# Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

## FY18 Annual Review

**15 October 2018**


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Project Manager

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Deputy Project Manager

**Laurie Grindle**
Associate Project Manager

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Chief Engineer

**April Jungers**
Lead Resource Analyst

# Agenda

| | | |
|---|---|---|
| 8:30– 8:45 | Welcome, Opening Remarks, Integrated Aviation Systems Program (IASP) Overview | Dr. Edgar Waggoner |
| 8:45 – 9:30 | UAS-NAS Overview | Davis Hackenberg |
| 9:30 – 10:15 | Technical Performance | William Johnson |
| 10:15 – 10:30 | Break | |
| 10:30 – 11:00 | Technical Performance | William Johnson |
| 11:00 – 12:00 | Project Level Performance & Fiscal Year (FY) 19 Look Ahead Review Summary | Laurie Grindle |
| 12:00 | Lunch | |
| 1:00 – 3:00 | Caucus | IRP and PRP separately |
| 3:00 – 4:00 | Initial Feedback | IRP and PRP |
| 4:00 | Adjourn | |

# Annual Review Overview

- Purpose - Conduct an assessment of the Project's quality and performance
- Approach - The Project will provide a programmatic review addressing the following:
  - Project's Goal and Technical Challenges (TC) and their alignment to NASA and Aeronautics Research Mission Directorate (ARMD) Strategy
  - Project background and alignment with community efforts
  - Key highlights and accomplishments for the Project's technical challenges
  - Project performance of the past year through examination of:
    - Cost/Resource, Schedule, and Technical Management
    - Progress in establishing partnerships/collaborations and their current status
  - Key activities, milestones, and "storm clouds" for FY19

# Outline

- UAS Integration in the NAS (UAS-NAS) Overview
  - FY18 Summary
  - UAS-NAS Project Background
- Technical Performance
- Project Level Performance & FY19 Look Ahead
- Review Summary

# FY18 Summary

- Successful completion of multiple Project Research Activities (simulations and flight tests) in support of Phase 2 Detect and Avoid (DAA) and Command and Control (C2) Technical Challenges (TC)

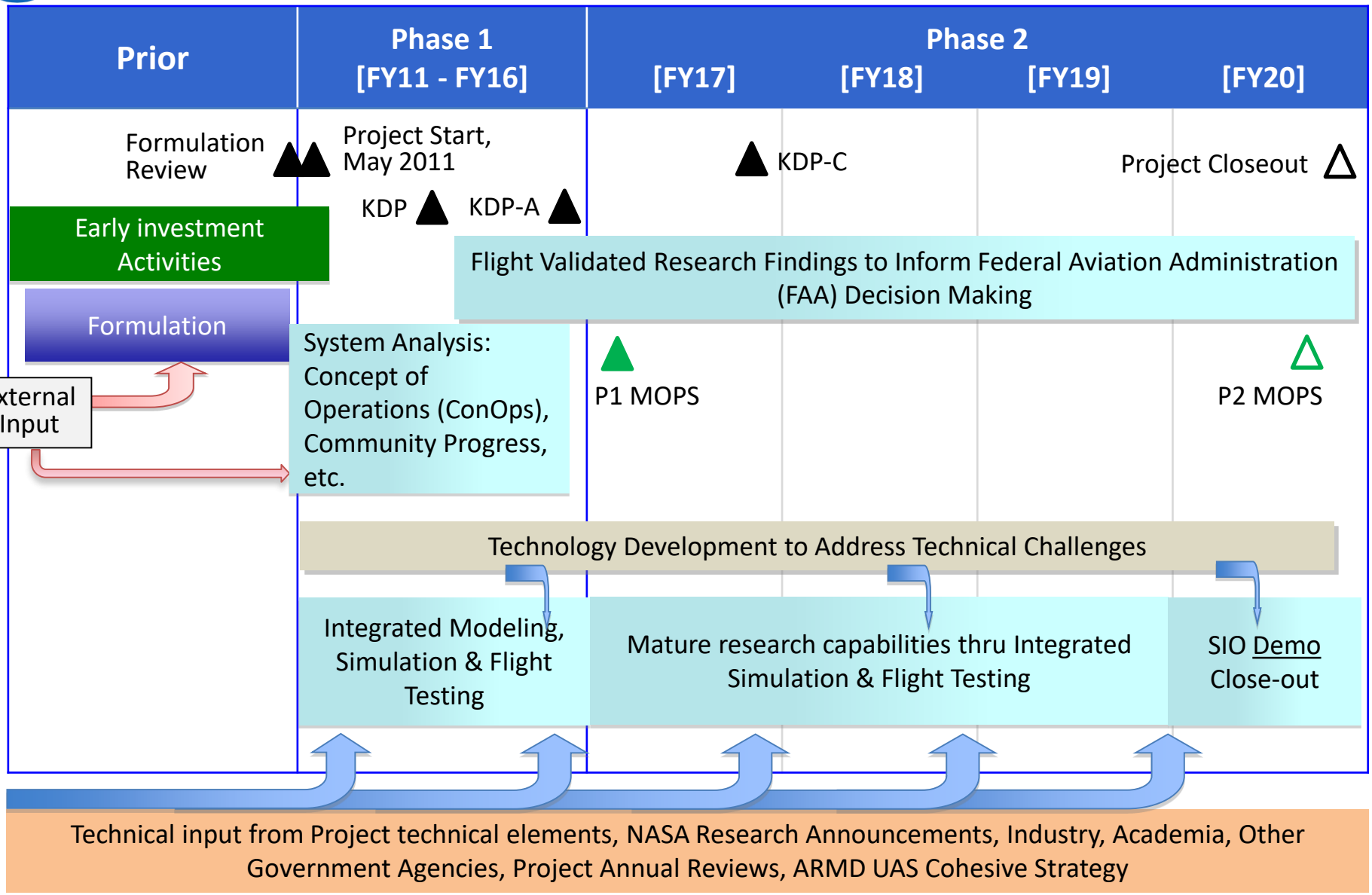
- Successfully advanced the Systems Integration and Operationalization (SIO) Demonstration through Cooperative Agreements (CA) with selected Industry Partners

- Established Research Transition Team (RTT) formally with the Federal Aviation Administration (FAA)

- Successful continuous risk management
  - Flight Test (FT) 5 and 6

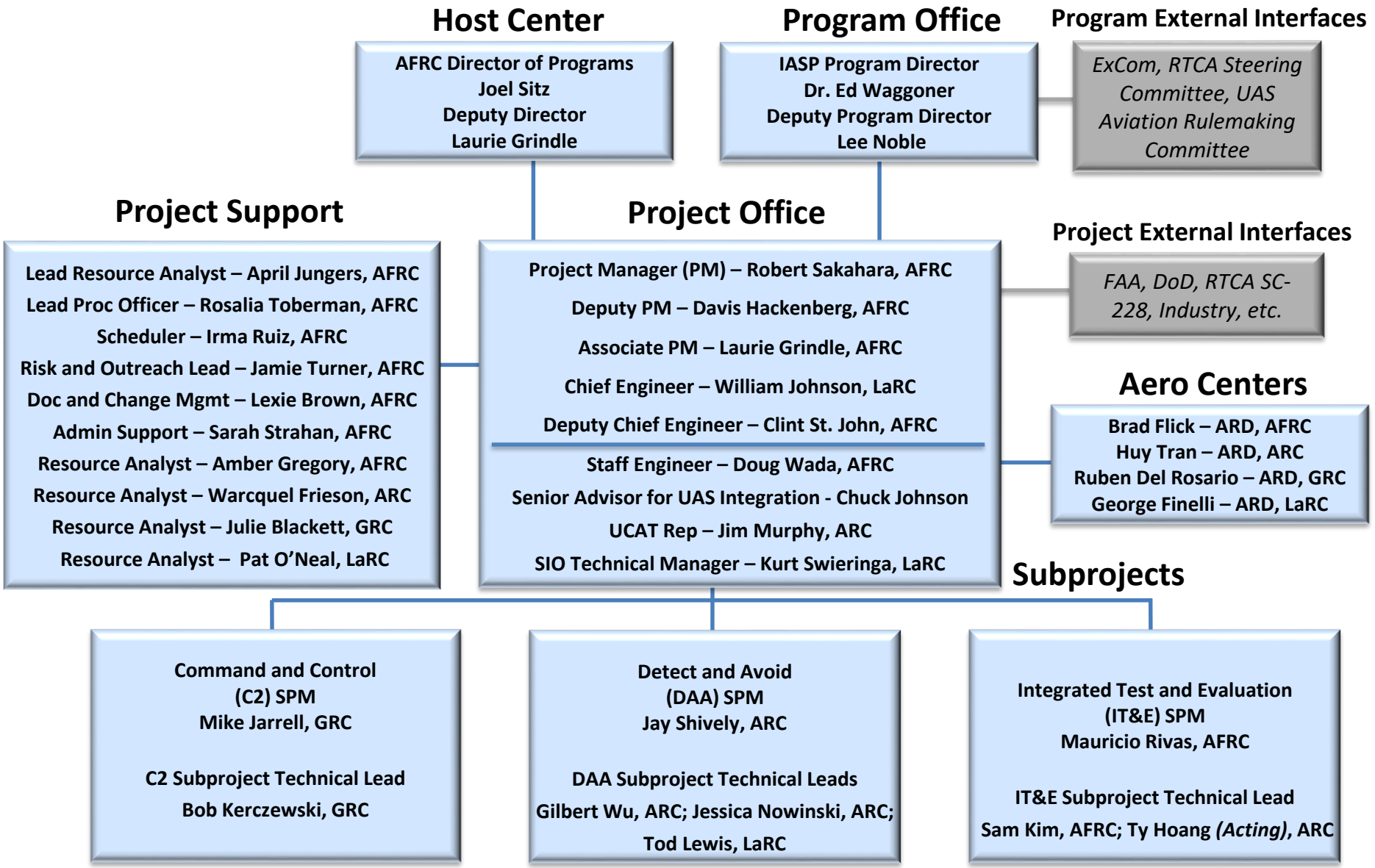
- Effective Schedule and Milestone management

