Telecommunications Research and Engineering at the Department of Commerce's Boulder Laboratories

With wireless networking and mobile cellular industries dependent on access to the spectrum and spectrum sharing, research in telecommunications is essential to the economic vitality of the United States. To ensure the continuation of the connected world the public has come to expect, research advances must keep pace as new wireless devices and applications demand greater access to the spectrum and advanced communication technologies. The Department of Commerce's Boulder telecommunications laboratories – the Institute for Telecommunication Sciences (ITS) and the Communications Technology Laboratory (CTL) – play an important role in communications research and engineering for the nation. ITS and CTL undertake research in key areas such as spectrum measurement, spectrum sharing, and wireless network access technologies. At the request of the National Telecommunications and Information Administration (NTIA) and the National Institute for Standards and Technology (NIST), the National Academies of Sciences, Engineering, and Medicine (the Academies) produced two reports that assess the capabilities and performance of ITS and CTL and discuss how the two labs can best satisfy the research needs of the nation's communications infrastructure. To understand the role that the Boulder telecommunications laboratories currently play and can play in the economic vitality of the country, it is important to understand the influence ITS has in making spectrum available to government and industry. ITS has, and with the addition of CTL, will continue to have, a significant impact on analyzing and developing approaches to spectrum management. In these reports, the Academies recommend that the Department of Commerce establish short and long term research strategies to support national goals in areas such as spectrum sharing, service coexistence, and spectrum repurposing.

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ASSESSMENT OF ITS

ITS has existed in various forms since the 1940s, but was established as a separate laboratory and became part of the NTIA in 1977. Traditionally, research at ITS has focused on radio propagation studies, but its current mission has expanded to include enhanced spectrum utilization, radio environment, network optimization, and public safety communications. In order to examine ITS's performance, resources, and capabilities, the study committee interviewed ITS leadership and staff as well as individuals from companies and federal agencies who have

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worked with ITS. The committee determined that ITS is a unique laboratory that could provide an essential service to the nation by being a principal provider of spectrum measurement services. However, shortages in funding and staff as well as the lack of a coherent strategy limits the ability of ITS to effectively manage its laboratories and execute a strategic plan.

Capabilities

Testing or verifying interference between users in order to enable spectrum sharing for applications such as wireless local area networks, cellular networks, and radar requires deploying both staff and hardware to the site in question. Although there are a few other laboratories with the resources and expertise to undertake this, ITS has a long history of acting as an objective authority in areas of contention. As a result, ITS is viewed as a trusted agent, a role that is likely to grow even more critical in the future as the need to arbitrate among competing uses of the spectrum increases.

RECOMMENDATION: ITS should maintain its capabilities in order to remain a principal provider of instrumentation and spectrum measurement services to other federal agencies and be available to commercial entities to provide services that cannot be found elsewhere.

Resources and Planning

Directly appropriated funds typically make up a third to a half of ITS's total annual budget, with the balance coming from interagency agreements with other federal agencies and a limited number of cooperative R&D agreements with private entities. The reliance on customer-funded projects limits the ability of ITS staff to focus on the long-term research needed to meet the future needs of the telecommunication industry. Even when this contractual work is aligned with significant national priorities, fragmentation into small customer-focused projects makes it difficult to fashion a coherent and sustained research program.

RECOMMENDATION: ITS should develop a strategic plan that identifies the overall research agenda needed to fulfill its mission and create a formal process to ensure that its activities are aligned with its mission, strategy, and national priorities.

RECOMMENDATION: ITS and the DOC should develop processes that allow for quicker formal agreements between the organization and ITS customers so that ITS can quickly address industry and government needs.

RECOMMENDATION: ITS should establish an advisory board consisting of government, industry, and academic experts to review ITS activities and suggest changes in direction to help ITS best align its work with its mission.

Workforce and Process Barriers

With declining, or at best flat, budgets for the past decade, ITS has been operating with a very lean and aging workforce. Without the resources to bring in new talent to learn from the experienced senior staff that may soon retire, ITS risks losing valuable know-how. Because it currently lacks direct-hire authority, ITS must work through a lengthy hiring process defined and managed by the Office of Personnel Management, which can take up to 6 months or more.

Bureaucratic barriers also impede ITS's ability to purchase basic computing equipment and instrumentation. Limited funding coupled with a cumbersome laboratory equipment acquisition process has prevented ITS from replacing aging equipment and purchasing cutting-edge technology for testing. This centralization of administrative control has eroded ITS's capability to perform as a research and engineering laboratory. In particular, ITS has not been able to maintain its very valuable Table Mountain Field Site and Radio Quiet Zone, which has led to the underutilization of these facilities.

FINDING: Unless the DOC supports ITS by (1) facilitating hiring to maintain the organization's personnel level and increase the overall technical expertise of the staff, (2) encouraging ITS to establish an equipment replacement plan, and (3) supporting the procurement and management of needed technology and resources, including improvements to the table mountain facility, ITS will not be able to effectively manage its laboratories and execute a strategic plan.

ASSESSMENT OF CTL

Drawing in part on existing NIST laboratories, CTL was formed in mid-2014 and is also located at the Department of Commerce's Boulder, Colorado campus. The goal of CTL is to evaluate and test advanced communications technologies while supporting research in related areas such as high-speed electronics, advanced optics, and network design. Since CTL has only recently been created, the early efforts of CTL leadership have been largely focused on operational basics such as acquiring space, hiring personnel, and developing a program for future research.

