Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554
and the
NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION
Washington, D.C. 20230

In the Matter of	)	
	)	
Creation of a Spectrum Sharing Innovation Test-Bed	)	ET Docket No. 06-89
	)	
and	)	
	)	Docket No. 060602142-6142-01
The President's Spectrum Policy Initiative Spectrum Sharing Innovation Test-Bed	)	

Comments of Shared Spectrum Company

I. Introduction

Shared Spectrum Company (SSC) submits these comments in strong support of the Spectrum Sharing Innovative Test-Bed described in the two *Notices* issued on June 8, 2006 by the Federal Communications Commission (FCC) and by the National Telecommunications and Information Administration (NTIA).[1] SSC congratulates both agencies for taking the lead and cooperating in advancing the frontier of innovative spectrum sharing technologies through a test-bed, which will demonstrate the benefits to all users of the spectrum by greatly increasing effective communications capacity.

In establishing and implementing the test-bed, SSC recommends that the Commission and NTIA focus their joint and respective efforts on facilitating technological advances in

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[1] *Public Notice*, Federal Communications Commission Seeks Public Comment on Creation of a Spectrum Sharing Innovation Test-Bed, ET Docket No. 06-89, FCC 06-77 (June 8, 2006); *Notice of Inquiry*, The President's Spectrum Policy Initiative Spectrum Sharing Innovation Test-Bed, Docket No. 060602142-6142-01, 71 Fed. Reg. 33282 (June 8, 2006). These comments jointly address key questions raised in both *Notices*.

spectrum sharing that will have the broadest applicability across the electromagnetic spectrum for the benefit of a wide variety of Federal and non-Federal users. In so doing, FCC and NTIA should ensure that *bona fide*, adequately funded entities are afforded easy access to adequate spectrum resources in government and non-government bands below 1 GHz through streamlined experimental licensing procedures and operational requirements that are flexible yet ensure against harmful interference to incumbent users.

SSC is a small business that is developing dynamic spectrum management applications and high performance, low-cost transceivers that operate from 30 MHz to 3 GHz.[2] In 2005, under Phase 3 of the Defense Advanced Research Project Agency's (DARPA) Next Generation (XG) Communications program,[3] Shared Spectrum was awarded a 26-month research and development contract to develop prototypes and demonstrate the ability to implement networks of spectrum-agile radios in military and urban environments with the objective of accessing 10 times more spectrum without causing harmful interference to other users.[4] These advanced, proven spectrum sharing technologies will enable military, public safety, critical infrastructure, industrial and commercial radio networks to dynamically adapt to changing spectrum needs and environments under the control of software-based usage policies. SSC intends to take full advantage of this test-bed opportunity to further demonstrate the advantages of dynamic spectrum sharing.

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[2] For more information about Shared Spectrum Company, s*ee* http://www.sharedspectrum.com/?section=about.

[3] *See* http://www.darpa.mil/ato/programs/XG/index.htm.

[4] *See News Release*, Air Force Research Laboratory (AFRL) Awards Contract for Research to Dramatically Increase Radio Frequency Spectrum Access, http://www.rl.af.mil/div/IFO/IFOI/IFOIPA/press_history/pr-05/pr-05-86.html.

II. Substantive Elements of the Test-Bed

A. Technology Selection Must Focus on Dynamic Spectrum Sharing and Cognitive Radio Technology

Both *Notices* provide several examples of technologies that could be considered for the Spectrum Sharing Innovation Test-Bed including adaptive technologies (geo-location, frequency avoidance, waveform detection), dynamic spectrum access techniques, cognitive radios, high-powered broadband, new interoperable public safety technologies, smart antennas, mesh networking, multiple-input/multiple-output (MIMO) systems and Federal/non-Federal sharing techniques. SSC suggests that the primary focus of the test-bed be on innovative, dynamic spectrum sharing technologies such as those currently being developed by DARPA and SSC as well as other cognitive radio technologies. Promoting such innovations will not only serve the primary objectives of the test-bed, as articulated in the reports on the President's Spectrum Policy Initiative,[5] but will foster development of a wide range of broadband, military/homeland security and public safety applications. Other technology advancements such as MIMO, advanced modulation techniques, mesh networking and adaptive antennas could also be tested and implemented as important ancillary components of these core dynamic sharing systems.

