Executive Summary

FOREFRONT:

Securing Pittsburgh's Break-out Position in Autonomous Mobile Systems.

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Prepared by: TEConomy Partners, LLC

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EXECUTIVE SUMMARY

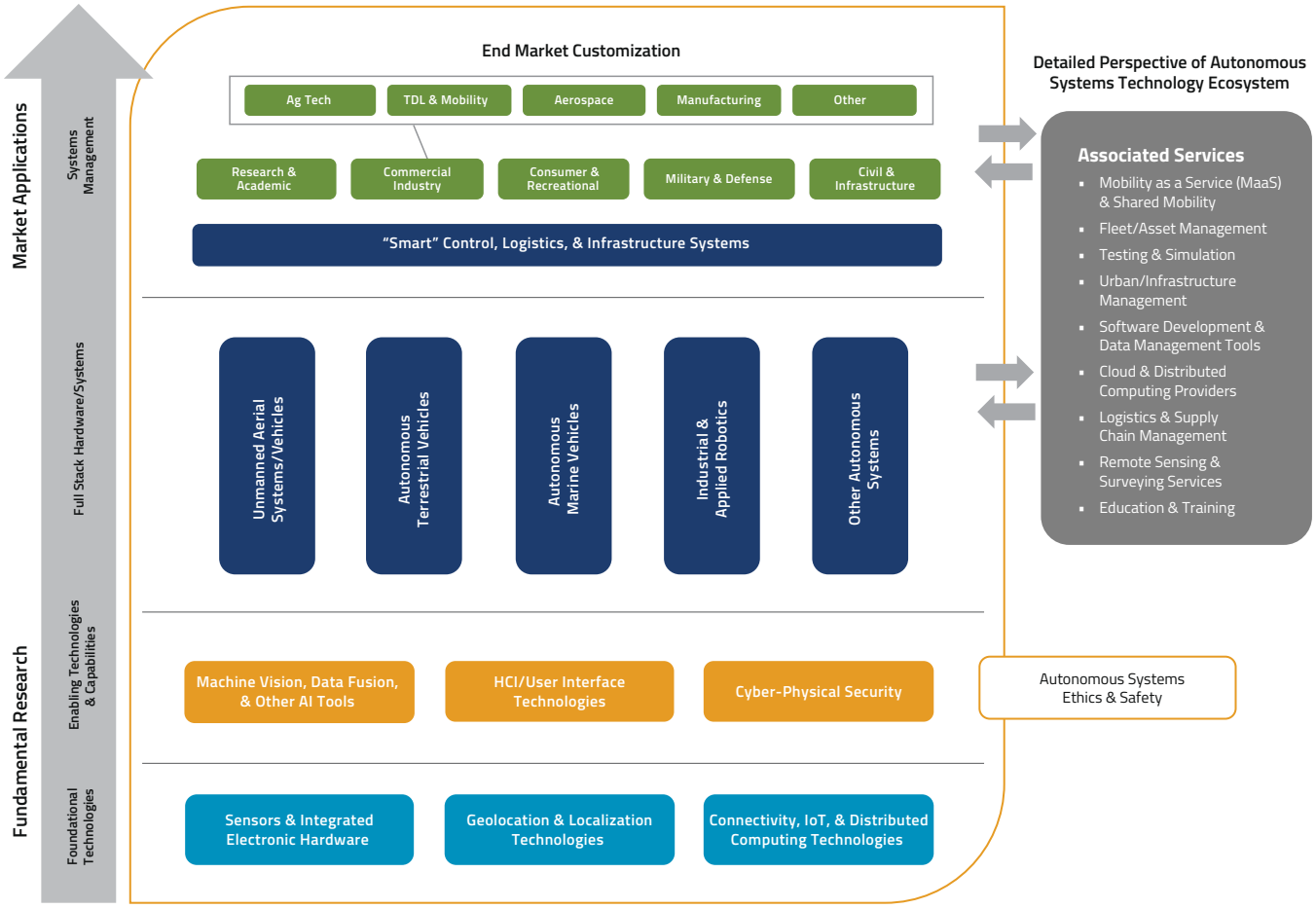
Autonomous Mobile Systems:
A Transformational Opportunity

Advancements in technology and the forces of convergence are impacting almost every industry and creating significant emerging growth opportunities. Some legacy industries are facing significant change as a result of new business models enabled by convergence of multiple technologies, while other entirely new industries are emerging. In one such area, multiple technology domains are converging to enable the development of Autonomous Vehicles (AVs) which have the potential to not only impact the characteristics of the vehicles themselves but create fundamental shifts in the future of mobility and the infrastructure that vehicles use and interface with. In recent years, major investments and prototyping efforts have focused public attention on this applications area and captured the imagination of industry and policymakers seeking to advance the next generation of technology-based industries.

While autonomous on-road vehicles are one of most publicized applications of autonomy (the ability of a machine to make decisions without the intervention of a human), they are only a part of a much wider landscape for autonomous mobile systems applications. Enabled by new technology convergence areas, significant change is coming to physical devices of any scale that both move and may be equipped with some form of sensing and decision-making system to intelligently perform tasks and navigate their environment. Many tasks that require human or machine spatial movement are potential prospects for automated mobile systems approaches, and this opens up vast and diverse market potentials for disruptive industries. **There is a large-scale economic development opportunity for regions of the country that have a distinctive position in the technologies and talent required to research, develop, and build complex integrated autonomous mobile systems products.** It is a very specialized space, however, and as Figure ES1 illustrates, the "full stack" of technologies needed to advance such products to prototyping and end market applications is quite complex.

To bring autonomous mobile systems solutions to market, it is not sufficient to build capacity in any one component of the technology stack. Rather, the goal of full deployment of autonomous end market solutions requires capabilities (or the ability to reliably source those capabilities) across the entire technology stack, as well as the means of linking the capabilities in each layer of the stack so that a system can perform as a fully integrated platform rather than a partial solution that requires further commercialization by others. **Regions who are able to build out their technology ecosystems to support this type of integration will be poised to realize major economic growth. Triangulating results from multiple recent market research reports places the terrestrial autonomous mobile systems market alone at an estimated $802 billion global market by 2025-26. When adding aerial, marine, and defense autonomous systems to capture the broader autonomous mobile systems market space context, the total likely climbs above $1 trillion in total market size during the mid- to late-period**

FIGURE ES1.
Autonomous Mobile Systems Stack



Source: *TEConomy Partners.*

of the present decade. If a region with a robust and well-supported technology ecosystem were to capture even 1% of the $1 trillion global autonomous mobile systems market, it would equate to a $10 billion growth opportunity developing within the next decade.

The implications for potential economic growth around a rapidly scaling multi-billion dollar autonomous mobile systems industry, in conjunction with the readily apparent base of expertise and assets relevant to these technologies in Pittsburgh, have been recognized by key regional stakeholders. While those engaged in advanced economic development for the Pittsburgh region have observed the organic growth of the autonomy sector to date, the opportunity presenting itself to the region and the Commonwealth of Pennsylvania today is of such a scale and importance that a detailed examination of the opportunity is required that includes an evaluation of existing industry activity, current regional innovation assets that can be leveraged towards this opportunity, any gaps in the ecosystem that need to be addressed, and a resulting strategy and action plan developed to guide realization of the full economic opportunity as it unfolds.

