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U.S. Department of Transportation
Office of the Secretary of Transportation

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October 30, 2000

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Ms. Magalie R. Salas
Secretary, Federal Communications Commission
The Portals
445 12th Street, S.W. TW-A325
Washington, D.C. 20554

Re: Ultra-Wideband Transmission Rules
ET Docket No. 98-153

Dear Ms. Salas:

Enclosed herewith are the original and four copies of the Reply Comments of, and Interim Test Results and Analysis sponsored by, the U.S. Department of Transportation in the above-referenced proceeding. I have also enclosed an extra copy of this document that I request be date-stamped and returned to the messenger.

Thank you for your assistance in this matter.

Sincerely,

Paul Samuel Smith

Paul Samuel Smith
Senior Trial Attorney
(202) 366-9285

Enclosures

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Before the
Federal Communications Commission
Washington, D.C.

In the Matter of	)	
	)	
Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems	)	ET Docket 98-153
	)	
	)	

Reply Comments of the
United States Department of Transportation

Interim Test Results and Analysis
Sponsored by the
United States Department of Transportation

Introduction

The Federal Communications Commission ("FCC" or "Commission") in this proceeding is concerned with the emergence of a new family of technologies that differs substantially from traditional devices that emit narrowband radiation and operate within a given spectrum allocation. It is the emission of ultra-wideband ("UWB") radiation that both enables this technology to offer the potential for public and private benefits and that threatens to interfere with existing services in restricted bands of the radio frequency spectrum. The U.S. Department of Transportation ("DOT" or "Department") is responsible for some of the most important of those services, first and foremost being safety-of-life functions carried out through communications, navigation, and surveillance ("CNS") systems, and in particular services based on the Global Positioning

System ("GPS").[1] These services are broadly employed by the transportation sector - - public and private - - to assure the safety, efficiency, and vitality of the nation's transportation infrastructure.

DOT's initial comments conveyed our understanding of the Commission's "fundamental premises" that govern this case:

> First, that UWB is a promising technology that may offer significant public and private benefits. Second, that existing technologies and their users, particularly those involved with safety-of-life functions like GPS, must continue to be protected from interference. Third, that carefully structured testing programs should determine the appropriate nature and extent of that protection insofar as UWB emissions are concerned.

Initial comments of DOT, at 2.

See also NPRM at ¶¶ 1-12, 24, 27, 28, 30, 39.

The record compiled to date reflects broad consensus on all of these points.[2] There is disagreement, however, on what DOT termed a "corollary" of these premises: "[T]hat, until test data are digested, translated into protective technical criteria, and then into regulatory provisions, the risk of interference precludes unfettered use of UWB technology." Id. In other words, some parties dispute the adequacy and meaning of the technical data acquired to date or to be compiled, and as a result there is no consensus at this time on the protections warranted by the data. We will accordingly address most of our attention in this document to that subject.

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[1]/ DOT hereby moves for leave to file its reply comments late. We had sought to combine reply comments with test results and file both on October 27. However, coordination difficulties prevented this. The reply comments are only one business day late, so no party would be prejudiced by the FCC's acceptance of this pleading.

[2]/ The agreement is not universal. For example, a few parties contend that UWB is akin to other emitters allowed under Part 15 of the Commission's regulations, and thus there is no need for extensive testing of the technology. *See* Initial comments of ANRO Engineering, Inc.; Endress + Hauss GmbH & Co.; Aviation Management Associates, Inc.

In addition, the Department tenders herewith technical data and analysis to bolster the substantive record on which decisions must be made. The first is a report on the results of the test program sponsored by DOT at Stanford University. *See* Initial Comments of DOT at 10-13. [3] We initiated that program in order to begin to assess the potential interference to GPS from UWB transmitters. Although the test program is incomplete, the results to date demonstrate a potential for such interference under a variety of conditions. Attachment 1. The second item is a copy of an interim report prepared for DOT by RTCA, Inc. that assesses a variety of factors involved in the potential for UWB interference with GPS-based systems. Attachment 2.

