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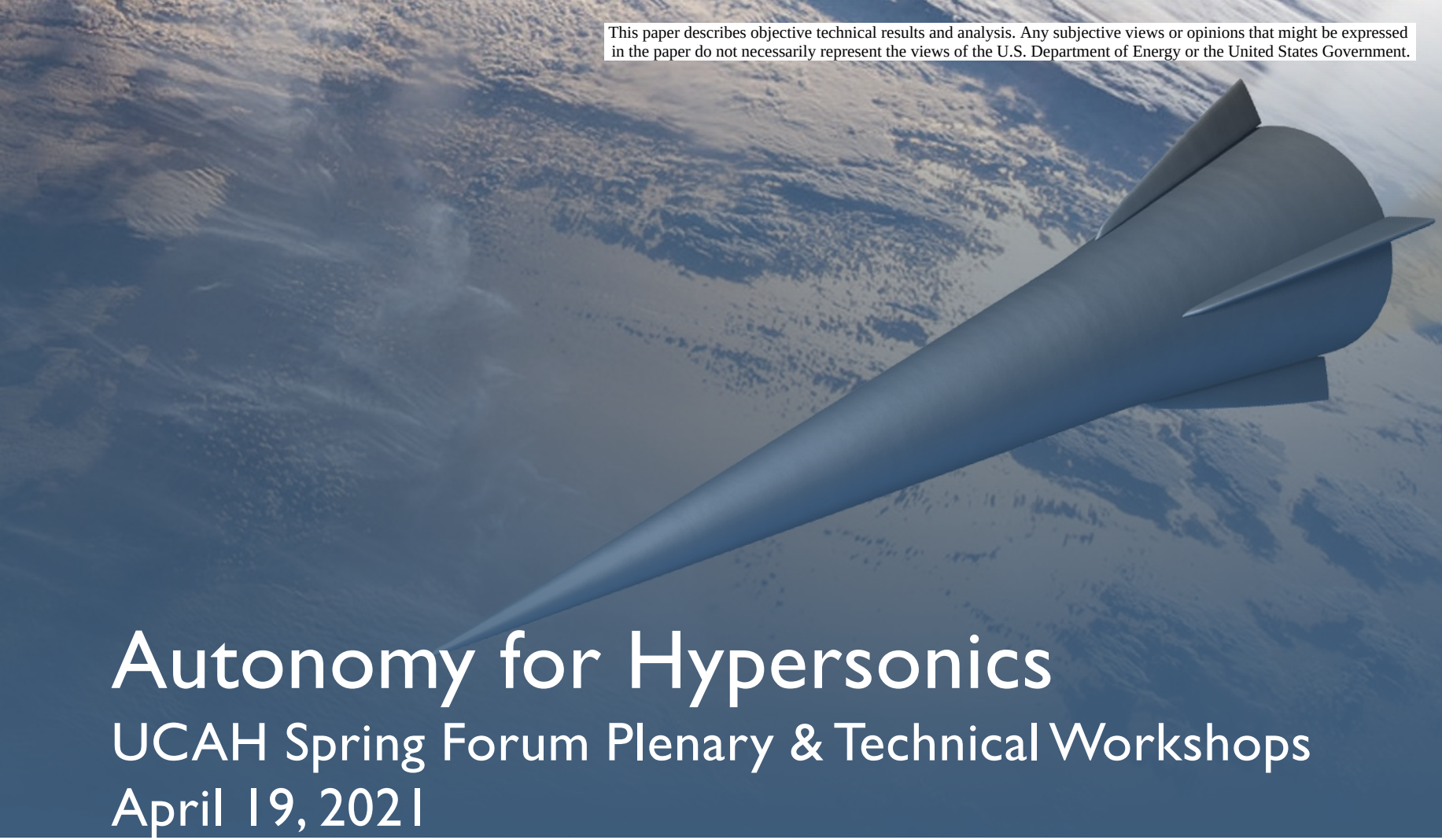

