind shear from these sensors. To achieve robustness, a wind shear detection algorithm must distinguish threatening wind shear from less hazardous gustiness, despite variations in wind shear structure. Statistical analysis methods to refine wind shear detection algorithm robustness are presented. Computational methods predict the ability to warn of severe wind shear and avoid false warning. Comparative capability of the detection algorithm as a function of its design parameters is determined, identifying designs that provide robust detection of severe wind shear
34	Runway landing safety analysis: a case study of Atlanta Hartsfield airport Yue Xie Shortle, J. Donohue, G. Dept. of Syst. Eng. & Operations Res., George Mason Univ., Fairfax, VA, USA This paper appears in: Digital Avionics Systems Conference, 2003. DASC '03. The 22nd Publication Date: 12-16 Oct. 2003 Volume: 1 On page(s): 5.A.2 - 51-12 vol.1	According to historical data, aircraft are subject to a higher accident risk during the landing phase than during other flight phases. With the growth in air traffic volume evaluating safety during the landing phase is an important problem. This paper presents an analysis and estimate of two safety metrics at ATL airport: probability of a simultaneous runway occupancy by two landing aircraft and probability of a collision on the runway. We begin with the first order analysis to estimate the simultaneous runway occupancy probability, based on field observations. To obtain a more accurate estimate and to evaluate the runway collision risk, we construct a stochastic model of the aircraft approaching and landing process. The result of Monte Carlo simulation gives an improved estimate for the simultaneous occupancy probability. We then numerically evaluate the runway collision risk using a generalization of the Reich collision model. Finally, we carry out sensitivity analysis to examine the impact on safety and capacity when the separation variance changes.
35	Safety benefits of PathProx - a runway incursion alerting system Cassell, R. Evers, C. Esche, J. Rannoch Corp., Alexandria, VA, USA This paper appears in: Digital Avionics Systems Conference, 2003. DASC '03. The 22nd Publication Date: 12-16 Oct. 2003 Volume: 2 On page(s): 9.B.4 - 91-10 vol.2	This paper analyzes the safety benefits of the implementation of PathProx, a runway incursion alerting system. Airport surface incursions have been identified by the National Transportation Safety Board (NTSB) as one of the most significant safety hazards in civil aviation. PathProx is a system development by Rannoch Corporation to help address this problem. It is an aircraft-based runway incursion alerting system, providing runway incursion alerts directly to the pilot(s) in the cockpit. PathProx has undergone a series of simulator and flight tests conducted by NASA over the last 3 years. It is part of the NASA Runway Incursion Prevention System (RIPS). These tests have validated the basic concept and design of PathProx. Several analyses have been performed related to the safety benefits of PathProx implementation. These include analysed of critical runway incursion scenarios and Monte Carlo simulation. The Monte Carlo simulation results indicated that the risk of collisions due to runway incursions could be nearly eliminated through aircraft equipage with PathProx. The simulations and analyses also found that PathProx provides significant improvement in runway safety even without full fleet equipage-where only of the two aircraft involved in a conflict is equipped. Analyses have also been done to compare the safety improvements provided by PathProx with that provided by ground system surveillance and alerting. PathProx provides more timely alerting than provided by ground-based systems, primarily by eliminating the delays associated with having the controller in the loop and associated communications delay..