In sum, it is the Department's view that the ongoing debate about test data and its implications, the utter indispensability of the safety-of-life systems at risk, and preliminary information showing a real threat to those systems, all require that the Commission exercise caution. *See* NPRM at ¶¶ 1, 6-8, 27, 30, 32. The National Telecommunications and Information Administration ("NTIA"), which oversees federal use of the spectrum, has properly reported that "the establishment of ... rules [for UWB applications] must provide protection to critical Federal radiocommunications and safety systems, protection that is not yet apparent." Initial comments of NTIA at 2. At this juncture, therefore, questions must be resolved in favor of obtaining more information prior to authorizing UWB operations generally.

Such an approach is also consistent with, if not mandated by, FCC policy that extends protection to the restricted bands in the first place and the policy that proponents of new uses in those bands demonstrate that their operations are compatible with the allocated use of the radio spectrum. *See* Supplemental Comments of Sprint PCS at 8, note 16 (FCC precedent). Until there is a clear demonstration, there can be no assurance of interference-free operations for

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[3]/ The raw data on which this report is based is available upon request.

critical services such as GPS, and thus no predicate for broad authorization of UWB transmission systems.

Safety-of-Life Uses of the Spectrum Must be Protected from Interference

Spectrum management authorities recognize that all uses of the radio spectrum are not equal. Some are more important than others. This includes national security purposes, as well as those that serve safety-of-life functions. In recognition of this fact, the Commission and the NTIA have for decades ensured that such systems can operate without threat of interference from other users of the spectrum. *See* Initial comments of NTIA; *also* 14 C.F.R. § 15.205; NPRM at ¶¶ 24, 28. The reason is both obvious and fundamental: interruption of these services can mean death or injury on a potentially catastrophic scale.

The initial comments of the Department and virtually every other party that addressed the issue have reaffirmed the primacy of continued interference-free operation for safety-of-life systems. *See, e.g.,* Initial comments of the NTIA at 5; Aircraft Owners and Pilots Association; Lockheed Martin Corp.; Aeronautical Radio, Inc. ("ARINC")/Air Transport Association ("ATA"); The Boeing Co. [4] No party has urged the FCC to disregard or reduce that primacy by allowing interference from UWB equipment into the bands that are allocated for safety-of-life services. [5]

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[4]/ Other parties have made the same point for other existing uses in sensitive bands. See Initial comments of the National Association of Broadcasters, Cisco Systems, Inc.; Lucent Technology; Nortel Networks, Inc.; Wireless Communications Association International.

[5]/ It is important to recognize that commenting parties from such safety-of-life communities as police, fire, and medical organizations that (like DOT) saw value in certain UWB applications, never even implied that interference with CNS systems, some of which they rely upon, was acceptable. *See, e.g.,* Initial comments of the Federal Law Enforcement Wireless Users Group; Fraternal Order of Police; City of Helena Fire Department; International Association of Fire Chiefs; Singing River Hospital.

Several parties, however, while perhaps conceding the necessity of protecting such services, have objected to approaches proposed by the Commission and NTIA to provide such protection (*e.g.*, reducing signal strength below Part 15 requirements, eliminating operations in some restricted bands, or limiting or prohibiting emissions below certain threshold frequencies) on the grounds that they would force the alteration of the UWB signal characteristics or add to the cost of UWB devices. *See, e.g.*, Initial comments of Time Domain Corporation ("TDC"); *also* NPRM at ¶ 23. The Department submits, on the basis of the test results and analysis submitted herewith, as well as material elsewhere in the record, that such approaches, at a minimum, may be necessary to protect GPS and other sensitive services. Furthermore, the Department believes that the public record in this proceeding does not support the claims that these restrictions would fundamentally undermine the evolution of UWB technology.

Comprehensive Technical Information and Careful Analysis Must Determine the Appropriate UWB Regulatory Treatment

Parties have likewise generally agreed that robust technical data derived from carefully structured testing programs must form the basis for the regulatory treatment to be afforded the UWB family of technologies. *See* Initial comments of Sirius Satellite Radio; ARINC/ATA; AT&T Wireless Services, Inc.; Delphi Automotive Systems Corp.; SiRF Technology, Inc.; Nortel Networks, Inc.; Rockwell Collins, Inc. This is the Department's objective in this proceeding, given our responsibility for safe and efficient transportation and the CNS systems that make this possible.

