Before the
Federal Communications Commission
Washington, DC

In the Matter of:	)	
Adaptrum White Spaces Waiver Request	)	ET 14-187
Sensifree, Inc. Request for Waiver	)	ET 15-284
Headsight, Inc. Request for Waiver	)	ET 16-44

Piloting Risk-informed Interference Assessment in Radio Operation Waiver Proceedings

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Summary

Quantitative analytical tools to aid decision making are used throughout the federal government. This filing endorses earlier recommendations that the Commission adopt such a tool, Risk-informed Interference Assessment ("RIA"); supports the use of waivers to develop the Commission's ability to use RIA by analyzing three test cases; and recommends that the Commission provide guidelines to support the use of RIA by parties seeking waivers in appropriate cases.

If adopted, RIA would complement conventional worst case assessments by considering all harmful scenarios and their corresponding probabilities. The integration of RIA into the waiver process by the Commission would provide improved decision-making capability in spectrum management by incorporating quantitative analysis.

The use of RIA requires that parties:

(1) Inventory all harmful interference hazards;

(2) Define consequence metrics to characterize hazards;

(3) Calculate the probability and consequence of each hazard; and

(4) Aggregate results into a broader picture to inform decision-making.

Waivers are appealing as pilot applications because of the low impact of the individual proceedings and the relative simplicity of the usage conflicts. Accordingly, we examine three waiver applications as test cases for piloting RIA, without taking a position on the merits in any of them.

Because interested parties are in the best position to gather information necessary to perform RIA, this filing does not perform risk assessments. Instead, it offers suggestions and illustrations which may help parties to perform their own analyses.

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Discussion

Efforts to incorporate analytical decision making into regulatory processes are ongoing in many areas of government.[1] We support TAC recommendations that one such process, risk-informed interference assessment ("RIA"), should be used by the Commission to improve spectrum management decisions through the use of probabilistic analysis. To facilitate the TAC's goal, the Commission should request RIAs from parties to selected radio operation applications for support or rejection of waiver requests and to gain experience and build confidence in RIA.

We also recommend that the Commission develop guidelines which it can provide to parties in cases where it desires a RIA. These suggested guidelines would facilitate petitioners' creation of RIAs to submit at the Commission's request. In addition to these recommendations, we offer a checklist which the Commission can use to frame its guide.

Finally, we explore three specific waivers that the Commission might use to pilot the larger incorporation of the RIA method. Because the parties are in the best position to gather necessary information about the respective technologies of each waiver, this filing does not attempt to calculate risks of interference for the candidate waivers. Rather, this filing offers suggestions and illustrations which may help the parties to perform their own risk analysis.

I. The Commission should embrace previous recommendations for the use of risk assessment as an additional tool for its decision-making process.

Risk-informed assessment is an analytical tool that improves agency decision making through quantitative analysis. Analytical requirements are being pursued at some of the highest levels of government as a means of improving decision making.[2]

While independent agencies such as the Commission have not been required to adopt such initiatives, there are significant administrative and economic benefits to doing so.[3] In spectrum policy

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[1] *See generally* Cong. Research Serv., Cost-Benefit and Other Analysis Requirements in The Rulemaking Process, pp. 2, 11 (2014), https://fas.org/sgp/crs/misc/R41974.pdf.
[2] *Id.*
[3] *See id.* at p. 1.

situations where the Commission uses cost-benefit analysis, quantitative risk assessment is a valuable adjunct because it provides a well-reasoned engineering basis for the scenarios in which costs and benefits are to be calculated.

The traditional approach for determining the risk of a new radio operation for incumbent services is often qualitative and typically based on worst case scenarios.[4] Qualitative worst-case assessments generally focus on a single, high impact scenario where deterministic factors take on extreme values without regard to the likelihood of occurrence.[5] RIA provides a more nuanced approach by addressing multiple interference scenarios, their consequences, and the likelihoods of occurrence.[6]

RIA allows for a more thorough comparison of hazards by considering and calculating probabilities of both pervasive but low-risk, and remote but severe risks for a given system. A decision-maker using RIA can therefore account for all known interference and non-interference hazards, and weigh the threats those possibilities present against their likelihood. This will lead to a more informed decision as to whether the benefits of allowing a new service is justified by any risks of harmful interference.

