Sandia National Laboratories

AUTONOMY FOR HYPERSONICS
VIRTUAL FIELD DAY 2020

Welcome & Introduction

Dr. Scott McEntire, *Sr. Manager, Pathfinder Systems*
Dr. Julie Parish, *Manager, Autonomy for Hypersonics*

U.S. DEPARTMENT OF ENERGY

NNSA

Purpose

To bring A4H collaborators together with their Sandia counterparts to build and expand the existing research network established through this mission campaign.

AUTONOMY FOR HYPERSONICS
VIRTUAL FIELD DAY 2020

Aug 4

AM Session 9-12:10 (MDT)

Mission Planning: Modeling & Trajectory Generation

PM Session 1:30-4:00 (MDT)

Onboard Sensing & Perception

Aug 5

AM Session 9:15-11:40 (MDT)

Control (Part 1)

PM Session 12:40-2:30 (MDT)

Control (Part 2)

Aug 6
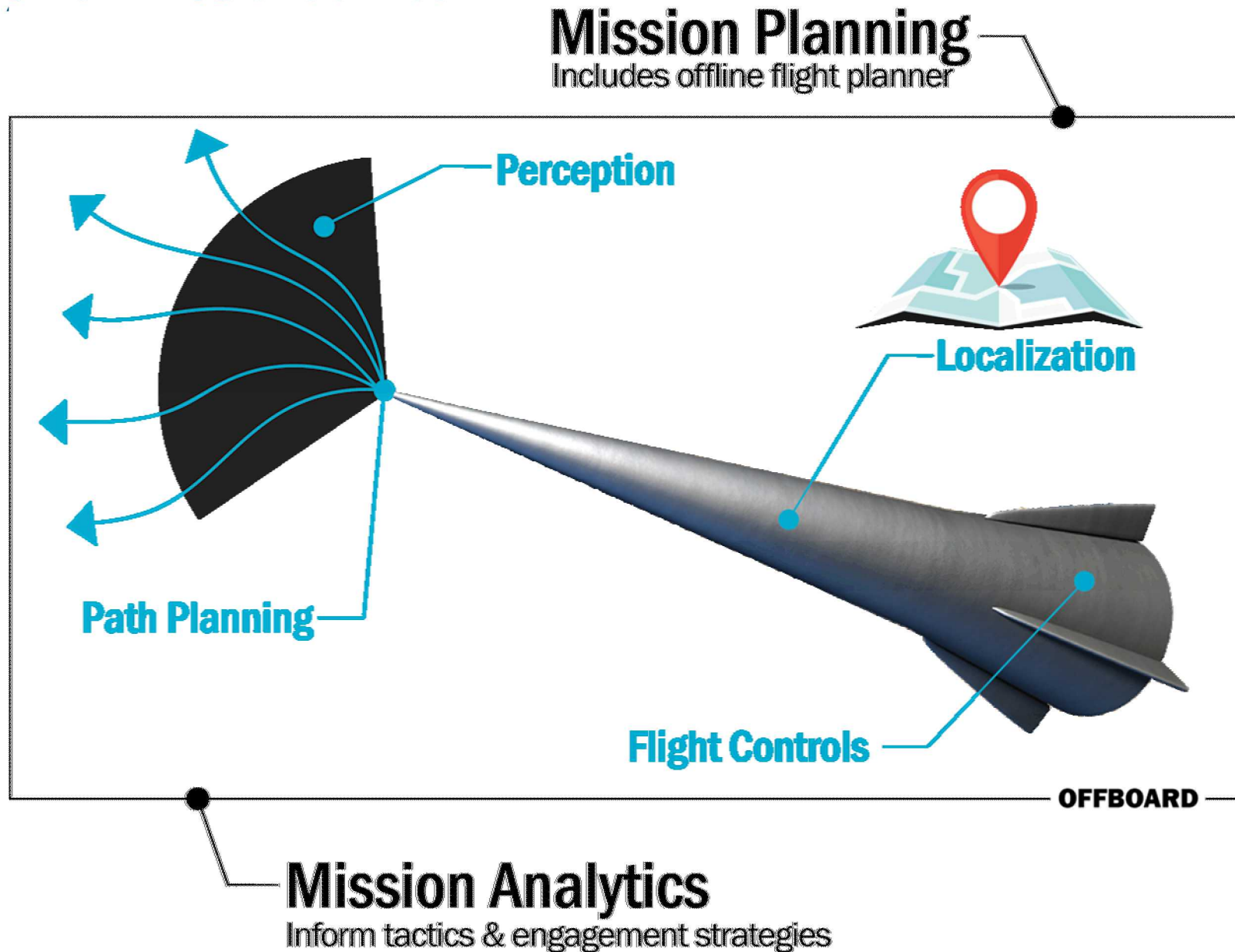
AM Session 9-12:00 (MDT)

