

Ansys

**EXPLORING THE FUTURE
OF MISSION ENGINEERING
FOR AUTONOMOUS SYSTEMS**



/ EXECUTIVE SUMMARY

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An introduction to mission engineering and why it is integral in the aerospace and defense (A&D) industry

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A look inside the process of developing a design reference mission, concept of operations, and operational contexts for A&D missions

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How to address the needs and challenges of optimizing and defining autonomous systems while ensuring compliance with system and safety requirements

4

The role of digital mission engineering in enabling the advancement of autonomous systems in A&D

MISSION ENGINEERING: A CORNERSTONE IN DEVELOPING AUTONOMOUS SYSTEMS FOR A&D



/ How do engineers land an unmanned spacecraft on the Moon? The answer to this question goes beyond rocket science and requires [a wide view of the entire mission](#), including defining the mission requirements for the full life cycle, analyzing the operational environment at all points of the spacecraft's journey from Earth to the Moon, planning an optimized trajectory, avoiding collisions, ensuring compliance, and defining the autonomous system itself.

All these tasks are included in the mission engineering process, which is the first functional step of the V-cycle product development process. In the mission engineering stage, engineers must determine if their designs are robust, compliant, and able to perform their mission in whatever harsh environment(s) the autonomous system they're developing will be deployed within.

According to the [U.S. Department of Defense \(DoD\)](#), "Mission engineering is an interdisciplinary process encompassing the entire technical effort to analyze, design, and integrate current and emerging operational needs and capabilities to achieve desired mission outcomes."

In this context, the term "mission" can refer to anything from the interactions between systems of systems — for example, a satellite taking a photo while navigating through space and communicating with a base on Earth — to studying objects in motion and their full surroundings, such as determining an autonomous drone's functionality in complicated operating environments like a crowded city. With mission engineering, researchers can systematically account for variables to determine actionable system requirements and designs.

As the adoption rate for autonomous technology in A&D continues to rise, so does the need to match this pace by accurately and rapidly analyzing functionality and compliance at the very beginning of your design process: the mission engineering stage. To accomplish this while continuing to remain at the forefront of innovation, engineers will need to increase the effectiveness and accuracy of the mission design process when developing autonomous systems.

EFFICIENTLY DEVELOPING A DESIGN REFERENCE MISSION, CONCEPT OF OPERATIONS, AND OPERATIONAL DESIGN DOMAIN



/ To succeed in mission engineering, engineers need to take a wide and comprehensive view of the entire mission. This includes the impact of each element, the environment(s) of the mission, the operational scenarios, the objectives, and all the resulting challenges, opportunities, and gaps that affect mission success.

To aid in gathering, organizing, and defining this information, engineers can create a design reference mission (DRM), concept of operations (ConOps), and operational design domain (ODD).

A DRM is a blueprint of the high-level mission scenario that a system or product needs to perform. DRMs outline the operational environment, mission objectives, and performance requirements. Engineers use DRMs as a key input to define operational and technical requirements for a studied product or system.

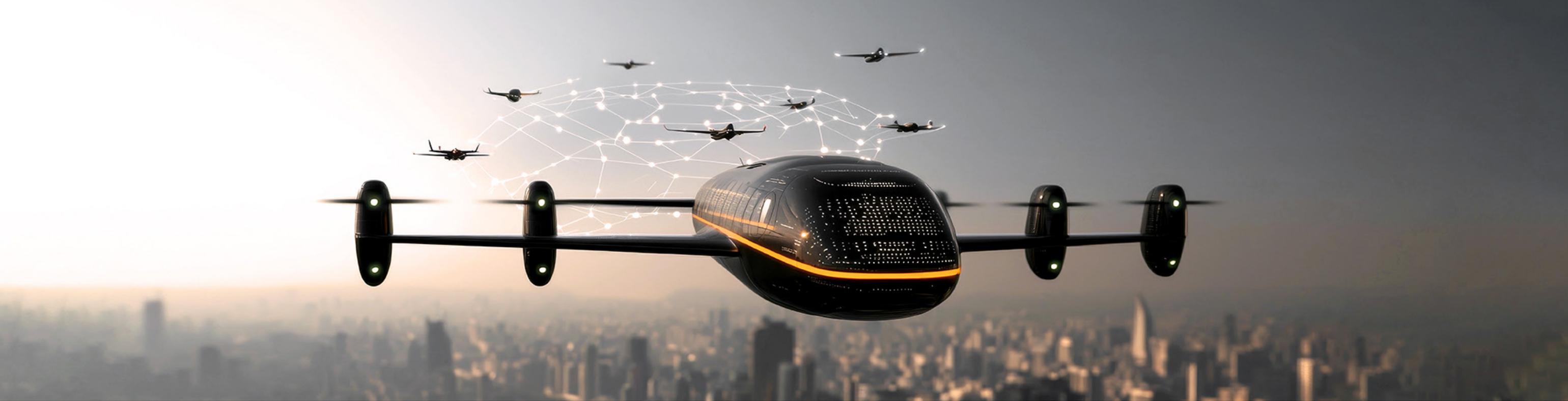
Meanwhile, a ConOps is a straightforward and brief verbal or visual statement describing how a product or system will be used to achieve the mission objectives defined by the DRM. This can include workflows, systems