Reaching Critical Mass:
The Profile of Pittsburgh's Autonomy Industry Today

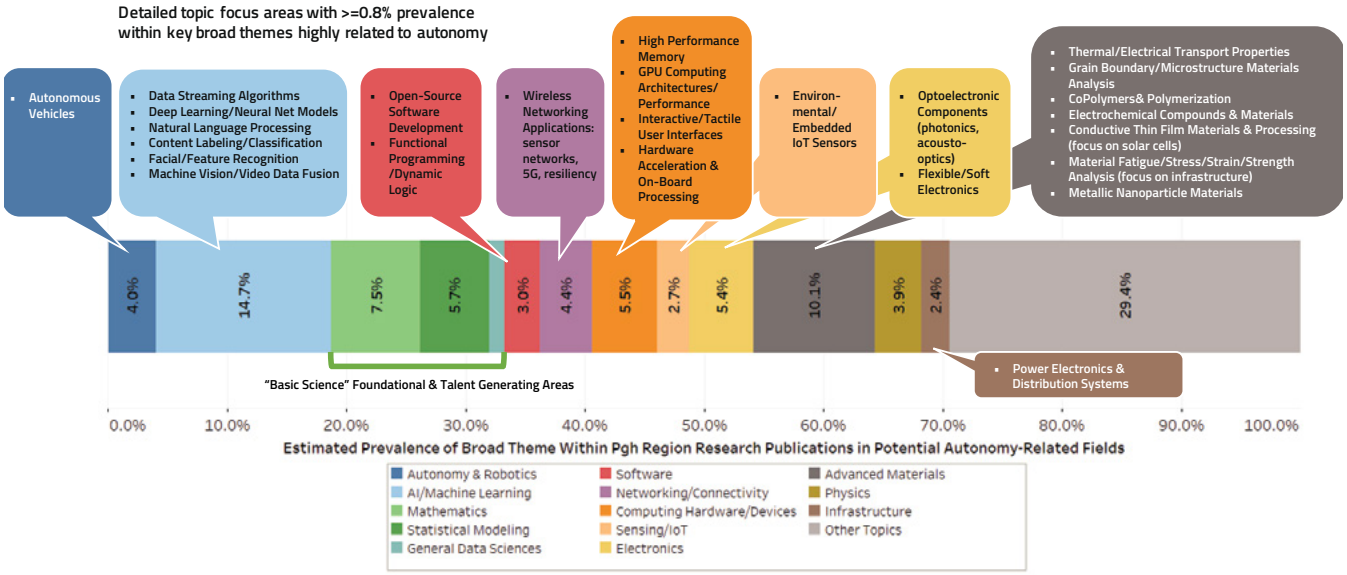
The Pittsburgh region has a long history of research leadership in software and robotics that, driven by its core academic research institutions, has evolved into a significant base of activity at the cutting edge of modern technology applications in areas like artificial intelligence (AI), machine perception, high performance computing, and autonomous systems. **Today, industry leaders, investors, and skilled talent agree that Pittsburgh represents one of the distinct hubs for autonomous systems activity in the country. Moreover, there is evidence that the regional ecosystem has reached an inflection point in developing a focus on mobile autonomous systems such that it has begun to drive an industry cluster of emerging and established companies that can serve as an economic development engine beyond supporting continued excellence in R&D.**

At the heart of the Pittsburgh region's innovation ecosystem is a broad base of academic research institutions that support translational research activity and produce highly skilled talent, anchored in particular by Carnegie Mellon University's global leadership in AI and robotics research. The strength of the academic research community in this regard is evidenced by the large-scale federal research funding coming to Pittsburgh to support robotics and associated fields. From 2015 to early 2021, combined grant funding received from the U.S. Department of Defense (DOD), National Science Foundation (NSF), the Department of Energy (DOE), and the National Aeronautics and Space Administration (NASA) was $162.9 million[1]. Particularly important is DOD funding, both in terms of the significant funding volume (over $115 million) and also because DOD activity spans a full-spectrum of integrated autonomy applications (driving research in fully autonomous air, ground, and space systems integration). These military focus areas drive research and innovation that translates well into commercial applications, in areas such as logistics and materials handling, agricultural and construction robotics, and human transportation.

The themes present in Pittsburgh's research across multiple indicators of research and innovation data (one of which, research publications activity, is shown in Figure ES2) represent a deep level of regional excellence in areas highly aligned with numerous elements of the autonomous systems technology stack. This represents a signature strength for Pittsburgh that positions it amongst the top ecosystems in the country in generating the technology and talent "push" that drives ideation and subsequent opportunities to commercialize innovative technologies.

1 Appendix E, Table E4.

FIGURE ES2.
Identification of Pittsburgh Institutional Research Competencies Using Latent Topic Modeling and Research Publications Data



Source: *TEConomy analysis of Clarivate Web of Science publications data*

The region's excellence in fundamental research has in turn driven organic growth of a cohort of thought leaders focused on the autonomy industry which has expanded the cluster over the last decade to its current critical mass. Often beginning as spinouts or founded by alumni affiliated with regional research institutions such as Carnegie Mellon and the University of Pittsburgh, several of these companies have grown to attract significant venture and direct corporate investments that have raised the region's profile in autonomous systems over the past five years. These efforts culminated in 2020 with multi-billion-dollar investments across several different Pittsburgh autonomous vehicles companies representing a significant milestone for the industry cluster's growth. The high-profile investments by leading original equipment manufacturers (OEMs) in a major autonomous systems end market have helped to firmly establish the region's reputation as a hub for the autonomous systems cluster and driven further attraction of strategic growth partners and skilled talent to the local ecosystem.

Pittsburgh's Autonomous Vehicle Companies are Driving Major Investment in the Region

- Argo AI has secured total investment from Ford and VW of $3.6B
- In December of 2020, Aurora acquired Uber's self-driving ATG unit. The company also recently announced its plans to go public with a pre-transaction equity value of $11 billion.
- First announced in March 2020, Motional was formed as joint partnership between Aptiv and Hyundai with major employment presence in Pittsburgh as a result of acquiring a Carnegie Mellon spinout.

It is also notable that the research ecosystem demonstrates a highly favorable fluidity, whereby people and knowledge are transferring between industry and the universities and vice versa. This flexible interface between the corporate and academic R&D and innovation communities is highly valuable, maintaining up-to-date understanding of the capabilities, advancements,

innovations, and trends on both sides, and sustaining robust pathways for talent to maximize their contributions to sector advancement. Such symbiosis between academe and industry is rare and represents a distinctive characteristic of the Pittsburgh autonomous mobile systems ecosystem.

Even though the region's growth in autonomous vehicles has received most of the national attention, Pittsburgh hosts a much broader set of companies focused on nearly every end market application for autonomous systems. As shown in Figures ES3 and ES4, not only does the current set of companies demonstrate a focus on deployment into multiple markets (which have further specialized applications within specific industries), but within those markets they are integrating and deploying multiple elements of the technology stack ranging from electronic components and software to full systems. Representing just a small set of the complete base of industry activity thriving in this ecosystem outside of the autonomous vehicles market, other applications areas include scaling local businesses in autonomous mobile robotics (AMR) systems, industrial and logistics automation solutions, autonomous inspection and imaging platforms, autonomous construction systems, and intelligent mobile manipulation solutions.

