FROST & SULLIVAN

BEST PRACTICES AWARDS

SiLC

2020 NORTH AMERICAN 3D/4D LIDAR IMAGING TECHNOLOGY INNOVATION LEADERSHIP AWARD

Contents

Background and Company Performance

Industry Challenges

Time-of-flight (ToF) pulsed light detection and ranging radar (LiDAR), which is a remote, optical sensing technology, uses laser pulses to illuminate the target object and a photodetector to measure the return time of the laser pulse back to the detector. The data received from the laser pulse provides a high-resolution, detailed picture of the object's surroundings. The reflection of the laser light from the target is detected and analyzed by a receiver/detector that calculates the range or distance between the sensor and target objects, including position, shape, height, and width.

With the proliferation of Internet of Things (IoT) devices and ecosystems, environment scanning is becoming an integral part of key industries, such as automotive and industrial, to provide real-time information about a machine's surroundings. Currently available image scanning technologies include cameras with complementary metal oxide semiconductor (CMOS) image sensors, radar sensors, and LiDAR sensors for obtaining 3D images. The following are key limitations of these image scanning systems:

Cameras: Conventional cameras have poor contrast because of varying lighting conditions and specular reflections. The glaring light effect makes the camera sensor blind, causing the inability to determine the depth information of the surrounding objects. Moreover, stereo cameras for 3D sensing can have poor resolution (a large depth error), making them unfeasible for precise object tracking and recognition.

Radar: Radar systems can successfully detect moving objects and relative speed; however, Doppler radar, which transmits and detects a change in frequency caused by a moving object, has difficulty detecting stationary objects. The radar output data lacks the resolution of LiDAR, and the technology cannot offer accurate information about unmapped objects in high-density environments.

LiDAR: Most LiDAR companies are developing pulsed ToF-based LiDAR sensors that generate highly controlled laser pulses for detecting surrounding objects in automotive applications. ToF-based LiDAR sensors can successfully operate at night, but during the bright daytime, photons from the sun or other vehicles can interfere with the transmitted signal, causing noise in the received signal. With this solar irradiance interference, LiDAR systems are prone to crosstalk and can become compromised by receiving pulses from several ToF-based LiDAR systems operating nearby. To overcome these issues, ToF-based LiDAR manufacturers are implementing programming techniques by slicing the transmitted signal into several pulses; however, this slicing method causes a drop in the detection range performance.

Currently available ToF-based LiDAR sensors typically operate at 905 nanometers (nm), which could potentially be harmful to human eyes. Moreover, these solutions require high-speed electronics to measure ToF precisely from the target and cannot adequately measure the velocity of the detected object. In addition, frequency modulated continuous wave (FMCW)-based LiDAR can address the crosstalk and background radiation issues and can provide instantaneous velocity of the targeted objects; however, the cost and

complexity of traditional solutions prevent the broad deployment of FMCW-based LiDAR. For this key reason, automotive manufacturers are restricted from commercializing Level 2+ vehicles to Level 3 and Level 4 vehicles and ultimately to L5 completely autonomous vehicles. Companies in this space need to develop compact, cost-effective, eye-safe, and accurate LiDAR solutions to overcome these challenges and secure a leadership position in this industry.

Technology Leverage and Business Impact

Commitment to Innovation

Founded in 2018, California-based SiLC Technologies has developed a highly integrated 4D+ Smart Vision chip based on the coherent FMCW-based LiDAR principle, which overcomes the aforementioned industry challenges and detects surrounding objects with high accuracy and precision. The key obstacle in materializing an FMCW solution has been the low-cost, high-volume manufacturing of the required high-performance components. SiLC Technologies has developed a technology that allows the integration of complex and expensive optical components into a silicon chip platform that leverages high-volume semiconductor manufacturing techniques. SiLC Technologies' Smart Vision chip operates at a 1550-nm wavelength and has the potential to replace existing ToF-based LiDAR sensors used in specific applications, such as automotive advanced driver assistance systems (ADAS) and self-driving autonomous vehicles, augmented reality, security, and industrial machine vision.