interactions, and user roles. In short, DRMs establish the “what” (mission goals), and ConOps establish the “how” (executing the mission goals).

In addition to the DRM and ConOps, engineers must also define the ODD, which involves capturing the range of operational contexts the autonomous systems will operate in.

By creating a comprehensive DRM, ConOps, and ODD, engineers can construct a strong foundation to enable mission success. This foundation provides a deep understanding of operational contexts, increased adaptability to varied and dynamic mission environments, and the ability to identify risks early in the design process to minimize costly and time-consuming late-stage changes.

However, creating these materials at a high enough fidelity to be useful for mission engineering is not a simple process, especially with the harsh and often unpredictable environments that A&D systems operate within — be that low Earth orbit (LEO), airspace in a crowded city, the ocean’s depths, or more.



CHALLENGES

ACCURACY

Precisely predicting operational conditions and scenarios

ALIGNMENT

Ensuring ODD, DRM, ConOps, system requirements, and designs align with mission objectives and system capabilities across environments

COMPLEXITY

Capturing and analyzing the diverse range of mission scenarios and operational contexts with their various outcomes and constraints

GOAL SETTING

Defining clear and achievable mission objectives

VARIABILITY

Accounting for the changing conditions that impact system performance

CAREFULLY DESIGNING **AUTONOMOUS SYSTEMS**



In addition to the mission at large, autonomous systems themselves must be thoroughly defined to achieve success in the mission engineering stage and beyond.

If a precise system definition is not used, any calculations or results obtained during this stage will be inaccurate, potentially rendering them useless.

By creating a detailed system design and architecture that aligns with predetermined requirements, engineers gain:

- An exhaustive blueprint for both the autonomous system's development and its integration
- A precise definition, which will help in building a system with enhanced reliability and performance

As with DRM, ConOps, and ODD, autonomous system designs must respond to a number of challenges.



CHALLENGES

ALIGNMENT

Designing a system architecture that aligns with all requirements and constraints

COMPLEXITY

Correctly defining the full complex system, including high-level structures and interactions among various system components

COMPLIANCE

Ensuring that the system design adheres to all safety goals and regulatory standards

INTEGRATION

Incorporating all system components to avoid compatibility issues and aid in a smooth development process

TECHNICAL SPECIFICATIONS

Aligning system requirements with clearly defined technical details and interfaces

ENSURING COMPLIANCE WITH **SYSTEM AND SAFETY REQUIREMENTS**



/ Safety and compliance are top priorities throughout the design and development process, and this holds true in the mission engineering stage, too. However, a major hurdle for those in the developing autonomous space is that safety regulations and compliance guidelines for autonomous systems are often undefined.

While engineers know that they need to design and develop autonomous systems with safety and documentation in mind, how to achieve this is unclear due to a lack of official certifications and standards for autonomous technologies. And even when these standards and certifications are created, they will not be easy to achieve.

Additional hardships in this area include growing community acceptance, deconflicting national airspaces, adapting existing infrastructure, developing Federal Aviation Administration (FAA)-approved production systems and software assurance levels, and creating new piloting standards for autonomous vehicles. Barriers to entry will also exist regarding quality control systems, materials, and personnel.



/ Throughout it all, achieving compliance will also involve proving that an autonomous design can handle all possible situations and the irregular and demanding environments common in A&D.

As one example, take an autonomous drone operating in a city. This drone would have to handle obstacle avoidance, signal interference, and weather conditions such as wind. The drone’s developers would also have to prove via thorough analysis how it would react to a signal loss, power loss, bird strike, and other scenarios. These analyses must be comprehensive and cannot be rushed. Further, to ensure that autonomous systems such as this drone can achieve compliance in every operational condition, creating a modular and adaptable design is key.