FIGURE ES3.
Estimated Current Employment at Autonomous Systems Companies in Pittsburgh, by Technologies Deployed and Markets Served*

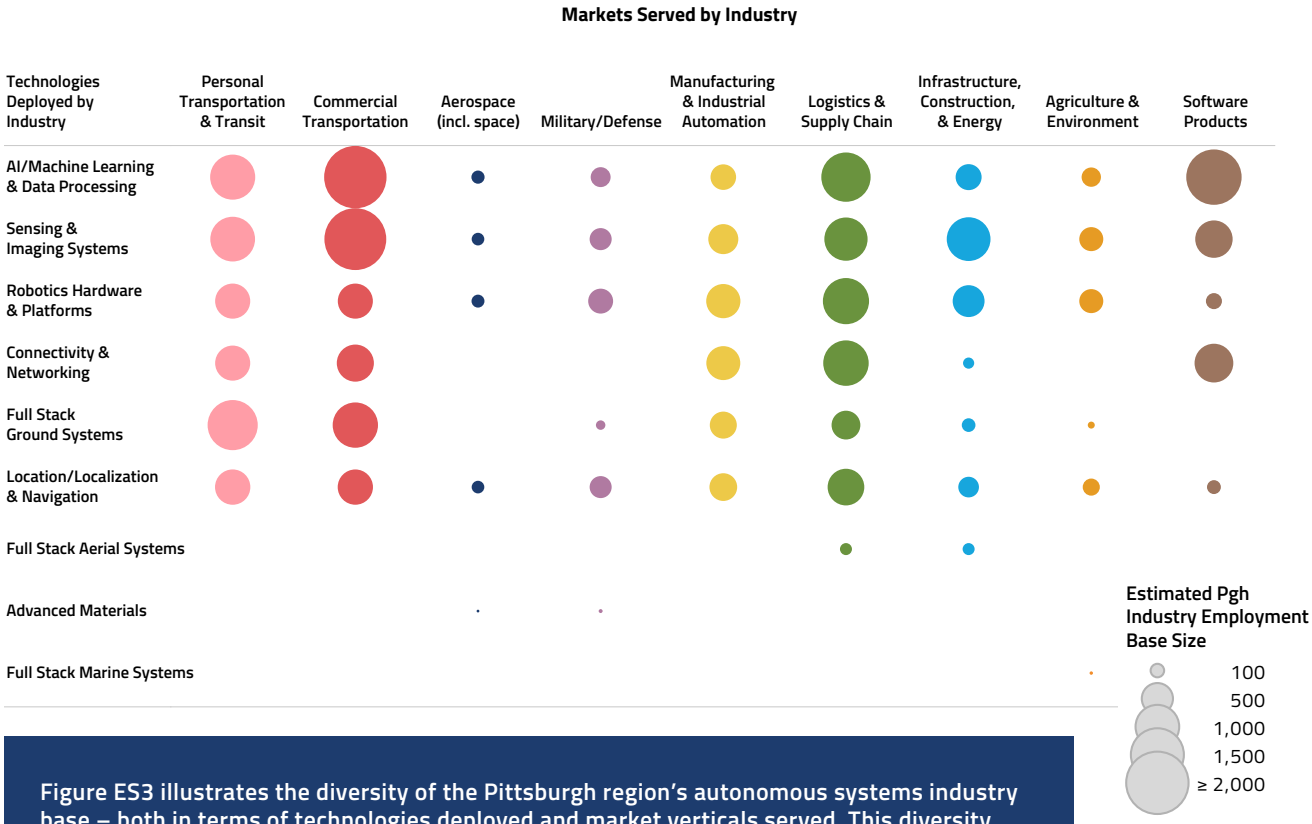
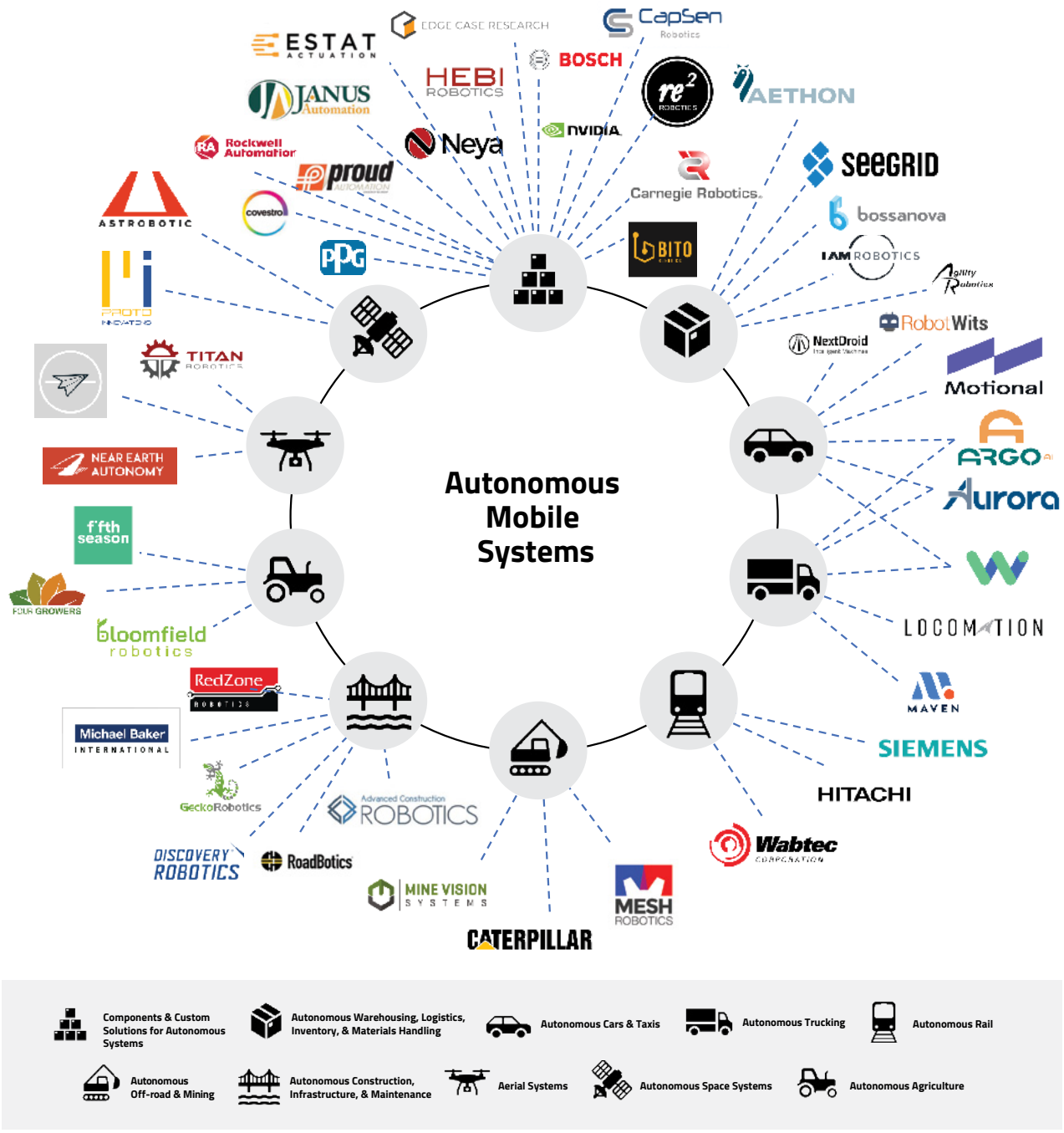


Figure ES3 illustrates the diversity of the Pittsburgh region's autonomous systems industry base – both in terms of technologies deployed and market verticals served. This diversity, spreads risk and provides multiple potential pathways to ongoing industry growth.