Autonomy for Hypersonics

UCAH Spring Forum Plenary & Technical Workshops

April 19, 2021

PRESENTED BY

Dr. R. Scott McEntire

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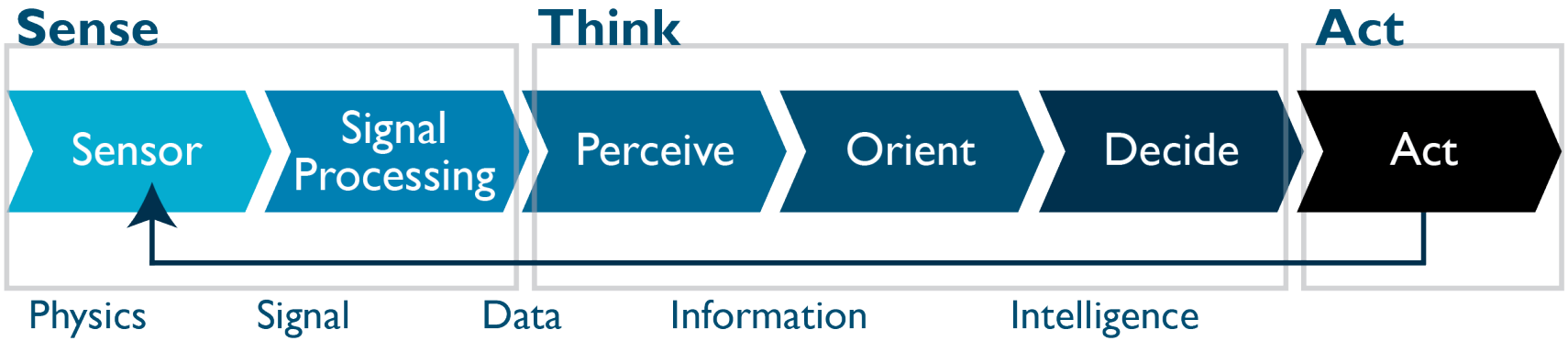
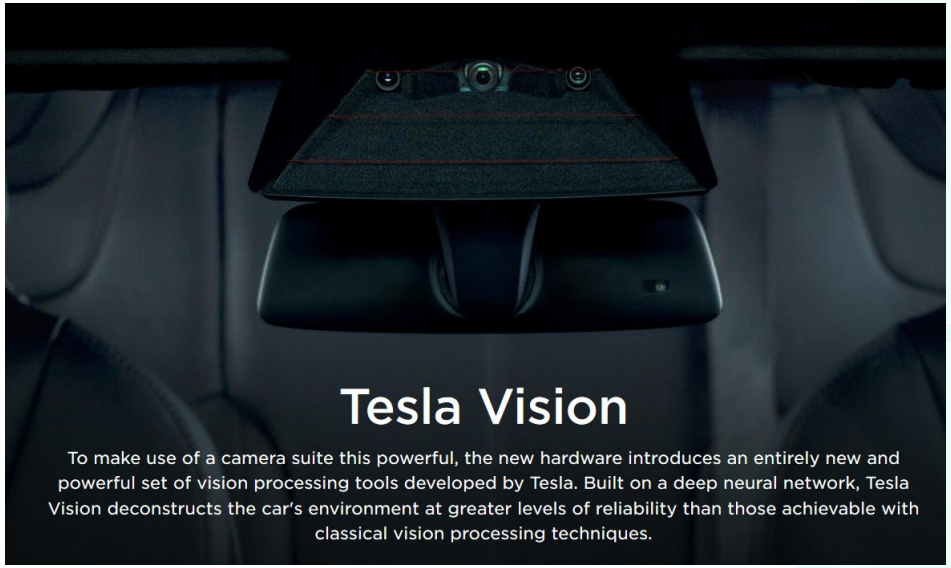
U.S. DEPARTMENT OF ENERGY