Navigation & Guidance

Meet the A4H Team

Scott McEntire
Senior Manager
Pathfinder Technologies

Julie Parish
Manager
Autonomy for Hypersonics

Meg Davidson
Business Development
Autonomy for Hypersonics
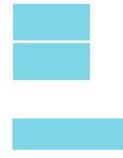
Autonomy for Hypersonics

PRE-PROGRAMMED

POSITIONALLY AWARE

POSITION ADAPTING

TARGET HUNTING

SITUATIONALLY AWARE
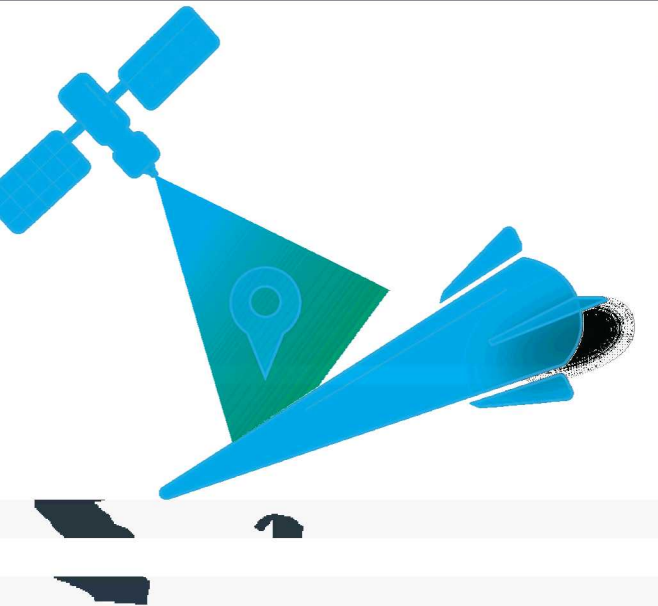
COORDINATE SEEKING CAPABILITY THAT IS ROBUST TO THE GPS CONTESTED ENVIRONMENT

POSITIONALLY AWARE

- Senses vehicle position throughout flight
- Delivers warhead to coordinates that are specified prelaunch
- Requires GPS for a substantial portion of flight
- GPS robust against spoofing and modest jamming environments
- Leverages simple sensors to enhance accuracy

RESEARCH CHALLENGES

- Rapid trajectory generation
- Adaptive control algorithms

**POSITION
ADAPTING**

COORDINATE SEEKING CAPABILITY THAT IS ROBUST IN THE NON-GPS ENVIRONMENT

- Senses vehicle position throughout flight

- Initial target coordinates are specified prelaunch

- Leverages GPS when available

- Employs alternate navigation scheme(s) to determine vehicle position

- Accepts updated target coordinates during flight

RESEARCH CHALLENGES

- Non-GPS navigation (sensors and algorithms)

- Mission planning with sensor constraints

- Real-time trajectory generation (RTTG)

## ROBUST CAPABILITY TO ADDRESS RELOCATABLE AND MOBILE TARGETS

TARGET HUNTING

- Approximate target coordinates and target signature are specified prelaunch

- Employs GPS and/or alternate navigation to localize

- Accepts updated target information during flight

- Employs a terminal sensor(s) to identify target

RESEARCH CHALLENGES

- Left-of-launch mission planning and analysis

- Sensor systems and window materials

- Vehicle perception—Image processing / Automatic Target Recognition (ATR) algorithms

