RAW4



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# Hypersonics and Autonomy in Near Space

*PRESENTED BY*

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**Slide 1**

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**RAW4** Need some better graphics!!!

Roesler, Alexander William, 4/10/2019

# Outline

- Hypersonics 101
- Autonomous Systems for National Security
- Autonomy for Hypersonics

# Hypersonics 101

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- Hypersonic is defined as five times the speed of sound.
- The speed of sound is about 750 mph* or about 1000 feet per second*.
- A mile is 5280 feet, so the threshold for hypersonic flight is about a mile per second.
- The speed of sound is the basis for a unit called Mach Number.
- Advanced fighters fly at about Mach 3; the SR-71 flew about Mach 4. The fastest human-piloted aircraft (X-15) achieved Mach 6.7.
- For reference, earth orbital velocity is about 25,000 feet per second and provides an upper limit to the hypersonic flight regime.

*** At flight altitude**

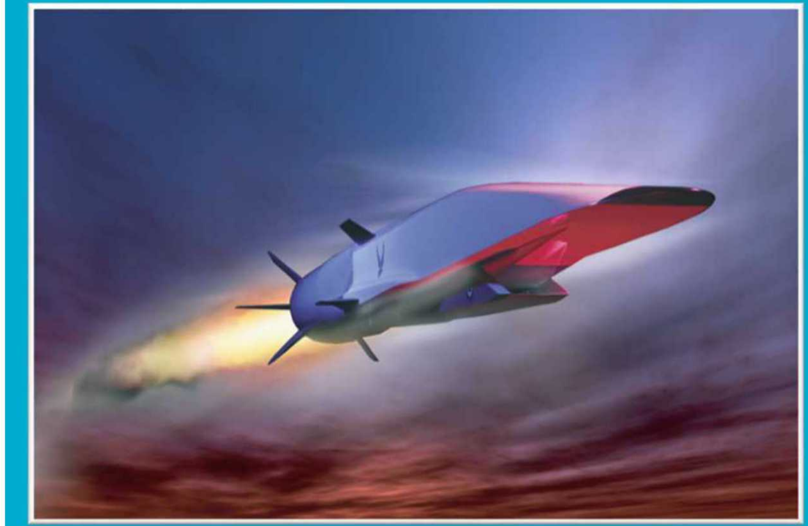
## Engineering Challenges

- Vehicle shape changes in hypersonic flight, creating challenges for flight control
- Difficult to simulate velocity, temperature, and Mach number on the ground
- Difficult to design sensors & actuators that can operate in a hypersonic flight environment
- Friction & separation happen in ways that causes calculations about materials to become "guesses"
- Calculations are extremely time consuming

# Different Hypersonic Systems

## Boost-Glide Systems

- Rocket boosted to velocity outside the atmosphere
- Reenters and establishes glide across upper atmosphere (near space)
- Cruise is typically between M 5 - 25
- Dives to target