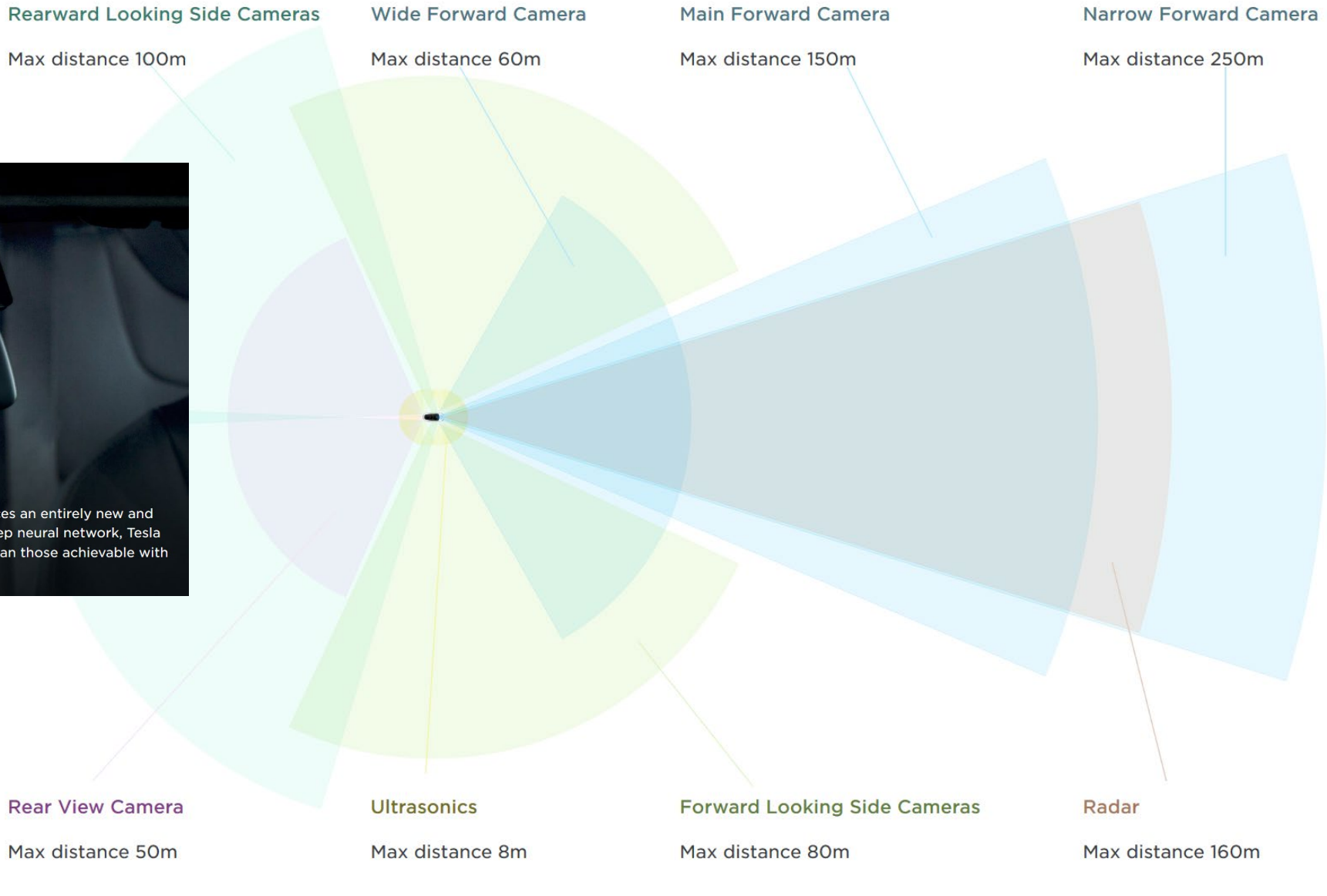
NNSA

Autonomous Systems – Tesla



Autonomous Systems – Tesla - Sensors





Commercial

- Structured environments
- Large tolerance for error
- Large labeled training datasets for accuracy
- Can deal with object classes (car, pedestrian, etc.)
- Short-range imaging modalities (e.g. RGB iPhone)
- Can typically rely on GPS and network connectivity, which allows off-board processing and simplifies C2

