



Understanding Spectrum Education and Workforce Needs

The Business-Higher Education Forum

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INTRODUCTION

Texas A&M University leads a multi-institutional collaboration funded by a National Science Foundation (NSF) planning grant to develop a comprehensive research plan for a National Center for Spectrum Innovation. NSF plans to invest \$25 million over five years to stand up a national center, one that is operational within two years. The center's goals are to conduct critical convergence-based research and technology development; serve as a hub for collaborative engagements; educate the workforce; propose appropriate policies, standards, and regulations; advance relevant economic issues; and address ethical issues, including attending to the needs of populations currently underserved by spectrum-related technologies.

To inform the planning grant's education and workforce efforts, the Business-Higher Education Forum (BHEF) developed this report to share preliminary findings from its background research and interviews, which subsequently informed a more comprehensive quantitative analysis of job postings data on current and emerging spectrum occupations, highlighting top skills, top employers, top industries, and top locations. The report demonstrates the broad, diverse, and high-demand landscape of spectrum's current and future education and workforce needs.

BACKGROUND RESEARCH

Methodology. BHEF and the Texas A&M research team¹ reviewed reports and online resources and utilized Emsi analytics to compile a preliminary list of spectrum occupations. A 2020 National Spectrum Consortium report from the Progressive Policy Institute titled *The Third Wave: How 5G Will Drive Job Growth Over the Next 15 Years* is the primary source for the current and projected 4G and 5G jobs and list of top industries. BHEF then performed additional analyses using both Emsi and LinkedIn platforms and conducted interviews, all of which supported the National Spectrum Consortium's findings.

Current and Emerging Occupations. The following table provides a preliminary list of the current and emerging occupations for spectrum. According to the 2020 National Spectrum Consortium report, spectrum fields will create 4.6 million additional jobs beyond the predicted job growth of 12.8 million in numerous employment sectors by 2034.²

¹ Texas A&M research team includes Greg Pearson, consultant in K-12 STEM education policy, and Matthew von Hendy, research librarian and owner/principal of Green Heron Information Services.

² Mandel, M. & Long, E. (2020). *The third wave: How 5G will drive jobs growth over the next 15 years*. Prepared for the National Spectrum Consortium. Progressive Policy Institute. Available at:

Jobs discovered by BHEF and the Texas A&M research team		4G Jobs ³ from the National Spectrum Consortium Report	5G Jobs ⁴ from the National Spectrum Consortium Report
<ul style="list-style-type: none"> • Satellite technicians • Other satellite-related jobs • TV broadcast people • TV broadcast related jobs • Radio technicians • Emergency responders • Police dispatchers • Fire/ambulance dispatchers • Space communication • Other space/aerospace jobs involved with radio/communications • Space researchers • Wireless technicians • Marine communications • Earth/geo researchers • Weather forecasters • Other weather-related jobs 	<ul style="list-style-type: none"> • Network/engineering architect • Computer-systems engineer • Computer-systems architect • Systems analyst • Network/systems support analyst • Computer-support specialist 	<ul style="list-style-type: none"> • Data scientist • Software developers • Software engineers • Information-security specialist • Database administrators • Network administrators 	<ul style="list-style-type: none"> • Field-sensor technician • Construction-drone operator • Household smart-meter maintenance • Robotics maintenance • Autonomous-vehicle maintenance • Elementary and high school telecom helpdesk • Telehealth installer • Tactical-communications specialist • Radio, cellular and tower-equipment installers and repairers • Wireless-core engineer

<https://www.progressivepolicy.org/publication/the-third-wave-how-5g-will-drive-job-growth-over-the-next-fifteen-years/>

³ 4G jobs in the 2020 National Spectrum Consortium report are referred to as “Wave 2 Jobs.”

⁴ 5G jobs in the 2020 National Spectrum Consortium report are referred to as “Wave 3 Jobs.”