# UAS-NAS Project Lifecycle
# Timeframe for impact: 2025




△ Key Decision Points △ SC-228 Deliverables, i.e. Minimum Operational Performance Standards (MOPS) Complete

# UAS Integration in the NAS Organizational Structure




ARD: Aeronautics Research Director, PM: Project Manager, SPM: Subproject Manager, UCAT: Urban Air Mobility Coordination Assessment Team, SIO: Systems Integration and Operationalization

# Personnel Changes

- Data Redacted

# NASA Strategic Plan Flow Down to UAS-NAS Project

**STRATEGIC GOAL**

**3:** Address national challenges and catalyze economic growth

**OBJECTIVE**

**3.2:** Transform aviation through revolutionary technology research, development, and transfer

**PERFORMANCE GOAL**
***UAS-NAS***

**3.2.6:** Support transformation of civil aircraft operations and air traffic management through the development, application, and validation of advanced autonomy and automation technologies, including addressing critical barriers to future routine access of UAS in the NAS, through the development and maturation of technologies and validation of data

**Annual Performance Indicators (APIs)**
***UAS-NAS***

**AR-18-10**: Complete the data collection, analysis, and reporting for DAA well clear / alerting requirements, foundational terminal operations, HITL simulation; and complete the initial test asset for the C2 Version 6 (V6) terrestrial communication system test

**AR-19-10**: Complete the data collection, analysis, and reporting for the DAA and IT&E FT5 and for the C2 V6 terrestrial communication system flight test

**Project GOAL**
***UAS-NAS***

Provide research findings, utilizing simulation and flight tests, to support the development and validation of DAA and C2 technologies necessary for integrating UAS into the NAS

# ARMD Strategic Plan Flow Down to UAS-NAS Project

*AERONAUTICS STRATEGIC THRUST

**Thrust 6:** Assured Autonomy for Aviation Transformation

AERONAUTICS OUTCOME

**Outcome (2015-2025):**
Introduction of aviation systems with bounded autonomy, capable of carrying out function-level goals

AERONAUTICS Critical Commitment

**Critical Commitment:**
Deliver validated flight data to RTCA for MOPS enabling persistent UAS flight in Class E airspace

UAS-NAS *Technical Content*

***TC-C2:***
***UAS Command & Control***

***TC-DAA:***
***Detect and Avoid***

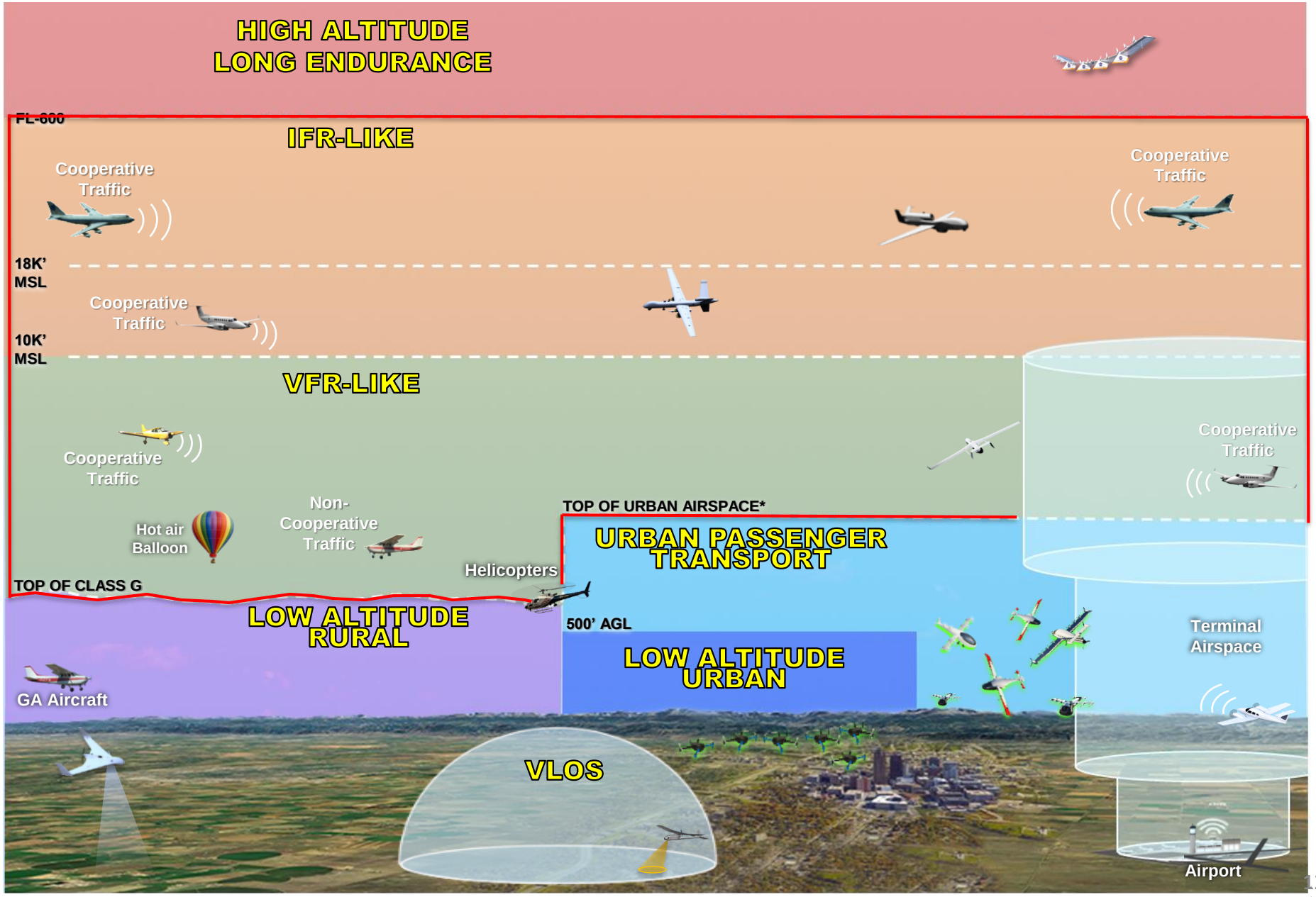
***SIO:***
***Systems Integration and Operationalization***

* Note: UAS-NAS is also related to Thrust 1 through the Thrust TC - Develop Operational Standards for UAS in NAS

# Full UAS Integration Vision of the Future

***Manned and unmanned aircraft will be able to routinely operate through all phases of flight in the NAS, based on airspace requirements and system performance capabilities***

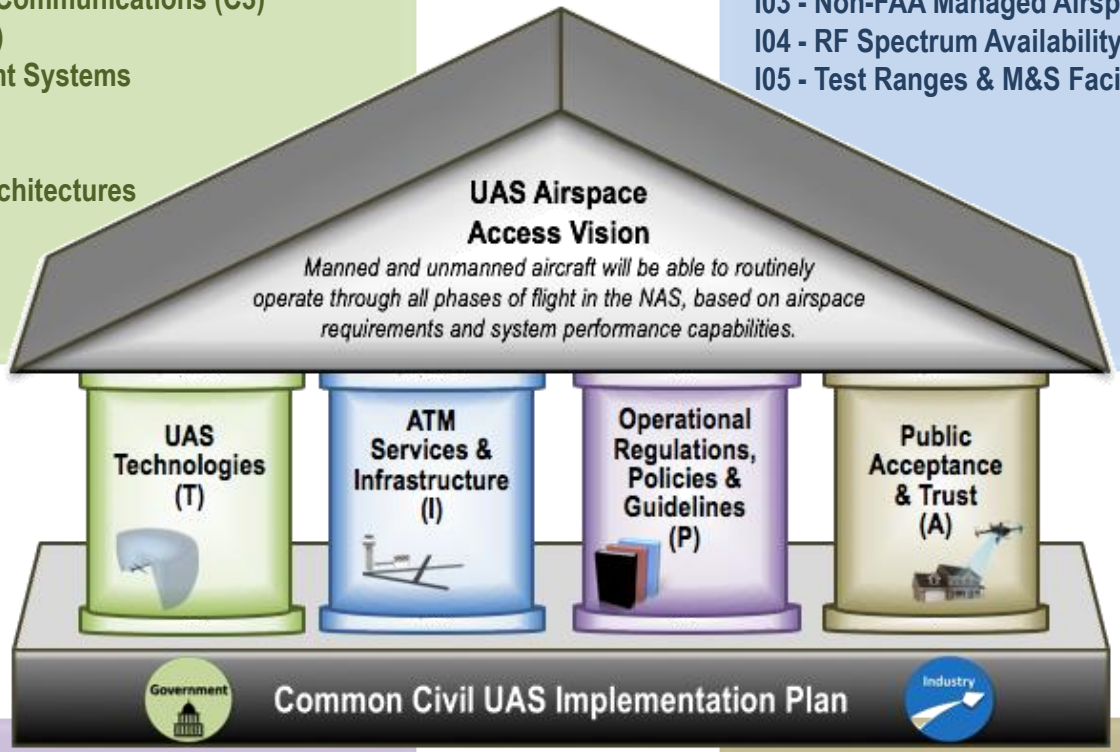
# Commercial Operating Environments (OE)