The Commission and NTIA have recognized the value and promise of dynamic spectrum sharing and cognitive radio (CR) technologies and have taken significant steps to facilitate their

[5] *See Spectrum Policy for the 21st Century – The President's Spectrum Policy Initiative: Report 1 Recommendations of the Federal Government Spectrum Task Force* at 22-26 (June 2004) ("Given the increase in new and innovative radio communication systems seeking access to the spectrum, the most challenging issue is interference problems inherent in using the latest technologies."); *Spectrum Policy for the 21st Century – The President's Spectrum Policy Initiative: Report 2 Recommendations From State and Local Governments and Private Sector Responders* at 23 (June 2004) ("Spectrum policymakers must not only anticipate, but must also help create an environment for important new technology developments. . . . Coordinating information developed in private and federal laboratories would provide the technical information necessary to allow standards committees, regulators, and policymakers to make meaningful decisions regarding the interference and sharing potential of new technologies.")

development and deployment.[6] As the Commission stated, "[t]he advent of cognitive radios and associated technologies has the potential to initiate a new era in radio frequency spectrum utilization. With radios that are able to recognize spectrum availability and able to negotiate protocols for rapid reconfiguration, these radios will employ software defined radio [SDR] technologies to change their operational characteristics and open new opportunities for spectrum use. . . . [A]pplications such as dynamic spectrum sharing, interruptible spectrum sharing, and rapidly reconfigurable secondary markets in spectrum use will be attainable with cognitive radios."[7] NTIA clearly understands the problems confronting both government and non-government wireless users that cognitive radios will address – "scarcity of spectrum, deployment difficulties, and transitioning to different technologies" – and is well aware of how "federal government agencies are placing an increasing emphasis on SDR and using SDR as the basic platform on which to build CR technology to resolve these problems. For example, through research projects such as the Defense Advanced Research Projects Agency (DARPA) neXt Generation (XG) program, the Department of Defense (DOD) is investigating how advanced sensing, modulation, and multiple access technologies can be used with a machine-intelligible spectrum policy framework to enable cognitive spectrum sharing that could improve spectrum usage efficiency by a factor of ten or more."[8]

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[6] *Report and Order*, Facilitating Opportunities for Flexible, Efficient and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Docket No. 03-108, FCC 05-57 at ¶¶ 18, 35 (2005), http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-05-57A1.pdf (*Cognitive Radio R&O)*; NTIA Comments in ET Docket No. 03-108 at 3-5, http://www.ntia.doc.gov/ntiahome/fccfilings/2005/cogradio/ETDocket03-108_02152005.pdf (*NTIA Cognitive Radio Comments*).

[7] *Cognitive Radio R&O* at ¶ 36. See also, *id*. at ¶ 35 ("The development of fully cognitive radio technologies is being actively pursued now through programs such as the US Department of Defense Advanced Research Projects Agency (DARPA) Next Generation (XG) Radio Program. . . . We believe that the XG Program will be a catalyst for many further developments in cognitive radio technology.") (footnotes omitted).

[8] NTIA Cognitive Radio Comments at 3-4. ("SDRs are likely to be the best platforms for implementing CR, and the tactical military SDRs being developed under the Joint Tactical Radio System (JTRS) may well be the beneficiaries of the XG technology. The application of XG technology to JTRS has the potential to address the spectrum scarcity

As the current prime contractor on the DARPA XG project, SSC is already substantially contributing to the development of these technologies through ongoing field tests of its prototype wideband XG radios, but to gain adequate regulatory and market acceptance it will be necessary to demonstrate and evaluate various hardware and network configurations, adaptive software algorithms and enhanced measurement techniques in real-world situations in a variety of urban, suburban and rural environments. If adequate and appropriate spectrum is expeditiously made available, the NTIA/FCC test-bed will allow SSC and others to immediately and significantly expand the development and accelerate the deployment of innovative spectrum sharing systems for both government and non-government users. Accordingly, SSC proposes that the test-bed program focus on facilitating the further development of dynamic sharing and CR technologies.

The NTIA *Notice of Inquiry* proposed eight "Selection Criteria" to evaluate and select the proposed technology or service to be implemented in the Test-Bed. SSC supports this approach and the proposed criteria, but SSC also recommends that the following additional criteria be considered:

- Whether the proposed technology is extensible to a substantial portion of the spectrum, not just the bands identified for the test-bed, and frequency agile over a significant number of potential test-bed bands;
- Whether the proposed technology promotes flexible and symmetric use of both Federal and Non-Federal bands by both Federal and Non-Federal users;
- Whether programmable radios (*i.e.*, software defined and cognitive radios) are to be tested and deployed in a variety of experimental and market environments;
- Whether the proposed technology is remotely controllable and configurable;
- How well the proposed technology can be adapted for a variety of services and applications, including broadband, military/homeland security, and public safety;
- Whether the proposed technology is able to provide meaningful innovative services; and
- Whether the proposed technology is capable of transmissions of adequate link distances (*e.g.*, up to 20 km).

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and deployment issues that could limit the military's broadband wireless end-to-end connectivity. Like DARPA's early work on the Internet, XG-based technology will become applicable to both military and civilian applications.") (footnotes omitted).

