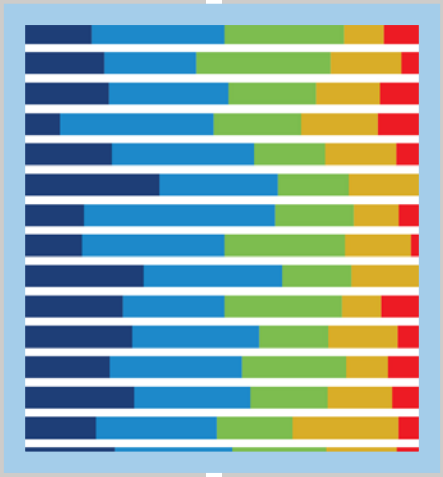
Vision Systems DESIGN®

THE MACHINE VISION AND IMAGING RESOURCE FOR ENGINEERS AND INTEGRATORS WORLDWIDE

SPECIAL REPORT

Solutions in Vision 2021 Survey Results

Two hundred twenty-nine machine vision community members—systems integrators, OEMs and machine builders, distributors, research and development experts, end users and manufacturers, and vendors—answered a large number of questions crafted by our staff and generated a tremendous amount of data to digest. What follows is a report of the survey results with a focus on the largest percentages and most frequent answers, culled from thousands upon thousands of data points provided by our respondents. We hope you gain a sense of what your colleagues are up to regarding technologies used, industries served, applications created, and challenges felt.



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The Solutions in Vision 2021 survey highlights challenges and successes

by Dennis Scimeca

At *Vision Systems Design*, we understand that, even after covering this industry for over 25 years, our audience does not in and of itself represent the *entire* machine vision and imaging community, considering how ubiquitous the technologies on which we report are becoming across the entire planet, in all walks of life.

Self-driving cars. Stores that require no checkout lines because cameras track the items you place in your cart or bag and charge you automatically as you leave. Drones that analyze entire crop fields to mark locations for additional water or fertilizer. Cameras that analyze vehicle and pedestrian road use to control traffic light systems.

Industrial inspection systems that can be trained to inspect wide swaths of potential products with only a few images of good products. Hyperspectral imaging that can analyze the chemical composition of items. Vision-guided robots that can inspect factories. AI assistants that can recognize and greet employees to track who is present at a facility. The more time we spend covering this growing, vibrant community, the more we realize how vision system design, in some cases, turns futurists' dreams into reality.

However, with our worldwide reach, the audience whose innovations we are fortunate to cover *does* represent a meaningful number of the companies, industries, and individuals who define machine vision and imaging. So, we are naturally curious about your thoughts considering new technologies, challenging applications, and where you are looking to grow in the future. Thus was born the *Vision Systems Design* Solutions in Vision 2021 survey.

The Solutions in Vision 2021 survey

Two hundred twenty-nine machine vision community members—systems integrators, OEMs and machine builders, distributors, research and development experts, end users and manufacturers, and vendors—answered a large number of questions crafted by our staff and generated a tremendous amount of data to digest. We thank everyone who responded to the survey.

What follows is a report of the survey results with a focus on the largest percentages and most frequent answers, culled from thousands upon thousands of data points provided by our respondents. We hope you gain a sense of what your colleagues are up to regarding technologies used, industries served, applications created, and challenges felt.

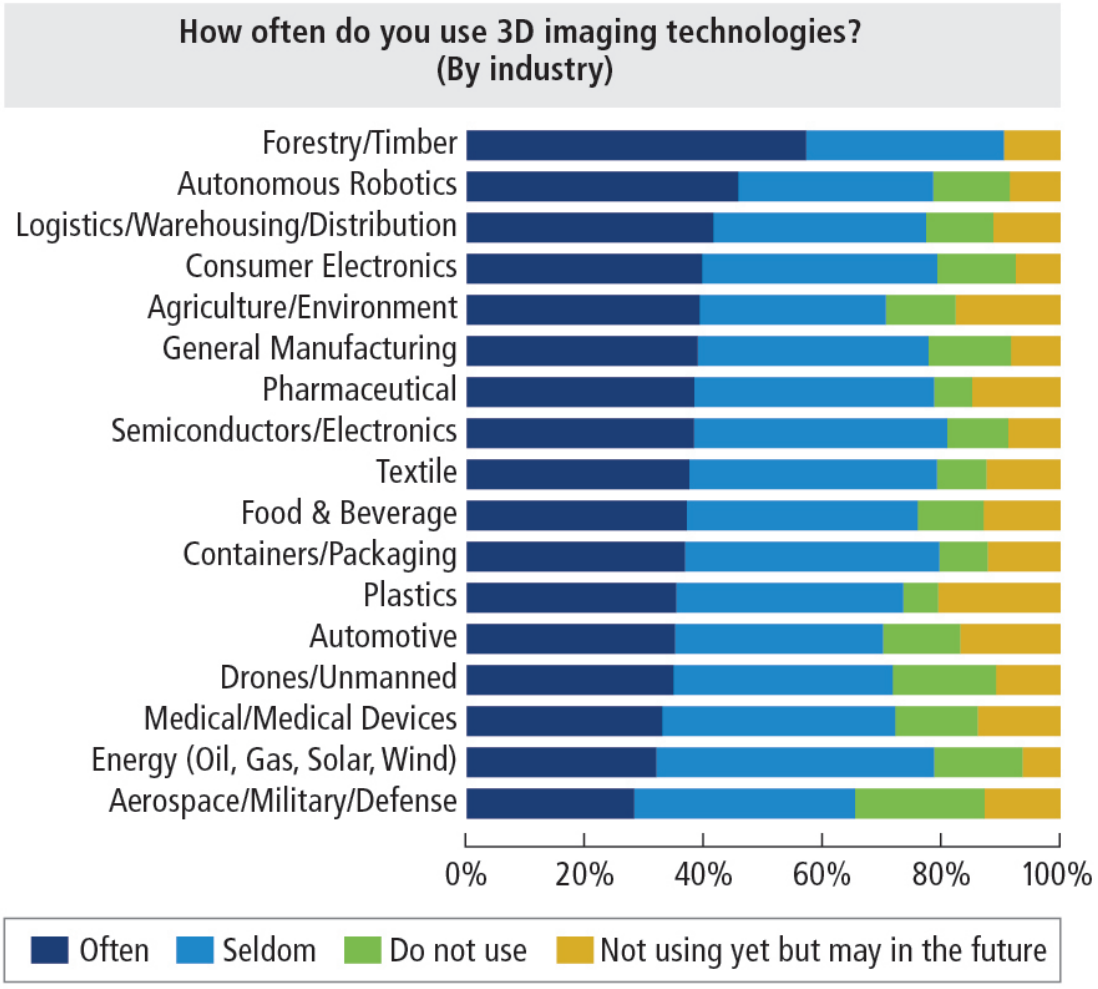
In this latter regard, we hope that you may find a sense of solidarity with one another as you collectively tackle problems and prepare for what challenges machine vision and imaging tasks will present in the future. So, please, enjoy this report on the results of our Solutions in Vision 2021 survey.