***Note:** companies may deploy multiple technologies and serve multiple end markets as a part of their business activity*

***Source:** TEConomy analysis of Pitchbook VC, SBIR, USPTO, company LinkedIn profile, and other data*

FIGURE ES4.
Examples of the Diverse Base of Companies Operating in Autonomous Mobile Systems Verticals Within the Pittsburgh Ecosystem



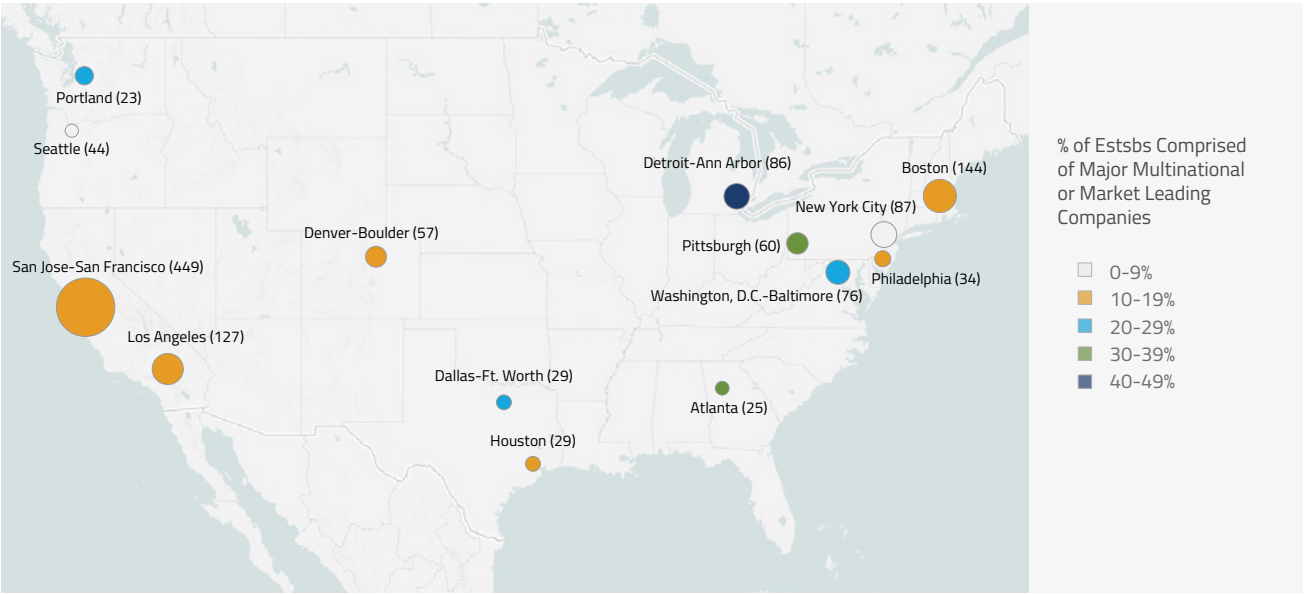
Relative to other locations with significant business establishments focused on the autonomous systems industry, this diversity stands out as a key competitive strength that can help the region remain agile to shifts in broader markets as adoption of autonomy solutions grows.

An Emerging Competitive Landscape:
The Need for Bold Action to Secure Pittsburgh's Position

Growing alongside the Pittsburgh region's industry and innovation presence, a broader global market for autonomous systems anchored by other regional innovation hubs has also emerged. **Within the U.S., states and regions are taking action to position themselves to be at the forefront of emerging technologies and market applications associated with the industry sector. Coupled with broad uncertainties about the exact pathway and timing to mass deployment of autonomous solutions within various end market verticals, the outlook for Pittsburgh's future within this increasingly competitive space is far from assured if the region takes a passive stance and relies solely on existing industry and innovation activities.**

As an emerging, R&D intensive industry that does not yet have widely productized goods and services or large volume consumer bases, the broader landscape of the autonomous systems industry is often difficult to fully characterize. However, the footprint of national mobile autonomous systems companies and their key supplier and supporting service companies (see Figure ES5) reveals the **Pittsburgh region's autonomous systems industry is hardly alone amongst a growing base of geographic regions who have their own expanding industry clusters.** This highlights the trend towards an increasingly competitive market landscape, with other regions seeking to build or expand their own industry bases to take advantage of new opportunities in autonomy deployment applications.

FIGURE ES5.
Distribution of U.S. Autonomous Systems Industry Establishments, Combined Statistical Areas with 20 or more Establishments



Source: *TEConomy analysis of BCC and IBISWorld Market Research, Pitchbook VC data, SBIR data, and AUVSI unmanned systems database.*

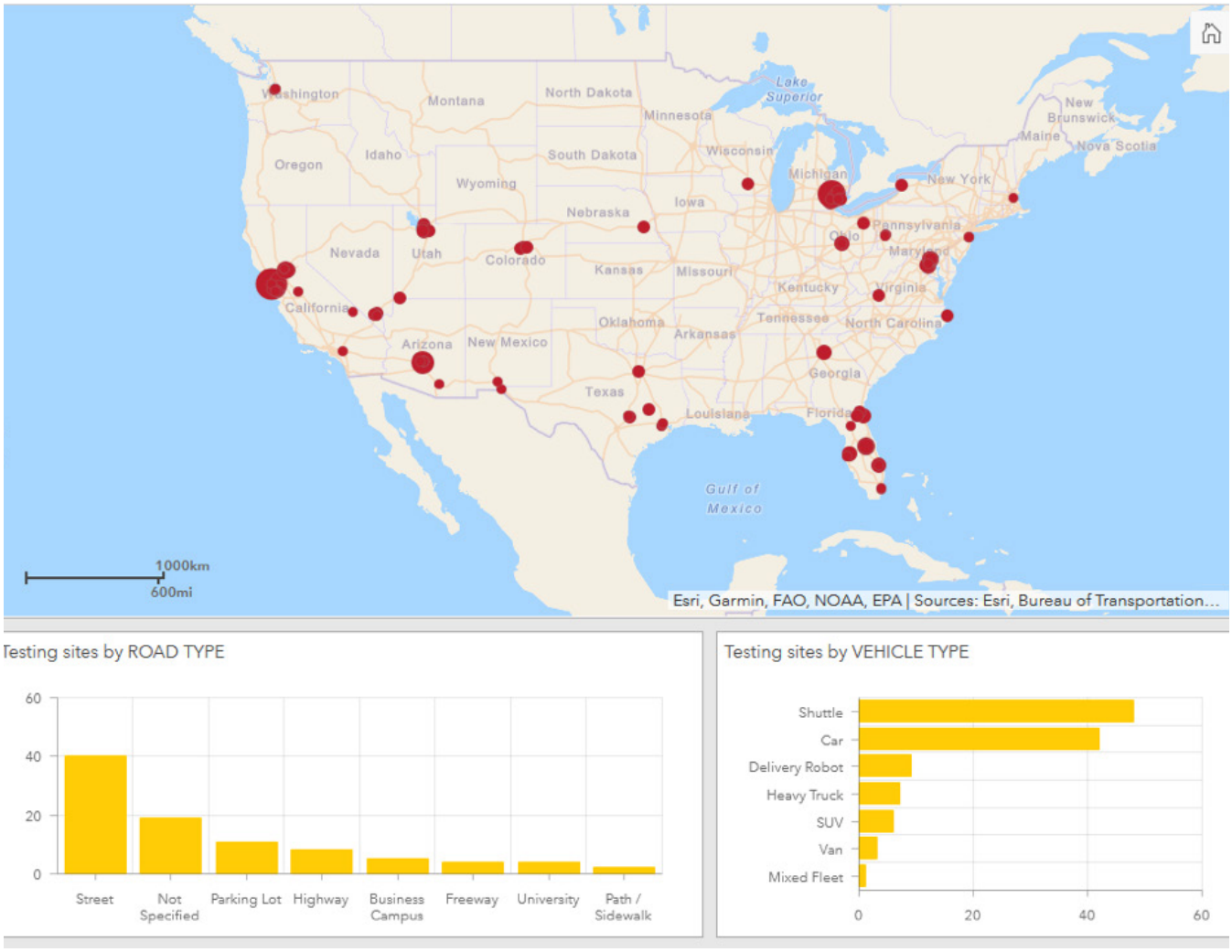
As the autonomous systems industry continues to expand nationally, **states are increasingly undertaking economic development and public policy actions to position themselves to capture market share.** Much of this activity is focused on policies that enable testing of autonomous systems within states as well as sources of funding for demonstration and infrastructure projects that incorporate autonomous solutions as a part of their efforts. This is most evident in state