As discussed next, the candidate frequency bands for the test-bed must have propagation and other characteristics that will allow for varied and robust testing for broadband applications. Moreover, the technology and bands chosen must not create a greater risk of causing harmful interference to incumbent users.

B. Candidate Frequency Bands Must be Below 1 GHz with at Least 2.5 MHz of Contiguous Bandwidth

The FCC and NTIA *Notices* seek comment on the criteria that should be used in identifying and selecting candidate frequency band(s) for the test-bed and ask several important questions about which bands should be chosen. Although the test-bed recommendations contained in the reports on the President's Spectrum Policy Initiative called for approximately 20 MHz to be dedicated to the test-bed, with 10 MHz coming from NTIA and 10 MHz coming from the FCC pursuant to their respective jurisdictions, SSC believes that each agency should consider their respective government/non-government spectrum "contribution" as a minimum objective without feeling constrained to provide access to additional spectral resources under the test-bed program . Therefore, <u>at least</u> 20 MHz should be identified for the test-bed and the bands chosen should be based on criteria that facilitate further development of dynamic sharing and CR technologies for broadband, military/homeland security and public safety applications. Experimenters seeking to demonstrate these technologies and applications in other bands should not be precluded from doing so just because such bands are not initially identified. Thus, the primary purpose of the FCC and NTIA designating certain frequencies for the test-bed should be to facilitate more expeditious, or streamlined, processing and coordination as discussed below.[9]

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[9] *See* Section III.A., *infra*.

In order to achieve the principal spectrum sharing objectives of the test-bed program, any criteria considered in pre-designating particular bands must be flexible to promote development of frequency agile equipment, yet it must also be targeted toward meeting other policy objectives and avoiding harmful interference. Such bands need not necessarily be contiguous, but must have sufficient bandwidth (*i.e.*, 2.5 MHz) to support broadband applications such as video. Eligible test-bed frequencies should be located in bands with good propagation characteristics (*i.e.*, below 1 GHz), wide geographic coverage and low or iterant occupancy. As to this last factor, SSC has collected a vast amount of spectrum occupancy data that shows which bands below 1 GHz are the least utilized.[10] Appendix A, Table 1 provides an aggregate listing of spectrum occupancy measurements that SSC has made at several locations.

C. Significant Steps Must be Taken to Avoiding Harmful Interference to Incumbent Users

An obvious and legitimate substantive concern of NTIA and FCC (as well as incumbents operating in potential test-bed frequencies) is the methods by which users of the test-bed will avoid causing harmful interference to other authorized operations. For example, the NTIA *Notice of Inquiry* asks whether an initial electromagnetic compatibility analysis (*e.g.*, computer simulations) should be performed to develop the operating conditions for the test-bed (*e.g.*, limits on radiated power levels, restrictions on antenna, geographic limitations). The FCC *Public Notice* suggests that experiments could be limited to rural areas or areas where there are relatively few incumbent users to reduce the risk of causing harmful interference to an incumbent user. In response to these concerns and suggestions, SSC proposes that clear and detailed

[10] *See* http://www.sharedspectrum.com/?section=measurements; *see also* Mark McHenry and E. Daniel McCloskey, *Multi-Band, Multi-Location Spectrum Occupancy Measurements* in Proceedings of the NTIA International Symposium on Advanced Radio Technologies at 167 (March 2006).

requirements be established to ensure that proposed spectrum sharing technologies can protect incumbents from harmful interference.

In Appendix B, SSC lists numerous system design guidelines that should be employed by the test-bed system to reduce interference. Some of these are conservative initial restrictions that can be lifted once successful interference-free operational experience is obtained. SSC also provides a list of field test procedures that should be employed by test-bed participants. While SSC agrees that incumbent operations should be completely protected, they should not be avoided with overly conservative geographic separations or restrictions. Therefore, SSC also believes that it is important for this spectrum sharing test-bed program to produce useful and timely information for regulators (and incumbents) that shows, in the test-bed bands with co-channel incumbent users, how:

- Dynamic spectrum access techniques can be investigated and proven;
- Remote modifications of the spectrum access algorithms and parameters can be made to adjust in-field, real-time operations in the presence of incumbent users;
- Secondary, spectrum pooling schemes can be implemented in a real-world setting; and
- Automated interference resolution capabilities work.

Based on SSC's experience in developing and conducting tests of spectrum sharing radios, to operate in bands with incumbent users a critical requirement is to use a variety of mechanisms to avoid harmful interference to these incumbent users. Some of these mechanisms are described below and in Appendix C.