Note: In the interests of providing the most interesting data, we have omitted results for application types that match the technology (i.e. heavy use of 3D imaging in 3D applications and heavy use of non-visible imaging in non-visible imaging applications) when reporting applications that use a particular technology.

Which companies use 3D imaging?

3D imaging is a fairly mature technology in the machine vision and imaging community, although we continue to see innovations and improvements as demonstrated by the wide variety of fields in which the technology is used.

Company types using 3D imaging most *often* are distributors of machine vision products and components and research and development organizations at 41% each. *Total* use of the technology (combining answers of *often* and *seldom*) stands at 88%



for machine vision products and components distributors, 76% of OEMs/machine builders, and 69% of systems integration companies.

End users and manufacturers reported *often, seldom, do not use,* and *not using yet but may in the future* almost evenly, hovering around 25% for each answer.

Which industries use 3D imaging?

The data indicated the popularity and usefulness of 3D imaging by very high usage reports. *Total* use of 3D imaging technology is no fewer than 70% in **all** categories save one: aerospace/military/defense, which missed the mark at 65%.

The forestry/timber industry reported 90% *total* use of the technology, with semiconductors/electronics reporting 81% and containers/packaging reporting

80%. Five industries reported 79% *total* use of 3D imaging: autonomous robotics, energy (oil, gas, solar, wind), consumer electronics, pharmaceutical, and textiles.

Industries reporting *least* use are aerospace/military/defense (35%), automotive (30%), and agriculture/environment (29%). The largest numbers for *not using yet but may in the future* for 3D imaging by industry were reported by the plastics (21%), agriculture/environment (18%), and automotive (17%).

What is 3D imaging used for?

Total use, *often* and *seldom* combined, was reported highest for logistics/warehousing/distribution applications at 88%, with motion analysis and intelligent transportation each reporting at 84%. Guidance/tracking systems reported at 81%, and unmanned/autonomous and web inspection reported at 80% each.

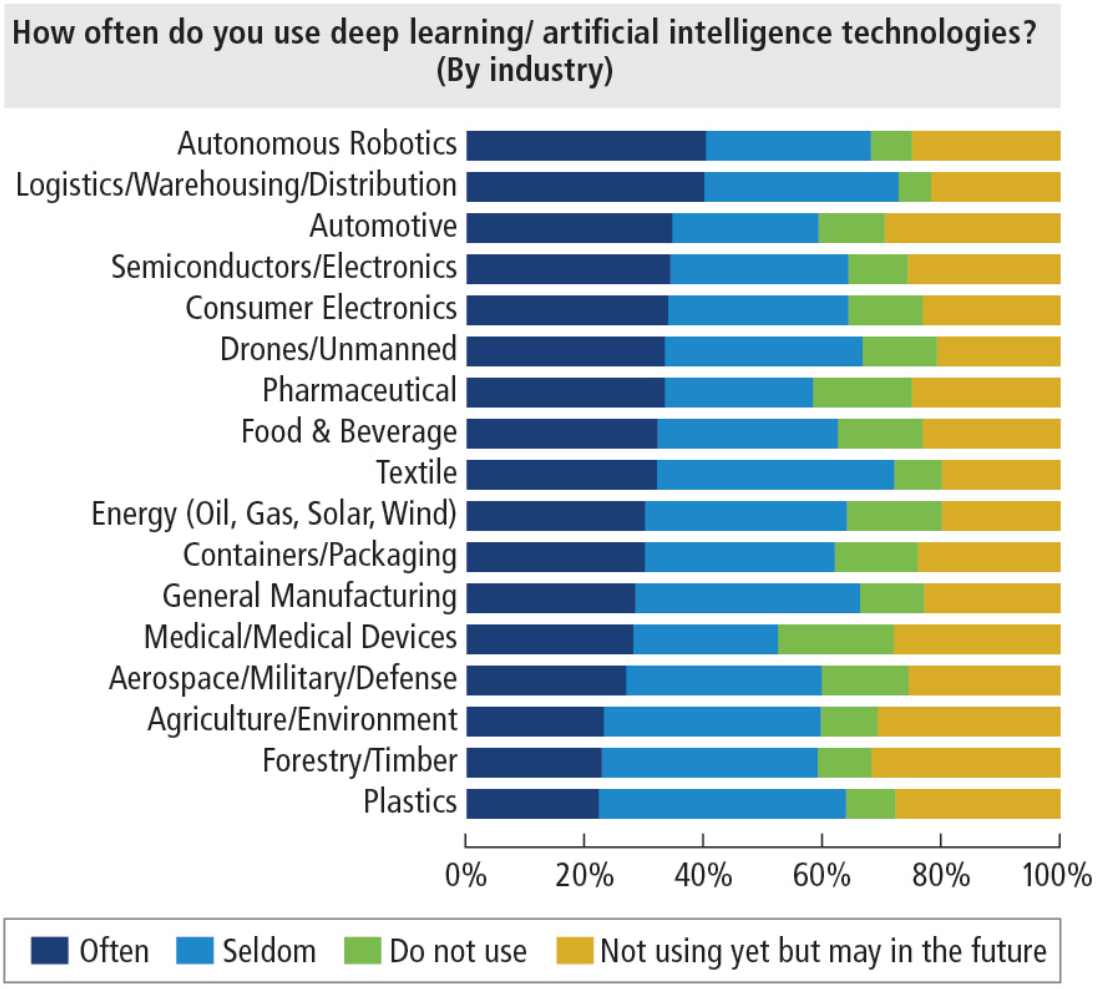
Highest use *often* was reported at 48% for intelligence transportation applications, 47% for life science applications, and 46% for X-ray imaging applications.

