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DEVELOPING SENSING AND PERCEPTION SYSTEMS FOR AUTONOMOUS DESIGNS

/ EXECUTIVE SUMMARY

In this e-book, you will discover:

1 The state of perception and sensing technology in the A&D industry

2 Prominent sensing and perception technologies used in autonomous designs

3 Core challenges engineers face when optimizing sensing and perception systems

4 What the future holds for sensing and perception technologies in autonomous vehicles

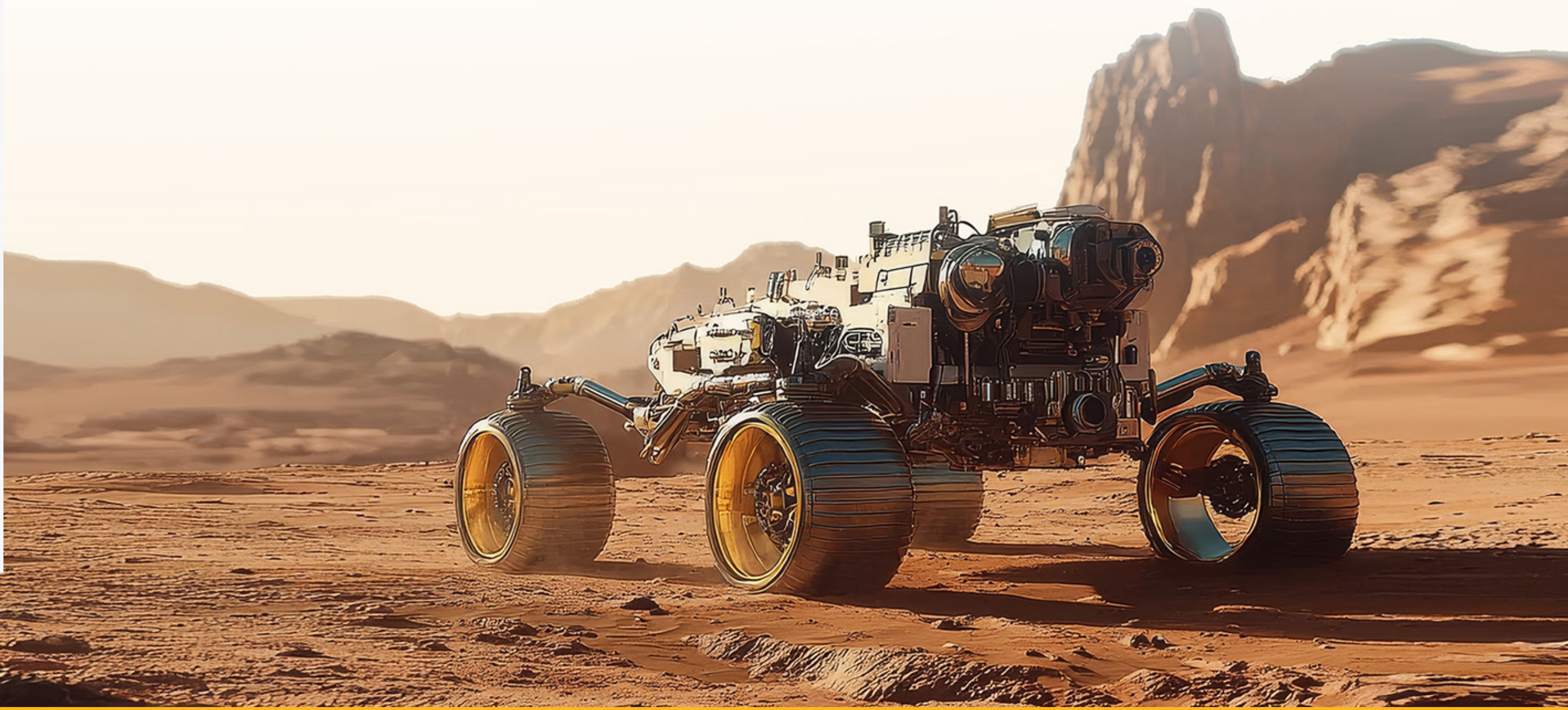
A LOOK INSIDE SENSING AND PERCEPTION SYSTEMS **IN AEROSPACE AND DEFENSE**

An autonomous ground vehicle (AGV) moves over the amber sands of a desert, transporting important supplies through this difficult terrain. A sandstorm picks up, but the AGV uses cameras that are optimized and adapt to withstand such conditions to continuously observe its surroundings and identify a clear path.