A key test-bed requirement should be the ability to remotely reconfigure spectrum access algorithms of radios operating in these bands. This is the only practical way to both avoid interference to incumbent users and to ultimately obtain regulatory approval of spectrum sharing technologies in a reasonable time and with the ability to operate at power levels for useful applications. As evidenced by the prolonged, multi-year long DFS (Dynamic Frequency

Selection) rulemaking and testing procedure, it is very difficult to develop static spectrum access and sharing rules because of the complex nature of interference problems. During the DFS process, a wide range of spectrum access measurement rates, threshold values, measurement frequencies (co-channel, adjacent channel, backup channel, *etc.*), mathematical operations on the data, time periods, and others were seriously considered. Many involved more than parameters changes.

In order to develop alternatives to this type of approach, NTIA and FCC should require that the test-bed spectrum access algorithms be remotely reconfigurable in both algorithm design and algorithm parameters. This will allow the exploration of many spectrum access methods and improved performance because the "worse case" methods and parameters do not have to be established and fixed into regulations. It will also provide network operators the ability to tailor the algorithms and parameters to the actual situation in the field and will give regulators the ability to adjust any feature without recalling equipment or imposing redeployment costs. For an appropriately large-scale spectrum sharing test-bed, it will be simply impractical to use traditional fixed spectrum access methods where there is only the ability to change algorithm parameters because of the complexity of the interference problem and the wide range of incumbent conditions and test-bed user configurations that will be encountered. Using remotely configurable spectrum access algorithms and parameters, test-bed radios can be iteratively adjusted in the field to arrive at both practical and "interference free" operating modes. Deploying the test-bed with fixed or only parameter adjustable spectrum access will cause endless delay with negotiations on the specific spectrum sharing algorithms to be employed or extreme operational limitations.

III. Procedural Elements of the Test-Bed Program

A. The Test-Bed Should Rely on FCC's Experimental Licensing System with Streamlined Processing and Coordination

In response to the questions in the *Notices* regarding the use of the Commission's experimental licensing program, SSC fully supports the general use of the existing experimental licensing rules in Part 5 of the Commission's Rules, 47 CFR Part 5, as well as NTIA's experimental authority under sections 7.11 and 8.2.27 of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management. The FCC's flexible rules permit experimental operations on a non-interference basis in any government or non-government frequency designated in the Table of Frequency Allocations, "provided that the need for the frequency requested is fully justified by the applicant." 47 CFR § 5.85(a), (c). Although a rulemaking is not necessary to implement the test-bed program, application and coordination procedures should be streamlined to encourage participation and facilitate rapid access to designated test-bed frequencies.

In 2002, the Commission's Spectrum Policy Task Force addressed the Commission's experimental licensing process and made a few modest recommendations regarding NTIA coordination, information sharing and expedited processing.[11] To facilitate experimentation, the Task Force recommended that the Commission and NTIA work together to "identify – or pre-clear – some location, frequency, and time combinations [in certain Federal government bands] where non-federal government spectrum users would be permitted to conduct experiments."[12]

[11] *Report*, FCC Spectrum Policy Task Force, ET Docket No. 02-135 at 60-61 (2002) (*SPTF Report)*, available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228542A1.pdf; *see also Report*, Unlicensed Devices and Experimental Licenses Working Group, FCC Spectrum Policy Task Force, ET Docket No. 02-135 at 20-23 (2002) (*E&UWG Report*), available at http://www.fcc.gov/sptf/files/E&UWGFinalReport.pdf.

[12] *SPTF Report* at 61. The Task Force also suggested that more direct communications between parties who have applied for experimental licenses and the federal government entities concerned about their pending experimental applications be permitted on a more regular basis. It also recommended that the FCC and NTIA consider

SSC agrees with the Task Force that, in the context of the spectrum sharing test-bed, pre-coordination of frequency and location pairs would reduce the risk and delays associated with applying for an experimental license and will stimulate radio technology experimentation in entrepreneurial firms.[13]

To further encourage participation in the test-bed, the experimental licensing and coordination process for access to pre-cleared test-bed frequencies/areas should be streamlined through a two-phase electronic filing improvement program. In the first phase immediately following the designation of available test-bed bands, areas and eligibility criteria, the Commission should immediately implement an auto-grant procedure for applications meeting basic technical and eligibility requirements for test-bed experimental licenses. During this phase, applications would be deemed granted within 15 days of filing unless the Commission issues an affirmative "stop order" indicating why the test-bed application requires further review or coordination or does not otherwise meet the test-bed criteria. The Commission would thus retain its control and the typical NTIA coordination timeframe would be preserved, but the party making the investment in the technology would be relieved of the inhibition that results from fears of delay in the event of non-action and lack of information. This will also permit experimenting parties to prepare for tests and demonstrations in an efficient and cost-effective way by assuring prompt authorizations.