Highest *do not use* results were reported for remote sensing (24%), security/surveillance systems (18%), and AR/VR (17%) applications. Forensics (33%) and life sciences (22%) were the top two application types reporting *not using yet but may in the future*.

Which companies use deep learning and artificial intelligence?

Deep learning/AI is one of the most popular technologies in discussions throughout the machine vision and imaging communities. Companies continue to realize what the technology is or is not good for and learn about maintaining and updating training datasets to tune performance, while scientists continue to make deep learning/AI applications smarter and faster.

Machine vision products and components distributors reported the highest *total* use, combining answers of *often* and *seldom*, of deep learning and artificial



intelligence technologies at 76%. These companies reported using *often* at 18%, *seldom* at 58%, *do not use* at 18%, and *not using yet but may in the future* at 6%.

Systems integration companies reported the second-highest result for *total* use at 71%, with 35% reporting *often*, 37% reporting use *seldom*, 6% *not using* at all, and 22% reporting *may use in the future*.

OEMs/machine builders come in third for *total* use of deep learning and artificial intelligence at 65%, with the highest response for reporting *often*, at 38%. Using *seldom* was reported at 27%, with 12% reporting *do not use* and 23% reporting *not using yet buy may in the future*.

Research and development organizations reported *total* use at 48%, with use *often* reported at 30%, use *seldom* reported at 18%, *do not use* reported at 20%, and *not using yet buy may in the future* reported at 32%.

Finally, end users/manufacturers reported *total* use at 39%, with 15% reporting *often*, 24% reporting *seldom*, 26% reporting *do not use*, and 35% reporting *not using yet buy may in the future*.

Which industries use deep learning and artificial intelligence?

The logistics/warehouse/distribution industry reported the highest *total* use of deep learning/AI at 73%, with 40% reporting use *often*, and 33% reporting use *seldom*. The textile industry reported the second highest *total* use at 72%, with 32% reporting use *often* and 40% reporting use *seldom*.

Most of the other industries that reported highest *total* use of this technology include autonomous robotics (68%), drones/unmanned (67%), and general manufacturing (66%). Semiconductors/electronics, consumer electronics and the energy (oil, gas, solar, wind) industry industries all reported 64% *total* use.

Industries reporting *least* use of deep learning/AI are medical/medical devices (48%), pharmaceutical (42%), and automotive and forestry/timber (41%). The largest numbers for *not using yet but may in the future* for deep learning/AI by industry reported by forestry/timber (32%), agriculture/environment (31%), and automotive (30%).

What are deep learning and artificial intelligence used for?

Deep learning and AI are used most *often* for augmented and virtual reality (AR/VR) applications (52%) and embedded vision and robotics applications (45% each). AR/VR is also the top application type for *total* use of this technology at 87%, with robotics (76%) and security/surveillance system (75%) applications next in line for highest, *total* use of the technology.

Similar to the "by industry" results, no application category reported less than 54% *total* use of deep learning and AI. Life sciences and biometrics applications reported *do not use* at 17% each, although 30% of life sciences applications reported *not using yet but may in the future*. Factory automation, infrared imaging, remote sensing, and measurement/gauging applications all reported *do not use* at 14%.