policymaking related to autonomous vehicles testing which has greatly expanded since 2013, where according to the National Conference of State Legislatures (NCSL):

> *Between 2013 and 2020, 31 states and the District of Columbia enacted legislation related to autonomous vehicles, governors in 11 states issued executive orders, and 5 states both issued an executive order and enacted legislation."*

T**he results of state action are starting to be realized through the attraction of autonomous systems testing efforts to regions across the country as companies continue to advance their platforms.** In the autonomous vehicles sector alone, the distribution of autonomous vehicle testing sites reported by industry (seen in Figure ES6) spans not only the major research and industry hubs in this sector, but also many additional states that have the appropriate environmental and regulatory conditions that are attractive to companies.

FIGURE ES6.
Autonomous Vehicle Testing Sites Reported to NHTSA AV TEST Initiative



Source: *NHTSA AV TEST Tracking Tool*

Pictured here is Aurora's fleet of vehicles. The Aurora Driver has been designed to be deployed across different vehicle types, be it a sedan, a van, or a Class 8 truck.

As states have primarily focused on the regulatory and testing landscape for autonomous systems, several regions and cities have simultaneously been making significant investments in establishing or expanding innovation ecosystems that support the autonomy technology stack to help drive their ability to capture market share. In order to boost their ability to attract and retain companies, talent, and investment capital, regions with significant autonomous systems industry presence across the U.S. are building programmatic efforts and other infrastructure that support their innovation ecosystems (see text box). **Pittsburgh will face increasing competition from regions with signature state and regional initiatives that support autonomous systems applications and must establish its own programs to reinforce its current innovation ecosystem as well as root emerging companies and talent in the region.**

In the midst of this changing national landscape, discussion with Pittsburgh's industry leaders and economic development stakeholders in this space identified several common themes that outline the risks and threats that Pittsburgh must navigate in order to realize long term success in growing the industry as a regional economic driver. Key industry and ecosystem trends raised in stakeholder discussions included:

Examples of Regional Programmatic Efforts to Support Autonomous Systems Innovation Ecosystems

- **Silicon Valley Robotics (SVR)** is a membership-driven coalition of robotics companies clustered in northern California.
- **Mass Robotics** functions as a cluster-development organization organized around a purpose-built business incubator featuring a collection of specialized prototyping and testing facilities aimed at startups in robotics and connected devices.
- **DriveOhio** is a formalized consortium of state agencies involved in "smart mobility," managed through an office of the Ohio Department of Transportation (ODOT) and able to contract under the latter's authority. Through DriveOhio, the ODOT and JobsOhio committed $45 million to a new Smart Mobility Advanced Research Center (SMART Center), an automated and connected vehicle-testing facility.
- **Mcity** is a test facility combined with an industry-sponsored research program created in 2014, all housed at the University of Michigan at a 32-acre artificial urban/suburban setting equipped with 5G vehicle-to-everything service and other advanced testing technologies. Mcity claims a cumulative total of $26.5 million invested since 2015 in R&D and deployment projects, with approximately 20 active research projects that pool funds from industry sponsors.

The Impact of Pittsburgh's Autonomous Systems Industry Cluster

A conservative estimate of the Pittsburgh region's autonomous systems industry today includes **71 companies and 6,300 jobs which generate significant economic impacts.**

- These direct jobs support more than 8,600 additional jobs through indirect and induced effects, for a total economic impact of over 14,900 jobs.
- These jobs support almost $651 million in estimated direct labor income, and $1.2 billion in total labor income.
- The industry generates an estimated $1.5 billion in direct economic output and supports nearly $3 billion in total economic output.
- The industry generates over $161 million in direct local, state, and federal tax revenues and nearly $347 million in total tax revenues.
- One employee in the autonomous systems industry sector supports approximately 2.36 additional employees in other industry sectors.

- Acknowledgement that the nascent industry will still be highly influenced by broader market headwinds.
- Concern that the state does not display a best practice regulatory and operating environment necessary to enable industry investment and growth, particularly for the autonomous vehicle industry.
- Concern that the region may risk being viewed as an "R&D outpost" for major companies rather than a headquarters destination.
- Recognition that significant portions of the components supply chain for autonomous systems are offshore.
- Current regional ecosystem organizations that are generally aware of the potential of this market space and supportive of tech-based entrepreneurial activity in autonomy, but that have programs and initiatives which are too diffuse and not focused at scale on this vertical.
- A perception that local venture funding gaps persist despite the autonomy industry's success in attracting investment from outside the region.
- Concern that the talent supply base of the region is facing skill gaps and other growing pains in the wake of the success of the initial cohort of autonomous vehicles companies.

These issues will require bold, forward-thinking action to mitigate the risks to future growth and reinforce Pittsburgh's position as a national leader, which could drive decades of future economic growth for the area once products reach mass deployment.