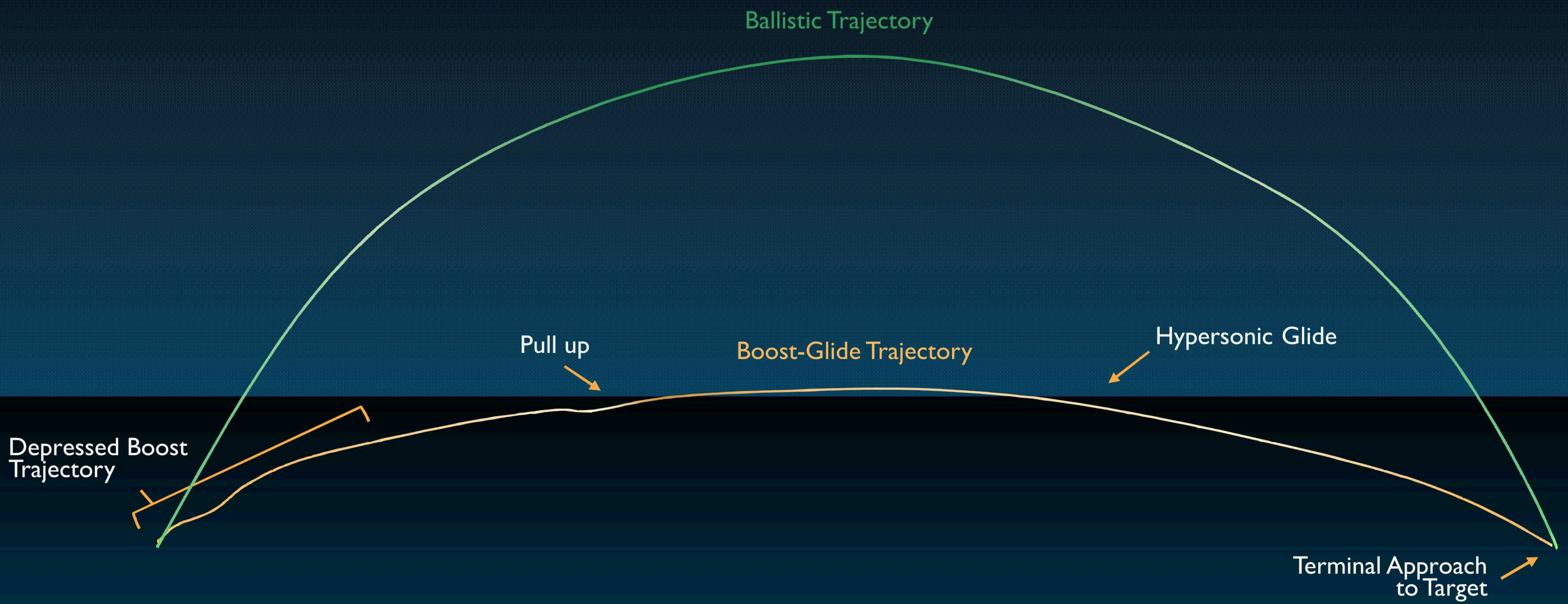


## Air-Breathing Systems

- Rocket boosted into altitude and velocity
- SCRAMJET propulsion cruise across upper atmosphere
- Cruise is typically between M 5 - 6
- Glides to target

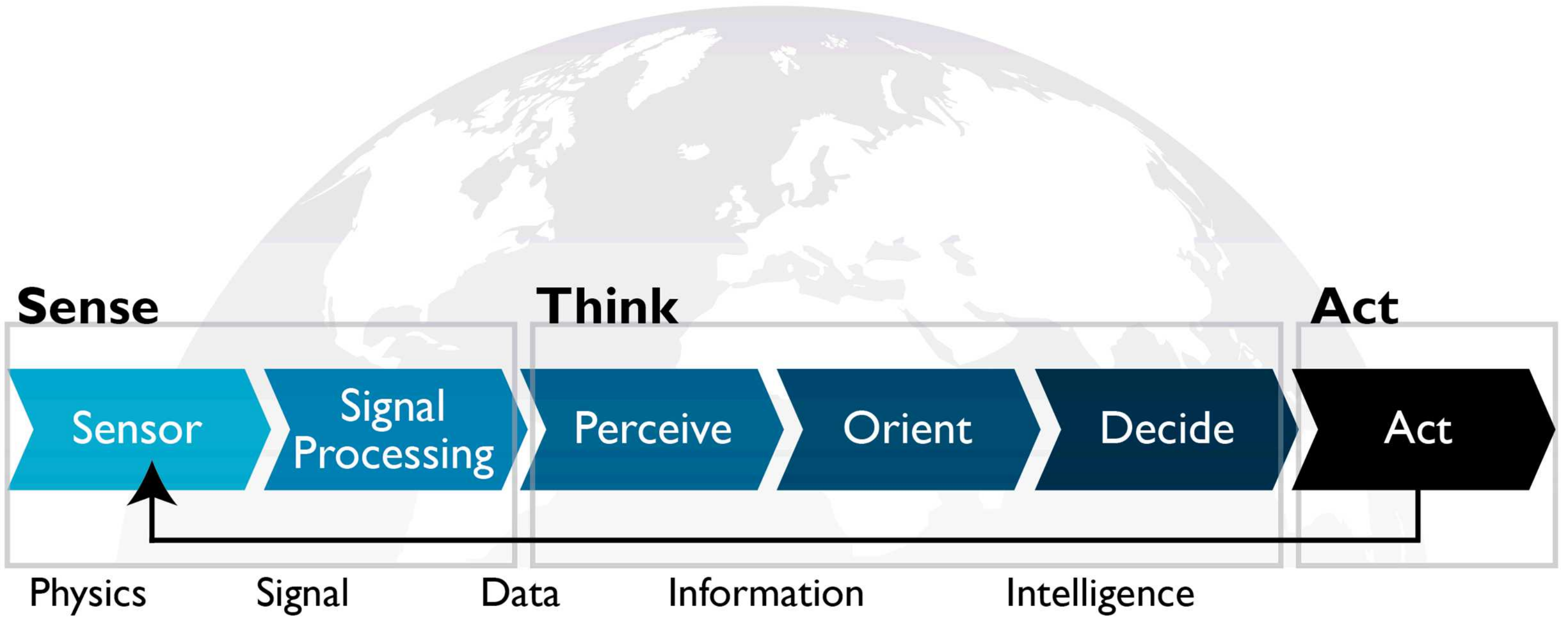
# Why Hypersonic Glide?