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
36	Safety of cooperative collision avoidance for unmanned aircraft Zeitlin, A.D. McLaughlin, M.P. Center for Adv. Aviation Syst. Dev., MITRE Corp., McLean, VA This paper appears in: Aerospace and Electronic Systems Magazine, IEEE Publication Date: April 2007 Volume: 22 , Issue: 4 On page(s): 9 - 13 Location: Phoenix, AZ, USA	For unmanned aircraft to be routinely used in civil airspace, an effective collision avoidance function is one area deemed essential for safe operation. Like manned aircraft, avoiding collisions with transponder-equipped, or "cooperative" traffic is among the primary hazards. This paper discusses the necessity of developing various models of environmental and system components in the collision avoidance functional chain. Potential sensitivities and shortcomings of the TCAS collision avoidance system for unmanned aircraft are discussed. The analysis method of fast-time simulation can develop a rich sample of collision encounter events from the numerous statistical distributions. This provides an established means to demonstrate system compliance with safety targets, when they are established
37	Safety performance of airborne separation: Preliminary baseline testing Consiglio, Maria C.; Hoadley, Sherwood T.; Wing, David J.; Baxley, Brian T. Source: *Collection of Technical Papers - 7th AIAA Aviation Technology, Integration, and Operations Conference*, v 1, p 427-436, 2007, *Collection of Technical Papers - 7th AIAA Aviation Technology, Integration, and Operations Conference*	The Safety Performance of Airborne Separation (SPAS) study is a suite of Monte Carlo simulation experiments designed to analyze and quantify safety behavior of airborne separation. This paper presents results of preliminary baseline testing. The preliminary baseline scenario is designed to be very challenging, consisting of randomized routes in generic high-density airspace in which all aircraft are constrained to the same flight level. Sustained traffic density is varied from approximately 3 to 15 aircraft per 10,000 square miles, approximating up to about 5 times today's traffic density in a typical sector. Research at high traffic densities and at multiple flight levels are planned within the next two years. Basic safety metrics for aircraft separation are collected and analyzed. During the progression of experiments, various errors, uncertainties, delays, and other variables potentially impacting system safety will be incrementally introduced to analyze the effect on safety of the individual factors as well as their interaction and collective effect. In this paper we report the results of the first experiment that addresses the preliminary baseline condition tested over a range of traffic densities. Early results at five times the typical traffic density in today's NAS indicate that, under the assumptions of this study, airborne separation can be safely performed. In addition, we report on initial observations from an exploration of four additional factors tested at a single traffic density: broadcast surveillance signal interference, extent of intent sharing, pilot delay, and wind prediction error.
38	Simulation of ice shedding from a business jet aircraft Papadakis, Michael1, 2, 3; Yeong, Hsiung-Wei1, 2, 3; Suares, Ian G.1, 3, 4 Source: Collection of Technical Papers - 45th AIAA Aerospace Sciences Meeting, v 9, p 6093-6117, 2007, Collection of Technical Papers - 45th AIAA Aerospace Sciences Meeting ISBN-10: 1563478900 Conference: 45th AIAA Aerospace Sciences Meeting 2007, January 8, 2007 - January 11, 2007 Publisher: American Institute of Aeronautics and Astronautics Inc. Author affiliation: 1 Wichita State University, Wichita, KS 672602 Department of Aerospace Engineering, Campus Box 443 AIAA4 Static Loads and Methodology Group, Cessna Aircraft	Ice particles shed from aircraft surfaces are a safety concern because they can damage aft-mounted engines and other aircraft components. Current ice shedding analysis tools have limited predictive capabilities due to the random nature of the shedding phenomena and lack of experimental aerodynamic data that can be used to compute forces and moments on ice fragments. This paper describes work performed as part of a long-term effort to develop and validate a methodology for computing the trajectories of large ice particles shed from aircraft surfaces. The methodology combines experimental aerodynamic characteristics of ice fragments, computational fluid dynamics, trajectory analysis and the Monte Carlo method to provide probability maps of shed particle footprints at desired locations. Trajectories of two simulated ice shapes, a flat plate and a glaze ice horn, shed from the wing and fuselage of a business jet are presented. Monte Carlo simulations performed to compute probability maps of trajectory footprints at the engine inlet plane showed considerable spread in the ice fragment trajectories due to variation in shed location, initial particle orientation and aircraft angle of attack. For the case of the flat plate released from the wing surface, approximately 5% to 7.8% of the fragments that crossed the engine inlet plane were ingested by the engine, depending on angle of attack. In the case where the flat plate fragment was released from the side of the fuselage, about 9.8% of the fragment that intersected the engine inlet plane was ingested by the engine. For the glaze ice horn, 0.25% to 0.7% of the fragments crossing the engine inlet plane entered the engine. (10 refs.)

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
39	Simulations of the MTR-R and MTR experiments at ISS, and shielding properties using PHITS Sihver, L. Sato, T. Gustafsson, K. Shurshakov, V.A. Reitz, G. Chalmers Univ. of Technol., Gothenburg This paper appears in: Aerospace conference, 2009 IEEE Publication Date: 7-14 March 2009 On page(s): 1 - 8 Location: Big Sky, MT	Concerns about the biological effects of space radiation are increasing rapidly due to the perspective of long-duration manned missions, both in relation to the International Space Station (ISS) and to manned interplanetary missions to the Moon and Mars in the future. As a preparation for these long duration space missions it is important to ensure an excellent capability to evaluate the impact of space radiation on human health in order to secure the safety of the astronauts/cosmonauts and minimize their risks. It is therefore necessary to measure the radiation load on the personnel both inside and outside the space vehicles and certify that organ and tissue equivalent doses can be simulated as accurate as possible. In this paper we will present preliminary results from simulations, using the three-dimensional Monte Carlo Particle and Heavy Ions Transport code System (PHITS), of long term dose distribution measurements performed with the joint ESA-FSA experiment MATROSHKA-R (MTR-R) led by the Russian Federation Institute of Biomedical Problems (IMBP). MTR-R is a spherical phantom located inside the crew cabin of ISS. We also show some results from PHITS simulations of the ESA supported experiment MATROSHKA (MTR), which consists of an anthropomorphic phantom containing over 6000 radiation detectors, mimicking a human head and torso. The MTR experiment, led by the German Aerospace Center (DLR), was launched in January 2004 and has measured the absorbed dose from space radiation both inside and outside the ISS. In this paper preliminary comparisons of measurements outside the ISS will be presented. For the purpose of examining the applicability of PHITS to the shielding design, the absorbed doses and dose equivalents in a cylindrical phantom with tissue equivalent material inside an imaginary space vessel on a geostationary orbit at solar minimum has also been estimated for different shielding materials of different thicknesses. All the results indicate that PHITS is - a suitable tool when estimating radiation risks for humans on manned space missions and when performing shielding design studies of spacecraft.
40	Space shuttle foam debris Monte Carlo risk analysis Brekke, John P. Eby, Matthew A.; Hardy, Brian S.; Williams, R.L.[5] Source: *Collection of Technical Papers - AIAA Applied Aerodynamics Conference*, 2008, *26th AIAA Applied Aerodynamics Conference* ISSN: 10485953 Conference: 26th AIAA Applied Aerodynamics Conference, August 18, 2008 - August 21, 2008 Publisher: American Institute of Aeronautics and Astronautics Inc.	After the STS-107 Columbia accident, caused by a large piece of Space Shuttle foam debris impacting the reinforced carbon-carbon (RCC) wing leading edge (WLE) of the Orbiter, NASA embarked to "determine critical debris sources, transport mechanisms, and resulting impact areas [and] based on the results of this assessment...recommend changes or redesigns that would reduce the debris risk."[1] The Aerospace Corporation and NASA developed a Monte Carlo analysis to study the debris impact phenomena in an end-to-end manner. The Aerospace Corporation integrated extensive testing, modeling, and observational data provided by Space Shuttle team members from NASA-JSC, NASA-MSFC, NASA-KSC, NASA-NESC, NASA-Ames, Lockheed Martin, Southwest Research Institute (SwRI), Boeing and The Aerospace Corporation into a simulation-based probabilistic risk assessment of ascent foam debris. This analysis predicts the answers to three questions: what can go wrong (debris release), what and how severe are the potential consequences (debris impact and damage), and what are the probabilities of occurrence for those consequences (resultant risk)? [2] Copyright © 2008 by The Aerospace Corporation.