II. The Commission should seek risk assessment from parties to waiver requests.

The Commission often requests documentation from a party regarding device testing procedures or radio operation metrics. Commission requests for information have historically been informal and often involve device power levels, propagation characteristics, areas of operation, safety issues, spectral wave forms, and studies already performed on the device characteristics—material that would also be used in a risk assessment.

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[4] The Spectrum and Receiver Performance Working Group, FCC Technological Advisory Council, A Quick Introduction To Risk-informed- Interference Assessment pp. ii, 1 (2015) [Introduction To RIA], https://transition.fcc.gov/bureaus/oet/tac/tacdocs/meeting4115/Intro-to-RIA-v100.pdf.

[5] *Id.* at p. 1.

[6] *Id.* ("quantitative risk assessments . . . broaden regulatory analysis from 'What's the worst that can happen?' to 'What can happen, how likely is it, and what are the consequences?'").

The Commission already requests information to support applications, and requesting risk assessments would be similar. For example, when requesting an experimental license, applicants must submit documentation detailing the planned experiments and ways they intend to mitigate interference; the Commission may subsequently request more information. The expected documentation will vary from case to case; while it is typically minimal, the Commission expects more details in cases where the risk for interference is greater. In instances where the parties fail to produce sufficient information, the Commission can request further details on a case-by-case basis. Moreover, waiver requests based on weak evidence may be conditionally granted with a requirement that the petitioning party continue to gather and file measurement data with the Commission.

In seeking RIAs from parties, the Commission would be merely codifying many of the requests that it already makes of parties, and would be making explicit how such requests should assess the risks of interference. This codification includes transparency and reproducibility requirements which notify parties of the need to provide both the methodology and data used in their calculations.[7] In any case, the Commission's decision making will be improved through greater clarity into the actual risk of a radio operation by using RIA.

III. The Commission should develop guidelines for risk assessment.

We recommend that the Commission develop guidelines for the performance of RIA to inform the parties to a waiver proceeding of informational requirements and how RIA is performed. Doing so would allow the Commission to gather information more efficiently to support waiver grant decisions. The guidelines could be published in the OET Knowledge Database.[8]

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[7] *See* Spectrum & Receiver Performance Working Group, FCC Technological Advisory Council, A Case Study of Risk-informed Interference Assessment: MetSat/LTE Coexistence in 1695-1710 MHZ, pp. ii-iii (v1.00 2015) [MetSat/LTE Case Study], https://transition.fcc.gov/bureaus/oet/tac/tacdocs/meeting121015/MetSat-LTE-v100-TAC-risk-assessment.pdf.

[8] Office of Engineering and Technology Laboratory Division Knowledge Database, https://apps.fcc.gov/oetcf/kdb/index.cfm; *see, e.g.*, SAR Measurement Guidance for IEEE 802.11 Transmitters (Oct. 17, 2014),

In particular, we suggest that the Commission frame its guidelines in terms of the four elements of RIA.[9] An example of a completed RIA incorporating the four elements can be found in the TAC's MetSat/LTE case study.[10] Each element is explained more fully below.

1) Create an inventory of significant harmful interference hazard modes.

First, a party should create an inventory of hazards by determining all expected harmful interference hazards for the given device or service. This may include co-channel interference, and adjacent band interference and out-of-band emissions from adjacent transmitters.[11]

2) Define consequence metrics to characterize such hazards in a uniform way.

Second, once the party creates an inventory of hazards, it must determine the impact of each hazard. This requires defining a consequence metric that represents the severity of all hazards on a single scale. Such metrics may be defined in many ways, and the choice of metric will depend on the facts and circumstances of each proceeding.[12] While there will usually be many candidate consequence metrics, the Commission will typically focus on one or two. Parties should therefore select a small number of metrics.

Consequence metrics fall into three primary categories:[13]

i. Corporate metrics look at how the overall operation, whether commercial or government-related, is affected. This includes impacts on ability to complete a mission (particularly relevant to government services), increased capital expenditure, losses in

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https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?id=28238&switch=P (The link to the guide may be found on this landing page).

[9] J. Pierre de Vries, Risk-informed Assessment: A Quantitative Basis For Spectrum Allocation Decisions, at p. 7 (2016) [Quantitative Basis], https://ssrn.com/abstract=2792395.

[10] *See generally*, MetSat/LTE Case Study.

[11] Introduction to RIA, at p. 5.

[12] *See Id.* at p. 6.