*Hypersonic systems fly distinctly different trajectories from Ballistic systems*



# Autonomous Systems for National Security

# Autonomous Systems



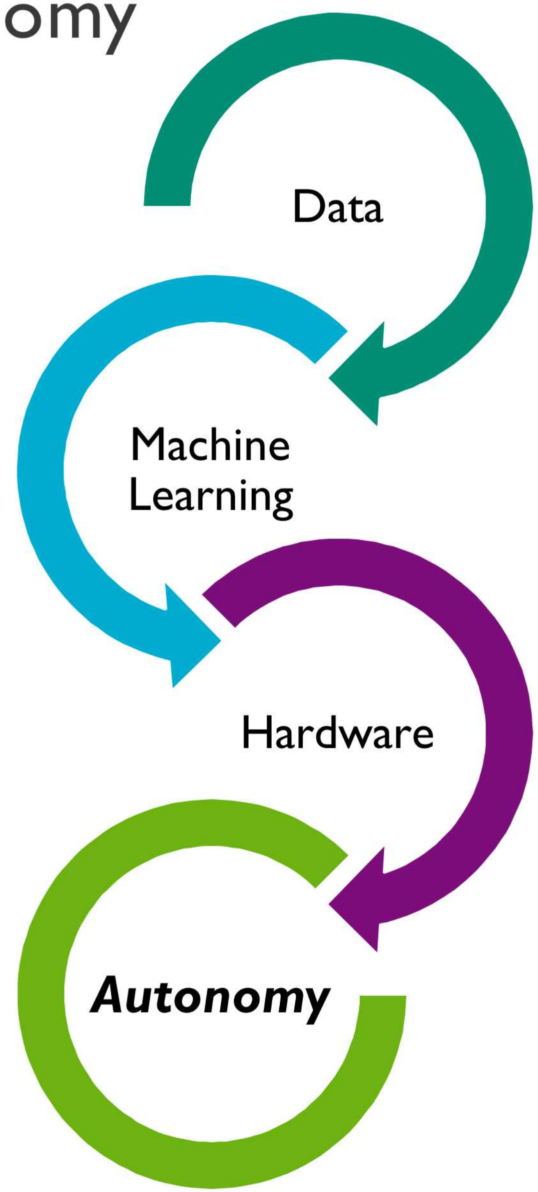

- Follow Sense-Think-Act paradigm
- Sensors provide signals & data
- Machine intelligence starts with data
- Sensor exploitation (target detection, identification, and characterization) provides information and intelligence
- High-level reasoning and dynamic sensor/platform/asset management close the loop with action