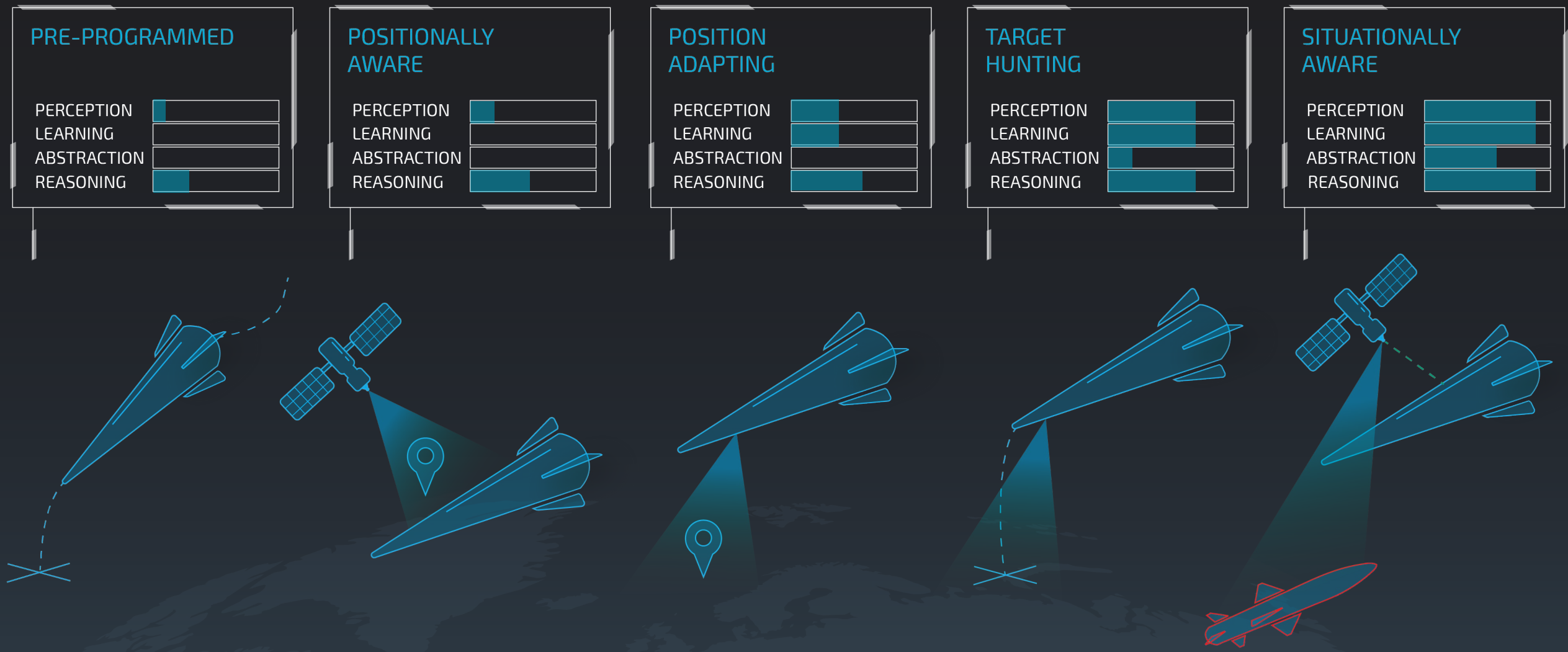
VS

Defense

- Unstructured, adversarial environments
- Low tolerance for error
- Lack of training data
- Requires precise object identification
- Remote EO/IR/SAR imaging modalities
- Operation in potentially contested environment with minimal to no network connectivity

Defense applications require different performance characteristics than their commercial counterparts, while managing SWaP and bandwidth limitations.