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
41	Stability of digital control systems implemented in error-recoverable computers Tejada, A.1; González, O.R.1; Gray, W.S.1 Source: International Journal of Control, v 81, n 11, p 1665-1681, November 2008 ISSN: 00207179 CODEN: IJCOAZ Publisher: Taylor and Francis Ltd.Author affiliation: 1 Old Dominion University, Norfolk, VA, United States	Safety-critical, real-time applications make use of fault-tolerant digital control systems to achieve their performance goals. Even though these digital control systems are fault-tolerant, they are susceptible to errors induced by common-mode faults, since these errors cannot be masked by standard redundancy provisions. Such errors can be handled by special error correction mechanisms, which could require stopping the control law computations while the errors are removed. Thus, the effect of these special error recovery mechanisms on digital control systems needs to be understood. This paper presents a comprehensive study of the effect of three error recovery mechanisms-rollback, reset and cold restart-on the stability of digital closed-loop control systems. The effect of the faults, detected and handled by these error recovery mechanisms, on the digital control system is modelled by a set of interference maps. It is assumed that the arrival and departure of common-mode faults can be represented by a Markov process. The overall system behaviour is then described by a Markov jump linear model, whose stability is explored using standard techniques from the literature. The result of this analysis is a new metric, the minimum average interarrival spacing (MAIS), which is useful for comparing the performance of different error recovery mechanisms and for designing new fault-tolerant controllers. The theoretical results are illustrated via Monte Carlo simulations that show the effects of common-mode faults on the closed-loop stability of the longitudinal dynamics of an AFTI/F-16 aircraft. (27 refs.)
42	Systemic accident risk assessment in air traffic by Monte Carlo simulation Stroeve, Sybert H.[1]; Blom, Henk A.P.[1]; (Bert) Bakker, G.J.[1] Source: *Safety Science*, v 47, n 2, p 238-249, February 2009 ISSN: 09257535 CODEN: SSCIEO Publisher: Elsevier Author affiliation: [1] National Aerospace Laboratory NLR, Air Transport Safety Institute, Anthony Fokkerweg 2, 1059 CM Amsterdam, Netherlands	A systemic accident model considers accidents as emergent phenomena from variability and interactions in a complex system. Air traffic risk assessments have predominantly been done by sequential and epidemiological accident models. In this paper we demonstrate that Monte Carlo simulation of safety relevant air traffic scenarios is a viable approach for systemic accident assessment. The Monte Carlo simulations are based on dynamic multi-agent models, which represent the distributed and dynamic interactions of various human operators and technical systems in a safety relevant scenario. The approach is illustrated for a particular runway incursion scenario, which addresses an aircraft taxiing towards the crossing of an active runway while its crew has inappropriate situation awareness. An assessment of the risk of a collision between the aircraft taxiing with an aircraft taking-off is presented, which is based on dedicated Monte Carlo simulations in combination with a validation approach of the simulation results. The assessment particularly focuses on the effectiveness of a runway incursion alert system that warns an air traffic controller, in reducing the safety risk for good and reduced visibility conditions. © 2008 Elsevier Ltd. All rights reserved. (28 refs.)