Strategic Goals

In contrast to ITS, CTL's annual budget of $20.7 million comes primarily from the DOC, with 82.8 percent of the budget funded directly by NIST. The high portion of funding that comes from appropriations provides significant stability to CTL. As such, CTL is well-positioned to carry out work directly relevant to its mission, including measurement science for next-generation wireless networks.

Technical advances in millimeter-wave radio frequencies are valuable for wireless communications because of the large amounts of unused millimeter-wave spectrum. CTL's development of the 5G Millimeter Wave Channel Model Alliance has contributed to the quality and visibility of CTL's millimeter-wave research and may serve as a model for further engagement with relevant research communities.

RECOMMENDATION: CTL should maintain a position of leadership in the 5G Millimeter Wave Channel Model Alliance, seek to expand the membership of the Alliance, and engage in millimeter-wave work with other standard and industry bodies.

In addition to millimeter-wave research, other research areas will be important, including techniques for increasing spectrum capacity and facilitating spectrum sharing. CTL staff has identified an appropriate set of communication technology priorities and has begun building the appropriate research activities to support future communication needs. However, this research agenda does not outline specific tasks to advance these priorities.

RECOMMENDATION: CTL should develop a more defined research agenda that outlines in detail its research goals and future plans.

CTL identified a handful of challenges, including staffing and equipment, most of which stemmed from the newness of the organization.

RECOMMENDATION: CTL should quickly hire and train personnel to establish a leading-edge skill set in areas associated with their research goals and upgrade aging facilities and instrumentation.

Engaging Stakeholders

It is important for a laboratory like CTL to stay engaged with the research community at large and in particular be attuned to the research and technology needs of the private sector. NIST can ensure that it understands the needs of the private sector by utilizing outside review. Outside technical reviews ensure that technical work aligns with national priorities and industry needs.

RECOMMENDATION: CTL should further develop opportunities to quickly and frequently engage outside stakeholders and obtain frequent outside technical reviews as it moves its research plan forward.

COLLABORATION AT THE BOULDER TELECOMMUNICATION LABORATORIES

Given that ITS and CTL are collocated in Boulder, Colorado, and have similar missions under the DOC, it is only natural that they collaborate and have established mechanisms to enhance such collaboration. The Public Safety Communications Research Program (PSCR) has been a highly successful long-term initiative between ITS and NIST. Two new programs, the Center for Advanced Communications (CAC) and the National Advanced Spectrum and Communications Test Network (NASCTN), were established in 2013 to facilitate collaboration between ITS and CTL. Collaboration between ITS and CTL is imperative, but given the newness of both CAC and NASCTN, it is unknown if the current models will be successful.

RECOMMENDATION: ITS and CTL leadership should work to build an environment of trust and collaboration across both laboratories.

RECOMMENDATION: The Public Safety Communications Research Program should be considered as a template for collaboration across the Boulder telecommunications laboratories.

NASCTN was established to increase commercial and federal access to the spectrum by helping to accelerate the design and deployment of spectrum-sharing technologies through accurate testing and modeling. NASCTN is structured as a one-stop shop for coordinating access to federally owned, federally operated, or federally funded spectrum test facilities. NASCTN, as described, would respond to important national needs, but its processes are still in their formative stages. Therefore, it has not yet demonstrated its ability to meet these needs or to effectively coordinate use of federally supported test facilities.

RECOMMENDATION: The National Advanced Spectrum and Communications Test Network should be made fully functional as soon as possible to be able to handle the important mission that it has been assigned. This includes the recruitment of customers and additional government, academic, and industrial organizations to utilize the skills in the various affiliated laboratories.

MEETING FUTURE RESEARCH NEEDS

Future demand for wireless communication will come not only from cell phones and tablets but from an increasing number other connected devices including vehicles, appliances, thermostats, and other familiar objects. However, new spectrum (both licensed and unlicensed) to support increased use of mobile devices has been slow in emerging. There is a need for objective expertise to determine when spectrum is underutilized, review technology for shared use, and evaluate interference. The Boulder telecommunications laboratories are in an excellent position—provided they are sufficiently funded and staffed—to provide independent evaluations of proposed sharing standards and to test sys-

tems for compliance with emerging standards-based sharing protocols.

RECOMMENDATION: The DOC should develop short- and long-term application and basic research plans that would provide the country with the necessary knowledge base in spectrum areas and enhance the capability for spectrum sharing and repurposing analysis. A research agenda should consider the most efficient use of the laboratories' resources and develop an effective organizational structure and funding strategy to ensure research goals are met and resources are effectively used.

The Boulder telecommunications laboratories have opportunities to take on additional responsibilities and leadership with regards to techniques and standardized approaches to spectrum measurement and, more generally, the technology standards needed for telecommunications.

RECOMMENDATION: The Boulder telecommunications laboratories should expand their visible leadership roles by providing technical expertise for agencies and policy makers and providing objective scientific expertise.

Interoperability standards are of critical importance to both the data-communications and cellular mobile communications industries. They enable a large number of vendors to supply the components necessary to assemble the vast and complex wired and wireless network infrastructure critical to connecting citizens and business in the United States and throughout the world.

RECOMMENDATION: The Boulder telecommunications laboratories should fully engage in the current and emerging work in IEEE 802 LAN/MAN Standards Committee, the 3rd Generation Partnership Project, and the Internet Engineering Task Force. This must be a long-term commitment, because the time constant for standards evolution is on the order of 3 to 10 years.