The difficulty is that some parties suggest that enough engineering data has been accumulated, and has been subjected to sufficiently thorough analysis, to warrant a rapid promulgation of regulations authorizing varied UWB applications with relatively few restraints. Initial comments of Xtreme Spectrum, Inc.; TDC; A. Peter Annan; Endress + Hauser GmbH & Co. As discussed below,

however, numerous other submissions demonstrate that that is certainly not the case where GPS and other safety-of-life systems are concerned. Further testing and analysis is essential before critical regulatory decisions can be made.

Interim Results Show that Additional Testing of the Potential for UWB Interference is Necessary

In its initial comments, the Department noted that it had developed a test plan for assessing the potential interference to GPS from UWB transmitters. Initial comments of DOT at 10-13. A copy of the test plan, developed through extensive consultation with parties inside and outside the government, was included in the filing. [6] The testing completed thus far is producing solid technical results that clearly show certain UWB parameters can affect accuracy and loss-of-lock in a GPS aviation receiver from single emitter UWB testing. The testing is ongoing and will provide results on additional aviation and land GPS receivers.

A. DOT/Stanford initial report

An initial report on the test program conducted by Stanford University is submitted with these comments. Attachment 1. [7] This report focuses primarily on the impacts of selected UWB parameters on the pseudorange accuracy and loss-of-lock effects on a GPS aviation receiver. The test program is not complete. Further work is currently underway, and the Department anticipates that it will be completed in January, 2001. However, the test results to date demonstrate

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[6]/ In addition, because of wide interest in this matter, the Department published the plan in the Federal Register and solicited comments on it. Only one set of comments was submitted, by TDC. A copy of the test plan, TDC's comments, and DOT's response thereto, is attached. Attachment 3.

[7]/ "Potential Interference to GPS from UWB Transmitters, Test Results. Phase 1A: Accuracy and Loss-of-Lock Testing for Aviation Receivers" M. Luo, D. Akos, S. Pullen, P. Enge. Stanford University, October 26, 2000.

that UWB can cause interference with GPS receiver accuracy and loss-of-lock on satellite signals.

Initial comments have questioned whether the presence of broadband noise and the approach taken for this testing is appropriate or correct. Initial comments of TDC. The RTCA report discusses this aspect of the test program as follows:

> The rationale for the objective to quantify the degree of equivalence in RFI [radio frequency interference] impact of UWB signals relative to broadband random noise is that the GPS impact and analysis method for broadband noise are reasonably well understood. In this plan, broadband random noise will refer to continuous noise from a noise diode that has power spectral density much broader than the sky noise and any other wideband interference sources *other than* UWB. UWB signals ... also have bandwidths ... that are greater than the front end of the GPS receiver, but they have an additional structure that may cause their RFI effect to be very different than broadband random noise. ... If the degree of RFI impact equivalence were known, that information would directly support the analysis of specific operational interference encounters (scenarios) with or without other interference sources. ... Since it is important to check the scaling of accuracy with interference especially with composite UWB and broadband noise, the test plan calls for using 2 different reduced noise starting values: N_{ACC} -4 dB (40% noise and 60% UWB in terms of RFI effect), and N_{ACC} -2 dB (63% noise and 37% UWB in terms of RFI effect). With UWB power as the independent variable, a wide range of UWB waveform parameter sets can be checked for RFI effect relative to broadband noise.

Attachment 2 at 3-5.