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
43	The roles of air traffic controllers and pilots in safety risk analysis De Jong, H.H.[1]; Stroeve, S.H.[1]; Blom, H.A.P.[1] Source: *Proceedings of the European Safety and Reliability Conference 2006, ESREL 2006 - Safety and Reliability for Managing Risk*, v 3, p 1811-1817, 2006, *Proceedings of the European Safety and Reliability Conference 2006, ESREL 2006 - Safety and Reliability for Managing Risk* ISBN-10: 0415416205 Conference: European Safety and Reliability Conference 2006, ESREL 2006 - Safety and Reliability for Managing Risk, September 18, 2006 - September 22, 2006 Publisher: Taylor and Francis/Balkema Author affiliation: [1] National Aerospace Laboratory NLR, Amsterdam, Netherlands	Air traffic controllers and pilots are crucial in achieving high levels of safety in air traffic operations. Their performance is consequently an essential subject of safety risk analyses, which need to be executed when advanced air traffic operations are developed. The paper describes a systematic and stepwise approach to safety risk analysis, which is integrated in the development of advanced air traffic operations. The approach recognizes and exploits the ability of air traffic controllers and pilots to provide operational expertise necessary to perform such analyses. The roles of air traffic controllers and pilots in the safety risk analysis steps are elaborated by means of an application for a proposed air traffic operation at Amsterdam Airport Schiphol in which taxiing aircraft pass an active runway. Controllers and pilots have the following important roles in safety risk analysis and operational development: pushing the boundary between imaginable and unimaginable hazards in hazard identification, providing expert knowledge for argumentation-based and Monte Carlo simulation-based safety risk analysis, identifying potential mitigating measures, and providing a basis for acceptance of the introduction of an advanced operation.
44	Theoretical and statistical evaluation of the physical height loss experienced during a missed approach by a heavy aircraft under vertical instrument guidance Stapleton, David P.1, 2, 3, 4 Source: 20th International Technical Meeting of the Satellite Division of The Institute of Navigation 2007 ION GNSS 2007, v 3, p 2990-2997, 2007, 20th International Technical Meeting of the Satellite Division of The Institute of Navigation 2007, ION GNSS 2007 Conference: 20th International Technical Meeting of the Satellite Division of The Institute of Navigation 2007 ION GNSS 2007, September 25, 2007 - September 28, 2007 Publisher: Curran Associates Inc.Author affiliation: 1 Innovative Solutions International, FAA AFS 4202 Department of Mathematics, University of Central Oklahoma3 FAA, Mike Monroney Aeronautical Center, Oklahoma City4 GPS, GPS/WAAS, GPS/LAAS	Recent efforts to validate the safety of a 200 ft (60 m) Decision Height (DH) for use during GPS/WAAS instrument-guided (LPV) airplane final approaches have entailed evaluation of the height loss that occurs when an airplane executes a missed approach. The total height loss consists of various components, including vertical navigation system error (with latency), altimeter error, pilot delay or anticipation, and physical height loss (which includes the influence of air temperature and density on aircraft performance). Although there is some discussion of the total height loss, this paper assesses primarily the physical height loss component of total height loss and estimates its value only for the important case of heavy, high speed (category D) approaches. Height loss simulation for this case is also considered. Two methods are applied in order to quantify physical height loss and its associated risk: (i) test flight data that was collected from precision (ILS) high speed (category D) missed approaches made by Air Force KC-10 aircraft, and (ii) predictions from a theoretical model devised by the late W. J. G. Pinsker. Calculated quantities include statistics for KC-10 physical height loss and total height loss during test flight missed approaches, physical height loss predictions made by the Pinsker model for the same approaches, statistics to estimate the possible violation of the missed approach protective surfaces during GPS/VAAS instrument-guided category D missed approaches - including risks in the socalled "faulted" cases of a glidepath 30 m high or 30 m low, and construction of a covariance-based Monte Carlo model for KC-10 missed approach trajectory simulation. (2 refs.)

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
45	UAS Safety: Unmanned Aerial Collision Avoidance System (UCAS) Asmat, J. Rhodes, B. Umansky, J. Villavicencio, C. Yunas, A. Donohue, G. Lacher, A. George Mason Univ., Fairfax, VA This paper appears in: Systems and Information Engineering Design Symposium, 2006 IEEE Publication Date: 28-28 April 2006 On page(s): 43 - 49 Location: Charlottesville, VA ISBN: 1-4244-0474-6 INSPEC Accession Number:9220660 Digital Object Identifier: 10.1109/SIEDS.2006.278711 Current Version Published: 2007-01-15	Lack of safety and regulatory framework currently prevent the routine use of unmanned aircraft systems (UAS) within the U.S National Airspace System (NAS). Demonstrating a level of safety equivalent to that of manned aircraft will allow UAS to fly and interoperate in civil airspace. An unmanned aerial collision avoidance system (UCAS) designed to communicate and interact with the traffic alert collision avoidance system (TCAS) implemented on manned aircraft is proposed. Considering intruding aircraft equipped with TCAS as cooperating aircraft, UCAS will also be able to sense, detect, and avoid non-cooperative aircraft through the use of sensor technology. Simulation and analysis has been carried out to generate a safety metric quantifying the safety of the UCAS system. A Monte Carlo simulation has been performed for a set of outer loop state variables to generate the probability of a near midair collision. A second encounter model is carried out to show the benefits of incorporating the mitigation strategy selected, in this case the collision avoidance capabilities. An existing case study is analyzed to demonstrate the value of the model and the efficiency of the system
46	Subramanian, C.; Subramanian, D.K., "Performance analysis of voting strategies for a fly-by-wire system of a fighter aircraft," Automatic Control, IEEE Transactions on , vol.34, no.9, pp.1018-1021, Sep 1989	Findings of studies on input processing of a digital fly-by-wire system of a fighter aircraft are presented. Objectives were to select a suitable software structure complying with reliability and fault tolerance requirements and to assess its computational load. Ramp and constant input signals with noise were studied based on Monte-Carlo methods. Voting strategies studied and compared include lower median, upper-median, and weighted average. Execution times and memory requirements of each strategy have also been assessed
47	Qian Wang; Stengel, R.F., "Robust nonlinear flight control of a high-performance aircraft," Control Systems Technology, IEEE Transactions on , vol.13, no.1, pp. 15-26, Jan. 2005	Abstract: This paper considers probabilistic robust control of nonlinear uncertain systems. A combination of stochastic robustness and dynamic inversion is proposed for general systems that have a feedback-linearizable nominal system. In this paper, the stochastic robust nonlinear control approach is applied to a highly nonlinear complex aircraft model, the high-incidence research model (HIRM). The model addresses a high-angle-of-attack enhanced manual control problem. The aim of the flight control system is to give good handling qualities across the specified flight envelope without the use of gain scheduling and also to provide robustness to modeling uncertainties. The proposed stochastic robust nonlinear control explores the direct design of nonlinear flight control logic. Therefore, the final design accounts for all significant nonlinearities in the aircraft's high-fidelity simulation model. The controller parameters are designed to minimize the probability of violating design specifications, which provides the design with good robustness in stability and performance subject to modeling uncertainties. The present design compares favorably with earlier controllers that were generated for a benchmark design competition.
48	Akmeliawati, R.; Mareels, I., "Nonlinear energy-based control method for aircraft dynamics," Decision and Control, 2001. Proceedings of the 40th IEEE Conference on , vol.1, no., pp.658-663 vol.1, 2001	Abstract: We approach control of aircraft dynamics from an energy perspective. The method is based on the passivity-based control technique, and similar to total energy control systems. The aircraft dynamics are presented through the energy functions. By modifying these functions, stabilisation and tracking can be achieved. The method is illustrated on an automatic landing system problem for a twin-engine civil aircraft, developed by Group for Aeronautical Research and Technology in Europe. To deal with the separation of the short-period and the phugoid dynamics, we use ideas from singular perturbation theory. Disturbance rejection and robustness analysis are performed via Monte Carlo simulations. The proposed control laws behave well even under extreme flight conditions