While comprehensive certification standards for autonomous vehicles do not yet exist, special conditions and guidance are currently available for developers in the autonomous space. These include [SAE ARP4754A: Guidelines for Development of Civil Aircraft and Systems](#), [SAE ARP4761: Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment](#), and [SAE ARP6983: Process Standard for Development and Certification/Approval of Aeronautical Safety-Related](#)

Products Implementing AI. These guidelines and standards emphasize the importance of accounting for the overall aircraft operating environment, meeting internal standards and external compliance, and other key themes.

Private companies are also creating helpful guides. This includes Honeywell’s [“State of UAS and UAM Certification”](#) datasheet, which shares use cases and types of certifications needed in the U.S. and EU for crewed and uncrewed Advanced Air Mobility (AAM) vehicles, and their [Regulatory Readiness Level \(RRL\) Checklist](#). Regarding the latter resource, Honeywell says that it proposes this nine-level checklist to “objectively measure progress toward civil certification of an aircraft.” Additionally, Wisk and Boeing have produced a [ConOps guide](#) for uncrewed, passenger-carrying UAM operations.

Looking ahead, even when official standards and certifications become available, achieving certification and proving airworthiness through aviation safety regulators (e.g., FAA, EASA, etc.) will not be easy. Working toward this goal requires immense focus and investment in standardization, documentation, and redundancy, says David Downey, President of Downey Aviation Services and former FAA employee.



CHALLENGES

ALIGNMENT

Confirming that safety requirements align with mission objectives

COMPLIANCE

Meeting industry standards, safety goals, and regulatory guidelines

FEASIBILITY

Ensuring requirements are clear, feasible, and verifiable within constraints

GATHERING REQUIREMENTS

Collecting and validating a comprehensive list of requirements from diverse stakeholders while also ensuring alignment with industry standards

INTEGRATION

Incorporating all system components to avoid compatibility issues and aid in a smooth development process

PROBABILISTIC SYSTEMS

Developing architectures and layered systems that try to understand redundancies, behavior bounds, etc, due to the probabilistic nature of AI systems in A&D autonomy solutions

TECHNICAL SPECIFICATION

Aligning system requirements with clearly defined technical details and interfaces

WHY THE FUTURE OF MISSION ENGINEERING IS DIGITAL



/ Missions cannot succeed without mission engineering. However, as discussed in this chapter, traditional mission engineering is filled with common pitfalls and challenges.