# AI Underpins Recent Advances in Autonomy

***"At least 80 percent of the recent advances in AI can be attributed to the availability of more computer power."***

- *Dileep George,*

*MIT Technology Review, 2013*



# Will AI tech plug-n-play for defense?

- *Andrew Ng,*
*Harvard Business Review*

***The AI community is remarkably open, with most top researchers publishing and sharing ideas and even open-source code. In this world of open source, the scarce resources are therefore:***

## Data.

Among leading AI teams, many can likely replicate others' software in, at most, 1–2 years. But it is exceedingly difficult to get access to someone else's data. ***Thus data, rather than software, is the defensible barrier for many businesses.***

## Talent.

Simply downloading and "applying" open-source software to your data won't work. ***AI needs to be customized to your business context and data.*** This is why there is currently a war for the scarce AI talent that can do this work.


# Autonomy for Hypersonics

# Autonomy for Hypersonics

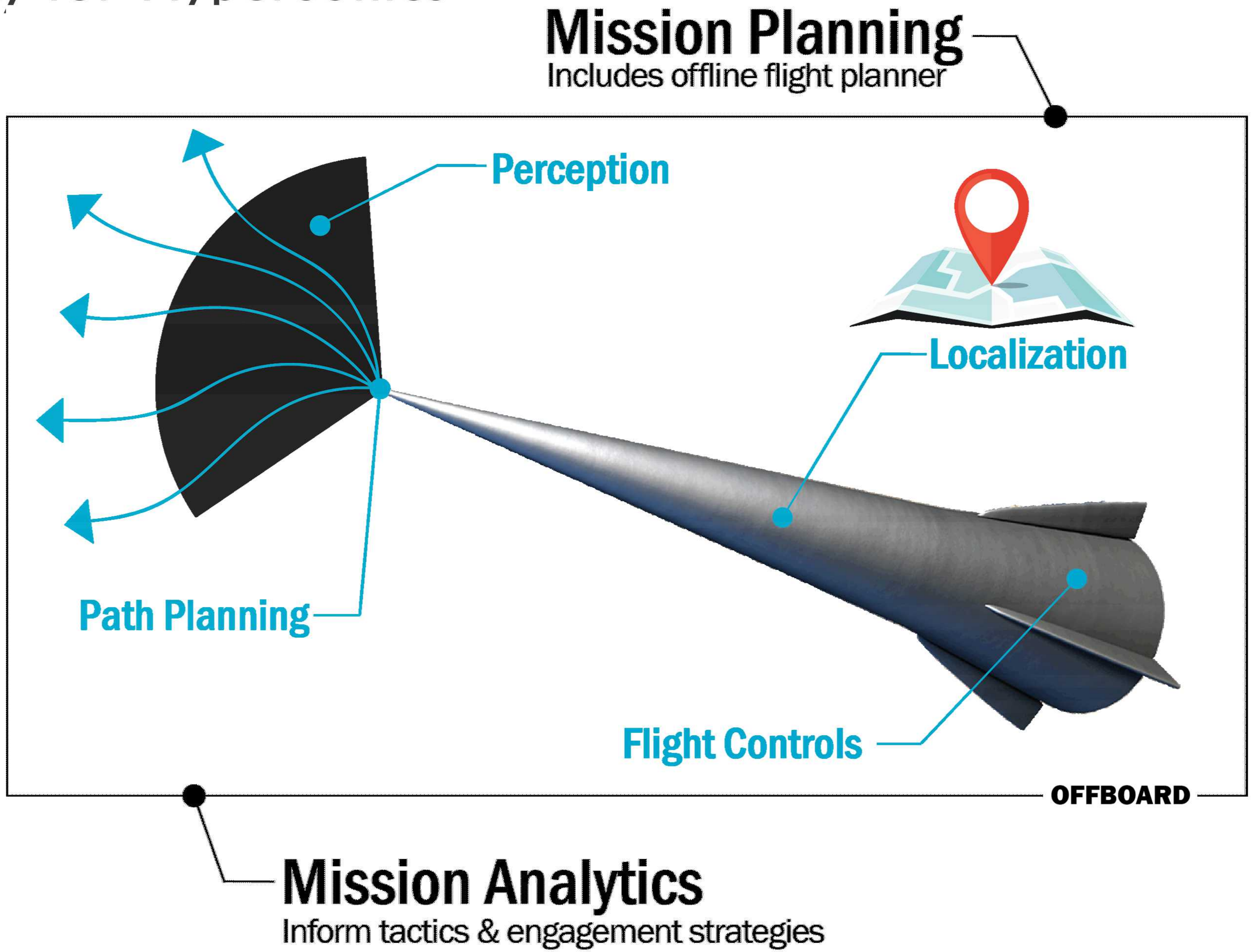
## Hypersonics provide a lot of military utility