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
49	Gonzalez, O.R.; Gray, W.S.; Patilkulkarni, S., "Analysis of memory bit errors induced by electromagnetic interference in closed-loop digital flight control systems," Digital Avionics Systems Conferences, 2000. Proceedings. DASC. The 19th , vol.1, no., pp.3C5/1-3C5/9 vol.1, 2000	This paper employs mean square stability conditions for worst case and random memory biterrors caused by high intensity electromagnetic (EM) disturbances to determine EM susceptibility of flight control systems. The perturbed closed-loop system is represented as a jump linear discrete-time system. This model is compared to other types of linear parameter varying representations. Two tests for EM susceptibility are presented and applied to a simple flight controller example. The second test, which uses the random bit-error interference model, is shown to be less conservative
50	Marrison, C.I.; Stengel, R.F., "Synthesis of robust control systems for a hypersonic aircraft," Decision and Control, 1994., Proceedings of the 33rd IEEE Conference on , vol.4, no., pp.3324-3329 vol.4, 14-16 Dec 1994	Stochastic robustness analysis is a flexible probabilistic framework for defining the robustness of control systems. Here, robust linear-quadratic-regulators are synthesized to control the nonlinear longitudinal dynamics of a hypersonic aircraft with uncertainties in 28 parameters. The compensators are designed using a genetic algorithm to search a design parameter space and Monte Carlo evaluation to define the robustness cost surface. The method is shown to produce control structures that satisfy nominal stability and performance goals, while minimizing robustness cost functions
51	Kellett, M.G.; Baguley, S.R.; Azinheira, J.R.; Rente, J.P., "Robustness analysis of a remotely piloted vehicle," Control '96, UKACC International Conference on (Conf. Publ. No. 427) , vol.2, no., pp. 776-781 vol.2, 2-5 Sept. 1996	The stability robustness of the longitudinal dynamics of a closed-loop remotely piloted vehicle the X7 half scale flying model of the ARMOR RPV-with uncertain parameters is considered. Techniques based on Lyapunov analysis and Gershgorin's theorem are used to predict a guaranteed parameter space for closed-loop stability. A large stochastic sampling is used to assess the conservatism of the results.
52	Yin Zong-Run; Mu Xiao-Dong; Shi De-Qin; Zhao Peng, "Baysian Reliability Assessment of Avionic Device Based on Markov Chain Monte Carlo Method," Testing and Diagnosis, 2009. ICTD 2009. IEEE Circuits and Systems International Conference on , vol., no., pp.1-4, 28-29 April 2009	This paper studies the computation problem involving Bayesian reliability assessment of avionic device. A method based on Markov Chain Monte Carlo is proposed to the issue. The noninformative prior distribution of the life distribution parameter is built at first, the kernel function of full conditional density function is figured out according to Bayesian theory, and sample scheme is chosen on the basis of the kernel function, at last, an example is given as an illustration. Test shows that, this method can simplify the computation greatly, and the result is in accordance with the engineering experience. It is a simple and effective approach in reliability assessment applications.
53	Zong-run Yin; Xiao-dong Mu, "Reliability assessment of avionic device based on GO methodology," System Simulation and Scientific Computing, 2008. ICSC 2008. Asia Simulation Conference - 7th International Conference on , vol., no., pp.76-78, 10-12 Oct. 2008	This paper studies the reliability assessment of avionic device. A method based on GO Methodology is proposed to the relative field, the state cumulative probability is introduced to simplify the operation, GO model is built with the consideration of shared signals, finally, an example is given as a illustration and the results is compared with the reliability parameters derived from Monte-Carlo Methodology. Test shows that, compared with traditional ways, this method is simple, direct while has higher compute precision and the simulation efficiency, it provides useful reference in the complicated, multiple states and time sequence problems.