Sandia's Hypersonics of the Future Roadmap



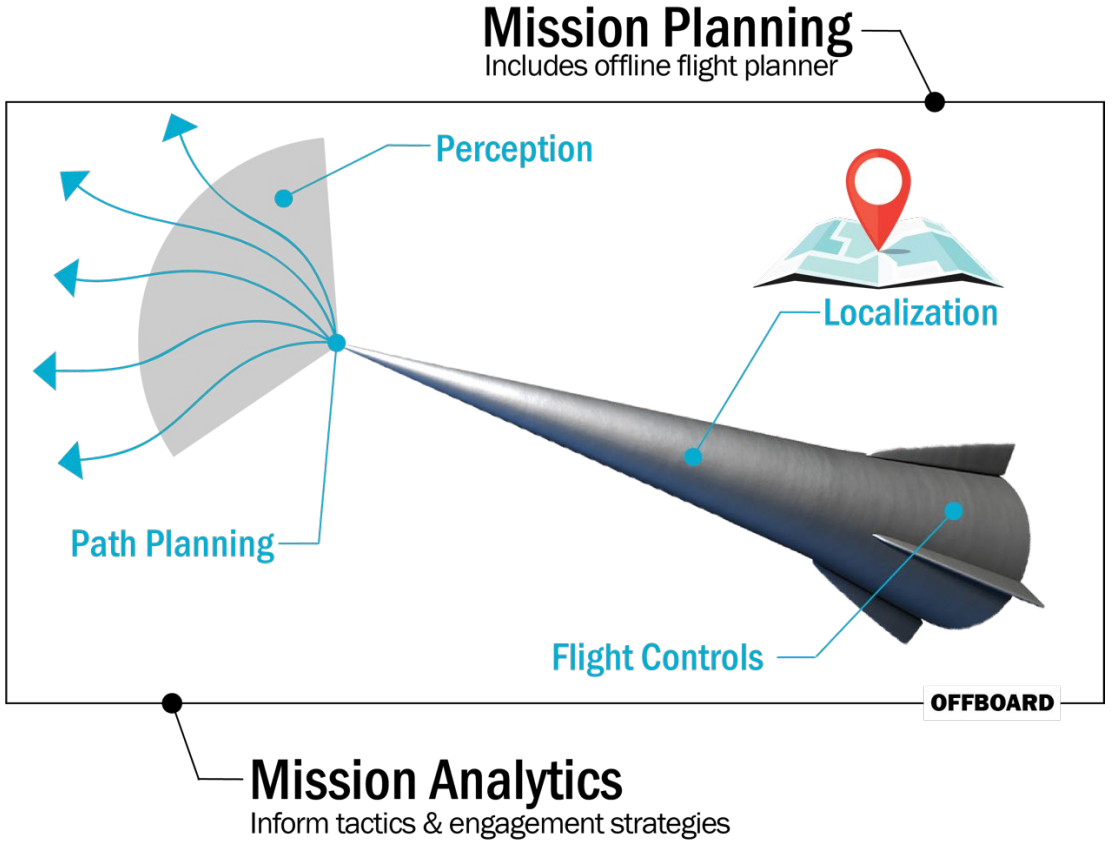
Autonomy for Hypersonics (A4H)

A4H will research and develop autonomous systems technologies that will enhance the warfighting utility of hypersonic flight systems

- Provide autonomous mission planning for rapid response to time-sensitive threats
- Enable adaptive, highly-maneuvering vehicles that intelligently navigate, guide, and control to targets

The developed autonomy solutions will strengthen conventional deterrence by enabling adaptive hypersonic systems that can:

- Prosecute fleeting targets in contested environments
- Provide a defense against adversary hypersonic weapons



Internal Sandia Investment | 6.5 years | 2018- 2023

Collaborating with Universities

ILLINOIS

Naresh Shanbhag
+ Craig Vineyard

Neural-Inspired Approaches and Implementations for Automatic Target Recognition

Zach Putnam
+ Daniel Whitten

Tightly Integrated Navigation and Guidance for Target Acquisition

Girish Chowdhary
+ Bart von Bloemen Waanders

Hyper-Differential Analysis to Mitigate Uncertainties for Control of Hypersonic Vehicles

Roy Dong
+ Kyle Williams

Coordinated Multi-Agent Reinforcement Learning in Continuous Action Spaces

Georgia Tech

Jonathan Rogers
+ Kyle Williams

Real-Time Evasive Maneuvers in Contested, Uncertain Environments

Ani Mazumdar
+ Katya Casper

Hypersonic Wind Tunnel Test Bed for Fault-Tolerant and Adaptive Control

Panos Tsiotras
+ Bart von Bloemen Waanders

Hyper-Differential Analysis to Mitigate Uncertainties for Control of Hypersonic Vehicles

Matthew Gomboley
+ Anirudh Patel

Learning Optimal Communication for Cooperative Sensor Fusion

Ani Mazumdar
+ Michael Sparapany

Eris: Chaotic Trajectories for Hypersonics

Evangelos Theodorou
+ Dave Kozlowski

Optimization & Robust Control Technique for use in Flight Control Design for Hypersonics

Ani Mazumdar
+ Kyle Williams

Real-Time Evasive Maneuvers in Contested, Uncertain Environments

Karen Feigh
+ Paul Schutte

Transparency & Operator Performance in Human Autonomy Teaming (TOPHAT)