Unlike competing imaging solutions that use image sensors with extra subsystems to map the surrounding environment and that are unsuitable for outdoor applications for converting photons to electrons to generate a 2D image, SiLC Technologies' powerful Smart Vision technology is a compact, low-power solution that achieves a long range of more than 300 meters. This functionality is achieved by integrating all optical components, such as coherent light source, optical signal processing, and germanium detectors, on a silicon chip using mature semiconductor fabrication processes that are used for manufacturing electronic integrated circuits. In addition, the Smart Vision technology enables the capture of additional information, such as object depth and velocity (effectively providing a 4D image of the object) present in the surrounding environment, thereby improving accuracy by the order of magnitude by leveraging a coherent method.

SiLC Technologies' Smart Vision is expected to disrupt the global LiDAR market in the next three to five years by providing in-depth, detailed information about objects in many user environments. Moreover, relative to other advanced technologies that result in high component and assembly costs, Smart Vision is cost competitive and offers low noise, low loss and polarization, and high-resolution image capturing capability for long-range objects, making SiLC Technologies' solution suitable for applications across multiple industries that increasingly depend on top-notch image data.

SiLC Technologies has a deep, clear understanding of key current and future needs in the market for improving the ability of LiDAR systems to make them eye-safe and to capture long-range, high-resolution 3D and 4D images, where objects may be in a static or

dynamic state of motion. SiLC Technologies has implemented an innovative, coherent sensing approach for improving the capture of the environment in 3D and 4D formats, which is a vital requirement for enhanced autonomous object detection and environmental awareness in key applications, including automotive, robotics, and unmanned aerial vehicles, that perform self-automated tasks. Essentially, SiLC Technologies' game-changing design strategy of utilizing a single silicon photonic chip to provide a 3D imaging solution empowers developers to attain high-quality 4D mapping and, at the same time, significantly reduce development costs incurred for building camera systems.

Commitment to Creativity

SiLC Technologies' commitment to creativity is manifested in its problem-solving approach and organizational activities. To overcome the prevalent ToF-based LiDAR issues with eye safety and range detection, the company has honed its technology expertise by taking inspiration from silicon photonic developments and experiments, where several trials have been conducted to determine the 3D and 4D image of detected objects. Based on the Smart Vision technology, the company has developed a 4D+ vision sensor chip that enables a range-extended, eye-safe integrated LiDAR sensor (see Figure 1). SiLC Technologies leverages existing detector technologies (e.g., a PIN germanium photodiode) and other electronics subsystems to reduce costs and encourage companies to integrate its higher-performance SiLC Vision Sensor with the latest CMOS image sensors to develop 4D+ cameras.

Figure 1: 4D+ Vision Sensor Chip

Source: SiLC Technologies

The introduction of this SiLC FMCW-based 4D+ LiDAR reduces component and assembly costs. In particular, the 4D+ Vision sensor chip can provide new capabilities to 4D imaging at a fraction of the cost, compared to competing solutions, and has a key opportunity to disrupt and replace incumbent technologies in the next three to five years. SiLC Technologies combines hardware and software to capture 4D data in real time; therefore, 4D camera products developed using SiLC Technologies' proprietary technology offer several advantages, such as longer range (greater than 300 meters), high reliability, and the precise deciphering of target objects under any weather condition.

Application Diversity

SiLC Technologies' FMCW-based LiDAR technology will find wide adoption across a range of applications, especially for extracting information from fast-changing, dynamic scenes, such as high-speed recognition and in tracking both immobile and fast-moving objects, while providing enhanced vision to regulate tasks optimally. The technology is expected to have a high impact in the automotive, gaming, security, unmanned vehicle, industrial, and robotics markets.