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
54	Jacopino, A.; Groen, F.; Mosleh, A., "Modelling imperfect inspection and maintenance in defence aviation through bayesian analysis of the KIJIMA type I general renewal process (GRP)," Reliability and Maintainability Symposium, 2006. RAMS '06. Annual , vol., no., pp.470-475, 23-26 Jan. 2006	To ensure the effective and efficient operation of Defence aviation equipment there is a clear need for a component life model that is representative of the true life of a component. However, the large and often sophisticated RAM models used to manage defence aviation platforms, through various engineering and logistics activities, use models that cannot accurately represent this life. The main difference is in the underlying repair assumption. Specifically, the Ordinary Renewal Process (ORP) uses an as-good-as-new repair assumption while the Non-Homogenous Poisson Process (NHPP) uses an as-bad-as-old repair assumption. However, it is highly unlikely that any component, typically referred to as a Repairable Item (RI), will readily fit into either repair assumption. Therefore, despite the best endeavours of both engineering and logistics staff given the underlying repair assumption and the limitation these impose on the model, any solution will be suboptimal. Accordingly, there is a need for a RI life model that can contend with imperfect maintenance, imperfect inspection and can adapt to the limitations in data and include a number of additional factors including aging of the component, number of repairs, effectiveness of the repair, skill of the technicians, etc. Eight cases were developed as part of the overall modelling scheme. These eight cases are further divided into 2 main types; the first type representing cases where failure times are known and the second type where failure times are unknown. The cases incrementally modify these types through the addition of factors including multiple failure http://ieeexplore.ieee.org/xpls/citationAct (1 of 2)10/22/2009 1:58:56 PM http://ieeexplore.ieee.org/xpls/citationAct modes and their inter-dependence, and imperfect inspection and maintenance, in order to achieve a more realistic representation. Each of these cases were then solved using utilising a Markov Chain Monte Carlo (MCMC) sampling procedure, concentrating only on the analysis of the KIJIMA Type I GRP model with an underlying Weibull Time-To- Failure (TTF) distribution. The MCMC was made possible through the use of a Slice Sampling and Auxiliary Variable techniques. The resulting models have the ability to accurately model, and specifically predict, the future failure trends. Furthermore, the model allows the analyst to compare the maintenance effectiveness either in isolation, or in comparison (benchmarking) of various maintenance activities/facilities
55	Gazit, R.Y.; Powell, J.D., "Aircraft collision avoidance based on GPS position broadcasts," Digital Avionics Systems Conference, 1996., 15th AIAA/IEEE , vol., no., pp.393-399, 27-31 Oct 1996	The current airborne collision avoidance system provides pilots with approximate information on the relative location of nearby traffic, and with recommended escape maneuvers in the vertical plane. It relies on range measurements, and suffers from high false alarm rate. This paper studies a new collision avoidance system, which is based on periodic broadcasts of aircraft position as derived by an on-board GPS receiver. Several collision detection algorithms were evaluated by using a Monte Carlo simulation of random encounters in a free-flight environment. The algorithm selected uses the miss distance vector for both detection and avoidance. This approach can significantly improve the effectiveness of the current collision avoidance system, while lowering both the probability of false alarm and the probability of late alarm

A cursory Internet search using Google yielded many documents supporting the use of Monte Carlo simulation techniques as part of safety analysis for applications beyond aviation. The table below provides but a few examples of Monte Carlo simulation techniques being applied to the assessment of safety for automotive, nuclear and commercial power systems.

#	Source Details	Abstract, Summary, Scope and/or Key Quotations
56	United States Nuclear Regulatory Commission Fact Sheet on Probability Risk Assessment http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/probabilistic-risk-asses.html Last accessed 10/20/2009	Background - One of the Nuclear Regulatory Commission's key responsibilities is to ensure the operation of nuclear power plants and other NRC-licensed facilities present no undue risk to public health and safety. The agency does this by applying and enforcing a set of technical requirements on plant design and operations, described in Title 10 of the Code of Federal Regulations (10 CFR). Generally, these are written in terms of traditional engineering practices such as "safety margins" in design, construction, and operations. Probabilistic risk assessment (PRA) systematically looks at how the pieces of a complex system work together to ensure safety. PRA allows analysts to quantify risk and identify what could have the most impact on safety. Risk Assessment Methods To perform a PRA, analysts go through many steps… Assuming that the initiating event has occurred, analysts identify each combination of failures (e.g., pump failure and valve failure) that lead to a specific outcome. The likelihood of each combination is then computed. The probabilities of all those sequences that lead to the same outcome are added. To determine how often this outcome might occur, these probabilities are multiplied by the frequency of the initiating event(s). Modern PRA uses several specific techniques to accomplish this analysis… Monte Carlo methods are used to compute the risks. This technique allows analysts to consider variations in each factor of the analysis, imperfect knowledge, as well as the many possible ways the factors can interact.
57	493-2007 (Gold Book) IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems. (Color Book Series - Gold Book) Status: Active Publication Date: 2007 Digital Object Identifier: 10.1109/IEEESTD.2007.380668	2.9 Methods of reliability and availability analysis The intent of the tools in this subclause—and the entire chapter—is to perform availability analyses for systems. These tools, particularly those resulting from the exponential distribution are directly applicable to one family of analyses: analytical. The PDFs introduced in 2.8 can be used to their greatest potential in numerical analyses using Monte Carlo simulation. 2.9.2.2 Monte Carlo simulation Monte Carlo simulation is the most versatile modeling methodology available. The methodology can be implemented in many forms from simple models in a spreadsheet environment to complex models that are "handcrafted" in a programming language of choice. There are also a variety of simulation software packages that provide drag-and-drop environments that can automate the creation of simulated models for the casual analyst.
58	Monte Carlo techniques for modeling & analysing the reliability and safety of modern automotive applications Hauschild, J.; Meyna, A. Source: *Proceedings of the European Safety and Reliability Conference 2006, ESREL 2006 - Safety and Reliability for Managing Risk*, v 1, p 695-702, 2006.	Due to standards like the IEC 61508, which become more and more relevant for the development of safety-related automotive systems, different methods of verifying the reliability and safety in terms of a Probabilistic Safety Assessment are still in use. Being a quantitative method, the Monte Carlo simulation seems to be a promising approach for the reliability and safety verification of large and complex systems as realistically as possible. Different Monte Carlo techniques like analog or biased, direct or indirect, last event or free flight estimator, and component or system state based approaches can be applied. To show the potentials of the different Monte Carlo techniques, an application example, which presents a simplified fail silent architecture, is analysed. To model the system as realistically as possible, the application example contains real conditions like time-dependent transition rates and minimal or full repair. In order to verify the results of the Monte Carlo simulation, an approximated analytical solution is given. © 2006 Taylor & Francis Group. (14 refs.)