# UAS Airspace Integration Pillars and Enablers

## UAS Technologies:
T01 - Airport Operations Technologies
T02 - Airworthiness Standards
T03 – Command, Control, Communications (C3)
T04 - Detect & Avoid (DAA)
T05 - Flight & Health Mngmt Systems
T06 - GCS Technologies
T07 - Hazard Avoidance
T08 - Highly Automated Architectures
T09 – Navigation
T10 - Power & Propulsion
T11 - Weather

## ATM Services & Infrastructure:
I01 - Airport Infrastructure
I02 - ATM Infrastructure
I03 - Non-FAA Managed Airspace Infrastructure
I04 - RF Spectrum Availability
I05 - Test Ranges & M&S Facilities




## Operational Regulations, Policies & Guidelines:
P01 - ATM Regulations / Policies / Procedures
P02 - Airworthiness Regulations / Policies / Guidelines
P03 - Operating Rules / Regulations / Procedures
P04 - Safety Risk Mngmt & Methods of Compliance

## Public Acceptance & Trust:
A01 - Cybersecurity Criteria & Methods of Compliance
A02 - Legal & Privacy Rules / Guidelines
A03 – Noise Reductions
A04 - Physical Security Criteria & Methods of Compliance
A05 - Public Safety Confidence

***The UAS Airspace Integration Pillars enable achievement of the Vision***

# UAS-NAS Project Value Proposition

## NASA UAS-NAS Project Activities

### TC C2 — C2 Performance Standards

- Research C2 SatCom Systems
- Develop C2 Prototype Terrestrial System
- Conduct C2 Flight Test and MS&A
  - *Data Link*
  - *CNPC Spectrum*
  - *CNPC Security*
  - *BVLOS/BRLOS ATC Interoperability*
- Develop C2 Requirements

### TC DAA — DAA Performance Standards

- Develop DAA Test beds
- Conduct DAA Flight Test and MS&A
  - *Human Factors Performance Trade-offs*
  - *Low Cost SWaP sensors*
  - *Well Clear*
  - *Collision Avoidance*
- Develop DAA Performance & Interoperability Requirements

### Integrated Test & Evaluation

- Develop DAA Prototype System
- Live Virtual Constructive (LVC) Test Infrastructure
- Conduct Technology and ConOps testing
  - ACAS Xu FT2
  - No Chase COA
  - Conduct FT5 Test Scenarios
  - Conduct FT6 Test Scenarios

### SIO — Systems Integration and Operationalization

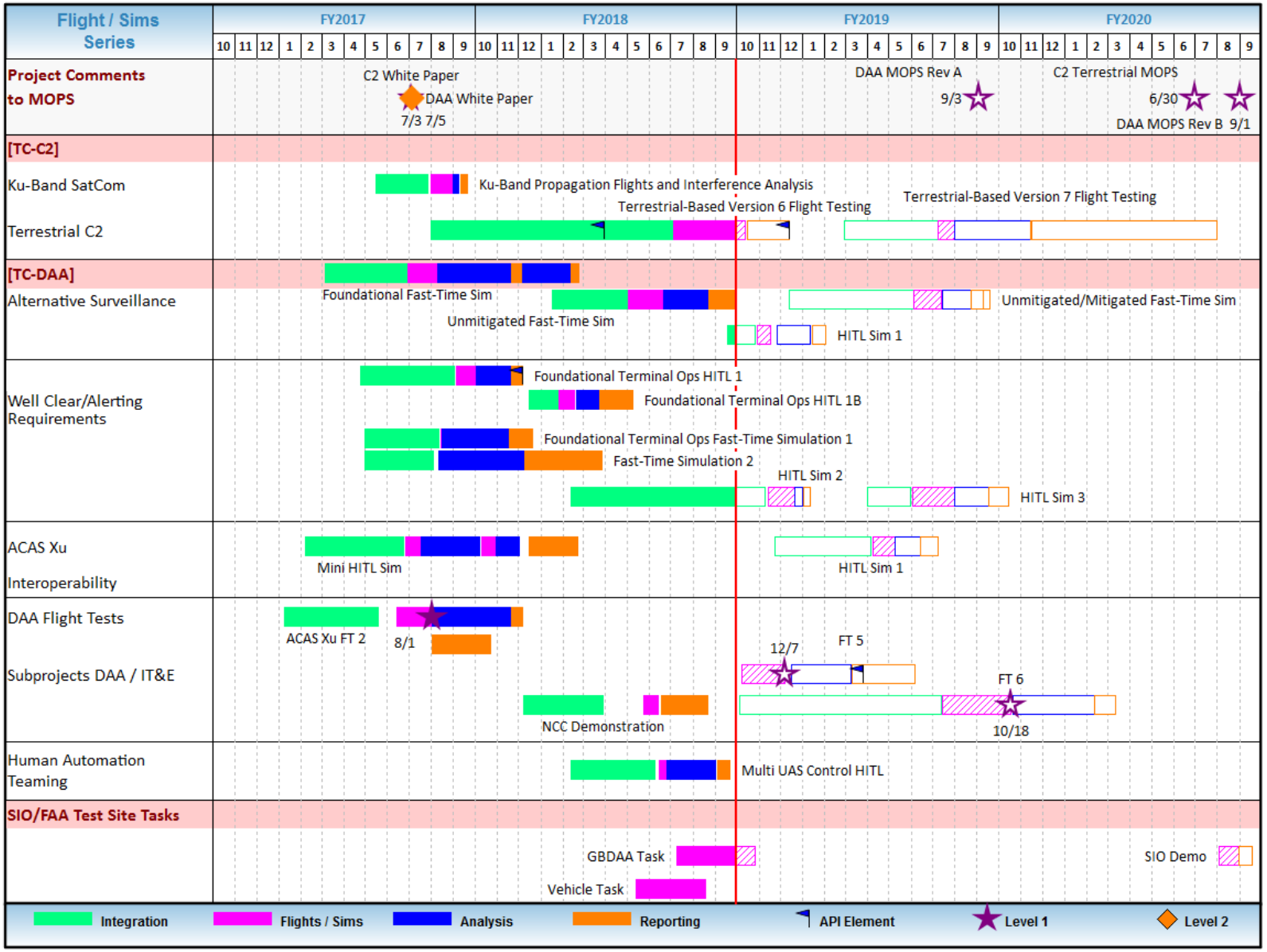
- Develop Robust NASA/Industry Partnership
- Document certification and airworthiness approaches
- Integrate Essential Technologies
- Conduct Demo

## Key Products

- *C2 Performance Requirements to inform C2 MOPS*
  - RTCA Terrestrial MOPS
  - C2 MASPS
  - → C2 Technical Standard Order (TSO)
- *DAA Performance Requirements to inform DAA MOPS*
  - RTCA Non-Coop Sensor MOPS
  - GBDAA MOPS
  - → DAA Technical Standard Order (TSO)
- *Re-usable Test Infrastructure*
  - RTCA DAA MOPS Rev A/B
- *Progress Toward Certification*
  - → Generic Certification and Airworthiness Approaches

## Resultant Outcomes

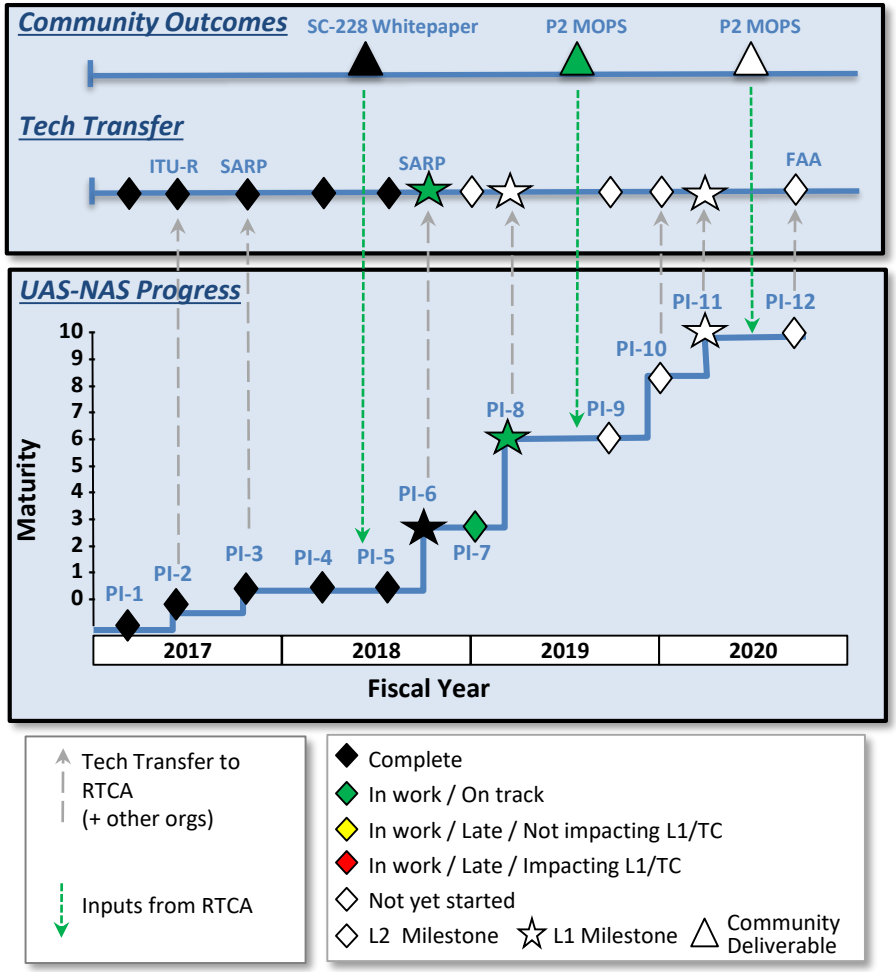
# Phase 2 Flight and Simulation Overview