- Hypersonics offer survivability and utility at long/strategic ranges, since they travel at exceptional speeds and are less susceptible to anti ballistic missile countermeasures and other defensive systems

## These systems will offer the most utility if they are able to:

- Utilize rapidly constructed flight plans (enable speed of action)
- Navigate without GPS
- Perceive their environment and adapt to it to ir counter moving targets
- Employ tactics and engagement strategies that are highly effective in complex, rapidly evolving environments and heavily defended areas
- Cooperate with other hypersonic systems

# Autonomy for Hypersonics



# Operational View

## Slide 14

**RAW5** I'd like to use these slides to show the autonomy elements, but need it to be UUR. I took off "Fuzing" and all but the basic descriptions on all of these slides.
Roesler, Alexander William, 4/14/2019

**RAW6** Would you please think of a different name for these?  I don't like the "Offensive DRM" title...
Roesler, Alexander William, 4/14/2019

# Mission Planning / Launch / Boost Phase

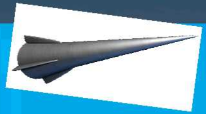
THRUST TERMINATION

**RAPID AUTONOMOUS MISSION PLANNING**

- Flight plan is loaded into the flight vehicle pre-launch
- Incorporates real-time situational awareness
- Involves human-automation integration
- Takes less than three minutes