APPENDIX D

Proposed Exclusions Zones

In order to implement exclusion zones, GEHC proposes the following specific revisions to the draft MBAN service rules.

§ 95.1603 Authorized locations.

(a) MBANS operation using frequencies of the upper MBANS band defined by § 95.1611 is authorized anywhere CB station operation is authorized under § 95.405.

(b) MBANS operation using frequencies of the lower MBANS band defined by § 95.1611 is authorized anywhere within a health care facility as defined under § 95.1103(b) provided the facility is located where a CB station operation is permitted under § 95.405 and is not located within the specified protection radius of any of the following aeronautical mobile telemetry receive locations:

Aeronautical Mobile Telemetry Receive Locations	Latitude (North)	Longitude (West)	Protection Radius (km)
Alamagordo, NM	32° 50' 24"	105° 59' 26"	9.7
Alamosa, CO	37° 26' 04"	105° 52' 03"	9.7
Albuquerque, NM	35° 11' 39"	106° 34' 30"	9.7
Amarillo, TX	35° 12' 49"	101° 42' 31"	9.7
Arlington, TX	32° 40' 0."	97° 05' 53"	9.7
Big Bear, CA	34° 16' 00"	116° 51' 00"	9.7
Bishop, CA	37° 22' 24"	118° 21' 54"	9.7
Bloomfield, CT	41° 51' 42"	72° 42' 12"	9.7
Blythe, CA	33° 37' 09"	114° 43' 00"	9.7
Blytheville, AR	35° 58' 00"	89° 57' 00"	9.7
Buffalo, NY	42° 56' 54"	78° 44' 15"	9.7
Burns Flat, OK	35° 20' 37"	99° 12' 12"	9.7
Carlsbad, CA	33° 08' 00"	117° 17' 00"	9.7
China Lake Naval Weapons Center, CA	35° 43' 59"	117° 38' 27"	37.7
Contravies J, AZ	32° 30' 36"	113° 33' 36"	9.7
Crows Landing, CA	37° 24' 00"	121° 06' 00"	9.7
Dade Collier Test and Training, FL	25° 51' 42"	80° 53' 49"	9.7
Davis Monthan AFB	32° 10' 00"	110° 53' 00"	9.7
Dothan, AL	31° 19' 00"	85° 27' 00"	9.7
Duluth, MN	46° 50' 20"	92° 12' 10"	9.7
Echols Crossroads, AL	34° 30' 28"	86° 45' 34"	9.7
Edwards AFB, CA	34° 54' 45"	117° 53' 8"	21.2
Eglin AFB, FL	30° 32' 8"	86° 34' 7"	17.2
Eugene, OR	44° 07' 39"	123° 13' 12"	9.7
Falcon Field Mesa, AZ	33° 27' 39"	111° 43' 42"	10.9
Flagstaff, AZ	35° 08' 18"	111° 40' 16"	9.7
Fort Huachuca, AZ	31° 35' 18"	110° 20' 39"	11.8
Fort Worth Naval Air Station, TX	32° 46' 49"	97° 26' 53"	9.8
Glasgow, MT	48° 25' 21"	106° 32' 10"	9.7
Greenville, TX	33° 03' 47"	96° 04' 10"	9.7
Hurricane Mesa, UT	37° 13' 40"	113° 13' 05"	9.7