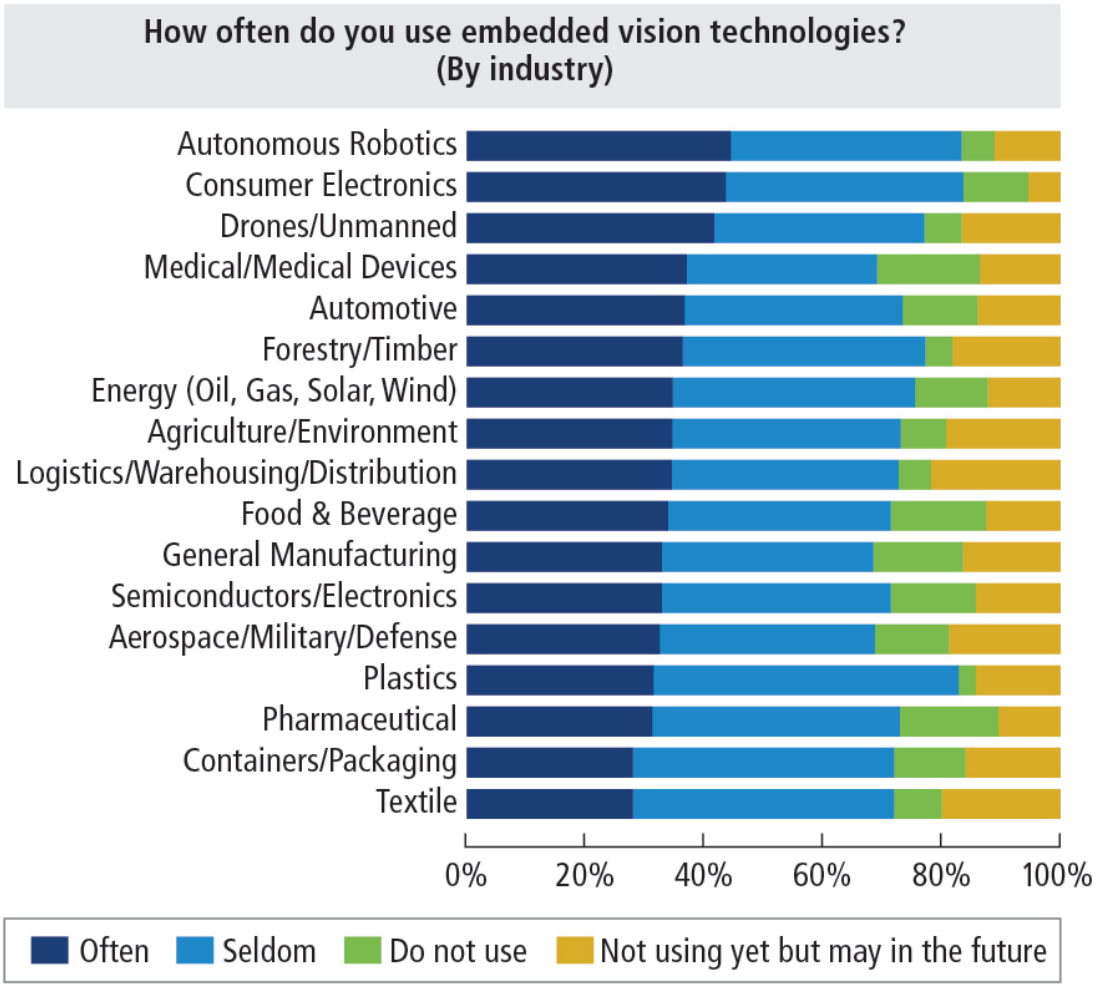
Other than life sciences applications, the largest, potential growth sectors for deep learning and AI suggested by the survey were medical imaging and X-ray imaging applications at 29% each.

Which companies use embedded technology?

"Embedded" technology covers a panoply of devices and applications, and the term is defined by or suggests different things to different people. Edge computing platforms, including systems-on-chips (SoCs) designed for deep learning processes, Internet of Things (IoT) platforms and applications, smart cameras, and unmanned vehicles may all be considered examples of embedded technology.

Distributors of machine vision products and components reported 71% *total* use of embedded technologies, though only 18% report use *often*, while 53% report use *seldom*. Systems integration companies, the next highest, reported *total* users of embedded technology at 69%, reported use *often* at 37%, and reported *seldom* use at 33%.

Embedded technology deployment is less prevalent among other company types covered by the survey. *Total* use was reported by OEMs/machine builders at 56%, research and development organizations at 53%, and end users/manufacturers at 40%. However, 31% of end users/manufacturers also say they *might use* embedded technology in the future, followed by research and development organizations at 27%.



Which industries use embedded technology?

Three industries reported greater than 80% *total* use of embedded technology: consumer electronics (44% *often*, 40% *seldom*), autonomous robotics (44% *often*, 39% *seldom*), and plastics (31% *often*, 51% *seldom*). No industry reported lower than 69% *total* use. Forestry/timber and drones/unmanned, both at 77% *total* use, round out the top 5.

General manufacturing (32%), aerospace/military/defense (31%), and medical/medical device industries (31%) reported *least use* of the technology. The logistics/warehousing/distribution industry reported highest for *not using yet but may in the future* at 22%, followed by textiles at 20% and agriculture/environment at 19%.

What is embedded technology used for?

Highest *total* use of embedded technology was reported at 93% (53% *often*, 40% *seldom*) for biometrics applications. Wide adoption was also reported for AR/VR (43% *often*, 39% *seldom*), intelligent transportation (52% *often*, 29% *seldom*), and security/surveillance systems (41% *often*, 39% *seldom*).

Application types reporting *least* use of embedded technology include X-ray imaging (46%) and process control and measurement/gauging (41% each). However, X-ray imaging also reported 29% for *not using yet but may in the future* followed by web inspection at 25%.