In the face of an emerging competitive landscape seeking to capitalize on the next phase of autonomous systems industry growth, the stakes are high for Pittsburgh's current industry base and the significant economic output it provides currently and promises for

the future. To illustrate the value the industry provides to the Pittsburgh region today, TEConomy analyzed the economic impact of 71 local firms (or in cases of major multinational corporations, divisions, or operating units of those firms) that were identified as having core business operations that primarily served the autonomous systems industry. **The estimated direct employment footprint of Pittsburgh's autonomous systems firms totals over 6,300 jobs which provide an estimated $651 million in labor income, $34.7 million in state and local tax revenues, and $126.7 million in federal tax revenues. These companies generated a further 8,604 full or part time jobs through indirect and induced effects to support a total of 14,923 jobs in the region.**

The total employment impacts described above are being generated by an industry sector that is still maturing and largely in pre-revenue stages for many of Pittsburgh's companies, including large employers in the autonomous vehicles space. The potential impact for the region as the industry continues to grow could scale exponentially in the coming decades, but only if Pittsburgh can continue to generate innovative companies advancing autonomous systems solutions, retain large industry employers and act as a site for their expanding testing operations, and provide an advantageous location for autonomous systems companies to grow their employment in manufacturing, business support, and other administrative and service functions as they expand in the course of products reaching widespread deployment.

To illustrate this point, consider just the market segment focused on autonomous vehicles. A 2019 study by the Boston Consulting Group and the Detroit Mobility Lab[2] estimates that the smart mobility market will generate 85,000 new U.S. jobs in autonomous vehicles and 7,000 U.S. jobs in smart-road infrastructure by 2028 across engineering, computer-related, and skilled trades occupations. **If the Pittsburgh region maintains its current market share and innovation ecosystem but does not take significant action to improve its competitive position it may be able to continue to grow organically but is not likely to attract a significant share of these new jobs that can accelerate the growth of the cluster beyond its current R&D-focused employment footprint. In the face of competition from other states for these new jobs, the majority of which do not require proximity to universities and labs to perform operations and support services-oriented functions within the AV industry, there is no guarantee that Pittsburgh will be the primary destination for ongoing growth as AV companies seek to find attractive environments to site their new business functions. As the BCG and Detroit Mobility Lab study notes:**

> *"If they are serious about creating or expanding as mobility hubs to boost the local economy, cities and states must be willing to become the main orchestrators of the environments they want to create. They must collaborate with academic institutions to support educational and training programs. They must be open to working with companies that are looking for incentives, such as tax breaks, to move into the area, and help companies navigate regulations governing testing, safety, certifications, and AV operations. They should also clear the way for the creation of testing grounds where car companies can try out new vehicles. Finally, they must offer the social, cultural, and recreational amenities that prospective students and people with in-demand skills want in the area where they work and live."*

These conclusions are equally applicable across the various sectors of the broader mobile autonomous systems sector and highlight the return on investment that proactive regions can expect to realize if they commit to supporting the growth of this industry.

2 "The US Mobility Industry's Great Talent Hunt", *Boston Consulting Group and Detroit Mobility Lab*, 2019

Realizing the Vision:
A Strategic Plan for Growing Pittsburgh's Autonomous Systems Industry

Pittsburgh's regional position in autonomous mobile systems can be significantly strengthened by taking bold action to invest in the opportunities presented by this cluster. Multiple strategies and actions must be implemented in a coordinated, high-commitment effort to build and sustain the complete ecosystem needed to secure Pittsburgh's leadership position and stay ahead of the competition. Actions are needed to rapidly evolve the opportunity from being predominantly R&D focused, to a diverse, full-range industry cluster that spans development of innovative new technologies all the way through the commercialization cycle of manufacturing, distribution, and service of high value products and services.

TEConomy has proposed a strategic plan that comprises six strategies and an associated set of 16 actions purpose-designed to optimize the regional ecosystem for autonomous mobile systems and catalyze substantial economic growth. The strategic plan has been developed based on multiple avenues of analysis and input received across the project from a wide set of public and private stakeholders. While it is prescriptive and actionable, it is also structured to have flexibility in terms of being adaptable and evolvable given that the trajectory and growth curve of various sectors, particularly in terms of timing of market acceptance and regulatory approvals is as yet indeterminate and subject to change. Because this is anticipated to be a fast-moving opportunity, the strategy is intended for implementation over a two- to three-year timescale (with recognition that some actions, such as expanding graduate output, are inherently more long-term in their realization).

The recommended strategies are shown on Figure ES7, indicating the crosscutting nature of advancing state support, and the general classification of each strategy by theme. The recommended actions associated with each strategy are summarized on Figure ES8. Detailed descriptions of each strategy and action are provided in Section IV of the full report.

FIGURE ES7.
Strategies for Growing Pittsburgh's Autonomous Mobile Systems Industry

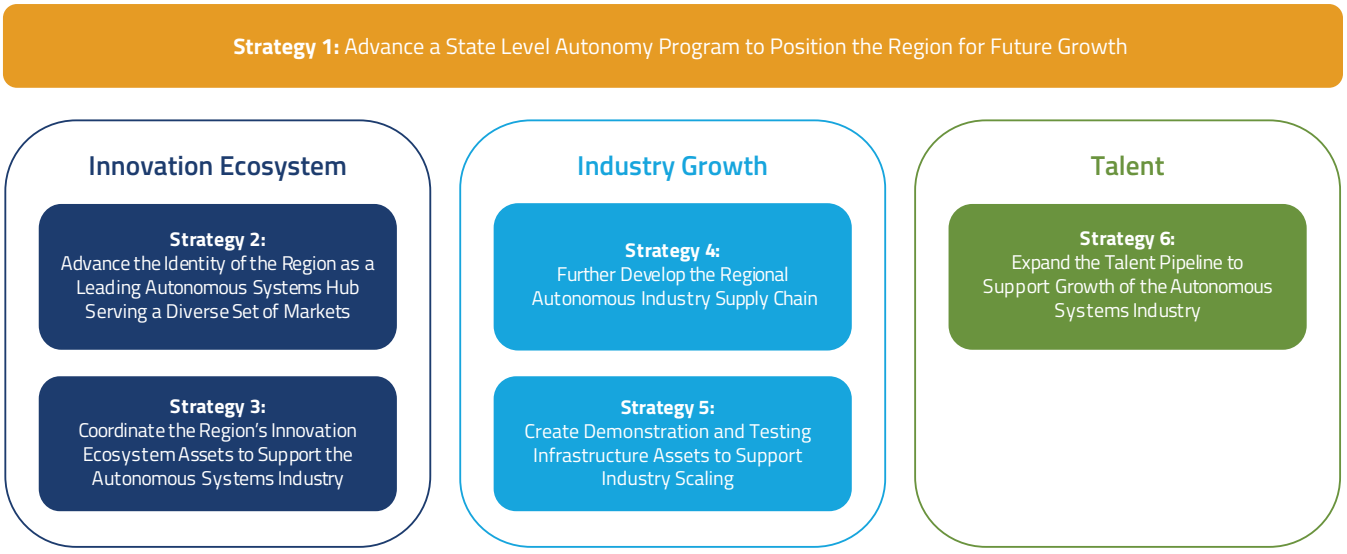


FIGURE ES8.
Recommended Actions Associated with Strategies for Growing Pittsburgh's Autonomous Mobile Systems Industry