[13] MetSat/LTE Case Study, at pp. 17-22.

revenue or profit (relevant to commercial services), or other detrimental effects on operation.[14]

ii. Service metrics measure the quality of the specified service supported by the radio link. Service metrics include:

- Availability metrics, which assess loss of access to the service due to interference. This may include the time, in length or percentage, of outages, or the percentage of users unable to access the service.
- Quality metrics, which assess the loss of service integrity. This may include bit error rates for data services, range reduction for radar systems, variations in acquisition time and location accuracy for navigation services, Mean Opinion Scores for broadcasting, etc.[15]

iii. RF metrics are quantities observable in the radio frequency ("RF") environment including absolute value or degradation of signal to noise ratio (C/N_0 or CNR) or interference-to-noise ratio (I/N), signal to interference and/or noise ratios (SINR, C/I), absolute interference signal level, and receiver noise floor degradation.[16] RF metrics often will be the easiest to measure or model of the three categories of consequence metrics.

Because harmful interference is defined in terms of loss of service, we expect that the Commission would prefer—but not require—higher level metrics such as corporate or service metrics as they are most indicative of actual harm from a new service.[17]

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[14] *Id.* at p. 18.
[15] *Id.*
[16] *Id.*
[17] 47 C.F.R. 2.1 (harmful interference is "[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service. . ..").

Metrics should be calibrated against a baseline of existing hazard incidence to put interference from the new service in context.[18] Where baseline information is not available, the Commission should request it from incumbents objecting to a waiver request on the grounds of increased interference.

3) Assess probability and consequence for each hazard.

Third, a party should calculate the likelihood that interference hazards of a given severity will occur.[19] If the impact of a hazard (i.e. the consequence metric) can take a continuous range of values, each with a different probability, this will result in a probability distribution for each harmful interference hazard.[20] If there is only one or a few discrete consequence levels for a particular hazard, then the likelihood for each such value should be estimated.[21] If it is difficult to calculate probabilities and/or consequences precisely, even estimates in the range of orders of magnitude will be useful.[22] While quantitative estimates are preferable, qualitative assessments that provide a general idea of events which are most likely to occur and which are most damaging may be acceptable in some cases.[23]

4) Aggregate the results into a single picture to support decision making.

Finally, once likelihood-consequence results have been generated for each of the individual hazards, they need to be combined so that the Commission can assess the overall risk. This is the reason for using the same consequence metric for all hazards; for example, all the results can then be plotted on a single chart. One can then identify whether one interference mode—e.g. co-channel interference, out-of-band emissions, adjacent band blocking, or intermodulation—dominates, or whether multiple hazards must be mitigated simultaneously.[24]

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[18] Quantitative Basis, at pp. 14-15.
[19] Introduction to RIA, at p. 6.
[20] Quantitative Basis, at p. 15.
[21] Introduction to RIA, at p. 9.
[22] *Id.*
[23] *Id.* at p. 7.
[24] Introduction To RIA, at p. 10.

To better facilitate the use of RIAs, the Commission could provide a checklist of information that petitioners are expected or encouraged to present:

- A risk assessment that provides all four elements listed above;
- A justification for all choices or omissions—e.g., of hazard modes and consequence metrics;
- Sufficient data and/or computer code used in calculations to allow an independent third party to easily validate or replicate the work;
- A discussion of steps being taken to mitigate the hazards, and how this affects the analysis;
- Baseline data on consequence metric values in the absence of the interference that is the subject of the waiver application; and
- A sensitivity analysis—i.e. the sensitivity of the results to variations in the parameters that influence interference.

The Commission could also help the parties by providing references to a prototypical risk analysis that petitioners could pattern their filings on. Possibilities include the TAC risk case study and earlier engineering studies that, while not framed as risk analyses, include many of their features.[25]

[25] *See generally* MetSat/LTE Case Study; Newfield Wireless, Chicago Channel 51 Interference Probability Study (2012) [Newfield Study], https://wireless2.fcc.gov/UlsEntry/attachments/attachmentViewRD.jsp?applType=search&fileKey=1650547767&attachmentKey=19265946&attachmentInd=applAttach; Fox Television Stations, *Comments of Fox Television Stations, Inc., Licensee of WPWR-TV*, WT Dkt. No. 14-17 (filed Mar. 4, 2014) [Fox Comments], https://ecfsapi.fcc.gov/file/7521088152.pdf; Laser Inc., *Field Study and Technical Analysis of the Potential for Interference from LTE UE Operating in the 700 MHz A Block to Reception of DTV Channel 51, WPWR-TV*, WT Dkt. No 14-17 (filed Jun. 18, 2015) [Laser Report], https://ecfsapi.fcc.gov/file/60001090656.pdf.; Rob Alderfer et al., Toward Expanding Wi-Fi Access in the 5GHz Band (2013), http://ssrn.com/abstract=2411683.