Top Industries. Below are the top industries emerging in spectrum according to the 2020 National Spectrum Consortium report.⁵

- **Agriculture.** Precision agriculture will rely on interconnected systems and equipment all powered by 5G to monitor field conditions while efficiently allocating water.
- **Construction.** Implementing a 5G communications grid will allow workers to use automated equipment. Digitizing this aspect of construction will reduce costs, decrease errors, and increase worksite safety.
- **Utilities.** Businesses and individuals can utilize the 5G smart grid to effectively control electronic use.
- **Manufacturing.** Manufacturing facilities can increase efficiency of U.S. domestic production by digitizing production, distribution, and developing new manufacturing platforms.
- **Transportation and Warehousing.** Transportation and logistics will be transformed using 5G connections between fully autonomous trucks and delivery drones. These technologies will need to be maintained by skilled technicians.
- **Education.** Implementing 5G-enabled virtual learning technology is vital for students and teachers to thrive in an online learning environment after COVID-19. Specialists familiar with online-learning platforms and telecommunications helpdesk professionals will drive this industry.
- **Healthcare.** Delivering quality video content, real-time medical imaging, and remote monitoring of patients using 5G technology is essential for providing healthcare to rural, low-density areas across the nation. The telehealth infrastructure will be driven by lab technicians, installers, nurses, and professionals specializing in electronic health records and databases.
- **Government.** 5G will have crucial impact on the government sector whether it is military or civilian use. Military application includes autonomous vehicles, command and control, augmented and virtual reality, surveillance and reconnaissance systems.

⁵ Mandel, M. & Long, E. (2020). *The third wave: How 5G will drive jobs growth over the next 15 years*. Prepared for the National Spectrum Consortium. Progressive Policy Institute. Available at: <https://www.progressivepolicy.org/publication/the-third-wave-how-5g-will-drive-job-growth-over-the-next-fifteen-years/>

INTERVIEWS

Methodology. To better understand and assess the education and workforce needs associated with spectrum technologies, BHEF conducted nine virtual and phone interviews⁶ from September 2020 to January 2021. The interviewees consisted of leaders from industry, academia, and government with expertise ranging across a variety of fields, including engineering, physics, cybersecurity, artificial intelligence, technology, policy, and wireless communications. Interviewees shared their perspective on a variety of topics, including the areas most critical for spectrum's growth and evolution, the largest spectrum-related occupations, the educational pathways leading to employment in these occupations, and the jobs or skills areas with the biggest talent shortages.

Education and Workforce Needs. Based on the interview findings, BHEF and the Institute-Spectrum Education & Workforce members identified the five distinct education and workforce needs that are essential to support spectrum's growth and advancement.

1. **General users** who represent the public with all levels of interest and experience.
2. **Regulators and teachers**, including legislators and educators, who work on policies, standards, regulations, and education. These individuals often have a BS, MPA, JD, MEd, or some field experience.
3. **Servers and maintenance**, including engineers, IT managers, communications managers, digital managers, and scientists, who deliver services, maintain infrastructure, and sell products. These individuals often have a BS, AS, certificate, or some field experience.
4. **Designers**, including engineers, chief technology officers, spectrum managers, and scientists, who advance the capabilities and availabilities of spectrum. These individuals often have a PhD, MBA, or strong field experience.
5. **Conceptualizers**, including faculty and chief researchers, who are thought leaders with a deep understanding of spectrum and can create new approaches. These individuals often have a PhD, JD, or strong field experience.

⁶ Cukier, Michel. Personal Interview. January 26, 2021.; Ghosh, Monisha. Personal Interview. November 24, 2020. Elachi, Charles. Personal Interview. November 13, 2020.; Odumosu, Tolu. Personal Interview. November 17, 2020.; Sarabandi, Jamal. Personal Interview. November 20, 2020.; Siegelmann, Hava. Personal Interview. November 23, 2020.; Watson, Karan. Personal Interview. October 5, 2020. Franklin, Rhonda. Personal Interview. October 6, 2020. Gammel, Peter. Personal Interview. September 30, 2020.

Talent Demand. Interviewees shared their perspective on the industries, potential jobs, and skills that would be in most demand for spectrum. These included technicians, electricians, and engineers. However, electricians and technicians were identified to have the biggest talent shortage. Interviewees noted technicians and electricians need an understanding of electrical systems, software programming, various models companies use for internet service, and the mechanics of how the internet is transmitted by satellite or cable. Additionally, skills that were identified to have a talent shortage were data privacy and regulation, radio frequency engineering, and electrical engineering and computing.⁷

Growth Areas. Interviewees also commented on areas most crucial for spectrum growth.

- **Influence.** Spectrum addresses both mobile and fixed markets for data services. From connected vehicles to infrastructure, spectrum technologies will allow faster connectivity between devices used for a variety of industries.
- **Availability.** A variety of devices must be able to access spectrum in diverse ways.
- **Education.** There is a need to develop fundamental science knowledge in high school/middle school curricula, including topics such as devices, physics, applied physics, material science, electrical engineering, hardware engineering, quantum physics, material science, chemistry, and hardware engineering.