Application areas include the following:

Automotive: With the increased adoption of driver aids in automobiles, SiLC Technologies' FMCW-based LiDAR technology will be in demand because of its high resolution, long-range object scanning and detection, and immunity to interfering sources of light. The technology will be useful for ADAS applications and will support autonomous driving in level 3 passenger vehicles and those with even higher levels of autonomy.

Gaming and entertainment: The technology can be used to develop augmented reality (AR) and virtual reality (VR) headsets that offer immersive gaming experiences.

***Security and surveillance*:** Biometric applications, such as facial and fingerprint recognition for personal identification, will find the technology highly impactful in terms of providing increased accuracy and eliminating unauthorized access by intruders.

***Industrial Machine Vision*:** With the proliferation of Industry 4.0, applications such as drones; vision-guided robots for object detection, asset tracking, and parts delivery; and collaborative robots (cobots) that can work safely around human workers have been gaining large-scale attention. The technology is expected to be highly adopted in cobots that are used for material handling, warehousing, and logistics and that require improved environmental perception and object detection. SiLC Technologies' FMCW-based LiDAR technology can be leveraged to capture 3D data from the environment to enable smarter decision making in these industrial environments.

SiLC Technologies' solution is differentiated from other commercially available 3D image scanning technologies because it uses a 1550-nm, FMCW-based LiDAR-on-a-chip solution that provides lower peak pulse power than ToF LiDAR; is immune to ambient light and interference (crosstalk); enables improved range and resolution; and allows an optimal trade-off between range and precision in a more affordable solution. Moreover, the company's technology enables the integration of complex optical electronic circuits into a small silicon chip for building portable consumer products and reducing integration and manufacturing costs.

Frost & Sullivan has identified SiLC Technologies' versatile approach to identifying diverse application fields that will specifically benefit from its technology as a viable strategy for gaining a competitive market advantage.

Customer Acquisition

SiLC Technologies builds its customer base by partnering with customers to obtain valuable feedback, which is used to determine and implement the correct and desired

specifications for current and future products. Frost & Sullivan finds that SiLC Technologies has constructed an effective means of gaining an increasing number of customers by fully understanding their pain points, including the traditionally high component and assembly costs of LiDAR and the challenges in conventional LiDAR to image the environment accurately under different atmospheric or lighting conditions, particularly in the automotive industry.

SiLC Technologies is well connected in the automotive and consumer electronics sectors and is gaining considerable traction with automotive customers by demonstrating its LiDAR solutions to original equipment manufacturers (OEMs) and Tier I suppliers to pave the way to mass produce its FMCW-based LiDAR products. Established in May 2018, SiLC Technologies raised a total of $12 million in seed funding in March 2020 from investors and venture capitalists, including Dell Technologies Capital, Decent Capital, ITIC Ventures, and undisclosed angel investors. The company intends to utilize this funding to continue refining its 4D+ Vision Chip LiDAR sensor technology and implement product enhancements. In addition, the company participates in various technical events, such as the Consumer Electronics Show (CES), and workshops to showcase its product worldwide. For instance, at the CES 2020 event, SiLC Technologies partnered with Varroc Lighting Systems, a leading global supplier of innovative exterior vehicle lighting systems and electronics, to demonstrate the integration of its LiDAR solution into a headlight used in production vehicles (see Figure 2).

Figure 2: 4D+ Vision Sensor Chip Integrated in the Vehicle's Headlight

Source: SiLC Technologies

Frost & Sullivan finds that SiLC Technologies' focused technology development, which offers a reduced cost in mass production, is a major factor in attracting more customers. The combined strength of the technology's attributes and its wide applicability, including in robotics, AR/VR, and biometric scanning, enables SiLC Technologies to impact the LiDAR market significantly and capture an impressive market share.