In summary, the DOT/Stanford plan tested the impacts of various UWB parameters against the effects of broadband noise (the effects of which are well understood). The test results demonstrate that certain UWB parameters can cause deterioration of accuracy and loss-of-lock in a GPS aviation receiver relative to broadband noise. As noted in the report, the impact of UWB depends upon several sets of signal parameters including pulse repetition frequency, duty cycle and modulation variations. Id. at 41. The impact of UWB is strongly dependent on the presence and location of UWB spectral lines, relative to the GPS operating frequency. In general, pulse position modulation, on-off keying,

and changes in duty cycles do not cause the spectral lines to disappear. Id. The tests to date demonstrate that "the presence of spectral lines in the main lobe of the GPS spectrum for an unmodulated UWB signal at 100% duty cycle with PRF near 20 MHz translates into a difference of about 9dB between the power level at which lock is lost with UWB and higher power level where lock is lost under broadband noise only." Id.

The report contains several additional important findings of which the Commission should be aware. It concludes that

> UWB signals are less damaging than broadband noise when very low UWB PRFs are used and only a single UWB emitter is interfering. On the other hand, UWB signals are significantly more damaging than broadband noise when large spectral spikes fall in the GPS band.

Id.

The results show that there is an impact to a GPS aviation receiver and that this impact is dependent on the UWB signal characteristics. Based on the preliminary results of this measurement effort, it is clear that the Commission must allow adequate time for the submission and analysis of, and public comment on, the data from this and other ongoing government and private sector testing before adopting final rules.

B. RTCA analysis

The DOT/Stanford tests were designed to enable application of the test results in a variety of operational scenarios. To develop a fuller understanding of the technical issues surrounding the total electromagnetic interference ("EMI") environment, the rising noise floor, and potential interference impacts to any signal of interest, the Department requested RTCA to assist in the analysis of certain critical issues. (RTCA is an appropriate body to undertake this task,

having previously been asked by the FCC and NTIA to determine appropriate interference criteria for Mobile Satellite Services ("MSS") and GPS.[8]) As part of a broader effort, DOT specifically requested RTCA to consider issues of interference with the GPS L1 civil signal (1575.42 MHz) and to include UWB in that analysis. The first interim report was due and delivered in September 2000. Attachment 2. [9]

The methodology selected by the RTCA is the classic source-path-receiver analysis method. This approach requires collection or generation of data on these three interrelated elements. Analysis is applied taking into account appropriate operational scenarios to determine how far apart the emission source and receiver will be, appropriate technical characteristics, and what level of protection is appropriate (or for safety services and safety-of-life services, required) to avoid harmful interference.

The RTCA analysis was based, in part, on interim results provided by the DOT/Stanford testing effort. The RTCA interim report includes an overview of that effort, review of the DOT/Stanford test plan,[10] the TDC-sponsored University of Texas Applied Research Laboratory ("UT:ARL") test plan,[11] and a

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[8]/ The result of this work to determine appropriate interference criteria for the MSS and GPS was published as: RTCA SC-159, "Assessment of Radio Frequency Interference Relevant to the GNSS," Document No. RTCA/DO-235, January 27, 1997, RTCA, Inc., Washington, D.C.

[9]/ "Ultra-Wideband Technology Radio Frequency Interference Effects to GPS and Interference Scenario Development," RTCA Special Committee 159 Working Group 6: First Interim Report to Department of Transportation, September 12, 2000. *See* http://www.rtca.org/comm/pmc-sc-159report.htm.

[10]/ The test plan can be found at: *http://ostpxweb.dot.gov*

[11]/ Further information can be found at: *http://sgl.arlut.utexas.edu/asd/Cure/testplan.html*

review of the NTIA test plans (both GPS- and non-GPS focused)[12] -- all of which were presented at various meetings of the RTCA by the sponsors and/or testing entities.

Since operational scenarios factor heavily in determining whether or not there is a potential for harmful interference, DOT asked that RTCA also work to develop appropriate operational scenarios for aviation, to include Category I through Category III precision approach requirements, airport surface operations such as runway incursion and ramp collision prevention, and also -- to the extent possible -- surface non-aviation requirements such as maritime, rail, road, Enhanced-911, telecommunications timing, and other appropriate applications or systems. *See* Attachment 2 at 27 and 31 (Table 5).

Based upon the information available by early September 2000, the RTCA interim report established a framework for the link budget analysis for certain applications. Substantial further analysis based on the results of the complete DOT and NTIA test programs will be required.