Diversity and Inclusion. Interviewees also expressed a keen interest in expanding diversity and inclusion efforts within spectrum. It is noted that historically black colleges and universities (HBCUs) produce the largest percent of Black engineers across the country, and Morgan State University is the only HBCU in the country with a microwave engineering program.

⁷ Industry popularity and demand has encouraged an increase in software engineers. However, interviewees believe there is a talent shortage in individuals with hardware engineering skills for wireless systems.

Diversity and Inclusion Perspectives from the Literature. Communities of color lack reliable and continuous access to broadband and mobile networks. In the United States, “35 percent of Hispanics and 24 percent of African Americans have no other online connection except through their smartphones or other mobile devices, compared to 14 percent of whites.”⁸ These smart-phone dependent populations have limited access to obtain the digital skills necessary for employment, making it difficult for them to meet current workforce needs. However, enabling a reliable 5G network can provide a wide breadth of opportunities for vulnerable populations and decrease these disparate impacts. Internet of Things (IoT) and physical devices connected through wireless communication can also be used to enhance the lives of communities of color. For example, IoT can be applied to industries such as education and healthcare to address essential community concerns. In education, 2.4 percent of Hispanic and 2.5 percent of Black students⁹ have little or no broadband connection. IoT can alleviate these disparities with tools to create a sufficient learning environment, such as tablets, printers, and e-books. In conclusion, advancing the next generation of mobile networks will achieve technological equity and ensure all populations have access to affordable, reliable technologies.

Overall, these interview findings confirmed a broader and more inclusive need for individuals with knowledge or experience in spectrum.

⁸ Lee, N.T. (2019). *Enabling opportunities: 5G, the internet of things, and communities of color*. Brookings Institution. Available at: <https://www.brookings.edu/research/enabling-opportunities-5g-the-internet-of-things-and-communities-of-color/>

⁹ Ibid.

JOB POSTINGS DATA ANALYSIS RESEARCH

To further explore the potential landscape of spectrum occupations identified in the background research and interviews, BHEF used job postings and professional profile data from Emsi and LinkedIn to create a more comprehensive list. As spectrum is not yet defined as a skill or an occupational/job title classification in the data, the analysis used 5G as a proxy for spectrum to illustrate the vast application of spectrum skills in the current and future workforce.

EMSI Data

About Emsi Analyst. Emsi Analyst¹⁰ scrapes more than 130 million professional profiles, 100,000 job-related websites, and 1.5 million company websites to compile job posting and professional profile data and analyze skills data as a compliment to traditional labor market data.

Methodology. In the Emsi Analyst tool, BHEF filtered for unique job postings in the United States using the term “5G” in the keyword search. The result was a sample of 62,924 job postings from February 2020 to February 2021. Looking at historical data over the last two years, there has been a significant increase in the number of job postings related to 5G. In February 2019, there were 3,967 unique job postings, and in February 2021, there were 18,929 unique job postings—a 377 percent increase, indicating a tremendous and growing demand for 5G skills.

Top Job Titles. This sample of job postings was then filtered by required education level listed in job postings to determine common job titles. Below is a list of the top 20 job titles by education level.¹¹

High School or GED

- | | |
|-------------------------------------|---|
| 1. Apprentice Technicians | 11. Inside Sales Representatives |
| 2. Wireless Center Sales Associates | 12. Business Acquisition Sales Executives |
| 3. Home Sales Associates | 13. Field Service Technicians |
| 4. Retail Managers | 14. Installer Technicians |
| 5. Customer Service Representatives | 15. Government Account Managers |
| 6. Inventory Specialists | 16. Mobile Experts |
| 7. Forklift Operators | 17. Account Managers |
| 8. Radio Technicians | 18. Tower Technicians |
| 9. Civil Technicians | 19. IoT Solutions Architects |
| 10. Sales Associates | 20. Engineering Operations Manager |

¹¹ Top 20 job titles after similar job titles were consolidated to demonstrate breadth of job opportunities available within spectrum (e.g., elite customer service representatives and retail customer service representatives consolidated to customer service representatives).