Red Status Line Date 9/30/18

# Progress Indicator Definition

- Technical Challenge progress is tracked by means of Progress Indicators (PI)
  - Schedule Package (SP) L2 milestones are the data points for these plots
- Progress Indicators, i.e. lower portion of the plot, represent execution/data collection of Project SP activities
- Tech Transfer (i.e. upper portion of the plot), plotted to coincide with execution, represents the data analysis and reporting of SP Activities
- Assessed individual contribution towards achieving the overall technical challenge
  - High = 2, i.e. Integrated Tests
  - Moderate = 1, i.e. multiple subproject technologies
  - Low = 0, i.e. foundational activities
- Results normalized and placed on a 10 point maturity scale represents meeting the content of the TC




- Progress is tracked against all the tasks in the schedule package using a color indicator

# Outline

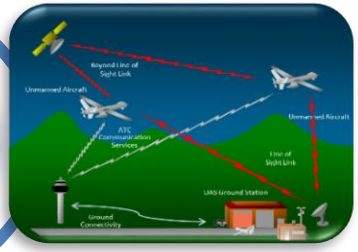
- UAS-NAS Overview
- Technical Performance
  - TC-DAA
  - TC-C2
  - SIO
- Project Level Performance & FY19 Look Ahead
- Review Summary

# TC-DAA:
# UAS Detect and Avoid Operational Concepts and Technologies

TC-DAA

Develop Detect and Avoid (DAA) operational concepts and technologies in support of standards to enable a broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to detect and avoid manned and unmanned air traffic

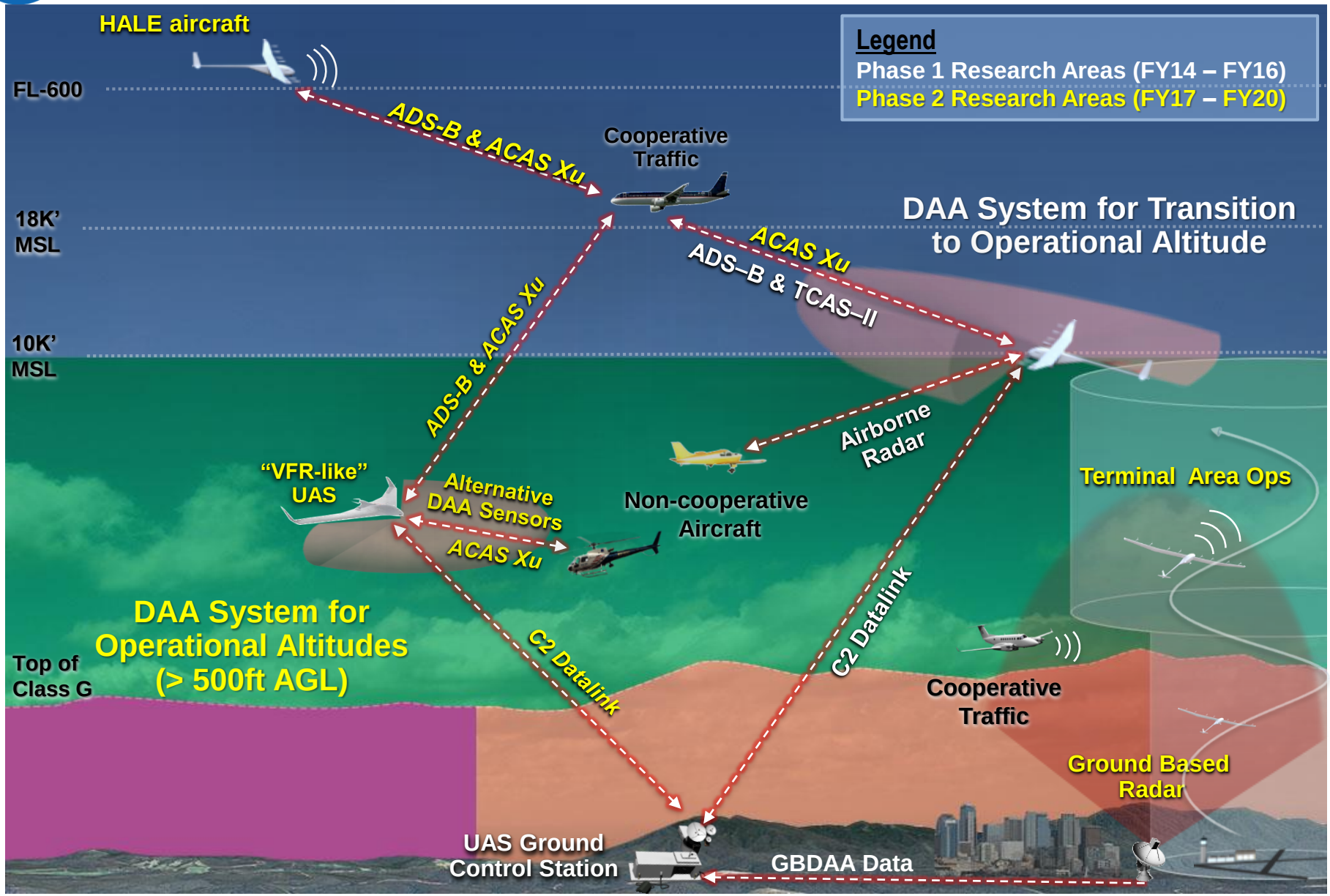
***Technical Challenge-DAA: Detect and Avoid (DAA)***

***Technical Challenge-C2: Command and Control (C2)***

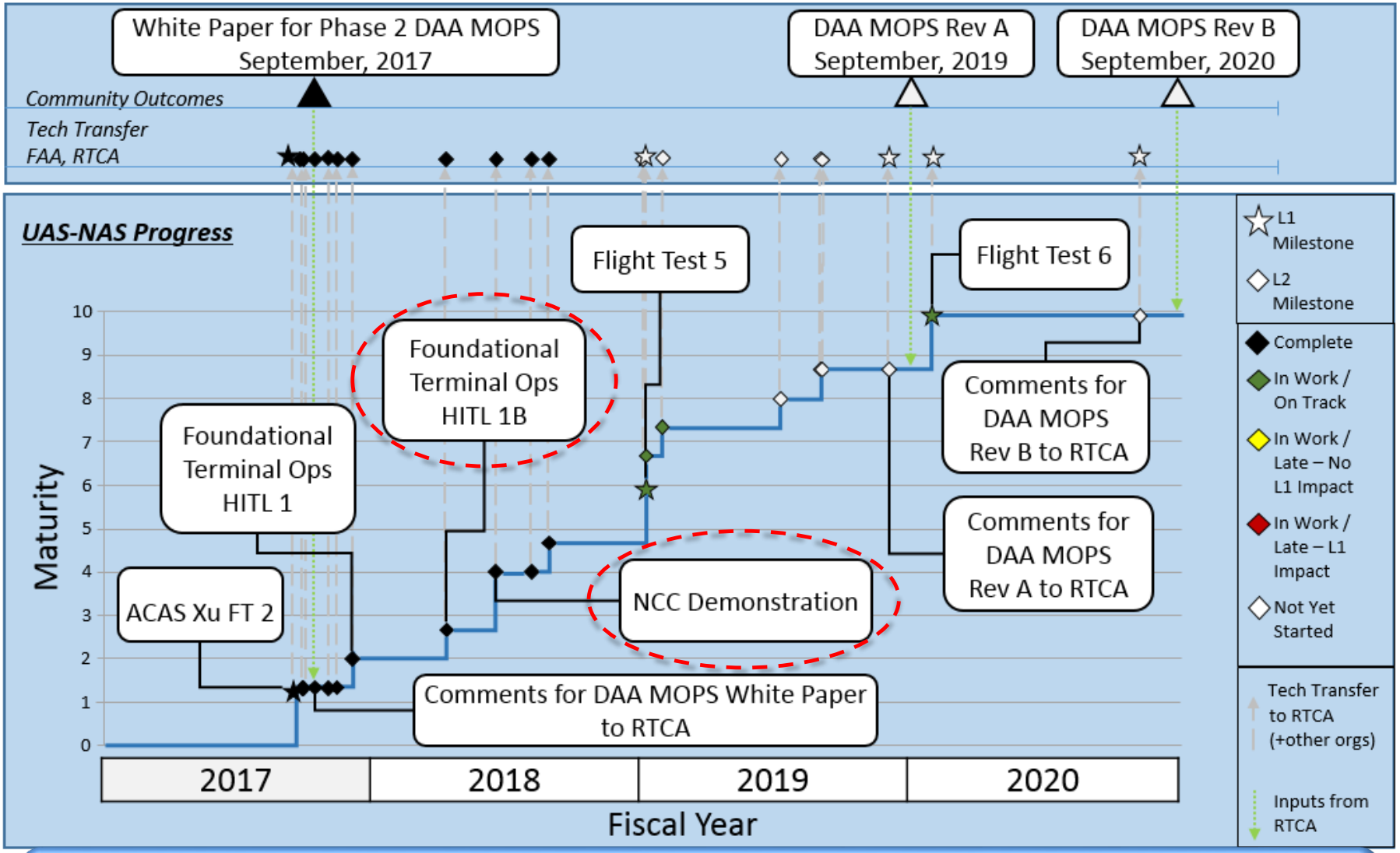
***Systems Integration and Operationalization (SIO)***