This work is continuing and the next report from the RTCA is currently due in December of 2000. Further work on scenario development is underway for the key aviation cases, and non-aviation groups have been invited to assist in development of non-aviation scenarios.

The RTCA summary includes the following:

> Four UWB RFI effects test plans were reviewed and 3 were found generally acceptable. There is some controversy surrounding the ARL:UT plan. Due to basic differences in approach with the two other GPS receiver test plans, it seems unclear at present whether their test data can be comparable with Stanford and NTIA.
>
> Stanford preliminary test data has be[en] reviewed and seems to indicate a potentially significant RFI effect for several UWB waveforms at present

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[12]/ Further information can be found at: *http://www.ntia.dic.gov/osmhome/uwbtestplan.*

> Part 15 limits. Considerable work remains to review the rest of the Stanford test data along with NTIA and other available data.

Id. at 31.

C. Further testing

As noted above, further testing continues at Stanford and additional analytical work in applying test results to safety-sensitive operational scenarios is underway at RTCA. Both efforts are scheduled for completion near the end of 2000 or in early 2001, and we intend to report the results to the Commission. Moreover, the testing programs of the NTIA also remain incomplete at this time. Subject to the results of those tests, as well as testing programs being conducted by private parties in this proceeding, the Department anticipates that additional areas requiring investigation may be identified. DOT is committed to continuing to work with NTIA and the Commission to assure that a thorough program is developed and executed that would permit UWB applications to go forward, while guaranteeing that there will be no interference with essential transportation safety services (GPS-based and others).

UWB Technology May Warrant a Distinct Regulatory Regime

The record shows that different UWB applications have widely varying technical characteristics. Furthermore, it is also clear from initial comments and the data submitted herewith that results for the ongoing measurement and analysis efforts must be obtained before one can reasonably assess those characteristics and impacts in the many different scenarios that are realistically in prospect for UWB equipment.

A. UWB characteristics

As the FCC and many commenters recognize, "ultra-wideband" is itself a generic term that covers a very broad range of technologies for generating, broadcasting and applying a signal. NPRM at ¶¶ 4, 13; Initial comments of Cisco Systems; Xtreme Spectrum. The FCC's proposal to define UWB in terms of

bandwidth and power level is an attempt to bridge over the broad variance among technologies, but unfortunately does not address many critical variables and parameters in UWB applications.

The results of testing sponsored by DOT at Stanford University have demonstrated that parameters such as pulse repetition frequency, modulation, and duty cycle, among others, can all have critical impacts upon the manner in which the UWB signal is received and the manner and extent to which it interferes with GPS receivers. Attachment 1. Moreover, other information in the record shows, for example, that factors as simple as bending the antenna of a UWB device (intentional or unintentional) can have a dramatic impact upon the distribution of energy from a UWB broadcast and thus its interference with other systems. *See* Initial comments of Multispectral Solutions, Inc.

B. UWB proliferation

Beyond the parameters involved in a single UWB broadcast, the impacts of multiple emitters, UWB devices linked in networked communications systems, and UWB emissions in the presence of other EMI – whether pulsed or broadband - have not been tested. Yet they are noted by many commenters as likely to involve more complex and potentially harmful interaction and interference with GPS, other aviation systems, and other broadcast services. *See* Initial comments of the Satellite Industry Association; Rockwell Collins, Inc.; National Business Aviation Association; Garmin International, Inc.; Supplemental comments of Sprint PCS. *Contra,* Initial comments of Aether Wire & Location, Inc.; Zircon Corp.

UWB communications systems that are used in a networked configuration could be particularly problematic, but also potentially very useful, as noted in other comments. *See* Initial comments of Fantasma Networks, Inc. Yet no definitive description of such systems, with technical specifications, is available

in the record in this proceeding. [13] The impact to GPS receivers and other critical systems from UWB systems designed for networked applications must be evaluated before final rules are established.

It is also worth noting that there appears to be no information in the record concerning the operation of the three types of devices (surface-probing impulse radar systems, ground-penetrating radar, and systems that can be used for covert communications or for detection of persons in buildings or behind walls) that the Commission authorized on a limited basis by waiver more than one year ago. NPRM at ¶ 6; *see also* Initial comments of Mobile Communications Holdings, Inc.; National Business Aviation Association; Rockwell Collins, Inc.