Growth Potential

Even though SiLC Technologies is a young company, it has shown strong growth, largely attributed to its entry into the LiDAR market at a relatively emerging and opportunistic stage of the technology. Interest in the field of FMCW-based LiDAR has increased because of the company's ability to provide both range and velocity information, higher range and

resolution, and immunity to interference. This technology in chip-based form allows SiLC Technologies to sustain its revenue growth and drive customer acquisition. Frost & Sullivan projects that the global market for CMOS image sensors will approach about $30 billion over the next few years, positioning SiLC Technologies, with its recent release of high-performance 4D+ Vision Chip, to achieve optimum growth in the near future.

Customers in developing markets are increasingly focused on providing fully automated product solutions; therefore, SiLC Technologies is in a good position for growth as well because it is focused on high-volume production and on developing and commercializing robust, cost-effective, and high-quality products. Additionally, SiLC Technologies' strong brand presence, innovative business model, and continuous delivery of high-quality LiDAR solutions ensure its credibility for investors, developers, and end customers, signifying the company's bright future growth potential.

Frost & Sullivan research shows that SiLC Technologies is well positioned to meet the current market needs and cater to future market trends, boding well for the company's solid growth potential.

Human Capital

Compared to conventional scanning technologies, LiDAR is more complicated and requires technical expertise from different disciplines. SiLC Technologies effectively maintains successful relationships with its investors, customers, and experts by providing dedicated support engineers. The company's employees have extensive professional and technical expertise in semiconductor engineering and optical sensors, where top management executives, including veterans from Mellanox Technologies, Kotura, and Texas Instruments, bring more than 25 years of combined experience in the commercialization of silicon photonics-based products. This leadership expertise positions the company to develop new technology innovation for next-generation LiDAR solutions. The company's skilled technologists have enabled key patents to be filed related to LiDAR data generation, optical sensor systems, and optical switching for tuning LiDAR output signal direction.

Frost & Sullivan research concludes that SiLC Technologies' patent-protected technology, in addition to its well-established contacts with OEMs, provides it with a vast growth opportunity to build a global footprint over the long term. As a pioneering market participant, the company's positioning and marketing strategy for its production-scalable technology will allow it to capture significant market share in the coming years.

Conclusion

With the growing demand for LiDAR solutions across emerging applications and industry trends, such as autonomous vehicles and Industry 4.0, SiLC Technologies is poised to emerge as a forerunner in the FMCW-based LiDAR solutions space because of its production-scalable technology that does not require the filtering of unwanted background light. SiLC Technologies' patented Smart Vision technology is positioned to meet the requirements of camera and automotive manufacturers that offer 3D and 4D images in high resolution and at a wide range of speeds. Frost & Sullivan research shows that SiLC

Technologies' agile leadership team and well-established industry connections with Tier I suppliers and OEMs position the company to establish strategic collaborations and acquire significant market share in the future. Moreover, Frost & Sullivan recognizes SiLC Technologies' Smart Vision sensor as a complete end-to-end LiDAR solution that can serve the demands of the autonomous vehicle market in the coming years. This innovative and energetic company is poised to transform the capabilities of imaging technology as nearly every industry moves into the age of IoT and requires volumes of high-quality visual data.

For its strong overall performance, SiLC Technologies has earned Frost & Sullivan's 2020 Technology Innovation Leadership Award in the North American 3D/4D LiDAR Imaging industry.

Significance of Technology Innovation Leadership

Technology-rich companies with strong commercialization strategies benefit from the demand for high-quality, technologically innovative products that help shape the brand, resulting in a strong, differentiated market position.

Understanding Technology Innovation Leadership

Technology innovation leadership recognizes companies that lead the development and successful introduction of high-tech solutions to customers' most pressing needs, altering the industry or business landscape in the process. These companies shape the future of technology and its uses. Ultimately, success is measured by the degree to which a technology is leveraged and the impact it has on growing the business.

Key Benchmarking Criteria

For the Technology Innovation Leadership Award, Frost & Sullivan analysts independently evaluated 2 key factors—Technology Leverage and Business Impact—according to the criteria identified below.