# UAS Detect and Avoid (DAA) Operating Environments (OE)



# TC-DAA: Progress Indicator

*As of 9/30/18*




***TC-DAA: Develop Detect and Avoid (DAA) operational concepts and technologies in support of standards to enable a broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to detect and avoid manned and unmanned air traffic***

# Well Clear/Alerting Requirements: Foundational Terminal Ops Human in the Loop (HITL) Simulation 1B

## ✓ Research Objective:

- Explore pilot performance and operational suitability issues associated with Class D terminal area operations
  - Implement two candidates for a terminal area DAA well clear (DWC) definition
  - Further investigate the efficacy of the DAA Corrective alert in the terminal area
  - Compare pilot and system performance to previous studies

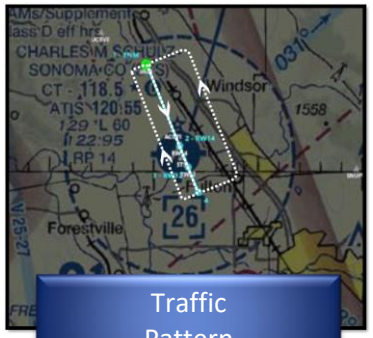
DWC Candidate (Within-Subjects):

| | No Tau | Tau |
|---|---|---|
| Horizontal Threshold* | 1500ft | 1500ft |
| Vertical Threshold | 450ft | 450ft |
| modTau | N/A | 15sec |

*HMD in Tau definition

DWC Candidates


Vigilant Spirit Control Station




Traffic Pattern

- **Status:**
  - Experiment design completed December 2017
  - Data collection completed February 2018
  - Results dissemination completed May 2018
  - Technical Baseline Element completed May 2018

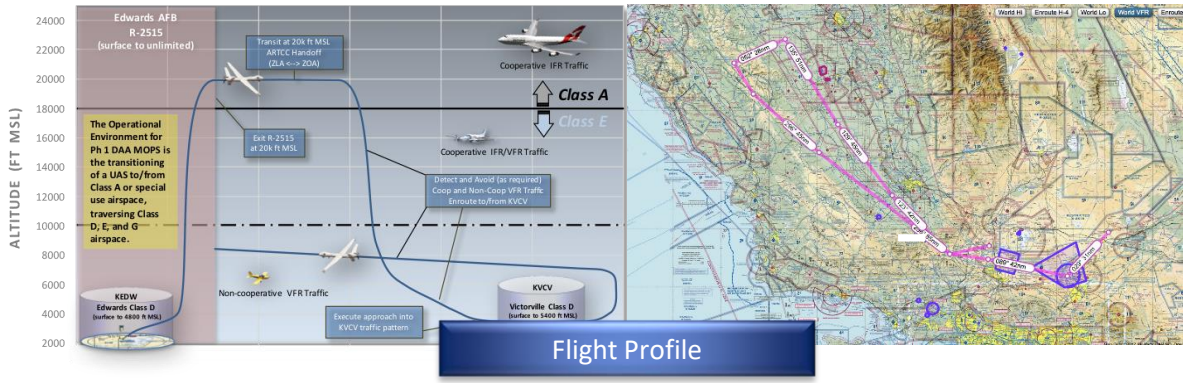
***Results support definition of Terminal Area Well Clear***

Technical Baseline Element Number: TBEN-024 (SP D.2.90)

# No-Chase Certificate of Waiver or Authorization Flight Demonstration

## ✓ Research Objective:

- Conduct unmanned aircraft flight demonstration as described in an FAA approved No Chase Certificate of Waiver or Authorization (COA)
- Transfer of technology proving the feasibility of integrating a UAS with an alternate means of compliance with FAA FAR Part 91.113 (see and avoid)




Flight Profile

| No Chase COA Demonstration | |
|---|---|
| Purpose | • Obtain Certificate of Authorization (COA) from FAA to fly Ikhana UAS without safety chase in multiple Classes of air space, including Class A, D and E.<br>• Demonstrate UA transitioning to/from Class A or SUA to Class E and Class D employing the Phase 1 Detect and Avoid (DAA) and A/A Radar MOPS Systems as alternate compliance for 14CFR 91.113b. |
| Approach | • Complete gap analysis and safety case analysis justifying alternative method of compliance with FAR Part 91.113.<br>• Work in partnership with General Atomics – Aeronautical Systems, Inc. (GA-ASI) to secure use of GA-ASI's DAA System as primary airborne de-conflicting tool. |
| Test Duration | • February, 2018 (2-3 flights) |
| Tech Transfer | • Demonstrate the Phase 1 DAA and Radar MOPS research findings through a "Capstone" event |
| Project Be | ies. |

Description

- **Status:**
  - No-Chase COA (NCC) Objectives defined May 2017
  - Conducted NCC Kick-Off meeting with FAA May 2017
  - NCC Approval received March 2018
  - NCC Demonstration Flights completed June 2018
  - NCC Flight Test Report completed August 2018

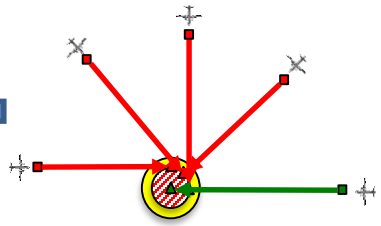
***FAA (AJT): "…successful event … no different than a manned flight …"***

Technical Baseline Element Number: TBEN-023 (SP T.8.20)

# DAA Flight Test 5 (FT5) - Original

NASA SIERRA-B
UAS


NASA AFRC
Test Range

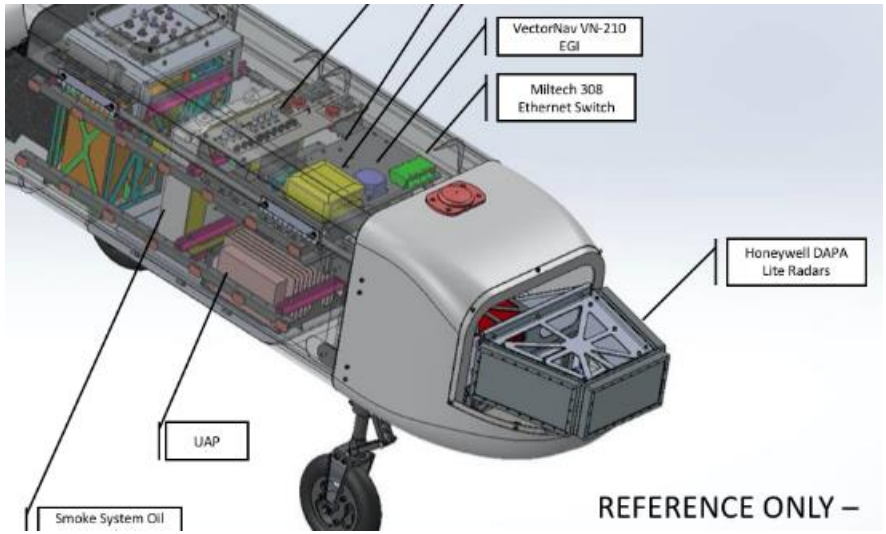


DAA Unmitigated
Encounters with
Intruders

Successful
Technology
Readiness for FT6

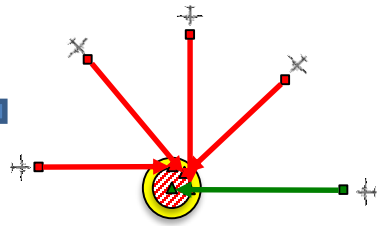
## Flight Test ConOps

- NASA Sensor Integrated Environment Remote Research Aircraft (SIERRA-B) Group 3 UAS equipped with Low size, weight, and power (SWaP) air to air (A/A) sensors performing unmitigated DAA encounters with manned intruder(s)
  - A/A sensor tracks downlinked to the Ground Control Station (GCS) for processing by DAA algorithm
    - NASA SIERRA-B equipped with non-cooperative and cooperative (Automatic Dependent Surveillance-Broadcast (ADS-B) In) sensors and a tracker to correlate multiple sensor tracks
  - DWC alerts and maneuver guidance provided on standalone DAA display
  - UAS pilot employs DAA display to meet encounter test objectives



# DAA Flight Test 5 (FT5) - New

Picture removed

Honeywell AStar Helicopter

Honeywell Test Range

DAA Unmitigated Encounters with Intruders

Successful Technology Readiness for FT6

## Flight Test ConOps

- ~~NASA SIERRA-B Group 3 UAS~~ Honeywell AStar manned helicopter equipped with Low SWaP A/A sensors performing unmitigated DAA encounters with manned intruder(s)
  - A/A sensor tracks ~~downlinked to the GCS~~ stored onboard the aircraft for post-processing by DAA algorithm
    - ~~NASA SIERRA-B~~ Helicopter equipped with non-cooperative and cooperative (ADS-B In) sensors and a tracker to correlate multiple sensor tracks
  - ~~DWC alerts and maneuver guidance provided on standalone DAA display~~
  - ~~UAS pilot employs DAA display to meet encounter test objectives~~

Picture removed

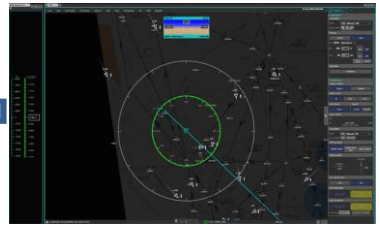
Addressed by analysis and post-processing of flight data