In the second phase of the proposed streamlining approach, the Commission and NTIA could incorporate recently implemented automation technologies to provide even quicker

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implementing a new interface for non-federal government spectrum users with IRAC members to help search for workable compromises for experimental license applications. Another possible approach mentioned by the Task Force would be to consider appointing an advocate or ombudsman for the private sector. *Id.*

[13] *See E&UWG Report* at 23.

processing and coordination. For example, the agencies could implement an experimental licensing system that resembles the approach used for the Millimeter Wave 70-80-90 GHz Radio Service, which consists of a non-exclusive nationwide license, combined with a site-based registration process.[14] Eligibility for a test-bed experimental license would first be established and then individual experiments in designated bands and areas could be registered without any delay (assuming all appropriate information and certifications are entered by the licensee).

B. The Commission Should Provide Incentives Through Forbearing From Imposing Limits on Market Studies and the Opportunity for Long-Term Access

To promote active participation, innovation and success by parties in the test-bed program, NTIA and the Commission should consider establishing limited incentives for *bona fide* entrepreneurs – and removing one potential disincentive. Parties need adequate incentives to undertake costly large-scale field testing of new wireless technologies. This is particularly true when the focus is on sophisticated interference avoidance techniques applicable to a wide assortment of spectral environments. The use of marketplace incentives to encourage parties to undertake the investments and risks can be quite effective and is a preferable alternative to total governmental funding of the tests. In other contexts there have been legitimate concerns that allowing experimental field testing to progress to full-scale commercial deployment might inhibit other future uses of the band. Such concerns should not be a deterrent with respect to the frequency-agile, cognitive radio technology that is the focus of the test-bed since such equipment is easily reconfigurable and operable on a large number of available bands and is remotely controllable. Nevertheless, the thoughts raised in the *Notices* concerning the possibility that a

[14] *See* Wireless Telecommunications Bureau Announces Permanent Process for Registering Links in the 71-76 GHz, 81-86 GHz, and 92–95 GHz Bands, DA 05-311 (Feb. 3, 2005); *NTIA New Release*, NTIA and FCC Launch On-Line Registration For High-Speed Wireless Links Sharing Spectrum in the 70-80-90 GHz Bands (Feb. 8, 2005).

successful experiment would translate into permanent usage or a rulemaking proceeding to explore rule changes consistent with the experiment results could also provide a compelling incentive if such expectations were made clear at the outset. While the key benefit of frequency-agile cognitive radio technology is the absence of the need for a permanently fixed, primary allocation, allowing long-term secondary access to certain bands beyond the two-year experimental license period would lower expected transaction costs associated with gaining access to other encumbered bands.

Whether or not there are any expectations of permanent or long-term access to the test-bed or other frequency bands, it is important that the Commission remove the disincentive created by the prospect of FCC-imposed limitations on "market studies" utilizing experimental licenses. Under section 5.3 of the Commission's Rules, the Commission staff has the discretion to define the permissible scope of such market studies on a case-by-case basis.[15] SSC proposes that the Commission affirmatively dispense with the three limitations potentially applicable to market tests in Part 5 authorizations. Specifically, to facilitate early deployment of cognitive radio technology in the test-bed bands, as well as in other bands, and for purposes of real-world experimentation, it should state as a general policy for such authorizations that the restrictions in section 5.3 will not be imposed unless and until the Commissions affirmatively directs the experimenter to cease using a specific experimental frequency or the authorization otherwise expires.

Since the test-bed technology proposed herein will be capable of remotely instituted software changes in the frequencies actually used without hardware changes and by central direction of the Part 5 licensee, there is no need to worry about possible future claims of

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[15] *Report and Order,* Amendment of Part 5 of the Commission's Rules to Revise the Experimental Radio Service Regulation, FCC 98-283 (released Oct. 27, 1998).

"squatter's rights" by experimenters. Moreover, strict application of limits on market tests will harm the ability to market cognitive radios that will also likely use non-test-bed bands. Since such devices are frequency agile and are likely to be mobile, they will potentially be hopping in and out of several bands even during a single transmission; some of the bands may be test-bed bands, while others may be unlicensed bands or bands to which access was obtained through secondary market negotiations with primary licensees.

Finally, imposing such limits will hinder the ability to rapidly deploy dynamic spectrum sharing devices and systems in times of emergency. For example, if an unmanned aerial vehicle (UAV) equipped with an XG transceiver (which was sold and marketed by a test-bed licensee to a government agency) needs to be quickly deployed to assist in disaster assessment and relief efforts using non-government test-bed frequencies, the mere fact that the equipment is not "owned by" the test-bed licensee should not require additional licensing procedures (*e.g.*, special temporary authority) or, in the absurd case, result in the inability to access test-bed spectrum on an non-interference basis.