IV. The Commission could evaluate the RIA process by applying it to three example waiver applications.

The FCC's Technology Advisory Committee recommended that RIA be widely adopted by the Commission.[26] To facilitate this goal, we recommend that the Commission gain experience with RIA method by encouraging its use in waiver requests.

We believe waivers make for better test cases than either rulemaking proceedings, or applications for experimental licenses ("ERS") and special temporary authority ("STA"). This is because waivers typically present relatively limited interference scenarios in scope, frequency and/or location compared to rulemaking proceedings. The added burden of requiring a RIA would thus be lower on the parties and on the Commission.[27] Waivers are also considerably easier to reverse in the event of unacceptable interference than rulemaking proceedings.

Conversely, ERS and STA applications tend to be so limited in application compared to waivers that they do not present issues that are challenging enough to justify the use of RIA. We believe RIA will impose a limited additional burden on the parties to well-chosen waiver petitions, and will generate information that will lead to better decisions. Waiver requests are thus a good way for the Commission to pilot the use of RIA.

This filing explores three petitions: Adaptrum, Headsight, and Sensifree.[28] Each of them requests waivers of Commission rules pertaining to radio operation, and are promising candidates to engage in developing the RIA method.

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[26] Introduction to RIA, at pp. 12-13; MetSat/LTE Case Study, at p. 49.

[27] *See* Tyler Cox et al., Piloting Risk-Informed Interference Assessment Using Waivers, pp. 2-3 (2015), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2543632 (arguing cases ideal for a pilot assessment are cases where the use of risk assessment would least disrupt the process, and cases with minimal and easy to calculate variables are the least burdensome).

[28] The full citations for each petition may be found in their corresponding sections below.

In choosing these examples, we:

- Selected petitions that ECFS designates as open (550 cases);
- Narrowed the selection to petitions before Bureaus that primarily deal with interference claims—Auctions, Engineering and Technology, and Wireless Telecommunications (22 cases); and
- Narrowed that selection to petitions where interference was a central concern (11 cases).

This section applies the four RIA elements using the limited information available in the example proceedings to illustrate how a risk assessment could be framed. Our choices of consequence metrics for each are intended to suggest potential approaches. Ultimately, however, it is up to each party—and the Commission—to determine whether the consequence metrics we describe are appropriate for their particular case.

The three example petitions are presented on a scale of difficulty in applying RIA, from Adaptrum as a prototypical case to Sensifree as the most challenging. RIA lends itself to uses where consequence metrics are both well-defined and readily calculable, such as Adaptrum and Headsight. RIA can be applied in more complex cases, such as Sensifree; however, the difficulty in defining consequence metrics complicates the process.

1) The Commission can readily apply RIA to a prototypical candidate like Adaptrum's petition for waiver.

Adaptrum is seeking a waiver of Rule 15.709(b)(2) that would allow it to place TV band devices at heights above the level currently allowed by the rules.[29] These devices would be used to provide broadband access in rural areas in northeast Maine.[30] Additionally, such devices would operate on a

[29] Adaptrum, *Request for Waiver*, ET Dkt. No. 14-187, p. 1 (filed Oct. 23, 2014) [Adaptrum Request], https://ecfsapi.fcc.gov/file/60000976684.pdf. These rules limit the height for TV band devices to 30 meters or below, and Adaptrum is seeking to install devices at 76 meters.
[30] *Id.*

limited number of TV white space channels picked specifically to avoid any interference with Canadian licensees.[31]

Adaptrum argues that the purpose of Rule 15.709(b)(2) was to protect users of TV spectrum from harmful interference.[32] Because there is little TV reception to protect in rural Maine, Adaptrum argues that the underlying purpose of the rule is not furthered by its enforcement, because it is overly burdensome.[33]

In its reply comments, the National Association of Broadcasters argues that if the Commission does grant Adaptrum its waiver, it should require extensive guard band protection.[34] Adaptrum counters that excessive guard band requirements would unnecessarily decrease the level of service available to areas with little TV reception to protect.[35] Other commenters support granting the waiver while downplaying the risk of harmful interference.[36] Thus, there is a clear question about the likelihood and extent of interference that RIA is designed to address.