Associates Degree

- | | |
|-------------------------------------|---|
| 1. Retail Sales Representatives | 12. Procurement Engineers |
| 2. Apprentice Technician | 13. Satellite TV Technicians |
| 3. Tower Climbers | 14. Network Systems Engineers |
| 4. Retail Sales Representatives | 15. Engineering Technicians |
| 5. Home Sales Associates | 16. Satellite TV Installers |
| 6. Customer Service Representatives | 17. Installer Technicians |
| 7. On-Site Engineers | 18. Information Assurance Systems Engineers |
| 8. Transport Engineers | 19. Radio Technicians |
| 9. Network Engineers | 20. Engineering Operations Managers |
| 10. IT Systems Analyst | |
| 11. Outside Plant Engineers | |

Bachelor's Degree

- | | |
|-------------------------------|-----------------------------------|
| 1. Network Engineers | 11. Senior Engineers |
| 2. Software Engineers | 12. Security Engineers |
| 3. Sales Consulting Managers | 13. Firmware Engineers |
| 4. Software Developers | 14. Product Managers |
| 5. Wireless Engineers | 15. Application Engineers |
| 6. Radio Frequency Engineers | 16. Network Architects |
| 7. Project Managers | 17. Systems Performance Engineers |
| 8. Solutions Architect | 18. Test Engineers |
| 9. Product Strategy Managers | 19. Business Intelligence Manager |
| 10. B2B Sales Representatives | 20. Cellular Technicians |

Master's Degree

- | | |
|-------------------------------------|-----------------------------------|
| 1. Senior Network Engineers | 11. Business Development Managers |
| 2. Senior Sales Consulting Managers | 12. Wireless Systems Engineers |
| 3. Wireless Engineers | 13. Embedded Software Engineers |
| 4. Senior Project Managers | 14. Principal Software Engineers |
| 5. Software Developers | 15. Marketing Product Managers |
| 6. Solutions Architect | 16. Data Scientists |
| 7. Public Relations Specialists | 17. Firmware Engineers |
| 8. Technical Product Managers | 18. IC Design Engineers |
| 9. Systems Engineers | 19. Design Verification Engineers |
| 10. Senior Software Engineers | 20. Modem System Test Engineer |

PhD or Professional

- | | |
|--|--|
| 1. R&D Engineers | 12. Data Scientists/Data Modelers/Architects |
| 2. Business Development Managers | 13. Solutions Architect |
| 3. Senior Consultants | 14. Communications Systems Engineers |
| 4. IC Design Engineers | 15. Analog/Mixed Signal Design Engineers |
| 5. Wireless Systems Engineers | 16. Photonics Engineers |
| 6. Systems Engineers | 17. DSP Engineers |
| 7. Standards Engineers | 18. Product Security Engineers |
| 8. Senior Software Engineers | 19. Hardware Engineers |
| 9. Directors of Safety and Standardization | 20. Legal Counsels |
| 10. Full Stack Software Engineers | |
| 11. Research Scientists | |

Top Companies. Lastly, BHEF noted the top 20 companies hiring for individuals with 5G skills.

- Verizon Communications
- Qualcomm Incorporated
- Oracle Corporation
- Dish Network
- Wireless Advocates
- Nokia Inc.
- HCL Technologies
- T-Mobile
- Synopsys
- Dell
- Intel Corporation
- Lipsey Communications
- Humana
- Micron Technology
- Apple
- Samsung
- Xilinx Inc.
- Ericsson
- Bell Laboratories

LinkedIn Data¹²

About LinkedIn Talent Insights. LinkedIn Talent Insights translates information from more than 722 million LinkedIn member profiles into unique data points on individuals, companies, jobs, skills, and academic institutions. This information is aggregated and standardized for comparison at a macro level.

Methodology. In the LinkedIn Talent Insights tool, BHEF filtered LinkedIn profiles for those with “5G” as a skill based in the United States. This resulted in a sample population of 17,368 LinkedIn profiles and 6,599 job postings (as of March 2, 2021).

Top Locations. The top locations for professionals with 5G skills are Dallas-Fort Worth metropolitan area, San Francisco Bay area, New York City, San Diego, Greater Seattle area, Washington DC-Baltimore area, Greater Chicago area, Atlanta metropolitan area, Los Angeles metropolitan area, and Denver metropolitan area.