C. NTIA Should Utilize and Streamline Cooperative Research and Development Agreements and Promote Other Funding Programs

In addition to, or as an alternative to, an experimental licensing approach, NTIA and other governmental agencies could enter into Cooperative Research and Development Agreements (CRADAs) that include the same terms outlined above and in the appendices for experimental licenses to ensure against harmful interference to incumbent users. This way, government spectrum users can take advantage of new and novel spectrum sharing technologies as they are being developed. Most importantly, since engaging in useful broad-scale test-bed experiments is likely to be a costly endeavor, government funding will be essential, especially for small businesses like SSC. Accordingly, SSC strongly advises the NTIA and FCC to establish or encourage the establishment of additional funding sources for spectrum sharing innovation test-bed research and development through new and existing programs including:

- XG and other DARPA programs;[16]
- Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) programs;[17] and
- National Science Foundation (NSF) programs, including the Networking Technology Systems (NeTS), Programmable Wireless Networks (ProWiN) and Global Environment for Networking Innovations (GENI) programs.[18]

For purposes of funding test-bed activities, SSC would be pleased to enter into a CRADA with NTIA's Institute for Telecommunications Sciences (ITS) or other Federal Laboratories.

IV. Conclusion

As the leading developer of dynamic spectrum sharing technologies for cognitive radios, Shared Spectrum Company encourages the rapid implementation of the Spectrum Sharing Innovative Test-Bed. SSC is currently finding solutions to difficult problems so that previously untapped spectrum capacity can be used more efficiently and effectively for a multitude of applications and platforms. However, efficient access to adequate spectrum resources without substantial transaction costs will be the key to the early successful development of advanced spectrum sharing technologies. This test-bed presents a unique opportunity for the Commission and NTIA to truly facilitate innovation and spectrum sharing.

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[16] *See* http://www.darpa.mil/ato/.

[17] *See* http://www.sbaonline.sba.gov/SBIR/indexsbir-sttr.html.

[18] *See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12765 and http://www.nsf.gov/cise/geni/*. The GENI initiative is tentatively planning to have a component focusing on cognitive radio technology. *See* GENI: Conceptual Design, Project Execution Plan at 48, GENI Planning Group (January 2006), available at http://www.geni.net/GDD/GDD-06-07.pdf.

Thus, rather than squandering this opportunity for major progress on small niche services dependent on the quirks of a single band, the goal of the overall test-bed program should be to develop broadly applicable technology that can be rolled out in numerous bands to meet the growing and shifting needs that are likely to characterize the future of telecommunications. SSC looks forward to working with both agencies to demonstrate the benefits to all users of the spectrum by greatly increasing effective communications capacity.

Respectfully submitted,

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Appendix A

Table 1: SSC Spectrum Occupancy Measurements (30 MHz to 1240 MHz) in Various Locations