Technology Leverage

Criterion 1: Commitment to Innovation
Criterion 2: Commitment to Creativity
Criterion 3: Technology Incubation
Criterion 4: Commercialization Success
Criterion 5: Application Diversity

Business Impact

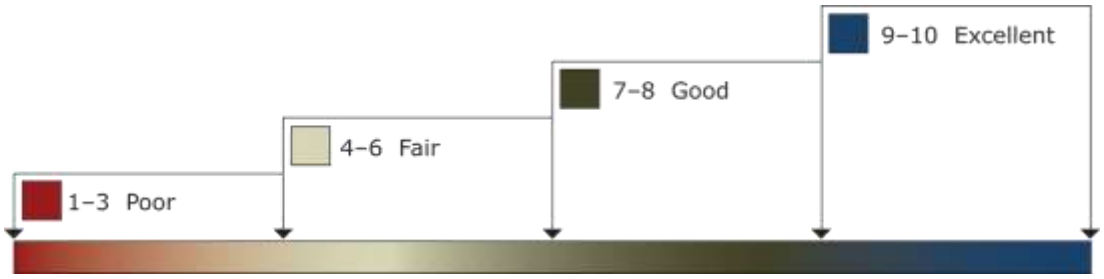
Criterion 1: Financial Performance
Criterion 2: Customer Acquisition
Criterion 3: Operational Efficiency
Criterion 4: Growth Potential
Criterion 5: Human Capital

Best Practices Award Analysis for SiLC Technologies

Decision Support Scorecard

To support its evaluation of best practices across multiple business performance categories, Frost & Sullivan employs a customized Decision Support Scorecard. This tool allows research and consulting teams to objectively analyze performance according to the key benchmarking criteria listed in the previous section, and to assign ratings on that basis. The tool follows a 10-point scale that allows for nuances in performance evaluation. Ratings guidelines are illustrated below.

RATINGS GUIDELINES



The Decision Support Scorecard considers Technology Leverage and Business Impact (i.e., the overarching categories for all 10 benchmarking criteria; the definitions for each criterion are provided beneath the scorecard). The research team confirms the veracity of this weighted scorecard through sensitivity analysis, which confirms that small changes to the ratings for a specific criterion do not lead to a significant change in the overall relative rankings of the companies.

The results of this analysis are shown below. To remain unbiased and to protect the interests of all organizations reviewed, Frost & Sullivan has chosen to refer to the other key participants as Competitor 1 and Competitor 2.

Measurement of 1–10 (1 = poor; 10 = excellent)			
Technology Innovation Leadership	Technology Leverage	Business Impact	**Average Rating**
SiLC Technologies	**9**	**9**	**9.00**
Competitor 1	8	8	8.00
Competitor 2	8	7	7.50

Technology Leverage

Criterion 1: Commitment to Innovation

Requirement: Conscious, ongoing development of an organization's culture that supports the pursuit of groundbreaking ideas through the leverage of technology.

Criterion 2: Commitment to Creativity

Requirement: Employees rewarded for pushing the limits of form and function by integrating the latest technologies to enhance products.

Criterion 3: Technology Incubation

Requirement: A structured process with adequate investment to incubate new technologies developed internally or through strategic partnerships.

Criterion 4: Commercialization Success

Requirement: A proven track record of commercializing new technologies by enabling new products and/or through licensing strategies.

Criterion 5: Application Diversity

Requirement: The development of technologies that serve multiple products, multiple applications, and multiple user environments.

Business Impact

Criterion 1: Financial Performance

Requirement: Overall financial performance is strong in terms of revenue, revenue growth, operating margin, and other key financial metrics.

Criterion 2: Customer Acquisition

Requirement: Overall technology strength enables acquisition of new customers, even as it enhances retention of current customers.

Criterion 3: Operational Efficiency

Requirement: Staff is able to perform assigned tasks productively, quickly, and to a high quality standard.