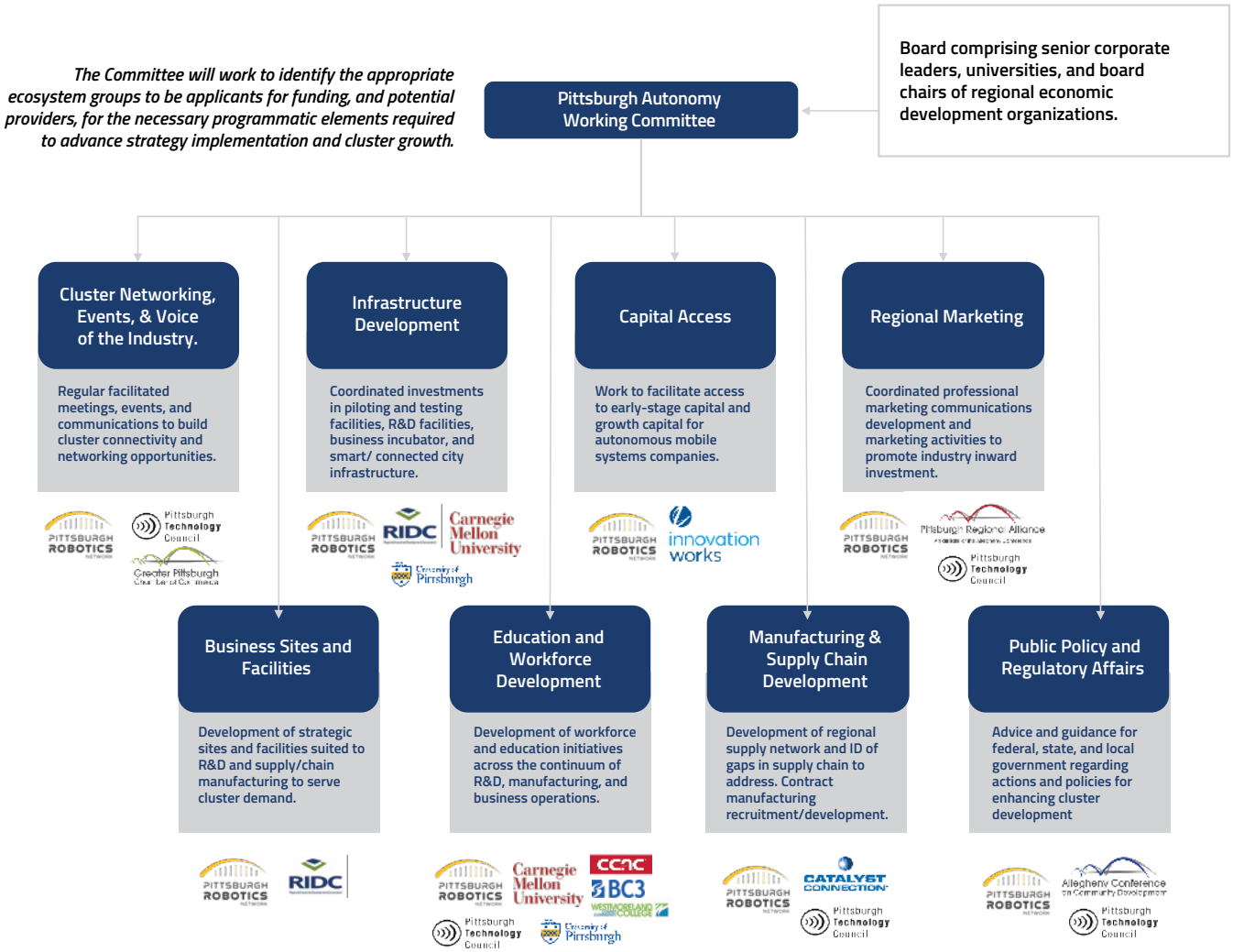
Strategy 1: Advance a State Level Autonomy Program to Position the Region for Future Growth	**Action 1.1:** Develop and advance a framework for a signature state initiative in autonomy **Action 1.2:** Take a proactive stance in developing forward-thinking regulatory guidance for policymakers **Action 1.3:** Advance public-private smart infrastructure projects that support autonomous systems deployment
Strategy 2: Advance the Identity of the Region as a Leading Autonomous Systems Hub Serving a Diverse Set of Markets	**Action 2.1:** Develop a branding and marketing initiative that can increase both external and internal public awareness **Action 2.2:** Develop a business attraction initiative targeting scaling and mid-size companies in the technology stack **Action 2.3:** Attract several leading trade shows, conferences, and other high-profile showcase events
Strategy 3: Coordinate the Region's Innovation Ecosystem Assets to Support the Autonomous Systems Industry	**Action 3.1:** Support a dedicated organization that can be the nexus for regional innovation and cluster development activity in autonomous systems **Action 3.2**: Address risk capital stack gaps **Action 3.3**: Enhance regional support mechanisms for autonomy industry entrepreneurs
Strategy 4: Further Develop the Regional Autonomous Industry Supply Chain	**Action 4.1:** Build out a contract manufacturing and regional supply chain consortium **Action 4.2:** Identify shared, noncompetitive, technology areas for collaborative industry projects and attraction of supply base
Strategy 5: Create Demonstration and Testing Infrastructure Assets to Support Industry Scaling	**Action 5.1:** Explore the potential for shared testing and demonstration projects that can serve as industry assets **Action 5.2:** Implement a set of ongoing, public-facing autonomous systems demonstration projects
Strategy 6: Expand the Talent Pipeline to Support Growth of the Autonomous Systems Industry	**Action 6.1**: Expand the talent pipeline through coordination across regional institutions **Action 6.2:** Address current gaps in the region's autonomy industry talent base

The Pittsburgh region benefits from having a broad range of experienced economic development-focused organizations that provide quite robust coverage of key innovation- and technology-based economic development services. Some of these services are specific, or have elements tailored to, the robotics and autonomous systems sectors, while others are more cross-cutting, available to service companies in most innovation sectors. The one organization that is 100% focused on the robotics and autonomous systems space is Pittsburgh Robotics Network (PRN), which is a relatively new and growing industry-led organization representing the sector.

Advancing the full strategic plan outlined herein will require significant governance oversight, since implementation will require the management and allocation of large-scale funds. With substantial funding likely to be sought from public entities, including the Commonwealth of Pennsylvania and the U.S. Federal Government (through EDA, DOT programs, etc.), together with philanthropic donations, there is a need to establish an oversight organization with the appropriate IRS designation and fiduciary protections required for the management, regulatory reporting, and disbursement of programmatic funding. As a placeholder name for the proposed organization, this document uses the "Pittsburgh Autonomy Working Committee" as a temporary descriptor. The Pittsburgh Autonomy Working Committee" is recommended not as a service provider nor a trade association, but rather the keepers of the cluster development strategy and evaluation arm that governs the expenditure of funds and their impacts.

The Working Committee may be organized with a fiscal agent and operate as an initiative rather than a staffed organization. As envisioned the Working Committee will be managed by a high level board comprising Presidents or CEO's of regional autonomous mobile systems companies, leadership of research universities, and the board chairs of primary ecosystem non-profit economic development organizations. The Working Committee would be responsible for supervising the implementation of the strategy and will seek proposals from ecosystem organizations to provide services in key functional aspects of strategy and action implementation. Figure ES9 shows this conceptual structure, the key categories of ecosystem functions needing to be addressed, and key examples of organizations that would likely be applicants and potential providers for the necessary programmatic elements.