Start Freq (MHz)	Stop Freq (MHz)	Bandwidth (MHz)	Spectrum Band Allocation	Riverbend Spectrum Fraction Used	Riverbend Occupied Spectrum (MHz)	Tysons Spectrum Fraction Used	Tysons Occupied Spectrum (MHz)	NSF Roof Spectrum Fraction Used	NSF Roof Occupied Spectrum (MHz)	NYC Avg Spectrum Fraction Used	NYC Occupied Spectrum (MHz)	NRAO Spectrum Fraction Used	NRAO Occupied Spectrum (MHz)	SSC Roof Spectrum Fraction Used	SSC Roof Occupied Spectrum (MHz)	Chicago Avg Spectrum Fraction Used	Chicago Occupied Spectrum (MHz)	Average Occupied Spectrum (MHz)	Average Percent Occupied
30	54	24	PLM, Amateur, others	0.03895	0.93	0.00763	0.18	0.00217	0.05	0.05275	1.27	0.00045	0.01	0.00400	0.10	0.21221	5.09	0.92	3.8%
54	88	34	TV 2 -6, RC	0.10593	3.60	0.11799	4.01	0.36654	12.46	0.52455	17.83	0.11056	3.76	0.10900	3.71	0.70902	24.11	6.93	20.4%
108	138	30	Air traffic Control, Aero Nav	0.00744	0.22	0.02768	0.83	0.04066	1.22	0.04650	1.40	0.15485	4.65	0.10000	3.00	0.02628	0.79	0.89	3.0%
138	174	36	Fixed Mobile, amateur, others	0.03372	1.21	0.07692	2.77	0.16865	6.07	0.17030	6.13	0.02745	0.99	0.07300	2.63	0.35175	12.66	3.65	10.1%
174	216	42	TV 7-13	0.10339	4.34	0.11652	4.89	0.18890	7.93	0.77840	32.69	0.00220	0.09	0.18100	7.60	0.44762	18.80	6.34	15.1%
216	225	9	Maritime Mobile, Amateur, others	0.00486	0.04	0.00842	0.08	0.01129	0.10	0.05905	0.53	0.00556	0.05	0.02300	0.21	0.04392	0.40	0.13	1.4%
225	406	181	Fixed Mobile, Aero, others	0.00002	0.00	0.00371	0.67	0.00576	1.04	0.00450	0.81	0.01842	3.33	0.01300	2.35	0.02728	4.94	1.29	0.7%
406	470	64	Amat, RadioLoc, Fixed, Mobile	0.02745	1.76	0.07243	4.64	0.10469	6.70	0.15680	10.04	0.00379	0.24	0.08100	5.18	0.17158	10.98	4.20	6.6%
470	512	42	TV 14-20	0.13313	5.59	0.12160	5.11	0.29794	12.51	0.21070	8.85	0.00379	0.16	0.15700	6.59	0.55847	23.46	7.64	18.2%
512	608	96	TV 21-36	0.26616	25.55	0.32736	31.43	0.49667	47.68	0.34895	33.50	0.04283	4.11	0.36400	34.94	0.55726	53.50	27.64	28.8%
608	698	90	TV 37-51	0.23484	21.14	0.39980	35.98	0.47044	42.34	0.46125	41.51	0.00156	0.14	0.51300	46.17	0.55477	49.93	28.00	31.1%
698	806	108	TV 52-69	0.07627	8.24	0.17337	18.72	0.20048	21.65	0.30185	32.60	0.00113	0.12	0.31300	33.80	0.42691	46.11	18.40	17.0%
806	902	96	Cell phone and SMR	0.14260	13.69	0.41188	39.54	0.46398	44.54	0.46320	44.47	0.00017	0.02	0.40000	38.40	0.54841	52.65	27.04	28.2%
902	928	26	Unlicensed	0.00000	0.00	0.03915	1.02	0.08687	2.26	0.22865	5.94	0.00004	0.00	0.01100	0.29	0.09333	2.43	0.89	3.4%
928	960	32	Paging, SMS, Fixed, BX Aux, and FMS	0.03460	1.11	0.06708	2.15	0.10438	3.34	0.24005	7.68	0.02459	0.79	0.10000	3.20	0.29634	9.48	2.79	8.7%
960	1240	280	IFF, TACAN, GPS, others							0.03820	10.70		0.00	0.00000	0.00	0.03602	10.09	1.45	0.5%
Total		1190			87.43		152.02		209.91		255.95		18.46		188.17		325.39	138.20	
Total Available Spectrum					910		910		910		1190		910		1190		1190	1190	
Average Spectrum Use (%)					9.6%		16.7%		23.1%		21.5%		2.0%		15.8%		27.3%	11.6%	

Appendix B – Test-Bed System Design Features Used to Minimize Interference

The Test-Bed should use the following system design features.

Omni-Directional Antennas

In the initial demonstrations, the Test-Bed nodes will use donut shaped gain, "omni-directional" discone type antennas. The transmitted effective radiated power is low.

As experience is gained and no interference reports received, the test-bed will be allowed to use directional antennas.

Low Antenna Heights

In the initial demonstrations, the Test-Bed will use an antenna height of two-meters or less and fixed antennas.

As experience is gained and no interference reports received, the Test-Bed will be allowed to use up to 30 meter antennas in fixed applications and 2 meter high mobile antennas.

Low Power Density Waveform

The Test-Bed signal instantaneous bandwidth should be at least 1.5 MHz. This will provide an 18 dB reduction in spectral density compared to the popular 25 kHz bandwidth signals.

In the initial demonstrations, the maximum Test-Bed signal transmit power should be 1 Watt average power. This limits the potential interference distance in non-line of sight conditions to a few km.

As experience is gained and no interference reports received, the Test-Bed will be allowed to use up to 10 W of average power.

Spurious Signals

The Test-Bed equipment should be tested for spurious signal output due to switch noise, switch control signal bleed through, harmonics, and other RF impairments. The Spectrum mask should meet the IEEE-802.16 or similar specification. An example would be to require that the power spectral density in a 100 kHz bandwidth to be down 25 dB when 4.75 MHz from the center frequency and 50 dB when 14.75 MHz. This assumes a 10 MHz wide Test-Bed signal. These frequency offset values would scale linearly for smaller bandwidth Test-Bed signals.

The spurious signal testing should be performed by the Test-Bed group and submitted to the FCC and NTIA as part of the application.

Frequency Lockout

Initially, only the frequencies authorized in the Test-Bed experimental license will be used by the Test-Bed system. A list of blocked out channels will be checked by the Test-Bed software in each node continually. If the Test-Bed software attempts to transmit on a blocked channel, the action will be blocked and the event recorded.