# DAA Flight Test 6 (FT6) - Original

## Original FT6 Operational Plans

NASA SIERRA-B
UAS


NASA AFRC
Test Range

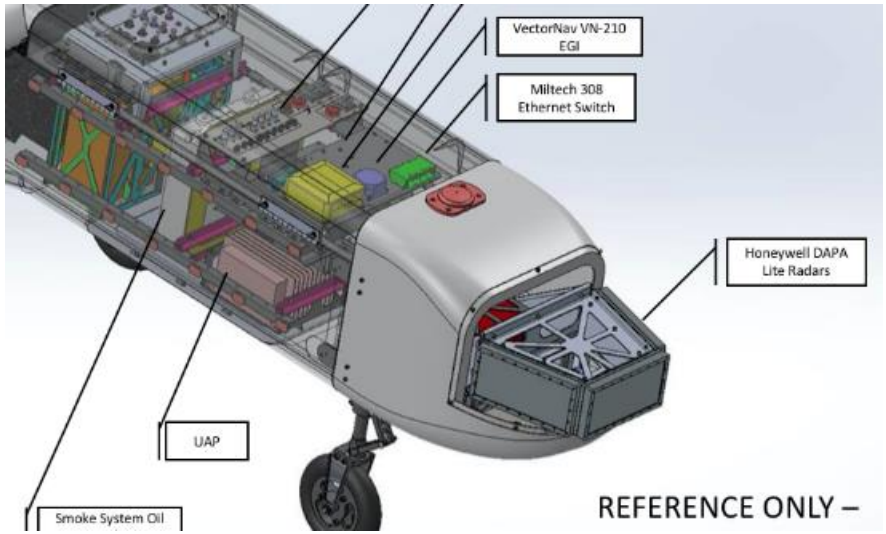


DAA Unmitigated
and Mitigated
Encounters with
Intruders

Successful Data
Collection for DAA
Standards
Development

## Flight Test ConOps

- NASA SIERRA-B Group 3 UAS equipped with Low SWaP A/A sensors performing unmitigated and mitigated DAA encounters with manned intruder(s)
  - A/A sensor tracks downlinked to the GCS for processing by DAA algorithm
    - NASA SIERRA-B equipped with non-cooperative and cooperative (ADS-B In) sensors and a tracker to correlate multiple sensor tracks
  - DWC alerts and maneuver guidance provided on Vigilant Spirit Control System GCS
  - UAS pilot employs DAA display to meet encounter test objectives
  - Full mission operations with pilot performance data to validate Human in the Loop (HITL) results




Note: Blue font represents changes from FT5

# DAA Flight Test 6 (FT6) – New

## New FT6 Operational Plans

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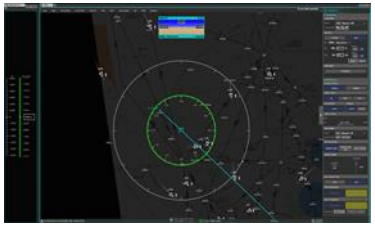
NASC TigerShark XP


NASA AFRC Test Range

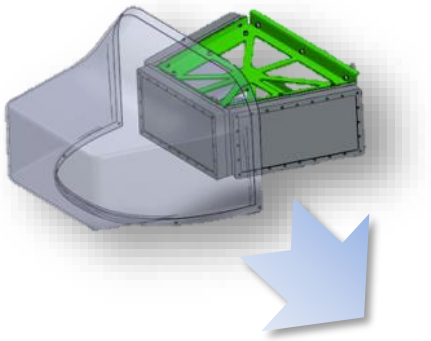


DAA Unmitigated and Mitigated Encounters with Intruders

Successful Data Collection for DAA Standards Development

## Flight Test ConOps

- ~~NASA SIERRA-B~~ Navmar Applied Sciences Corporation (NASC) TigerShark XP Group 3 UAS equipped with Low SWaP A/A sensors performing unmitigated and mitigated DAA encounters with manned intruder(s)
  - A/A sensor tracks downlinked to the GCS for processing by DAA algorithm
    - ~~NASA SIERRA-B~~ NASC TigerShark XP equipped with non-cooperative and cooperative sensors and a tracker to correlate multiple sensor tracks
  - DWC alerts and maneuver guidance provided on Vigilant Spirit Control System GCS
  - UAS pilot employs DAA display to meet encounter test objectives
  - Full mission operations with pilot performance data to validate HITL results

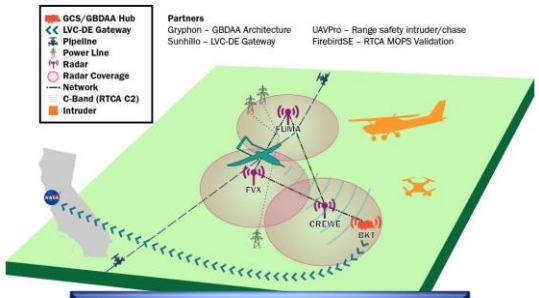


Picture removed

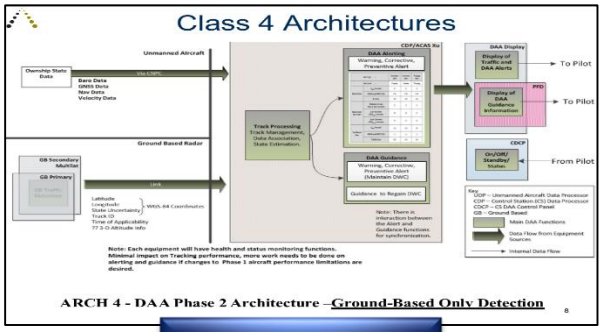
Nose section to be modified to accommodate the DAPA-Lite sensor and radome

# FAA Test Site Ground Based Detect and Avoid Demonstration

- **Goal: Implement a GBDAA system with long term strategic value to NASA, FAA, and industry partners**
  - Provide a foundation and testbed for validation and iteration of RTCA standards
  - Provide a foundation for FAA Beyond Visual Line of Sight (BVLOS) rulemaking activities
  - Provide a means for industry to evaluate technologies and procedures for low level BVLOS use cases
  - Provide a foundation for future commercial waivers seeking operational capability for industry applications



GBDAA Range Configuration



GBDAA Architecture

- **Status:**
  - Two of three flight campaigns using General Aviation (GA) aircraft have been completed
    - Campaign 1 completed July 10-12. 29 test instances flown with 1 GA aircraft using 3 radar sites
    - Campaign 2 completed August 1-2. 11 test instances flown with 2 GA aircraft using 3 radar sites
  - Sensor model development is ongoing
- **Next Steps**
  - Complete Campaign 3 fight test October 22-26
  - Sensor models and final report to be provided to NASA December 2018



Not included in Project Technical Baseline

# TC-C2:
# UAS Command and Control

TC-C2

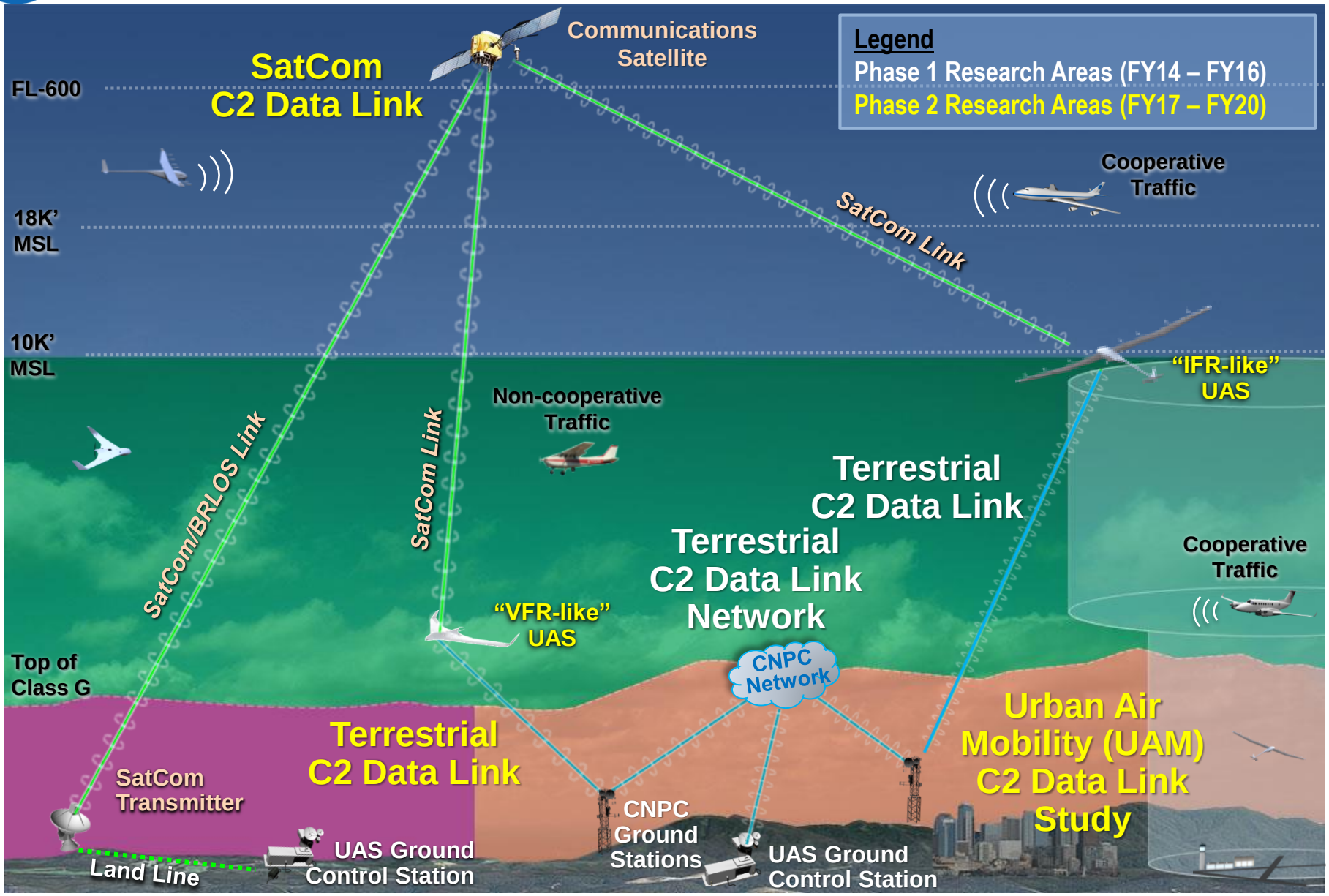
Develop Satellite (SatCom) and Terrestrial based Command and Control (C2) operational concepts and technologies in support of standards to enable the broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to leverage allocated protected spectrum