Across the globe, an autonomous helicopter flies above a forest at night. It searches for a missing hiker by using a thermal camera to detect heat and create thermal images of the forest below. Suddenly, the helicopter identifies a thermal signature that potentially matches a human's. To investigate further, the drone uses a lidar system to scan the forest floor to find a flat and safe area to land.

Meanwhile, two autonomous electric vertical takeoff and landing (eVTOL) vehicles are trying to land in a busy airport. They each use advanced real-time radar systems that can detect other aircraft while accurately identifying their own signals and avoiding interference. At the same time, the eVTOLs rely on mature connectivity technology to clearly communicate with the nearby air traffic management systems.

These are only a few examples of the importance of sensing and perception technology in aerospace and defense (A&D). Sensing and perception systems are used to, in short, detect physical stimuli — such as light, sound, heat, or radio frequency (RF) — and generate data based on this information. Collecting data via sensors and deciphering via perception systems serves as the first functional step in an autonomous system.



Both sensing and perception technologies and their applications are far-reaching. On the technology side, sensing and perception systems can include cameras, radar, lidar, thermal cameras, ultrasonic sensors, global positioning systems (GPS), and inertial measurement units (IMUs). As for applications, these range from taking high-resolution pictures of distant locations on the ground while in flight to using radar to identify unexpected objects in the skies around you.

It is also important to mention that while these systems are a key hardware component in autonomous designs, there are other essential physical components. For example, beyond sensing and perception, engineers also need to consider connectivity and vehicle-to-everything (V2X) in their designs. Ensuring that autonomous systems have the hardware they need to consistently and effectively communicate to infrastructure, networks, other vehicles, and devices is imperative for many autonomous designs. During the vehicle engineering stage, all hardware components must also be fully integrated with software components, such as control systems.

When designing this essential hardware, engineers throughout the A&D industry must focus on developing accurate and reliable integrated designs. As this technology gets increasingly complex, designing these hardware systems will become even more of a hurdle that teams must push past to innovate in this space. Further, ensuring that sensing, perception, and connectivity systems fulfill safety-critical requirements and certifications for autonomous flight operations will also add difficulty for those working in this space.

IDENTIFYING PROMINENT SENSING AND PERCEPTION TECHNOLOGIES THAT ARE

DRIVING THE FUTURE OF AUTONOMY

While the types of sensing and perception technologies used in autonomous vehicles are quite broad, in this e-book, we will focus on four key types that are relied upon across a wide variety of autonomous vehicles in the A&D industry. Autonomous systems process the information gathered from these technologies and return it in a format that they can interpret and act upon based on pre-programmed actions.

/ 1. Cameras

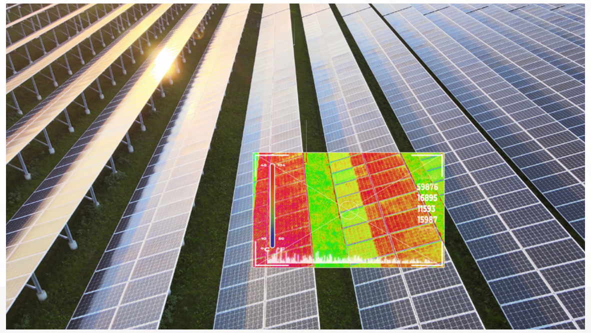
Autonomous vehicles use cameras to record and capture visual images of the world around them. As such, engineers focus on developing high-resolution cameras that can capture high-quality visual information for accurate perception and analysis, no matter the speed of the autonomous systems, distance between the camera and subject, weather conditions, or other external phenomenon such as sunlight or glare.

/ 2. Lidar Systems

Lidar (light detection and ranging) is a remote sensing technology that uses light pulses to map an environment. In addition to autonomous systems, lidar is often used for topography analysis, mapping, and robotics. Autonomous vehicles use lidar systems to create detailed 3D maps and accurate object detection for enhanced perception.

/ 3. Radar Systems

Radar (radio detection and ranging) systems use electromagnetic radio waves for robust object detection and ranging. A few common applications of radar are air traffic control and weather forecasting. Radar systems are capable of reliable object detection and distance measurement in varied conditions.