The first element in a risk assessment is an inventory of interference hazards. In this case, the dominant sources of interference would be an Adaptrum transmitter in the same channel as a TV signal, or in the first or second adjacent channels.

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[31] *Id.* at p. 6. Adaptrum provides a list of stations that are listed in the US TV white space database, and have no Canadian TV station within 150 km, and no non-TV Canadian licensees within 50 km.
[32] *Id.* at p. 7.
[33] *Id.* at pp. 7-8.
[34] National Association of Broadcasters, *Reply Comments*, ET Dkt. No. 14-187, p. 4 (filed Dec. 9, 2014) [NAB Reply Comments], https://ecfsapi.fcc.gov/file/60001008546.pdf. The NAB opposes granting the waiver; however, it does so primarily on the grounds that it believes Adaptrum has a history of flaunting FCC rules.
[35] Adaptrum, *Response Comments*, ET Dkt. No. 14-187, p. 4 (filed Dec. 12, 2014).
[36] *See generally*, Dynamic Spectrum Alliance, *Comments*, ET Dkt. No. 14-187 (filed Nov. 24, 2014), https://ecfsapi.fcc.gov/file/60000988121.pdf; Open Technology Institute at the New America Foundation, *Comments*, ET Dkt. No. 14-187 (filed Nov. 24, 2014), https://ecfsapi.fcc.gov/file/60000988198.pdf; Wireless Internet Service Providers Association, *Comments*, ET Dkt. No. 14-187 (filed Nov. 24, 2014), https://ecfsapi.fcc.gov/file/60000988031.pdf. These comments, broadly speaking, support the grant of Adaptrum's request on the belief that it will provide expanded broadband internet coverage.

Previous petitions are a useful inspiration for consequence metrics. One example is Cricket Wireless' 2014 waiver petition.[37] Cricket petitioned the Commission for a waiver of Section 27.60 digital television protection rules to further deploy Cricket's 700 MHz A block license.[38] In that proceeding, the primary risk of interference was to the adjacent Channel 51 digital television broadcast station.[39] While the Cricket petition was ultimately resolved through private negotiation between the parties, the proceeding generated a number of risk assessment studies that resemble the type of assessment process we are advocating the Commission adopt.[40]

A straightforward service metric is the number and/or percentage of customers who are affected by the interference. This is the metric identified in the risk assessment commissioned by Cricket.[41] Not every commenter agreed with the Newfield service metric, however. The Meintel, Sgrignoli & Wallace report to Fox, the owner of the station subject to interference, took issue with Newfield, arguing that since the rules specifically refer to the Desired to Undesired signal ratio (D/U), D/U was the only acceptable metric in this type of study.[42] D/U exceedance is a suitable RF metric, and could be used in this case as an alternative or complement to affected population.

These metrics can be used in the Adaptrum case by calculating the D/U exceedance for all channels at risk throughout the potentially affected geographical area.[43] These calculations would need to consider the relative positions and directionality of Adaptrum and TV transmitters, and

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[37] Cricket License Company, LLC, *Petition of Cricket License Company, LLC for a Waiver of DTV Protection Criteria*, WT Dkt. No. 14-17 (filed Dec. 6, 2013) [Cricket Petition], https://www.fcc.gov/ecfs/filing/6017588571.

[38] *Id.* at p. 1.

[39] *Id.*

[40] *See* of Request for Waiver, Laser, Inc., *WTB Seeks Comment on Cricket Request for Waiver of DTV Protection Criteria in Chicago*, WT Dkt. No. 14-17 (filed September 18, 2015), https://ecfsapi.fcc.gov/file/60001324408.pdf; Newfield Study; Fox Comments; Laser Report.

[41] Newfield Study at p. 4.

[42] Fox Comments at p. 5.