The University of Arizona

Roberto Furfaro
+ Bethany Nicholson

Real-Time, Nonlinear, Optimization-Based Control Algorithms for Hypersonics

Texas A&M University

John Valasek
+ Daniel Whitten

Tightly Integrated Navigation and Guidance for Target Acquisition

Johnny Hurtado
+ Lisa Hood

Surrogate-Constrained Vehicle Modeling to Enable Rapid and Real-Time Trajectory Generation

NM State

Hyeongjun Park
+ Bethany Nicholson

Real-Time, Nonlinear, Optimization-Based Control Algorithms for Hypersonics

The University of New Mexico

Don Hush
+ Mary Moya

Improving Model-Based Training of ATR for Rapidly Responding to Evolving Threats

The University of Texas at Austin

Todd Humphreys
+ Kyle Williams

Coorindated Multi-Agent Reinforcement Learning in Continuous Action Spaces

Maruthi Akella
+ Mike Grant

Autonomous 6DOF RTTG for Highly Constrained Hypersonic Missions

Karen Willcox
+ Patrick Blonigan

Rapid High-Fidelity Aerothermal Responses with UQ via Reduced-Order Modeling

Renato Zanetti
+ Felix Wang

NeuroGrid: Robust Autonomous Localization through Multi-Resolution Grids

Purdue University

Kaushik Roy
+ Craig Vineyard

Neural-Inspired Approaches and Implementations for Automatic Target Recognition

Ali Raz
+ Kyle Williams

Real-Time Evasive Maneuvers in Contested, Uncertain Environments

Tim Pourpoint
+ Katya Casper

Hypersonic Wind Tunnel Test Bed for Fault-Tolerant and Adaptive Control

USC University of Southern California

Roger Ghanem
+ Cosmin Safta

Unsupervised Learning Algorithms for Autonomous Trajectory Analysis

Desired A4H Core Outcomes

Mission-Agile Intelligent NG&C

Advance traditional navigation, guidance, and control techniques beyond rules-based algorithms to more agile and intelligent architectures.

Distributed Execution of Complex Missions

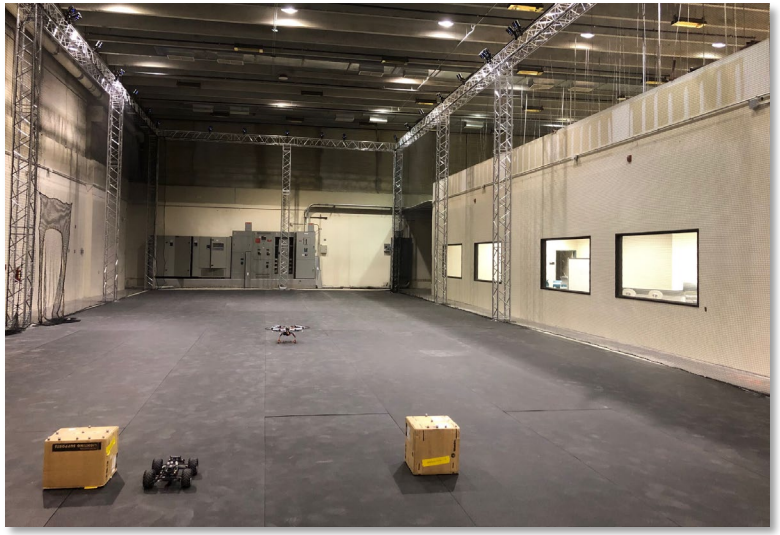
Ability to quickly and collaboratively determine tasking of multiple agents in a dynamically changing mission environment for successful prosecution of targets.

Agent Driven Mission Analysis

Leverage advances in complex gameplay for developing novel maneuvers and strategies for future warfighting scenarios.