/ 4. Thermal Cameras

Thermal cameras are used to detect temperature variations and thermal patterns and can enable autonomous systems to more easily perceive their surroundings in low-visibility settings, such as dark environments.

A SNAPSHOT OF THE CHALLENGES IN DEVELOPING **SENSING AND PERCEPTION TECHNOLOGIES**

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/ What challenges do designers of sensor and perception systems face? When looking at these systems in general, there are a few common difficulties.

First, there is the need to optimize size, weight, power, and cost (SWaP-C) throughout the design and development process. This relates not only to optimizing the sensor and perception designs themselves to make them advanced yet affordable, but also to optimizing the design process to increase efficiency. To keep up with a fast-moving industry, designs must be expedited; however, this proves challenging because perception training and validation requires analyzing thousands of scenarios at a rate faster than real time. At the same time, the critical considerations of safety and performance must remain at the forefront.

The often-hazardous environments that autonomous vehicles operate in for A&D cause additional challenges. Extreme temperatures, intense pressure, long distances, a lack of light, obscured surroundings — these are just a few of the impediments that advanced sensors, perception technology, and communication systems need to overcome to perform flawlessly in real-world conditions. No matter if an unmanned underwater vehicle (UUV) is navigating through murky, deep waters or an eVTOL is flying during a snowy winter's night, being able to accurately sense and perceive the surrounding environment in complex and varying mission scenarios is imperative.

To achieve precise perception in these complex environments, a multisensor approach is often required. This, however, adds additional difficulty because all sensors must be optimized and seamlessly integrated into existing designs. Ensuring that sensing and perception systems are durable enough to function in these varying environments is another known hurdle. Conquering these complications historically has taken a great deal of time, physical testing, and validation.

EACH SENSING AND PERCEPTION SYSTEM ALSO **COMES WITH ITS OWN CHALLENGES**

CAMERA	RADAR	LIDAR	THERMAL CAMERA
Achieving high image quality in varying lighting conditions.	Ensuring accuracy in cluttered environments.	Achieving high resolution and range.	Achieving high sensitivity and resolution.
Balancing resolution, frame rate, motion, and power consumption.	Managing interference from other radar systems.	Ensuring performance in adverse weather conditions.	Integrating thermal data with other sensor data.

TAKEAWAYS AND **LOOKING TO THE FUTURE**

/ In the coming years, autonomous systems will continue to grow and increase their prevalence in A&D. To keep pace with this rapid growth, innovators need to further optimize sensing and perception systems to create designs that are not only functional, but also efficient, accurate, robust, and ready for deployment as quickly as possible. In doing so, we will see great leaps in these technologies, including:

- *Cameras with enhanced visual perception, better multiwaveband imaging systems, and improved object recognition and tracking*
- *Radar with reliable detection in all weather conditions, enhanced distance measurement, object tracking, minimal weight, and ghost target elimination*
- *Lidar with precise 3D mapping and object detection, optimal placement, and enhanced navigation with obstacle avoidance*
- *Thermal cameras with improved perception in low-visibility conditions and enhanced detection of thermal patterns and anomalies*

These technical developments will not happen overnight. Creating the essential hardware that will form the core of A&D autonomous systems is a complex, costly, and lengthy process involving multidisciplinary teams of experts who will take a holistic approach and leverage a variety of solutions to develop hardware components and systems for autonomous platforms.

/ As a result, engineering simulation software has emerged as a necessary solution that enables engineers, researchers, and innovators to:

- *Using AI, optimize imaging systems and create more robust products using a comprehensive multiphysics approach that accounts for heat, vibration, deformation, and more*
- *Virtually validate and optimize antenna and array designs with ray tracing and RF analysis*
- *Integrate and validate systems in different conditions and realistic environments across air, land, sea, and space*
- *Increase efficiency and reduce time to market via scalability, more efficient testing, a reduced need for physical prototypes, and automation*

Thanks to digital engineering, teams can design sensing and perception systems that are optimized for a variety of mission scenarios, thereby ensuring that — no matter the environment or application — their autonomous technology will be able to function and correctly perceive their surroundings. By enhancing this technology, engineering teams will be taking an imperative step toward the future of autonomy.

To learn more, check out the resources on this page.

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ANSYS, Inc.
www.ansys.com
ansysinfo@ansys.com
866.267.9724