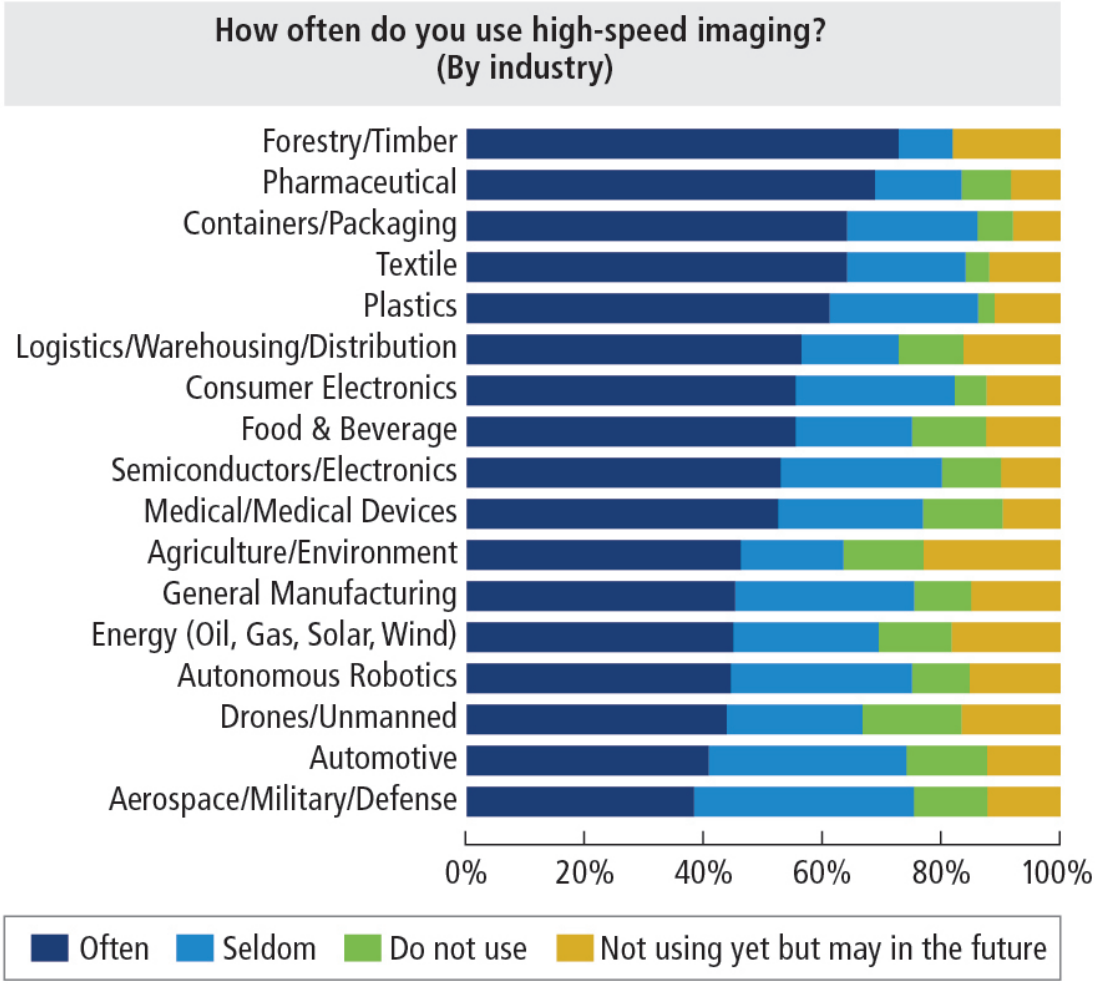
Which companies use high-speed imaging?

High-speed imaging is a new category polled for this year's Solutions in Vision survey. The category was added in part because of rising interest in this technology. It is an interest prodded by advancements like the CoaXPress 2.0 standard, the ever-increasing presence of 10 GigE and even faster interfaces, and the continued evolution of line scan cameras.

OEMs/machine builders reported the highest use of any technology *often* by any company type polled in the survey at 61%, with use *seldom* reported at 23%, for 85% *total* use. *Do not use* and *not using yet but may in the future* both reported at 8%. Machine vision products and components distributors reported an even higher *total* use of high-speed imaging at 88%, with 53% reporting *often* and 35% reporting *seldom*.

Systems integration companies reported using the technology *often* at 39% and *seldom* at 29% for a *total* reported adoption of 68%. Research and development organizations reported use *often* at 30% and *seldom* at 32%.

End users and manufacturers reported lowest *total* use of high-speed imaging at 56%. However, 22% also reported *not using yet but may in the future*.



Which industries use high-speed imaging?

Seven industries reported 80% or greater *total* use of high-speed imaging: plastics and containers/packaging (86% each), textiles (84%), pharmaceutical (83%) consumer electronics and forestry/timber (82% each), and semiconductors/electronics (80%). For all 17 industries covered by the survey, in every case, use *often* was reported higher than use *seldom*.

For example, forestry/timber reported use *often* at 73% and use *seldom* at 9%; pharmaceutical reported use *often* at 69% and use *seldom* at 15%; containers/packaging reported use *often* at 64% and use *seldom* at 22%; and textiles reported use *often* at 64% and use *seldom* at 20%.

The industries reporting *least* use of using high-speed imaging were agriculture/environment (37%), drones/unmanned (33%), and energy (oil, gas, solar, wind) (31%). Agriculture/environment also reported 23% for *not using yet but may in the future*, while energy (oil, gas, solar, wind) reported 18%, and drones/unmanned reported 17%.

What is high-speed imaging used for?

The top three application types reporting heaviest use of high-speed imaging were web inspection (55% *often*, 35% *seldom*), motion analysis (64% *often*, 23% *seldom*), and guidance/tracking systems (55% *often*, 31% *seldom*). Other high results for *total* use included optical character recognition (78%) and measurement/gauging and biometrics (77% each).

Use of high-speed imaging *often* was higher than use *seldom* in **all** 23 application types covered by the surveys.

This technology is used *least* for security/surveillance system applications (35%); remote sensing applications (30%); and intelligent transportation, process control, and robotics applications (29% each). Highest answers for *not using yet but may in the future* were reported by forensics and robotics (20% each) and intelligent transportation (19%).

Which companies use hyperspectral/multispectral/SWIR imaging technologies?

Hyperspectral/multispectral/SWIR imaging technologies (heretofore referred to as "non-visible imaging") have found homes in a wide variety of industries and applications including food and beverage inspection, materials analysis, industrial inspection, and agriculture.