Jonathan Dickinson Missile Tracking Annex, FL	26° 58' 57"	80° 06' 28"	9.8
Kauai West, HI	22° 03' 00"	159° 47' 00"	9.7
Kennedy Space Center	29° 36' 00"	80° 40' 00"	24.7
Laguna Peak, CA	34° 06' 30"	119° 03' 50"	10.2
Leadville, CO	39° 13' 13"	106° 19' 0"	9.8
LeMoore Naval Air Station, CA	36° 20' 00"	119° 57' 00"	9.7
Long Beach, CA	33° 49' 09"	118° 08' 23"	9.7
Los Angeles, CA	34° 22' 51"	118° 11' 50"	9.7
Makaha Ridge Kokee, HI	22° 7' 35"	159° 41' 50"	12.8
Marietta, GA	33° 54' 24"	84° 31' 09"	9.7
McConnell AFB, KS	37° 37' 38"	97° 16' 40"	9.7
Mesa 1, AZ	33° 24' 00"	111° 46' 00"	9.7
Mojave, CA	35° 04' 00"	118° 09' 00"	9.7
Moses Lake, WA	47° 12' 46"	119° 19' 21"	9.7
Mt. Lemmon, AZ	32° 25' 31"	110° 47' 22"	9.7
National Lab, CA	37° 41' 19"	121° 42' 29"	9.7
Nellis, AFB	37° 48' 00"	116° 45' 00"	9.7
New Castle, DE	39° 40' 54"	74° 35' 52"	9.7
Oatman Mountain, AZ	33° 03' 33"	113° 08' 41"	9.7
Palmdale, CA	34° 37' 18"	118° 4' 43"	11.1
Palo Pinto, TX	32° 43' 36"	98° 25' 57"	9.7
Parrot, CA	36° 04' 59"	117° 28' 54"	9.7
Patuxent River Naval Air Station, MD	38° 17' 22"	76° 25' 24"	9.7
Philadelphia, PA	39° 51' 38"	75° 19' 11"	9.7
Phoenix 1, AZ	33° 18' 28"	111° 39' 19"	9.7
Phoenix 2, AZ	33° 26' 34"	112° 00' 23"	9.7
Pico Del Este, PR	18° 16' 04"	65° 45' 29"	9.7
Pillar Point, CA	37° 29' 57"	122° 29' 57"	9.7
Point Magu Naval Air Station, CA	34° 07' 01"	119° 06' 59"	11.5
Puerca Point, PR	18° 13' 53"	65° 35' 42"	9.7
Roswell International Air Center, NM	33° 17' 60"	104° 31' 40"	10.2
Salton Sea, CA	33° 14' 00"	115° 57' 00"	9.7
San Diego, CA	32° 42' 53"	117° 09' 21"	9.7
San Nicholas Island, CA	33° 14' 54"	119° 30' 1"	17.7
Sandia Labs, NM	34° 49' 20"	106° 26' 30"	9.7
Santa Ynez, CA	34° 36' 27"	120° 04' 28"	9.7
Sault St. Marie, MI	46° 14' 52"	84° 28' 15"	9.7
Savannah, GA	32° 08' 09"	81° 11' 38"	9.7
Seattle, WA	47° 32' 11"	122° 18' 51"	9.7
South Lake Tahoe, CA	38° 54' 00"	120° 00' 00"	9.7
St. Charles, MO	38° 55' 35"	90° 25' 23"	9.7
St. Louis (STL), MO	38° 45' 04"	90° 21' 24"	9.7
Stratford, CT	41° 15' 03"	73° 06' 01"	9.7
Stringer, AL	34° 26' 40"	86° 45' 32"	9.7
Telluride, CO	37° 57' 13"	107° 54' 30"	9.7
Thermal, CA	33° 37' 35"	116° 9' 36"	9.8
Tucson, AZ	32° 06' 58"	110° 56' 28"	9.7
Tyndall AFB, FL	30° 3' 40"	85° 34' 40"	10.1
USAF Vetro, FL	29° 40' 39"	85° 20' 58"	9.7
UT Test and Training Range (Granite Peak)	40° 09' 29"	113° 21' 01"	9.7
UT Test and Training Range (Grassy Mountain)	TBD	113° 05' 12"	9.7
UT Test and Training Range (Wendover Peak)	40° 45' 11"	114° 01' 11"	9.7
Vandenberg AFB AMT Sites 1-3	34° 33' 56"	120° 30' 04"	9.7
Waco, TX	31° 38' 21"	97° 04' 08"	9.7
Wallops Island, VA	37° 51' 03"	75° 28' 14"	9.7

Watkins, CO	39° 47' 26"	104° 32' 53"	9.7
West Palm Beach, FL	26° 54' 24"	80° 19' 14"	9.7
White Sands Missile Alamo (Lookout), NM	32° 52' 21"	105° 48' 43"	9.7
White Sands Missile Range (Salinas Peak), NM	33° 17' 55"	106° 31' 56"	9.7
White Sands Missile Range (South), NM	32° 23' 03"	106° 24' 06"	16.7
Wichita (Beech), KS	37° 41' 38"	97° 13' 12"	9.7
Wichita (Mid-Continent), KS	37° 39' 16"	97° 25' 42"	11.4
Wrightwood, CA	34° 21' 07"	117° 40' 29"	9.7
Yuma (Airport), AZ	32° 39' 12"	114° 37' 09"	9.7
Yuma (North), AZ	32° 43' 00"	114° 37' 00"	9.7
Yuma Proving Ground / Laguna AAF, AZ	32° 51' 36"	114° 23' 48"	28.2

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§ 95.1611 Frequency use policy.

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(d) MBANS stations operate using frequencies selected from lower and upper bands. The lower band is defined as 2360-2390 MHz. The upper band is defined as 2390-2400 MHz. Use of the lower and upper bands by MBANS stations is limited by § 95.1603.