- Sensor-aided terminal guidance and control

SITUATIONALLY AWARE
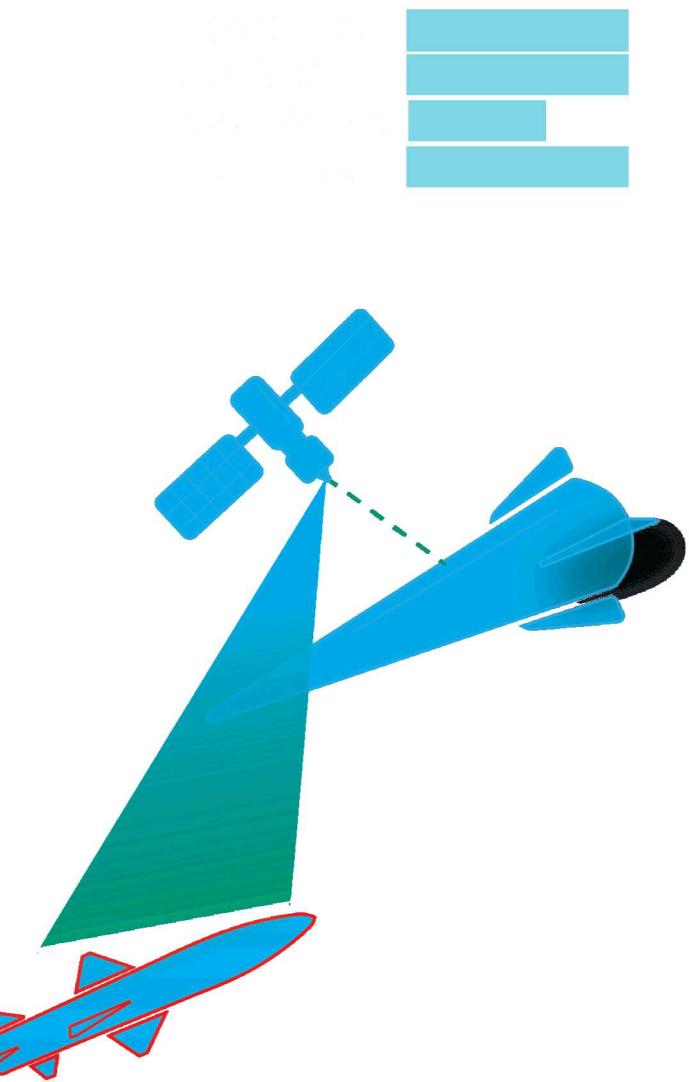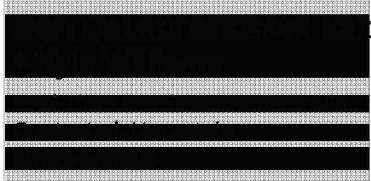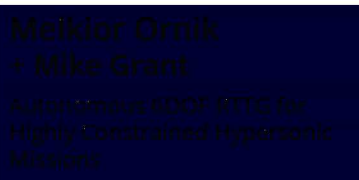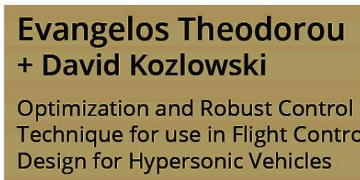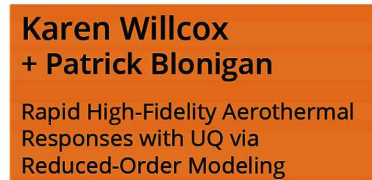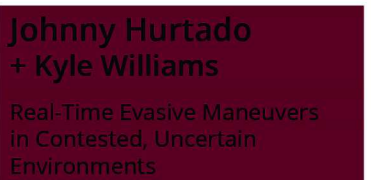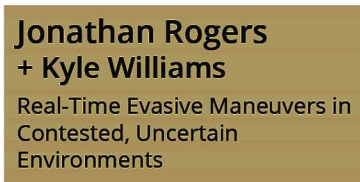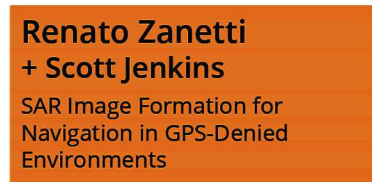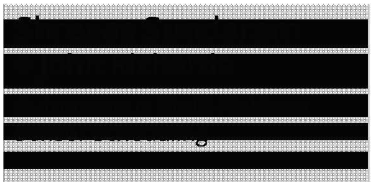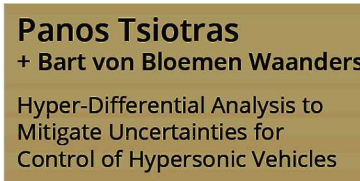
AUTONOMOUS ADAPTATION TO MAXIMIZE STRIKE EFFECTIVENESS

- Senses many elements of its environment
- Fuses data from off-board sensors
- Learns from the experiences of other strike vehicles
- Develops holistic view of mission challenges
- Adapts flight plan for optimal engagement

RESEARCH CHALLENGES

- AI-enabled mission analysis
- Autonomous mission planning (left of launch)
- Human-machine teaming
- Cooperative sensor fusion and exploitation
- Dynamic mission re-planning (right of launch)