As experience is gained and no significant interference reports received, the Test-Bed will be allowed to gain access to other government and non-government bands pursuant to additional experimental licenses, other assignments, through secondary market transactions or other authorized means.

Inherent Test-Bed Interference Avoidance Functionality

The Test-Bed system will use dynamic spectrum sharing technology to detect non-cooperative "victim" transceivers within the Test-Bed radio's interference distance. When this condition occurs, the Test-Bed transceiver selects another channel. Information about observed frequency use will be stored for a time period to be determined and considered with respect to subsequent possible use of the channel. Thus, recurring non-cooperative channel use will be a factor to considering the channel for use – not just whether use is detected at present. In particular, for both simplex and duplex frequencies the equipment will estimate the usage of transmitters that can not be directly observed based on the frequency observations that are detectable.

For example, the Test-Bed system may use channel detectors that are much more sensitive than normal receivers in making observations about whether a channel is in use. This is possible due to knowledge of the modulation which is being looked for and the fact that the detector does not need to have an adequate signal-to-noise ratio to demodulate the signal with usable fidelity, rather it only needs enough signal-to-noise ratio to detect the present of the assumed modulation. The detection versus reception advantage depends on the non-cooperative signal emission type and varies from 5 dB for FM modulation to 20 dB for BPSK.

Appendix C -- Precautions to be Used to Minimize Interference During the Field Demonstrations

During the initial Test-Bed field demonstrations, the following procedures will be used to minimize interference to other spectrum users. Each of these precautions greatly reduces the probability of interference to non-cooperative "victim" receivers. All of the precautions together make the probability of interference very low.

As experience is gained and no significant interference reports received, the Test-Bed will be afforded more flexibility.

Continuous Spectrum Monitoring and Logging

Before each demonstration, the spectrum authorized by the FCC will be monitored at a "command and control center" using a spectrum analyzer, a pre-amplifier and an elevated, dedicated antenna. The monitoring will be done for a 30 minute period before the demonstrations and during the operation.

An initial check of incumbent spectrum occupancy should be made. All channels with received signal levels above –154 dBm/Hz (-174 dBm/Hz + 20 dB NF + 25 kHz BW) will be excluded from use by the Test-Bed equipment. Both co-channel and adjacent channel signals will be monitored.

During each demonstration, the spectrum will be monitored to check from proper Test-Bed operation. If a Test-Bed node has a fault and transmits on a non-approved frequency, the operator at the command and control center will stop the demonstration.

Command and Control

Centralized Control of All Test-Bed Transmitters.

All Test-Bed transceivers will be networked to a command and control system via a back-haul system consisting of fixed or mobile data links, commercial satellite internet stations or some other backhaul method. The command and control system can stop all transmissions by of any Test-Bed node within 10 seconds. If the Test-Bed node to command and control center connection is lost for more that 5 minutes, the Test-Bed node will limit transmissions to a reduced list of frequencies that are "assigned" as emergency backup with temporary primary status.

The Test-Bed group shall provide points of contact that are available to immediately cease transmission if interference occurs.

Continuous Connection to the Outside World via the Internet and/or Other Means

The command and control station should have continuous connection to the outside world (*i.e.*, to the local spectrum manager) via the Internet and/or telephone. If an interference complaint is received from the outside world, the Test-Bed system will be immediately turned off to minimize any problems and to diagnose if the Test-Bed system is the cause.

Test-Bed group should maintain a secure web site with both up to date test schedule information and contact information and will provide access information to FCC and other entities designated by FCC.

The Test-Bed group should agree to work with NTIA and FCC once a location is decided to determine what a reasonable notification of "neighbors" is.

Accountability

The Test-Bed nodes should log the time, location, frequency and transmit power levels continuously. These logs should be used for analysis of the Test-Bed algorithms and to analyze any interference events that might occur.

Brief Transmission Periods

The initial Test-Bed demonstrations will involve short transmission periods (several minutes or less). All of the equipment (Test-Bed nodes, non-cooperative "victim" receivers and test transmitters) are centrally controlled via computer. They will be switched off between experiments.

As experience is gained and no interference reports received, the Test-Bed will be allowed to use continuous transmissions.

Demonstration Location

The demonstration areas should be selected to be at least 1 km away from other co-channel non-cooperative transmitters without prior coordination with the potentially affected party. The transmitter locations of all known incumbent users should be made available to the Test-Bed user by the FCC/NTIA.

Personnel Experience

All field testing should be overseen by an experienced engineer with significant RF expertise. This person should be qualified to operate spectrum analyzers and other test equipment to be able to determine if incumbent signals are present, and to determine the actual Test-Bed frequency, bandwidth and power levels.