C. Appropriate regulatory treatment

The regulatory treatment of UWB transmission systems must be based on the results of the ongoing measurement and analysis efforts. Therefore, the adoption of a regulatory structure for UWB must wait for the completion of comprehensive and thorough testing, analysis and public comment. Through a distinct regulatory regime tailored to the singular characteristics and applications of UWB, the FCC can comprehensively address the multiple technical and operational variables involved. Such a regulatory system could maximize the potential for UWB while protecting other services.

But DOT must emphasize that the extent of interference risk from these devices, and the controls necessary to guard against adverse effects, remain to be proven by UWB proponents. We reiterate our agreement with the FCC's commitment to a comprehensive testing and analysis program to identify the

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[13]/ The DOT/Stanford test report notes that the aggregate impact from multiple unsynchronized UWB emitters has the potential to combine coherently, but this potential effect has not been studied. Attachment 1 at 19.

UWB parameters and operating conditions in order to protect safety-of-life services in restricted bands. *See* NPRM at ¶¶ 1, 24, 28-30. [14]

UWB and Aviation Safety-of-Life

At least one party has suggested that UWB technology could perform some safety-of-life services in aviation. *See* Initial comments of Aviation Management Associates, Inc. Because this notion is so central to DOT's responsibilities and to this proceeding, we wish to address such comments separately. The short answer is that UWB technology may ultimately prove beneficial to aviation safety and efficiency, but there is now only an inadequate understanding of the technology's functioning and development potential. Far more important and immediate is a growing awareness of UWB's existing potential to interfere with the CNS systems on which aviation now relies.

The FAA administers the National Airspace System ("NAS"), the centerpiece of which are CNS systems such as the Wide Area Augmentation System and the Local Area Augmentation System that enable aircraft to take-off, fly, and land safely every moment of every day. Initial comments of DOT at 3-4. These systems are GPS-based. At the recent World Radio Communications Conference, spectrum for new civil GPS signals (in the 1164-1188 MHz band) was allocated on a worldwide basis, thereby underscoring the critical role of satellite-based CNS systems internationally as well as domestically.

It is also important to clarify that, contrary to the implication of some comments, the FAA cannot use unlicensed (Part 15) CNS systems in the NAS. The stringent accuracy, reliability, and integrity requirements of aeronautical safety-of-life services that necessitate protection from interference in the first place simply preclude adoption of technology that operates on a "sufferance" basis, and is subject to interference at any time. Initial comments of DOT at 3, 10.

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[14]/ Such services exist above the 2 GHz level noted in the NPRM. *See, e.g.*, Initial comments of ARINC/ATA; National Business Aviation Association.

In point of fact, the FAA must undertake a rigorous review of all technology and equipment considered for inclusion in the NAS. Candidate devices must satisfy all applicable standards, their failure modes must be fully evaluated, and their emissions must be band-limited within the spectrum allocated for the required service. They must also be compatible with existing NAS systems, conform to applicable rules, and satisfy all FAA certification and non-interference requirements. These processes have not yet been initiated for any UWB applications.

Conclusion

The record in this proceeding evidences broad consensus for continuing to protect safety-of-life and other services from the threat of interference from UWB emissions. The only real dispute centers on the adequacy of the technical data compiled and the regulatory restrictions those data support. The Department submits that the information developed to date indicates that UWB emissions can affect GPS-based and potentially other safety-of-life systems. This impact must be thoroughly understood before appropriate protections can be identified. Additional testing by NTIA and DOT is underway and, depending on the results of these efforts, further work may be necessary to achieve this understanding. DOT will continue to supply test data as it becomes available. We will work with the Commission and the NTIA to arrive at regulatory terms that, consistent with the underlying imperative to protect safety-of-life services from interference, will foster the development of the promising array of UWB technology.

Respectfully submitted,

ROSALIND A. KNAPP
Acting General Counsel

October 30, 2000