Of the five technologies covered by this survey, the numbers for use *often* were collectively the lowest. OEMs/machine builders reported 27%, research and

development organizations reported 22%, machine vision products and components distributors reported 12%, systems integration companies reported 10%, and end users/manufacturers reported 4% use *often*.

Total use of non-visible imaging, combining responses of *often* and *seldom*, still presents the lowest numbers comparatively of all the technologies covered by the survey. Machine vision products and components distributors report 59% *total* use, OEMs/machine builders report 58%, research and development organizations report 52%, systems integration companies report 45%, and end users/manufacturers report 27%.

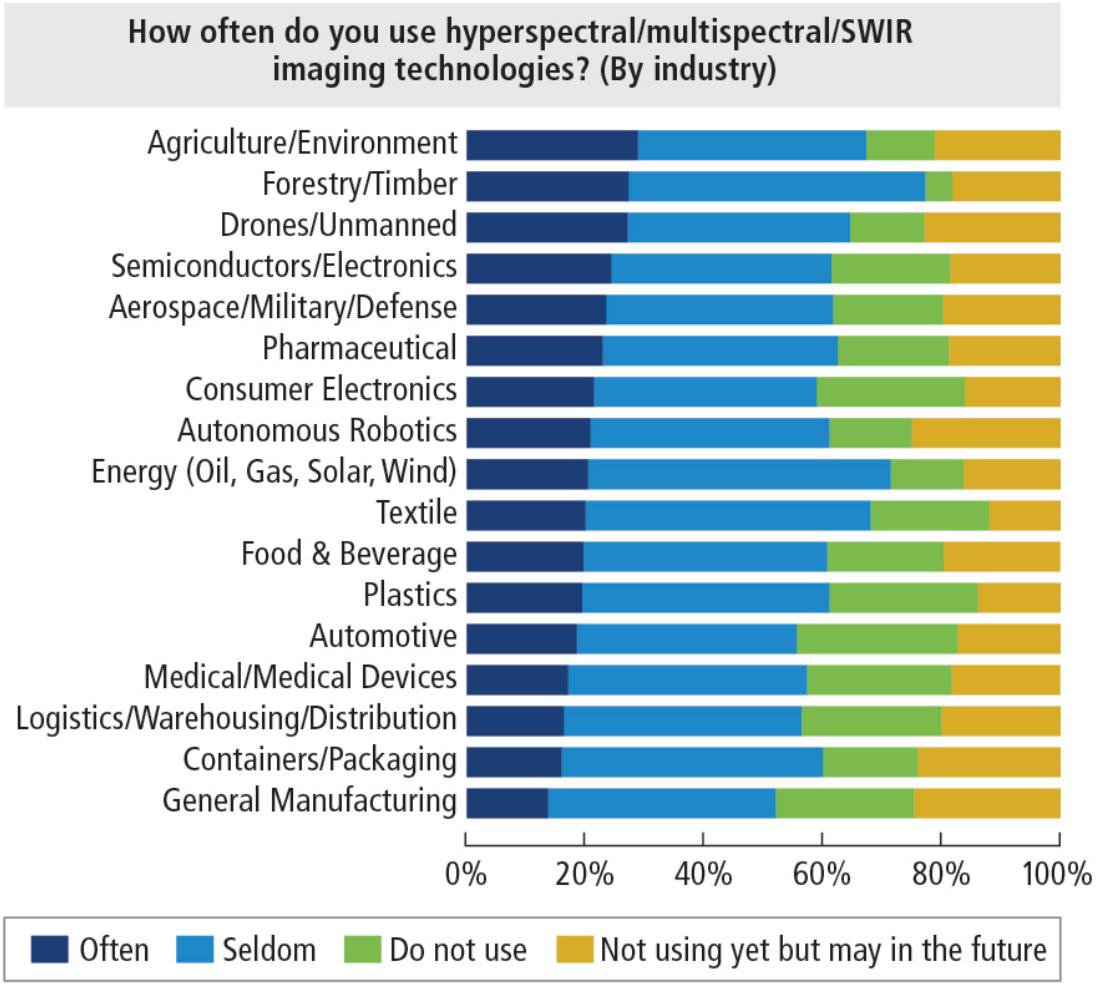
The highest potential for growth of non-visible imaging use by company, or answers of *not using yet but may in the future*, were reported by research and development organizations (33%) and systems integration companies and end users/manufacturers at 27% each.

Which industries use hyperspectral/multispectral/SWIR imaging technologies?

Highest results for non-visible imaging use, the *total* of answers of *often* and *seldom*, were reported by forestry/timber at 77%, energy (oil, gas, solar, wind) at 71%, textiles at 68%, and agriculture/environment at 67%.

However, responses of use *often* compared with use *seldom* were lower than in other categories. Forestry/timber reported *often* at 27% and *seldom* at 50%; energy (oil, gas, solar, wind) reported *often* at 20% and *seldom* at 51%; textiles reported *often* at 20% and *seldom* at 48%; and agriculture/environment reported *often* at 29% and *seldom* at 38%.

Industries reporting *least* use were general manufacturing (48%), and automotive and logistics/warehousing/distribution (44% each).



The highest potential for growth of non-visible imaging use by industry, or answers of *not using yet but may in the future*, were reported by autonomous robotics and general manufacturing at 25%, and containers/packaging at 24%.

What are hyperspectral/multispectral/SWIR imaging technologies used for?

Heaviest *total* use, answers of *often* and *seldom* combined, of non-visible imaging was reported for biometrics (77%), augmented and virtual reality (71%), and intelligent transportation and logistics/warehousing/distribution applications reporting at 68% each. Augmented and virtual reality applications also present the highest result for use *often* at 43%, with forensics reporting 40%.