FIGURE ES9.
Potential Leadership for Strategy Implementation and Ecosystem Organizations to Engage



Autonomous mobile systems will represent a fast emerging $1 trillion global industry opportunity by 2025/26, and Pittsburgh's robust core competencies positions it well to be a major participant in this transformational economic opportunity. Realizing this full potential, however, requires addressing some of the shortfalls and gaps in the regional ecosystem, coordinating strategies and actions designed to optimize the regional autonomy environment and supporting ecosystem for competitive success. Addressing these needs requires investment of both dollars and human capital across the multiple strategies and actions outlined herein.

To place some bounds around the likely level of investments needed, an initial budget estimation has been prepared covering each of the strategies and actions (Table ES1). In total, it is estimated that full strategy and action plan implementation will require approximately $154 million, with the Commonwealth of Pennsylvania funding 36.4% ($56 million), the Federal Government 13% ($20 million), and regional or local resources funding 50.6% ($78 million). The resources required to implement these strategies will build on the billions in corporate and institutional research investments that have already been made in Pittsburgh region.

TABLE ES1.
Anticipated Funding Requirements for Strategy Implementation[3]

Strategies	Commonwealth Funding	Federal Funding	Regional Funding	Notes
Strategy 1: Advance a State Level Autonomy Program to Position the Region for Future Growth	$53,250,000	$17,500,000	$24,750,000	Includes investment in test and demonstration infrastructure, business incubator, geofenced demonstration corridors, smart city infrastructure, incentives for attracting contract manufacturing, and operational support funding for PRN.
Strategy 2: Advance the Identity of the Region as a Leading Autonomous Systems Hub Serving a Diverse Set of Markets	$0	$0	$800,000	Includes development of branding and marketing initiative and collateral materials, business attraction activities, and attraction of cluster focused conferences/events.
Strategy 3: Coordinate the Region's Innovation Ecosystem Assets to Support the Autonomous Systems Industry	$0	$0	$50,250,000	Includes $50 million venture capital fund and grant funding support for entrepreneurship programs.
Strategy 4: Further Develop the Regional Autonomous Industry Supply Chain	$1,000,000	$1,000,000	$500,000	Major $'s required for this strategy are captured under Strategy 1. Includes building regional supply network, attraction of contract manufacturing, and ID of shared development initiatives.
Strategy 5: Create Demonstration and Testing Infrastructure Assets to Support Industry Scaling	$1,000,000	$1,000,000	$1,000,000	Major $'s required for this strategy are captured under Strategy 1. Implementing a set of ongoing, public-facing autonomous systems demonstration projects.
Strategy 6: Expand the Talent Pipeline to Support Growth of the Autonomous Systems Industry	$750,000	$500,000	$1,000,000	Coordination of workforce and education initiatives across the continuum of R&D, manufacturing, and business operations.
	State $56,000,000	**Federal $20,000,000**	**Regional/Local $78,300,000**	**Combined Total $154,300,000**

The recommended additional strategic investment profiled on Table ES-1 will have a compounding effect on the deep investments already made or committed within the sector by leading regional organizations, philanthropies, universities, companies, and investors. It will be central in enabling the next level of growth in the cluster to occur, whereby R&D innovations will further translate into on-the-ground manufactured technologies and innovative business growth. The autonomous mobile systems and robotics ecosystem in the Pittsburgh region has experienced intensive recent investment in research and development infrastructure – with

3 Further detail on funding estimates is provided in Chapter IV. Numbers are approximations based on costings of similar programs and initiatives nationally and budgets of example initiatives working in cluster based program advancements in other states and regions.

particularly robust investment taking place in R&D at Carnegie Mellon University, investment that, importantly, demonstrates a focus on applied research and engagement with industry. Table ES-2 summarizes recent signature investments relevant to the sector in the Pittsburgh region, showing **investment exceeding $522 million.** The strategies and actions outlined in this report are designed to build upon these existing investments, with additional public-private investments that strategically reinforce the ecosystem so that it may realize the full commercial promise of a fast growing, transformational industry sector.

TABLE ES-2.
Recent Investments of Relevance to the Expansion of the Pittsburgh Autonomous Mobile Systems Ecosystem

Investment	Estimated Amount	Notes
Advanced Robotics for Manufacturing (ARM) Institute	$250 million	ARM funded by the Department of Defense and catalyzed by Carnegie Mellon. Both ARM and MFI (Manufacturing Futures Initiative at Mill 19), an interdisciplinary research initiative, were launched with the help of a $20 million gift from the Richard King Mellon Foundation, which provided significant support for research and the new Mill 19 facility.
RK Mellon Grant to Carnegie Mellon University	$150 million	$75 million for new science building on the Carnegie Mellon campus in Oakland, and $75 million for the robotics innovation center and an institute focused on advanced materials and manufacturing at Hazelwood Green.
Corporate Test Track Investments	>$50M	Over $50M in private investment commitment focused on testing facilities, tracks, and associated infrastructure.
Carnegie Mellon University U.S. DoT University Transportation Center	>$32 million	Since 2012 the US Department of Transportation has provided over $32 million in funding to the Technologies for Safe and Efficient Transportation (T-SET) and Mobility21 University Transportation Centers at Carnegie Mellon University. These centers focus on research, education and technology transfer of intelligent transportation systems, including automated vehicles, and utilize the Pittsburgh region as a real-world test bed. The centers have been directed by Professor Raj Rajkumar, who is recognized leader in connected and automated vehicle research, and have spun off four transportation technology companies in Pittsburgh.
Carnegie Mellon University-CCDC Army Research Laboratory Cooperative Agreement	$25 million	Carnegie Mellon University and the U.S. Army Combat Capabilities Development Command's (CCDC) Army Research Laboratory (ARL) have entered into a $3.5 million cooperative agreement that supports machine learning-enabled additive manufacturing to enhance the expeditionary manufacturing capability of the Army. The funding marks the beginning of a five-year program, led by CMU's College of Engineering, with the Army awarding up to four years and totaling as much as $25 million.
Argo AI Center for Autonomous Vehicle Research at Carnegie Mellon University	$15 million	A five-year, $15 million sponsored research partnership funding research into advanced perception and next-generation decision-making algorithms for autonomous vehicles.
US DOT Grant to HERL at the University of Pittsburgh	$1M	U.S. Department of Transportation awarded $1 million to the Human Engineering Research Laboratories (HERL) at the University of Pittsburgh, for a study of how automated vehicles can help people with disabilities.
RK Mellon Job Training & Career Readiness Grants	$250,000 + $125,000	Advanced Robotics for Manufacturing Institute - $250,000 for the Keystone Space Collaborative. And, StartUptown - $125,000 to support the Pittsburgh Robotics Network's work to build a robotics industry cluster network of highly engaged stakeholders to fosters business growth and talent development.
RK Mellon Grant to Pittsburgh Robotics Network	$125,000	June 2021 grant of $125,000 to support the continued growth of the Pittsburgh Robotics Network.
Total	**$523.5 million**	

Conclusion

An opportunity of this magnitude – an opportunity to lead in a fast growth technology sector and advanced industry – presents itself very rarely, and it has the potential to advance the region and state's economic development for decades to come. Public and private sector stakeholders in the region and the Commonwealth of Pennsylvania must act and invest with urgency and purpose to capture the full potential represented by this dynamic sector for transformative economic growth.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