Criterion 4: Growth Potential

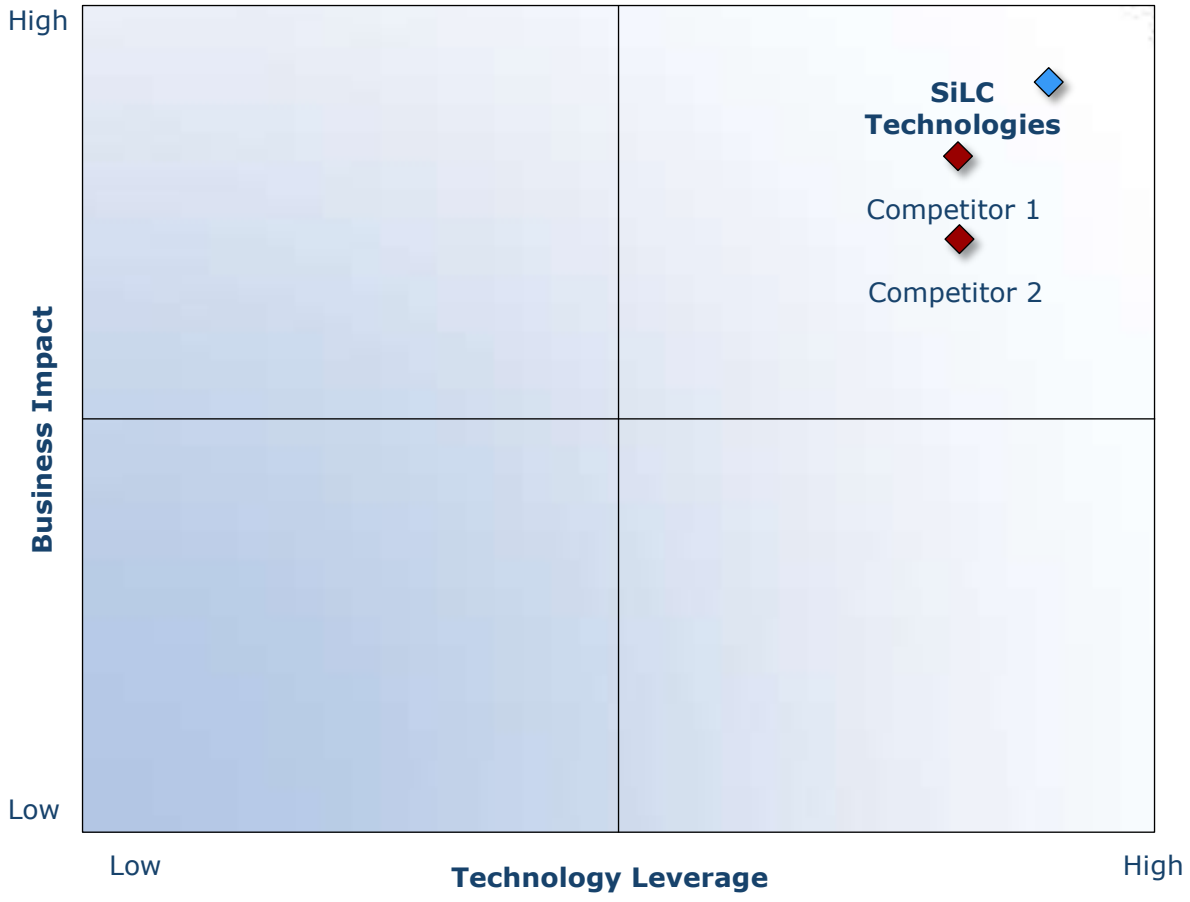
Requirements: Technology focus strengthens brand, reinforces customer loyalty, and enhances growth potential.

Criterion 5: Human Capital

Requirement: Company culture is characterized by a strong commitment to customer impact through technology leverage, which enhances employee morale and retention.

Decision Support Matrix

Once all companies have been evaluated according to the Decision Support Scorecard, analysts then position the candidates on the matrix shown below, enabling them to visualize which companies are truly breakthrough and which ones are not yet operating at best-in-class levels.