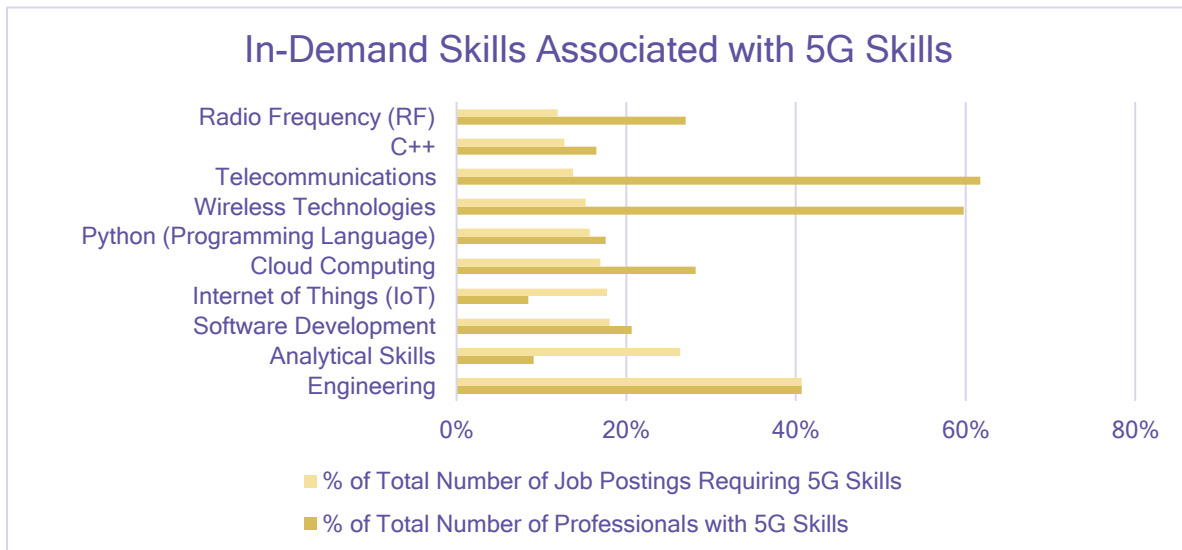
Figure 1: Top 10 locations where 5G-related jobs and professionals with 5G skills are located; bubble size indicates the number of professionals in high to very high hiring demand locations.

¹² LinkedIn Data Insights, Available at: www.linkedin.com/insights.

Top Growing Job Titles. Below are the fastest growing job titles among professionals with 5G skills.

- Product Marketing Manager
- Wireless Engineer
- Director of Technology
- General Manager
- Solutions Manager
- Tower Technician
- Solutions Engineer
- Senior Design Engineer
- Integration Engineer
- Senior Solutions Architect
- Radio Frequency Engineering Manager
- Radio Access Network Engineer
- Wireless Specialist
- Test Engineer
- Architectural Engineer
- Field Technician
- Network Engineer
- Field Engineer
- Radio Frequency Design Engineer
- Software Engineer

Top Growing Skills. Employers that need 5G skills are also looking for individuals who have the following skills.¹³



¹³ Limited to the Top 10 In-Demand Skills sorted by Number of Job Postings.

This data indicate that:

1. A skills gap in IoT and analytical skills could exist for people with 5G skills as demand exceeds supply.¹⁴ However, there are indications this gap is closing. Over the last year, professionals that have 5G have increasingly included analytical skills (102 percent growth) and IoT (65 percent growth) over this past year;
2. The majority of people already working in the 5G space have telecommunications and wireless technologies skill sets; and
3. Skills related to digital technology are becoming more prevalent in this space with half of these in-demand skills being related to coding, computing, and analytics.

Other skills that are growing rapidly within this sample population over the course of the last year are listed below.¹⁵

- Engineering
- Business Analysis
- Process Improvement
- 5G New Radio
- Customer Satisfaction
- Analytical Skills
- Technical Support
- Operations Management
- Finance
- Information Technology
- Artificial Intelligence
- Network Engineering
- Machine Learning
- Data Analysis
- Customer Experience
- Cloud Computing
- SQL
- Sales Management
- New Business Development
- Cisco Systems Products
- Edge
- Sales Operations

¹⁴ A limitation of LinkedIn data is participation bias. The data is pulled from LinkedIn profiles and thus depends on individuals to provide information on their profiles.

¹⁵ Limited to skills reporting more than 80% growth in the sample of LinkedIn profiles.

ADDITIONAL RESOURCES

Below are select additional resources to learn more about spectrum.

- Business-Higher Education Forum. (2019). *Future skills, future cities: New foundational skills in smart cities*. Available at: <https://www.bhef.com/publications/future-skills-future-cities-new-foundational-skills-smart-cities>
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