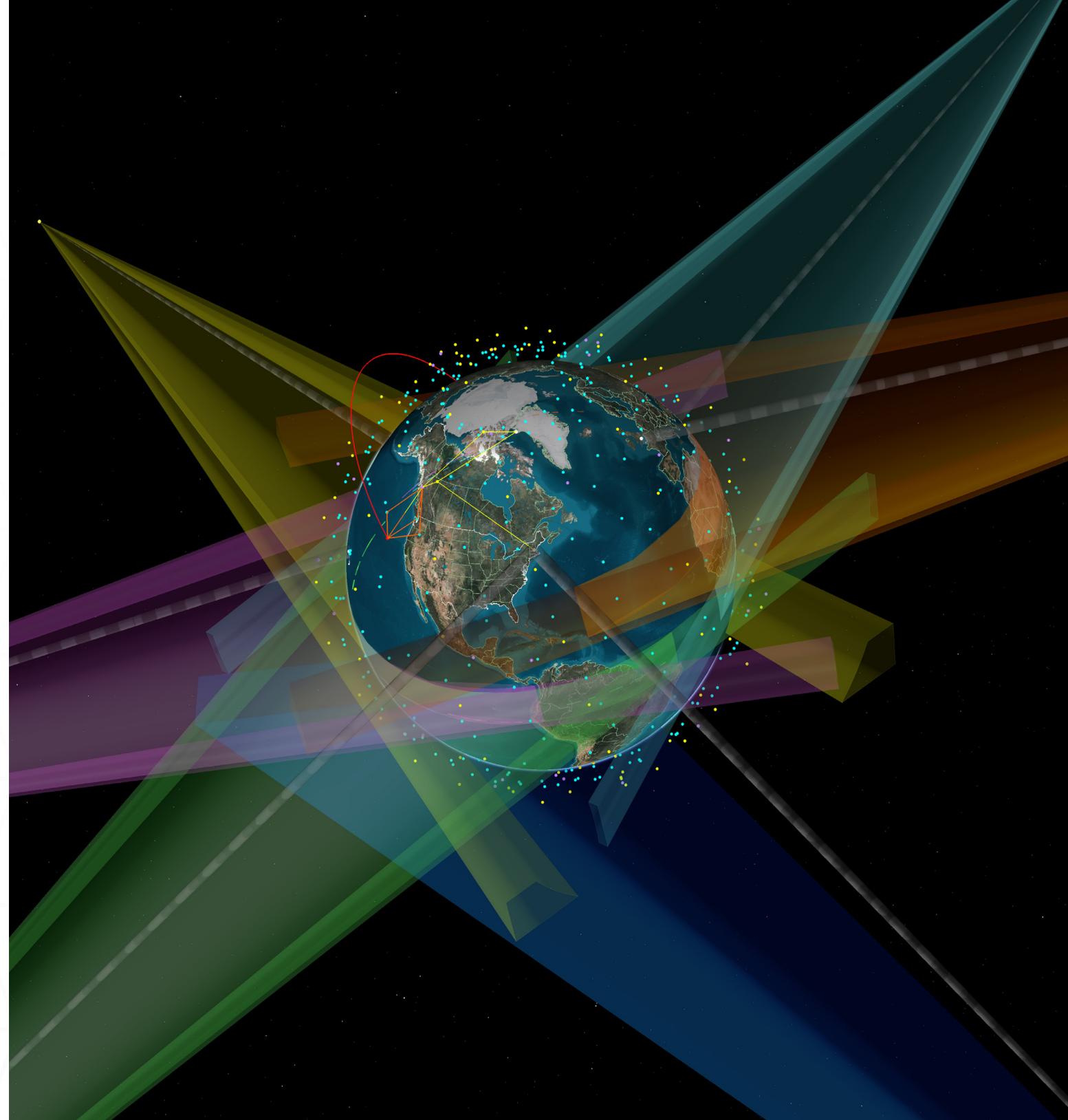
That is why engineers rely on digital mission engineering (DME) to create autonomous systems that will revolutionize the A&D industry. While DME began in the aerospace and defense industries, its popularity and use are expanding rapidly, with innovators in other industries, such as automotive, using it to design autonomous products.

Put simply, **DME** is the use of digital modeling, simulation, and analysis to represent systems within a realistic operational environment and evaluate mission outcomes and effectiveness at every phase of the system engineering design life cycle. DME provides a foundation on which engineers and researchers can integrate digital mission and system models to develop a true engineering analysis environment that measures mission effectiveness and defines outcomes across all levels of fidelity.

/ Using DME, engineers can understand performance before moving to real-world prototyping and testing. Additionally, by applying Ansys DME for autonomous systems, engineers will gain a few concrete benefits.

1. An enhanced ability to develop comprehensive ODD, DRM, ConOps, system requirements, and designs

- Improved mission understanding and analysis, leading to better preparation and system alignment with mission objectives
- Mission designs that are optimized and validated for real-world mission scenarios and reduce field failure risks
- Decision-making that uses data-driven insights for confident mission planning
- Enhanced automated workflows and repeatable tasks by linking engineering tools and requirements
- Better understanding of the environments autonomous systems will operate in to determine training data and testing/verification needs, as well as generating test environments and training data that is representative of the operational environment to better identify what may lead to unexpected behavior





2. An improved system architecture definition

- A thorough system definition to guide autonomous system development through a comprehensive, high-level system architecture blueprint
- Early validation and testing of system interactions to reduce integration risks
- More efficient optimization of system architecture by accessing trade studies and comparing design alternatives

3. Assistance in achieving certification and safety and standards compliance

- Lower risk by identifying potential issues early in the mission design process
- Enhanced communication and consistency of mandatory compliance goals across stakeholders
- Comprehensive evaluation of environmental conditions in a wide range of operational environments
- Well-defined system redundancy requirements and emergency procedures
- A reduction in safety certification costs by simplifying critical control application design and automating verification, qualifiable and certified code generation, and documentation generation
- More efficient and consistent execution of the key safety analysis methods required for electronic systems



These are just the start of the benefits engineers can achieve with the power of DME.

DME helps engineers achieve their mission goals in an accurate, detailed, time- and cost-efficient manner, accelerating time to market for autonomous systems.

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

LEARN MORE ▶



Powering Innovation That
Drives Human Advancement

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