Best Practices Recognition: 10 Steps to Researching, Identifying, and Recognizing Best Practices

Frost & Sullivan analysts follow a 10-step process to evaluate award candidates and assess their fit with select best practices criteria. The reputation and integrity of the awards are based on close adherence to this process.

STEP		OBJECTIVE	KEY ACTIVITIES	OUTPUT
1	**Monitor, target, and screen**	Identify award recipient candidates from around the world	• Conduct in-depth industry research • Identify emerging industries • Scan multiple regions	Pipeline of candidates that potentially meet all best practices criteria
2	**Perform 360-degree research**	Perform comprehensive, 360-degree research on all candidates in the pipeline	• Interview thought leaders and industry practitioners • Assess candidates' fit with best practices criteria • Rank all candidates	Matrix positioning of all candidates' performance relative to one another
3	**Invite thought leadership in best practices**	Perform in-depth examination of all candidates	• Confirm best practices criteria • Examine eligibility of all candidates • Identify any information gaps	Detailed profiles of all ranked candidates
4	**Initiate research director review**	Conduct an unbiased evaluation of all candidate profiles	• Brainstorm ranking options • Invite multiple perspectives on candidates' performance • Update candidate profiles	Final prioritization of all eligible candidates and companion best practices positioning paper
5	**Assemble panel of industry experts**	Present findings to an expert panel of industry thought leaders	• Share findings • Strengthen cases for candidate eligibility • Prioritize candidates	Refined list of prioritized award candidates
6	**Conduct global industry review**	Build consensus on award candidates' eligibility	• Hold global team meeting to review all candidates • Pressure-test fit with criteria • Confirm inclusion of all eligible candidates	Final list of eligible award candidates, representing success stories worldwide
7	**Perform quality check**	Develop official award consideration materials	• Perform final performance benchmarking activities • Write nominations • Perform quality review	High-quality, accurate, and creative presentation of nominees' successes
8	**Reconnect with panel of industry experts**	Finalize the selection of the best practices award recipient	• Review analysis with panel • Build consensus • Select recipient	Decision on which company performs best against all best practices criteria
9	**Communicate recognition**	Inform award recipient of recognition	• Inspire the organization for continued success • Celebrate the recipient's performance	Announcement of award and plan for how recipient can use the award to enhance the brand
10	**Take strategic action**	Upon licensing, company is able to share award news with stakeholders and customers	• Coordinate media outreach • Design a marketing plan • Assess award's role in strategic planning	Widespread awareness of recipient's award status among investors, media personnel, and employees

The Intersection between 360-Degree Research and Best Practices Awards

Research Methodology

Frost & Sullivan's 360-degree research methodology represents the analytical rigor of the research process. It offers a 360-degree view of industry challenges, trends, and issues by integrating all 7 of Frost & Sullivan's research methodologies. Too often companies make important growth decisions based on a narrow understanding of their environment, resulting in errors of both omission and commission. Successful growth strategies are founded on a thorough understanding of market, technical, economic, financial, customer, best practices, and demographic analyses. The integration of these research disciplines into the 360-degree research methodology provides an evaluation platform for benchmarking industry players and for identifying those performing at best-in-class levels.

360-DEGREE RESEARCH: SEEING ORDER IN THE CHAOS

About Frost & Sullivan

Frost & Sullivan, the Growth Partnership Company, helps clients accelerate growth and achieve best-in-class positions in growth, innovation, and leadership. The company's Growth Partnership Service provides the CEO and the CEO's growth team with disciplined research and best practice models to drive the generation, evaluation and implementation of powerful growth strategies. Frost & Sullivan leverages nearly 60 years of experience in partnering with Global 1000 companies, emerging businesses, and the investment community from 45 offices on 6 continents. To join Frost & Sullivan's Growth Partnership, visit http://www.frost.com.