[43] An exceedance is the probability that a value will be met or exceeded, also known as a complementary cumulative distribution function. The areas at risk are locations within the protected service contours of affected TV broadcasts; affected broadcasts are those where an Adaptrum transmission occurs either in the broadcast, or first or second adjacent, TV channels.

would also need to make assumptions about the types of antennas viewers use—e.g. distant viewers may use high gain outdoor antennas pointed at the TV transmitters. The D/U metric would be plotted as the probability that threshold D/U values are exceeded, for different Adaptrum antenna heights. To calculate the affected population (i.e. service) metric, one would deem all locations where the D/U is above a predetermined unacceptable level to have lost TV service.[44] One could use a population database to calculate the number of people affected (discounted, perhaps, by a factor reflecting the number of people per household, the number of OTA households, the viewership percentage of the given channel, etc.).[45]

It is possible to imagine corporate metrics such as the loss of broadcaster advertising revenue due to loss of service to some households. However, this would be difficult to calculate, as it would require not only per-channel viewership and advertising revenue data—which may be difficult to obtain for the area under study—but also a demonstration that any changes in advertising revenue are a direct result of this interference.

The Adaptrum request is a prototypical candidate to pilot risk informed interference analysis because of its focus on interference from one well-understood service to another, and extensive experience in the spectrum community with defining and calculating consequence metrics for interference to TV service. Its candidacy is bolstered because equipment is outdoors, and the study involves a wide coverage area, concerns narrow and well defined spectrum, and uses continuous transmissions with easily understood RF metrics. There have been many cases that resemble the Adaptrum waiver in terms of a small number of transmitters, outdoor operation, continuous transmission and well-defined RF metrics; they include rulemaking proceedings about WCS/SDARS

[44] 47 C.F.R. 76.616(e)(1)

[45] Oakridge National Laboratory, *LandScan*, http://web.ornl.gov/sci/landscan/ (last visited Nov. 19, 2016).

interference, previous TV/cellular coexistence concerns, LTE in unlicensed spectrum, commercial and federal coexistence 3.5 GHz, AWS-3 MetSat/cellular and Globalstar TLPS.[46]

2) The Headsight petition is a difficult yet still appropriate candidate for RIA.

Headsight, Inc. is requesting a waiver of Rules 15.509(b) and 15.503(f) to market a UWB device to be used on farm equipment for detecting ground conditions obscured by crops.[47] The device itself transmits between 1 and 6 GHz with two modified bowtie antennas with a boresight gain 4-6 dBi.[48]

Headsight argues that its UWB device meets the essential requirements of UWB devices through low device proliferation and infrequent usage.[49] The device will be operated at various heights dependent upon the height of the crop as well as the type of harvesting equipment used, but in all cases never more than a meter above the top of the crop.[50] Moreover, ground imaging in

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[46] *See Amendment of Part 27 of the Commission's Rules to Govern the Operation of Wireless Communications Services in the 2.3 GHz Band*, WT Dkt. 07-293, Notice of Proposed Rulemaking (Dec. 21, 2007), https://ecfsapi.fcc.gov/file/6520027006.pdf; Cricket Petition, note 37; *Office of Engineering and Technology and Wireless Telecommunications Bureau Seek Information on Current Trends in LTE-U and LAA Technology*, Public, WT Dkt. 15-105, Public Notice (May 05, 2015), https://ecfsapi.fcc.gov/file/60001111048.pdf; *Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, GN Dkt. 12-354, Notice of Proposed Rulemaking and Order (Dec. 12, 2012), https://ecfsapi.fcc.gov/file/7022080889.pdf; *Amendment to the Commission's Rules with Regard to Commercial Operations in the 1695-1710 MHz, and 2155-2180 MHz Bands*, GN Dkt. No. 13-185, Notice of Proposed Rulemaking and Order on Reconsideration (Jul. 23, 2013), https://ecfsapi.fcc.gov/file/7520933026.pdf; Commerce Spectrum Management Advisory Committee, Working Group 1 – 1695-1710 MHz Meteorological-Satellite Final Report (Rev. 1 2013), www.ntia.doc.gov/files/ntia/publications/csmac_wg_1-jan_17_13v3.2_final.pdf; *Terrestrial Use of the 2473-2495 Mhz Band for Low-Power Mobile Broadband Networks*, IB Dkt. No. 13-213, Notice of Proposed Rulemaking (Nov. 01, 2013), https://ecfsapi.fcc.gov/file/7520955370.pdf.

[47] Headsight Inc., Petition for Waiver, ET Dkt. No. 16-44, pp. 9, 13. (filed Jan. 21, 2016) [Headsight Petition], https://ecfsapi.fcc.gov/file/60001516236.pdf. Section 15.503(f) requires that the Ground penetrating radar (GPR) system cannot operate more than a meter above the ground, Section 15.509(b) limits the permitted uses of GPR to law enforcement, emergency rescue or firefighting organizations, as well as construction and mining operations.