Applications reporting *least* use of non-visible imaging are process control (58%), and machine vision and factory automation at 55%. Applications reporting highest for *not using yet but may in the future* are 3D imaging and web inspection at 30% each, and measurement/gauging and process control at 28% each.

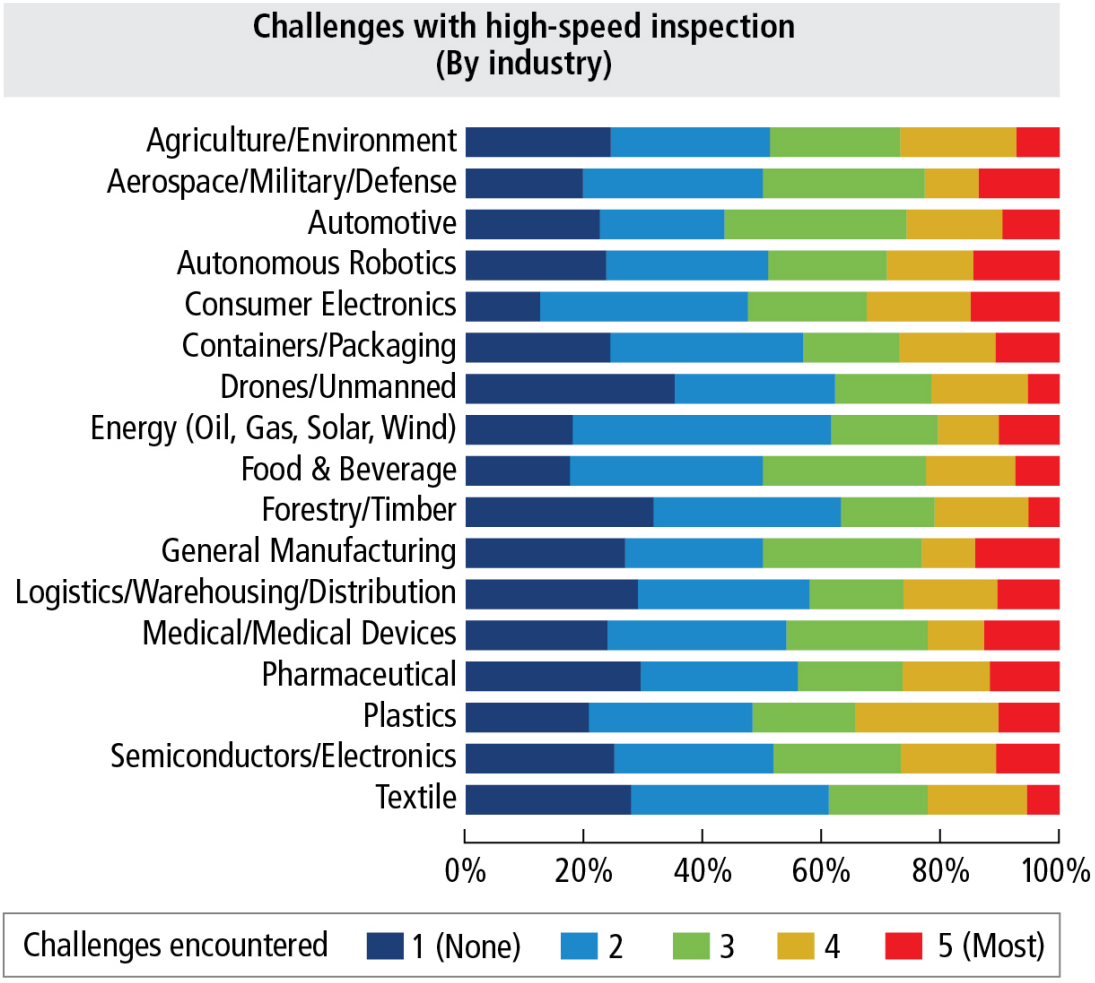
What machine vision challenges are most difficult to overcome?

So far, the survey has asked and answered broad questions. 3D imaging, deep learning/AI, embedded, high-speed imaging, and non-visible imaging each have long reach into the machine vision and imaging community, and all of them are used in a wide range of disciplines.

The final question asked about specific types of applications, rather than about technologies generally. Respondents were asked to rate on a scale of 1 to 5—1 meaning *no challenges encountered,* and 5 meaning *most challenges encountered*—how difficult it is for their industries to incorporate nine machine vision technologies:

- High-speed inspection
- Multispectral/hyperspectral imaging
- Defect/flaw detection
- Imaging or inspecting glossy, reflective, and shiny metal parts
- Random object picking/bin picking
- Random box depalletizing
- Camera mobility
- Vision-guided robotics
- Embedded vision

Here are the top results for each level of challenge presented by the nine technologies.



High-speed inspection

Industries encountering the *least* challenge incorporating high-speed inspection, measured by the *total* of all answers of 1 or 2, are the forestry/timber (63%), drones/unmanned and energy (oil, gas, solar, wind) (62% each), and textile industries (61%).

Top results for industries that experience *moderate* level of challenge, an answer of 3, are the automotive (31%), food and beverage (28%), and aerospace/military/defense and general manufacturing industries (27% each).

The industries that present the *greatest* challenge incorporating high-speed inspection, the *total* of all answers of a 4 or a 5, are plastics (34%), consumer electronics (33%), and autonomous robotics (29%).

Multispectral/hyperspectral imaging

The textile (60%) and pharmaceutical (48%) industries, with energy (oil, gas, solar, wind), food and beverage, and plastics tied for third place (46%), experience the *least* level of challenge incorporating multispectral/hyperspectral technologies.