AutonomyNM

*Autonomy Innovation hub for advanced **flight** and **space systems***



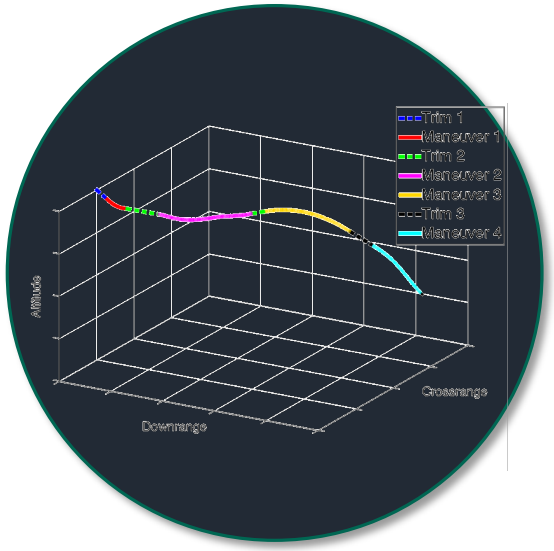
- AutonomyNM's goal is to promote and attract collaborative research and education programs with universities
- Provide a low-cost testbed for rapid iterative testing to support advanced autonomous algorithm development

- **FEATURES:**
  - ~4000 sq. ft. of high bay space that will be used as a low-cost test bed for UAS
  - Onsite assembly lab
  - Collaborative office space

AutonomyNM

AutonomyNM: Risk Reduction & Tech Transition

Demonstrating existing concepts and algorithms in real hardware & attracting customer investments in autonomy for national security applications.



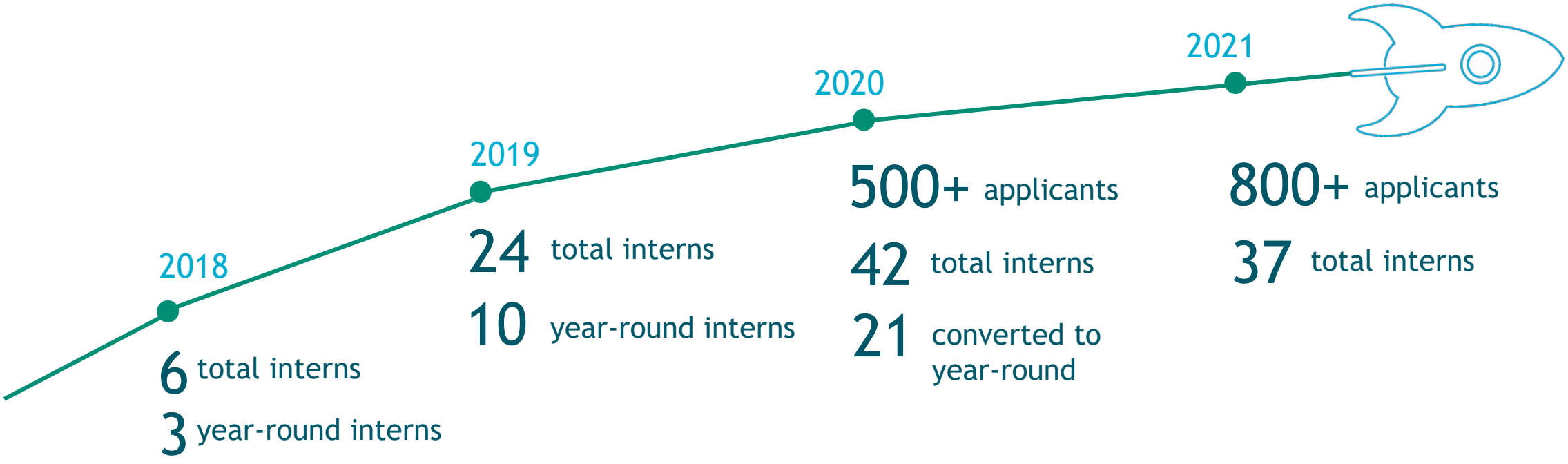
Develop New Ideas to Proof-of-Concept in Simulation

Demonstrate Algorithm in AutonomyNM SWIL Sim Environment

Fly Algorithm Real-Time on 'Real Hardware'

Demonstrate Algorithm in High Fidelity SWIL/HWIL Sim Environment

Building a Talent Pipeline



AutonomyNM's internship program has seen consistent growth in the level of interest since it was created. The goal is to expose students to autonomous systems for Sandia's impactful national security missions.

Some final thoughts….

National Power → Software Defined

Data → Currency of Warfare

Agility → Drives Dominance

Algorithms → Trained by Agents

Questions? Interested in learning more? Contact Scott McEntire: rmcenti@sandia.gov