[48] *Id.* at p. 4.

[49] *Id.* at p. 10.

[50] *Id.* at p. 7.

agriculture is a rural use, thereby limiting cumulative interference, and such emissions are directed towards the ground or horizontally away from airborne or satellite receivers.[51] This limits interference by allowing for more rapid attenuation of the emissions and greater probability that the emission will be obstructed before reaching a victim receiver.[52]

The operating bandwidth of Headsight's UWB devices covers a wide variety of services including GPS, aeronautical radio navigation, radiolocation, mobile and fixed satellite, as well as mobile.[53] Trimble, the lone industry commenter, is concerned about the potential for interference from a UWB device on the same farm equipment as a GPS system, as well as the heights of the UWB device above the one meter limit set by the Commission.[54] Headsight argues that it is not asking for a relaxation of UWB emission limits and technical standards, and consequently its device will not cause harmful interference.[55] Moreover, Headsight argues that it tested co-located GPR and GPS devices on the same farm equipment and has found no interference.[56]

RIA would be useful in this case to determine if there is a meaningful risk to the GPS since there are contending claims—neither of them quantified—about interference risk by Headsight and Trimble. Following the recommendation of Section III, Headsight could submit risk assessment as an effective means of demonstrating compliance with the rules, and low risk of harmful interference with incumbent devices. If Trimble or any other party disagreed, it could likewise back up its claims with a risk analysis.

The first step in a risk assessment is an inventory of hazards. In this case, the hazards are that energy from a Headsight device that overlaps with an operative channel of a device in any of the

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[51] *Id.* at p. 10.
[52] *Id.* at pp. 10-11.
[53] United States Frequency Allocation Chart, (last visited Nov. 3, 2016) [Allocation Chart], https://www.ntia.doc.gov/page/2011/united-states-frequency-allocation-chart.
[54] Trimble Navigation Limited *Comments*, ET Dkt. No. 16-44, pp. 3-4 (filed Mar. 21, 2016), https://ecfsapi.fcc.gov/file/60001546546.pdf.
[55] Headsight Inc., *Reply Comments*, ET Dkt. No. 16-44, p. 3 (filed Apr. 5, 2016) [Headsight Reply], https://ecfsapi.fcc.gov/file/60001568509.pdf.
[56] *Id.* at pp. 4-5.

many services in the 1–6 GHz band. GPS interference has served as the test hazard in previous UWB interference studies, and we will focus on it here.[57]

As noted in Section III above, RF consequence metrics are likely the simplest to calculate or measure, and generally feed into a service or corporate metric.[58] Headsight might choose to use GPS as the test case for interference to all services in its 1–6 GHz operating band. Since Headsight cannot predict or control the performance of GPS receivers, it might calculate a probability distribution of the signal-to-noise ratio (I/N) in a volume around a ground penetrating radar (GPR) transmitter[59]. Since the RF performance of GPS receivers varies and since they generally do not provide third party access to the value of I/N inside the receiver (the metric favored by the GPS industry), this would be a proxy value that assumes a nominal GPS antenna gain, receiver filter mask and system noise level, convolved with the wideband UWB interference at the antenna input. Given these assumptions, the Commission would have to make a judgment about what proxy I/N ratios are acceptable. A probability distribution of proxy I/N values would allow the agency to assess the risk of interference without having to take a public position on GPS receiver performance parameters.

If suitable data is available that maps I/N to service metrics like break lock and reacquisition time—more likely to be readily available to GPS device manufacturers than Headsight—one of the parties may choose to model these quantities.[60]

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[57] *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, ET Dkt. no. 98-153, First Report & Order, (April 22, 2002), https://ecfsapi.fcc.gov/file/6513194036.pdf [UWB First Report & Order].

[58] Section II.

[59] It may choose to provide these calculations for various heights of the GPR above ground level and various crops. Rather than one volume, it might distinguish on-harvester, near-use, and long-distance scenarios by studying a spherical volume between 1 and 10 meters from the GPR; 10 m to 1 km; and 1 km to the horizon.