Moderate challenge was reported by the aerospace/military/defense (38%), forestry/timber (37%), and energy (oil, gas, solar, wind) industries (35%). The *greatest* level of challenge incorporating multispectral/hyperspectral technologies was reported by the agriculture/environment and semiconductors/electronics industries at 33% each and by the consumer electronics industry at 32%.

Defect/flaw detection

Machine vision, in general, and deep learning, in particular, have proven their value in the detection of damaged goods or flawed parts. Time and again there is evidence of increased inspection speed and accuracy when machine vision techniques are applied to these tasks.

The industries experiencing the *least* challenge integrating detect/flaw detection are the textile (59%), drones/unmanned (55%), and containers/packaging industries (52%). *Moderate* challenge was reported by the energy (oil, gas, solar, wind) (41%), autonomous robotics (39%), and food and beverage industries (38%).

The *greatest* level of challenge integrating defect/flaw detection was reported by the medical/medical device (36%), automotive (34%), and pharmaceutical industries (30%).

Imaging or inspecting glossy, reflective, and shiny metal parts

Stable, consistent lighting is integral for a successful vision system. Reflective parts are high on, if not at the top of, the list of objects that can challenge creating successful lighting geometry. In some cases, only polarization techniques can

account for reflective materials and allow a machine vision inspection system to operate as designed.

Imaging or inspecting glossy, reflective, and shiny metal parts presents the *greatest* challenge for the plastics (46%), automotive (43%), and aerospace/military/defense industries (42%). *Moderate* challenge was reported by the textile (53%) and forestry/timber (42%) industries, with the food and beverage and consumer electronics industries tying for third (34%).

The *least* challenge employing inspection or imaging of glossy, reflective, and shiny metal parts was reported by the drones/unmanned (54%), logistics/warehousing/distribution (47%), and pharmaceutical industries (44%).

Random object/bin picking

Sorting and pick-and-place applications are often found in industrial automation and logistics, warehousing, and distribution. The technology has evolved from simple picks to deep learning-enabled applications where robots are presented with mixed varieties of objects to sort.

The top three industries reporting the *least* amount of challenge incorporating random object-/bin-picking technologies are the textile (53%), drones/unmanned (49%), and plastics industries (48%).

Top results for *moderate* challenge were reported by the food and beverage (38%), semiconductors/electronics (37%), and pharmaceutical industries (36%).

The industries that experience the *greatest* challenge deploying random object-/bin-picking technologies are the automotive (40%) and general manufacturing (36%) industries, with the plastics and autonomous robotics industries tied for third, reporting at 33% each.

Random box depalletizing

Programming a robot to depalletize goods when each pallet is stacked precisely the same way and with the same number of goods is relatively straightforward. This application may require 3D imaging and/or deep learning technologies when the type and position of boxes change constantly from pallet to pallet.

The *greatest* level of challenge incorporating random box depalletizing was reported by the consumer electronics (31%) and automotive and drones/unmanned industries (30% each). Industries reporting the *least* challenge were the drones/unmanned and consumer electronics industry at 51%, textiles at 47%, and containers/packaging at 46%.

Top results for *moderate* challenge were reported by the energy (oil, gas, solar, wind) (41%); forestry/timber and food and beverage (37% each); and the textile, semiconductors/electronics, and aerospace/military/defense industries each reporting 35%.

Camera mobility

Not all camera placements in vision systems are static. Imaging from multiple, different angles can increase fidelity. Camera movement may alter working distance, and lighting geometry may have to account for variable camera positions.

The plastics industry reported the *greatest* level of challenge incorporating camera mobility at 38%. The containers/packaging industry reported at 34%, and the consumer electronics industry reported at 33%.

The automotive (47%), drones/unmanned (43%), and aerospace/military/defense industries (42%) experienced the *least* challenge incorporating camera mobility. *Moderate* level of challenge was reported by the textile (47%), general manufacturing (42%), and food and beverage industries (41%).

Vision-guided robots

Historically, a robot's base was fixed or moved very little, with robot arms performing tasks. Now, with more compute available on smaller chips and both robots and cameras decreasing in size, this historic relationship is moving into the realm of mobile robots like those deployed for logistics operations in warehouses.

The industries reporting the *least* challenge incorporating vision-guided robots were the agriculture/environment (54%), textile (53%), and forestry/timber industries (50%). Top results for *moderate* challenge were reported by the textile (47%) and energy (oil, gas, solar, wind) industries (38%), with the pharmaceutical and containers/packaging industries tying for third place (35% each).

The *greatest* challenge for incorporating vision-guided robotics was reported by the autonomous robotics (37%), automotive (31%), and plastics industries (28%).

Embedded vision

The *least* challenge incorporating embedded technology was reported by the automotive (51%), pharmaceutical (50%), and general manufacturing industries (48%). The *greatest* challenge was reported by the plastics (32%), agriculture/environment (24%), and medical/medical device industries (22%).

Moderate challenge was reported by the agriculture/environment industry at 45%, while the energy (oil, gas, solar, wind) and aerospace/military/defense industries reported 44% each, and the food and beverage and drones/unmanned industries tied for third at 43% each.

Looking toward the future

Machine vision and imaging community members are undeterred from staring down challenges and solving even the most difficult problems. The innovations and solutions developed by this community are the beating heart of *Vision System Design's* ongoing coverage over the past 25 years. We hope this report described

a community you recognize, challenges you understand that are shared by your colleagues, and the path along which machine vision and imaging are growing.

Thank you again to all the respondents to our Solutions in Vision 2021 survey and to everyone for reading *Vision Systems Design* magazine for over 25 years.