RAPID
AUTONOMOUS
MISSION PLANNING

# Glide Phase



ENERGY MANAGEMENT &
FUTURE MANEUVER PLANNING

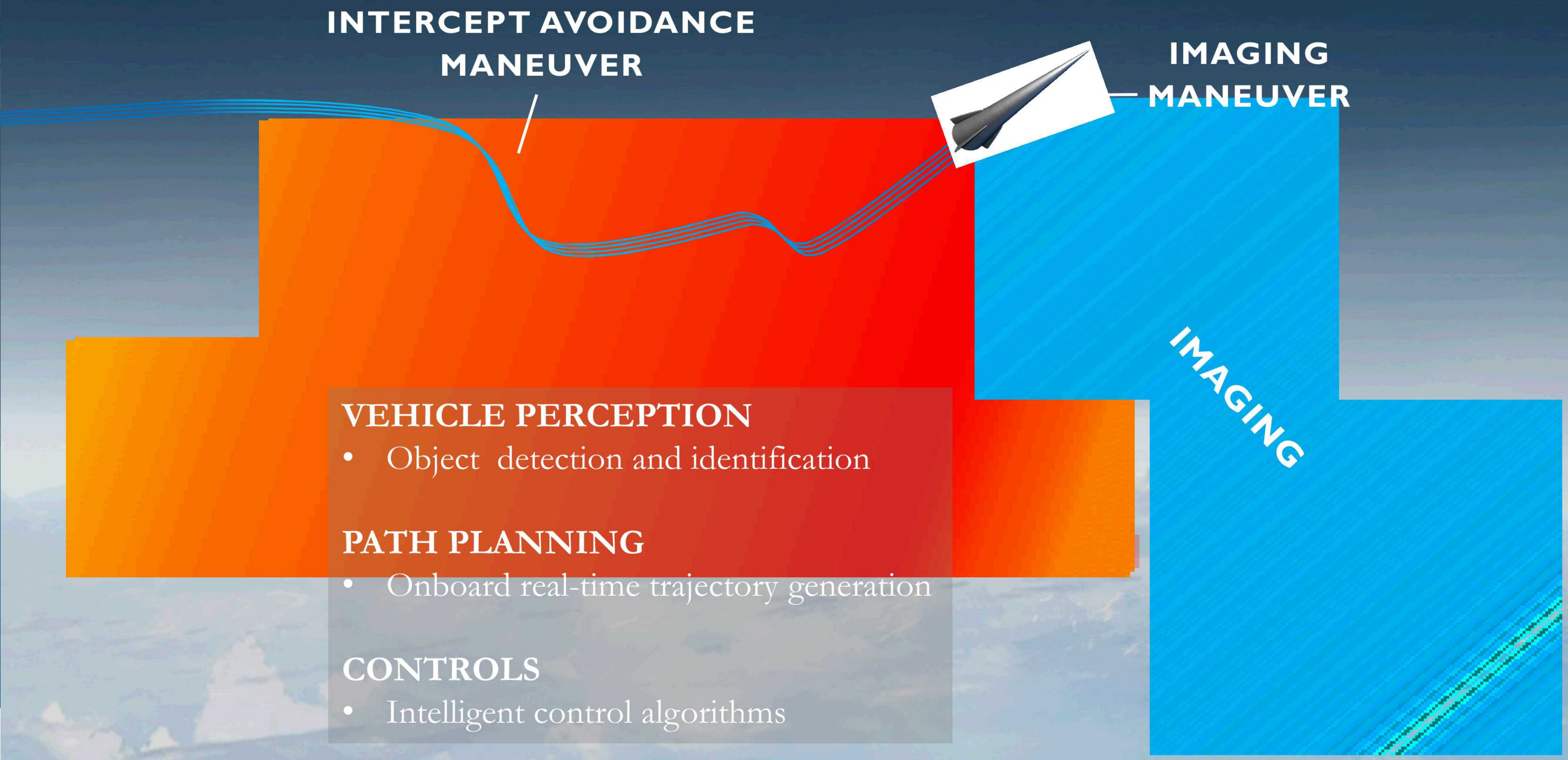
PULL UP

**LOCALIZATION**
- GPS-Denied navigation

**PATH PLANNING**
- Onboard real-time trajectory generation

**CONTROLS**
- Intelligent control algorithms
  - Adaptive
  - Fault-tolerant

# Target Approach Phase




**VEHICLE PERCEPTION**
- Object detection and identification

**PATH PLANNING**
- Onboard real-time trajectory generation

**CONTROLS**
- Intelligent control algorithms

# Terminal Phase

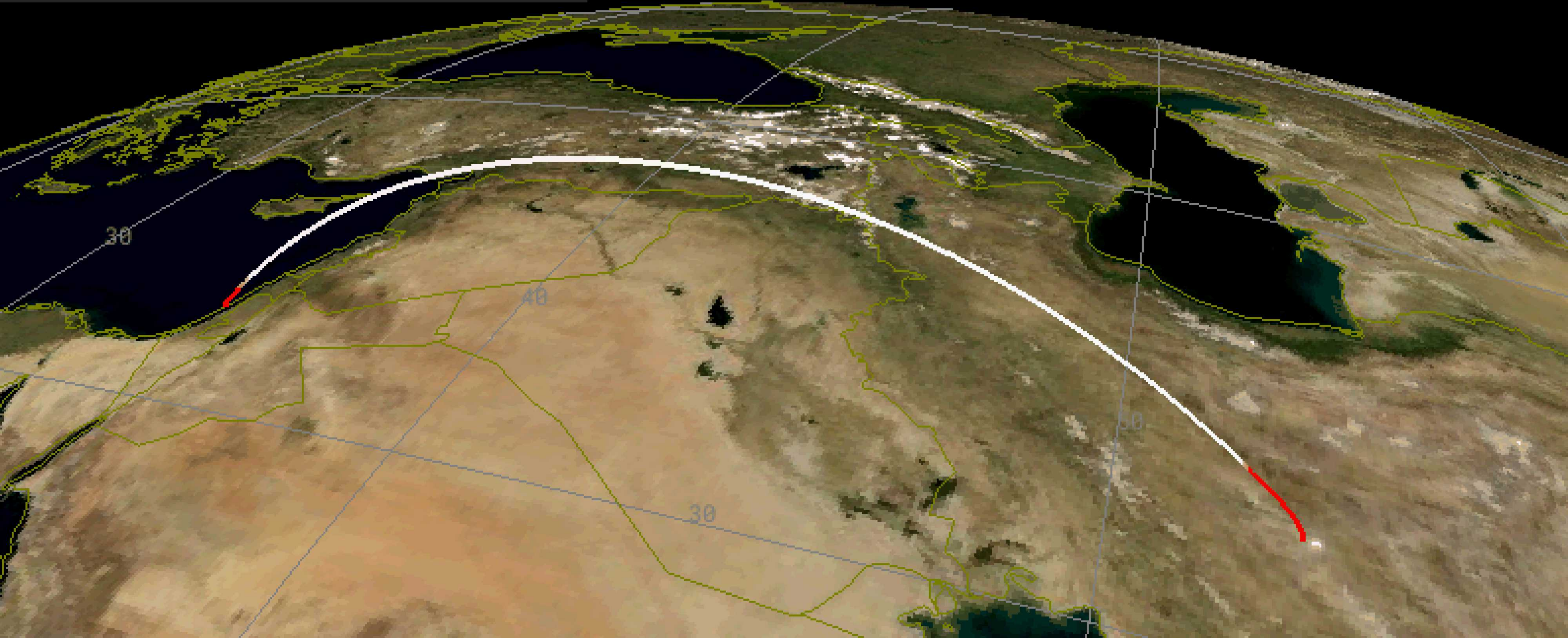
**CONTROLS**

- Intelligent control algorithms

PULL DOWN

# Mod/Sim Environment

To build the necessary AI, we need tools that aim to improve our ability to model key components of the complex environment.



# Evolution of Hypersonic Strike Capability

**POSITIONALLY AWARE**
2-5 YEARS

**POSITION ADAPTING**
4-7 YEARS

**TARGET HUNTING**
5-10 YEARS

**SITUATIONALLY AWARE**
7-15 YEARS

# Autonomy for Hypersonics 2050: Research Challenges

**Limited Training Data**

**Complicated Rules**

**Processing Power Limitations**

**Need for Global Optimization**

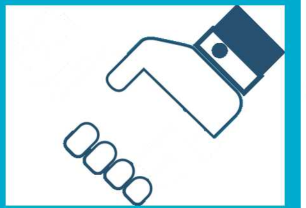
# Autonomy for Hypersonics: Long Term Concepts

**Encoding physics** engines into machine learning – both to help with learning processes and to more quickly replicate via inference what those engines can produce

Looks to create a machine that will learn more like a human, i.e. from first-order principles knowledge, to accelerate the learning process…make the learning much more efficient

**Lifelong learning** by letting the system "dream" and scrimmage when specific tasks/labels are unavailable, change its computational architecture based on task context, and develop new functions based on internal and external state changes.

Imagine a future where hypersonics are plugged in and constantly learning



**Human-AI symbiosis** is a critical need, with an emphasis on trying to help people understand the decision making behind the complex system

Create assurance measures for learning-enabled systems to operate at design time (simulation) and run time (verification), to ensure NNs behave correctly