[60] US Dept. Of Commerce, Addendum to NTIA Report 01-384: Measurements to Determine Potential Interference to GPS Receivers from Ultra-wideband Transmission systems, p. 15 (Sept. 2001), http://www.its.bldrdoc.gov/publications/download/TR-01-389.pdf. Break lock defines a break in the signal tracking and reacquisition time is the time required to reestablish tracking.

We are not aware of suitable corporate metrics for GPS, let alone for the full range of services in 1–6 GHz that could be affected by a UWB device.

3) The Sensifree petition exemplifies significant challenges for applying RIA in certain circumstances.

Sensifree, Inc. ("Sensifree") is requesting that the Commission waive Rule 15.03(d) and testing procedures which govern the allowed bandwidth of ultra-wideband ("UWB") devices in order to operate a body-worn UWB heart rate monitoring device.[61] The device itself operates with a transmit power of -5 dBm at a rate of 5 microseconds per pulse, with typically 16 pulses every 33.33 milliseconds.[62] The frequency range varies depending on the device location on the body, but can be from 5 to 10 GHz, 3.1 to 7 GHz, and 3.1 to 4.1 GHz.[63]

Sensifree argues that the lack of clarity in the Commission's rules surrounding the instantaneous bandwidth precludes any sort of modulation scheme in the band except for continuous wave signals of 500 MHz.[64] Additionally, Sensifree argues that the current rules requiring UWB devices to meet a specific fractional bandwidth minimum results in devices which occupy more bandwidth than they might otherwise require, and which increases noise in the occupied bandwidths.[65] Sensifree also argues that without a change in interpretation to the rules, any devices that do not meet the bandwidth requirements at all times during their transmit cycle would need a waiver.[66]

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[61] Sensifree, Inc., *Request of Sensifree, Inc. for Waiver of Part 15 of the Commission's Rules Applicable to Ultra-Wideband Devices for a Pulsed, Frequency-Hopped Body-Worn Medical Device*, ET Dkt. 15-284, p. 1, (filed Aug 24, 2015) [Sensifree Request], https://ecfsapi.fcc.gov/file/60001409002.pdf. Under Section 15.03(d) of the Commission's rules, a UWB transmitter is defined as an "intentional radiator that, at any point in time, has a fractional bandwidth equal to or greater than 0.20, or has a UWB bandwidth equal to or greater than 500MHz, regardless of fractional bandwidth." 47 C.F.R. § 15.503(d).

[62] Sensifree Petition at p. 2.

[63] *Id.*

[64] Instantaneous bandwidth is the measure of how wide a spectrum a system can respond to, without any type tuning. *See* Sensifree Request at p. 5.

[65] *Id.* at p. 8.

[66] *Id.* at p. 9.

The Sensifree Request is the most challenging of the three candidates for RIA. It will be difficult to devise a single consequence metric to measure harm to the wide variety of services in its operating band. Its operating frequencies do not cover GPS, which has functioned as the test service for interference assessment both in the UWB rulemaking and in the Headsight case.[67]

Other challenges include the nature of the request itself, the technology being developed, and the resultant effect on usage of consequence metrics. To begin, the 2002 UWB rulemaking explicitly excluded technology like Sensifree's, and therefore the petition appears to be for a change in service rules rather than a waiver.[68] Since a rule change has wider applicability than a waiver, the burden on the analysis is heavier. The technology is unusual because it has a low duty cycle and frequency occupancy, but a high peak to average ratio and extremely short pulses. [69] The result is that conventional RF metrics (SNIR, C/I, I/N) do not readily apply, because they implicitly assume a roughly continuous transmission like TV broadcasting or communications. Corporate metrics are not practical for Sensifree given the wide diversity of services with which the UWB technology potentially interferes. Service metrics may work if Sensifree can devise a few metrics that characterize a variety of similar services—e.g. bit error rate for a communications service—and makes an order-of-magnitude guess about how their device would affect services in each allocation the device might affect.

[67]UWB First Report & Order, para. 5

[68] *Id.* at p. 32 ("We recognize that this may preclude certain types of modulations, such as swept frequency (e.g., FMCW), stepped frequency or frequency hopping systems.").

[69] Sensifree is effectively a radar, and the coexistence of radar and communications systems is an open research question. *See* Joseph Evans, *Shared Spectrum Access for Radar and Communications (SSPARC)*, Defense Advanced Research Projects Agency (accessed on Nov. 20, 2016), http://www.darpa.mil/program/shared-spectrum-access-for-radar-and-communications.

Respectfully submitted,

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