Current Research Collaborations

ILLINOIS

**Naresh Shanbhag
+ Craig Vineyard**

Neural-Inspired Approaches and Implementation-Be Automatic Target Recognition

**Zach Putnam
+ Daniel Whitten**

Tightly Integrated Navigation And Guidance for Target Acquisition

**Melkior Ornik
+ Mike Grant**

Autonomous 6DOF RTTG for Highly Constrained Hypersonic Missions

**Rakesh Nagi
+ Michelle Hummel**

Justification and Transparency in SAR ATR using AI Rule Extraction and Real-Time, Nonlinear,

**Girish Chowdhary
+ David Kozlowski**

Optimal Event Control Allocation and Fault Detection/Recovery for Hypersonic Flight Vehicles

Georgia Tech

**Jennifer Hasler
+ Craig Vineyard**

Neural-Inspired Approaches and Implementations for Automatic Target Recognition

**Ani Mazumdar
+ Katya Casper**

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

**Evangelos Theodorou
+ David Kozlowski**

Optimization and Robust Control Technique for use in Flight Control Design for Hypersonic Vehicles

**Jonathan Rogers
+ Kyle Williams**

Real-Time Evasive Maneuvers in Contested, Uncertain Environments

**Panos Tsiotras
+ Bart von Bloemen Waanders**

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

**Ani Mazumdar
+ Kyle Williams**

Real-Time Evasive Maneuvers in Contested, Uncertain Environments

TEXAS — The University of Texas at Austin

**Ufuk Topcu
+ David Kozlowski**

Optimization & Robust Control Technique for use in Flight Control Design for Hypersonic Vehicles

**Todd Humphreys
+ Daniel Whitten**

Tightly Integrated Navigation and Guidance for Target Acquisition

**Karen Willcox
+ Patrick Blonigan**

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

**Renato Zanetti
+ Scott Jenkins**

SAR Image Formation for Navigation in GPS-Denied Environments

**Maruthi Akella
+ Mike Grant**

Autonomous 6DOF RTTG for Highly Constrained Hypersonic Missions

PURDUE UNIVERSITY

THE UNIVERSITY OF NEW MEXICO

**Meeko Oishi
+ John Richards**

Autonomous Multi-Platform Sensor Scheduling

TEXAS A&M UNIVERSITY

**Johnny Hurtado
+ Jason Searcy**

Magnetometer-Aided GPS-Denied Navigation

**John Valasek
+ Daniel Whitten**

Tightly Integrated Navigation and Guidance for Target Acquisition

**Johnny Hurtado
+ Kyle Williams**

Real-Time Evasive Maneuvers in Contested, Uncertain Environments

USC University of Southern California

**Roger Ghanem
+ Cosmin Safta**

Unsupervised Learning Algorithms for Autonomous Trajectory Analysis

THE UNIVERSITY OF ARIZONA

**Roberto Furfaro
+ Bethany Nicholson**

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

KANSAS STATE UNIVERSITY

**Bill Hsu
+ Jason Searcy**

Magnetometer-Aided GPS-Denied Navigation

NM STATE

**Hyeongjun Park
+ Bethany Nicholson**

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

**Liang Sun
+ Michelle Hummel**

Justification and Transparency in SAR ATR using AI Rule Extraction and Fused Classification

AutonomyNM Update

Features:

- Highbay robotarium
- Onsite Assembly Lab
- Collaborative office space
- Offices for visiting professors

August 4

Session 1:

Scott McEntire & Julie Parish, SNL

Maruthi Akella, UT Austin

Ali Raz, Purdue

Karen Willcox, UT

Ani Mazumdar, GT

Jon Rogers, GT

Roger Ghanem, USC

Panos Tsiotras, GT

Session 2:

Naresh Shanbhag, UIUC

Jennifer Olson Hasler, GT

Rakesh Nagi, UIUC

Kaushik Roy, Purdue

Meeko Oishi, UNM

All

Future Collaboration Discussions

GOAL:
- Identify ways we can continue to collaborate on advanced autonomous systems research and development.
- Make connections with fellow researchers interested in the same topics

August 5

Session 3 :

Ufuk Topcu/Steven Carr/Frank Djeumou, UT

Girish Chowdhary, UIUC

Melkior Ornik, UIUC

Shreyas Sundaram, Purdue

Roberto Furfaro, UA

Todd Humphreys/Nick Montalbano, UT Austin

Session 4 :

Evangelos Theodoro, GT

Hyeongjun Park, NMSU

Liang Sun, NMSU

All

Agenda: Day Three

August 6

Session 5:

Renato Zanetti, UT

Manoranjan Majji, TAMU

Zach Putnam, UIUC

Johnny Hurtado/Greg Arleth, TAMU

John Valasek,/Hannah Lehman TAMU

Felipe Guzman, TAMU

All