***Technical Challenge-DAA: Detect and Avoid (DAA)***

***Technical Challenge-C2: Command and Control (C2)***

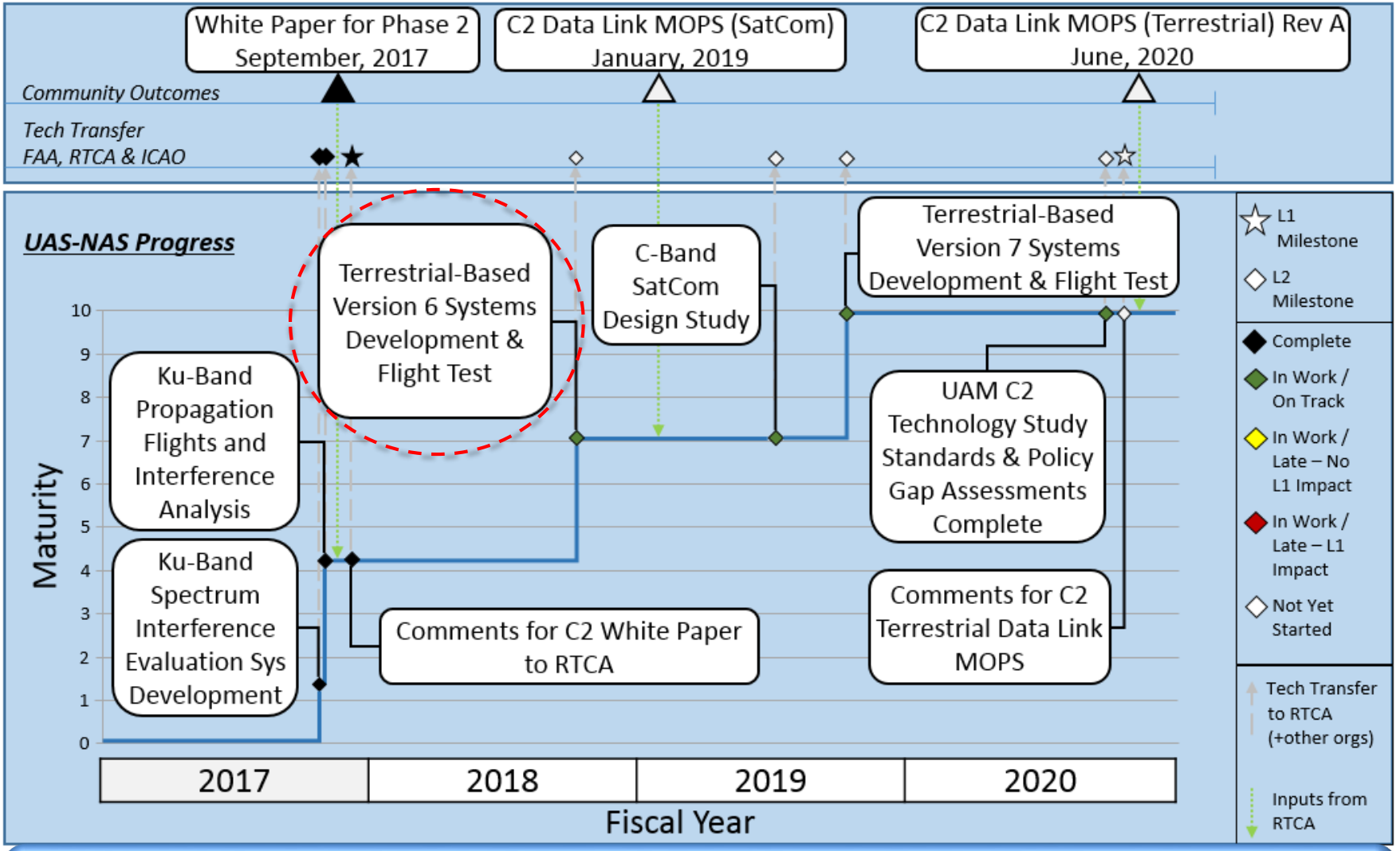
***Systems Integration and Operationalization (SIO)***

# UAS Command and Control Operating Environments (OE)



# TC-C2: Progress Indicator

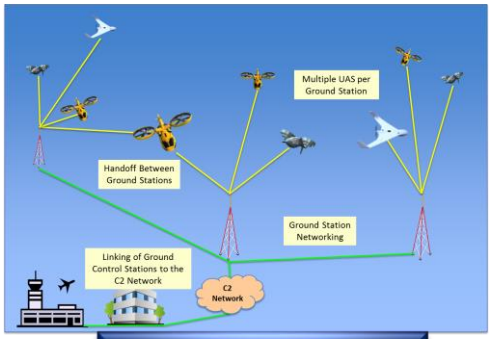
*As of 9/30/18*




***TC-C2: Develop Satellite (SatCom) and Terrestrial based Command and Control (C2) operational concepts and technologies in support of standards to enable the broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to leverage allocated protected spectrum***

# Terrestrial C2 Radio Evaluation System Development

- **Research Objective:**
  - Develop a Terrestrial C2 data link radio system and transfer technology and research data for the development and validation of standards for Terrestrial C2 data link



Terrestrial Challenge


Phase 1 C2 Radio


Phase 2 C2 Radio

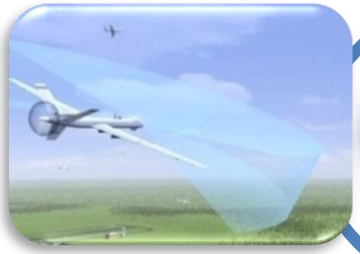
- **Status:**
  - Established Cooperative Agreement for C2 Terrestrial Extension radio January 2017
  - Version 6 (V6) Preliminary Design Review (PDR) completed July 2017
  - V6 Critical Design Review (CDR) completed October 2017
  - V6 Flight Test started July 2018
- **Next Steps:**
  - Terrestrial-Based V6 Flight Test to be completed October 2018
  - Terrestrial-Based Version 7 (V7) Flight Test to be completed July 2019
  - Terrestrial-Based UAS Command & Control Final Report to be completed July 2020

Technical Baseline Element Number: TBEN-004 (SP C.6.10, SP C.6.11)

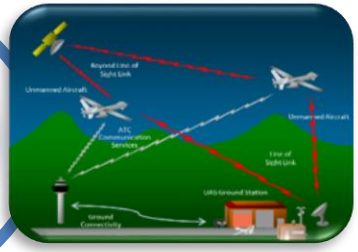
# SIO:
# Systems Integration and Operationalization

SIO

Integrate state of the art DAA and C2 technologies into Unmanned Aircraft Systems (UAS) to ensure sufficient aircraft level functional and operational requirements, and perform demonstrations in the NAS to inform Federal Aviation Administration creation of policies for operating UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations



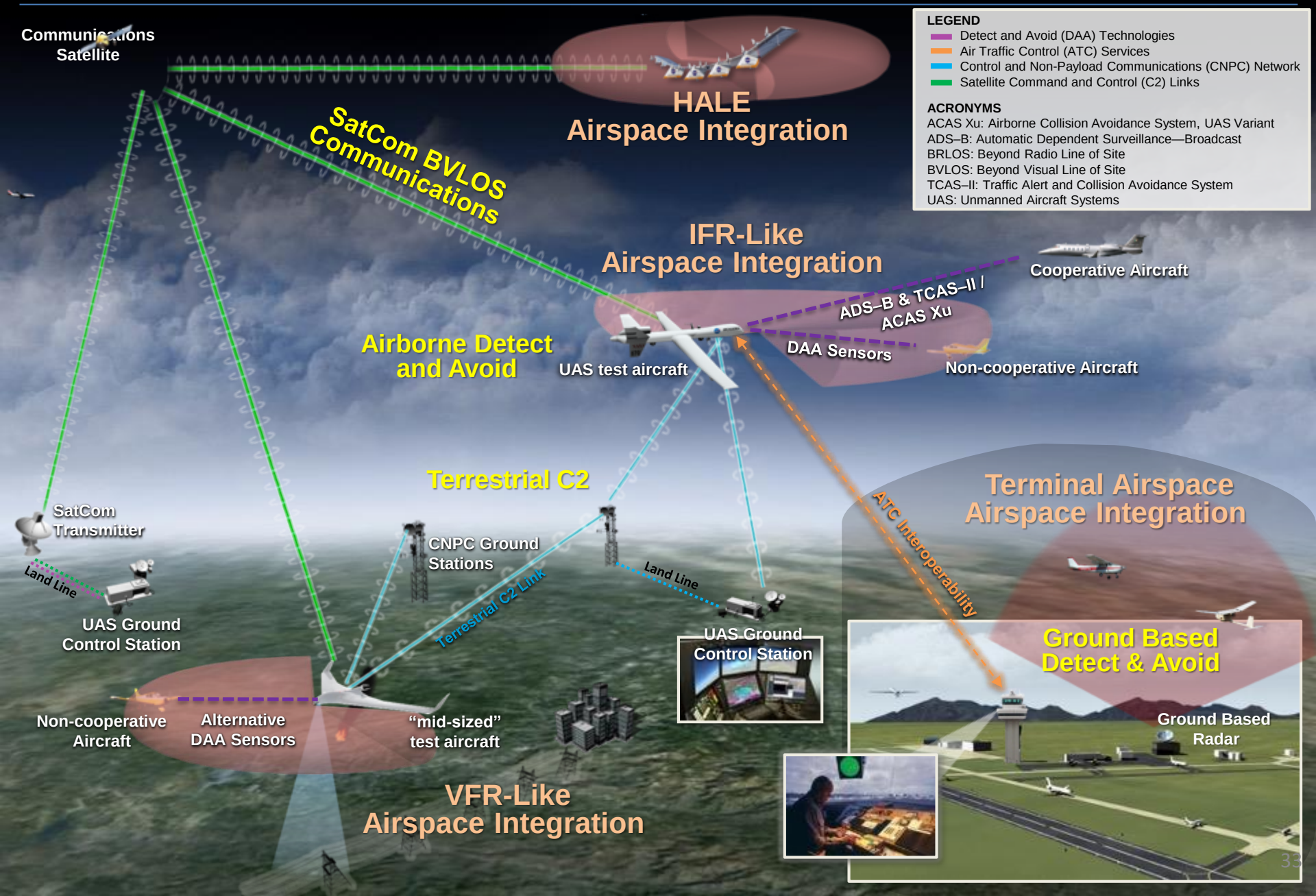
***Technical Challenge-DAA: Detect and Avoid (DAA)***

***Technical Challenge-C2: Command and Control (C2)***

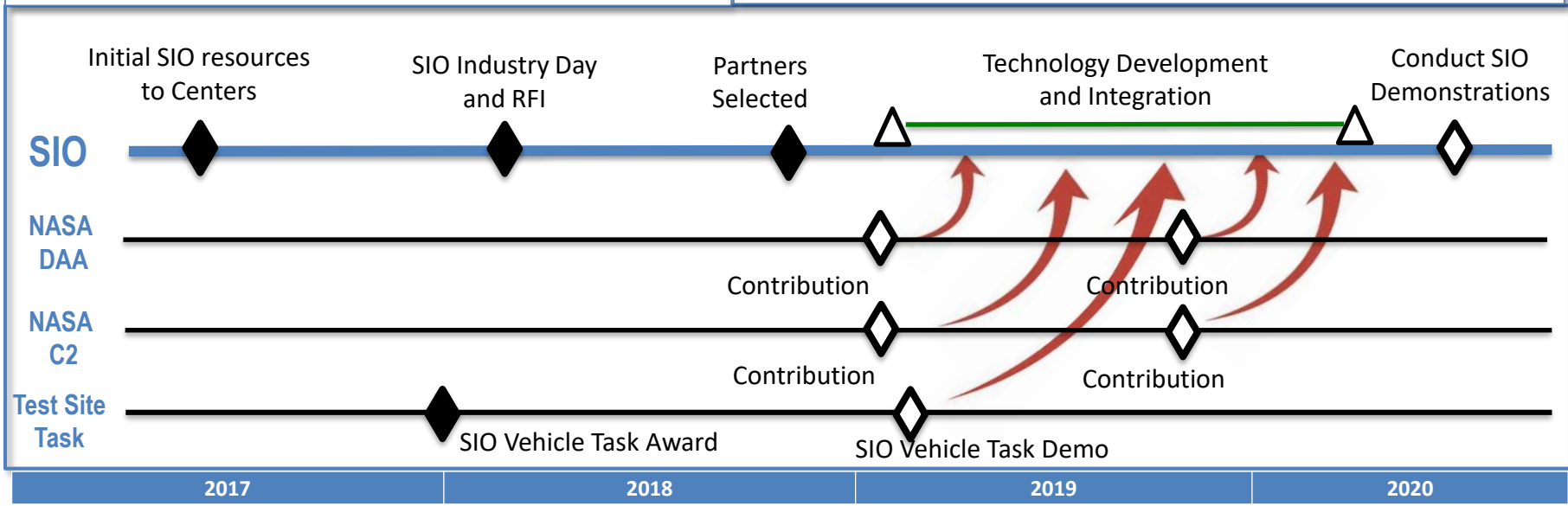
***Systems Integration and Operationalization (SIO)***

# UAS-NAS Project – SIO Operational View Representation



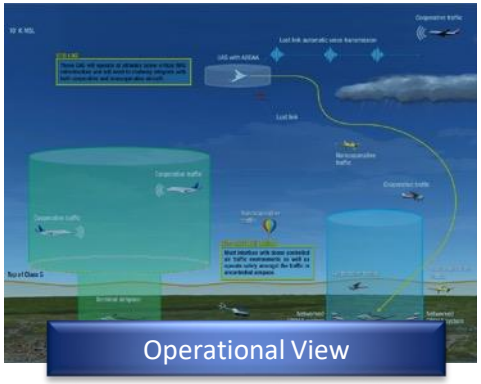
# SIO Notional Demonstration Strategy

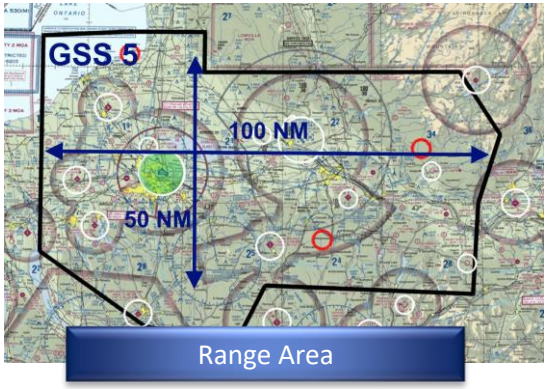
| SIO Goals | SIO Partnership Strategy |
|---|---|
| Goal: Work toward routine commercial UAS operations in the NAS<br>• Obtain approval to operate in the NAS for a FY20 flight demonstration<br>• Demonstrate integrated DAA and C2 technologies<br>• Progress toward Type Certification | Industry Partnership Strategy<br>• Agreements established to conduct industry centric SIO demonstrations in FY20<br>• Leverage NASA expertise to inform UAS development and integration of DAA, C2, and other technologies required for commercial missions<br><br>FAA Partnership Strategy<br>• Work through the UAS Integration RTT to obtain approvals, and impact policy, procedures, and regulations |



# FAA UAS Test Site Vehicle Technology Demonstration Task

- **Research Objective:**
  - Assess the state-of-the-art of individual UAS vehicle technologies for a Concept of Operations (ConOps) that is consistent with NASA's UAS Operational Environments


Operational View



Range Area

- **Status:**
  - Two UAS flight demonstrations completed
    - Demo 1: Completed May 14-16, focused on nominal UAS operations
    - Demo 2: Completed July 16-19, focused on demonstration of technologies for lost link operations, including weather avoidance, an automated voice capability, and obstacle detection during taxi
  - An outreach day was held on July 19, and included representatives from NASA, Air Force Research Lab (AFRL), and industry

- **Next Steps:**
  - Key data from the flight demonstrations will be analyzed to inform RTCA SC228 and future NASA research areas
  - A report will be provided to NASA by October 2018



Not included in Project Technical Baseline

# Selected/Awarded SIO Partners

## Bell

**Mission:** Cargo delivery in urban areas

**Vehicle:** Autonomous Pod Transport - 70 (APT70) electric Vertical Take Off and Landing (VTOL) (240 to 500 lb, depending on configuration)

**Test Locations:** Wrangler Field (remote area), and Arlington Municipal Airport (urban), Texas


## General Atomics

**Mission:** Infrastructure inspection in Instrument Flight Rules (IFR)-Like airspace

**Vehicle:** SkyGuardian (12,500 lb)

**Test Location:** Southern California and Arizona

## PAE ISR (Awarded September 25)

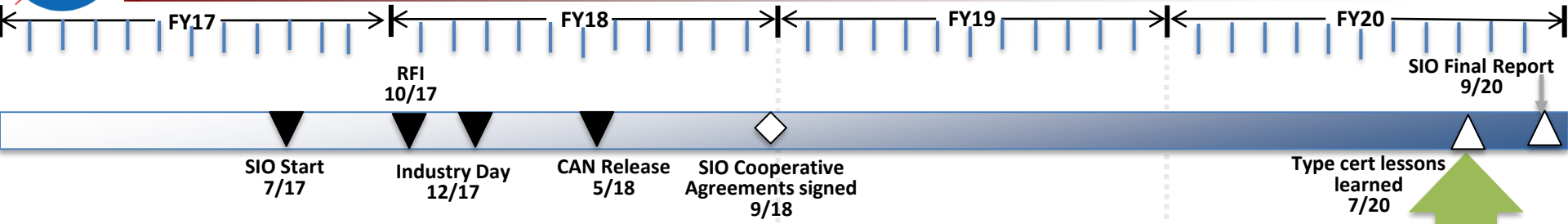
**Mission:** Pipeline inspection in Visual Flight Rules (VFR)-Like airspace

**Vehicle:** Resolute Eagle (210 lb)

**Test Location:** Pendleton Oregon UAS Range (part of Alaska FAA UAS test site)

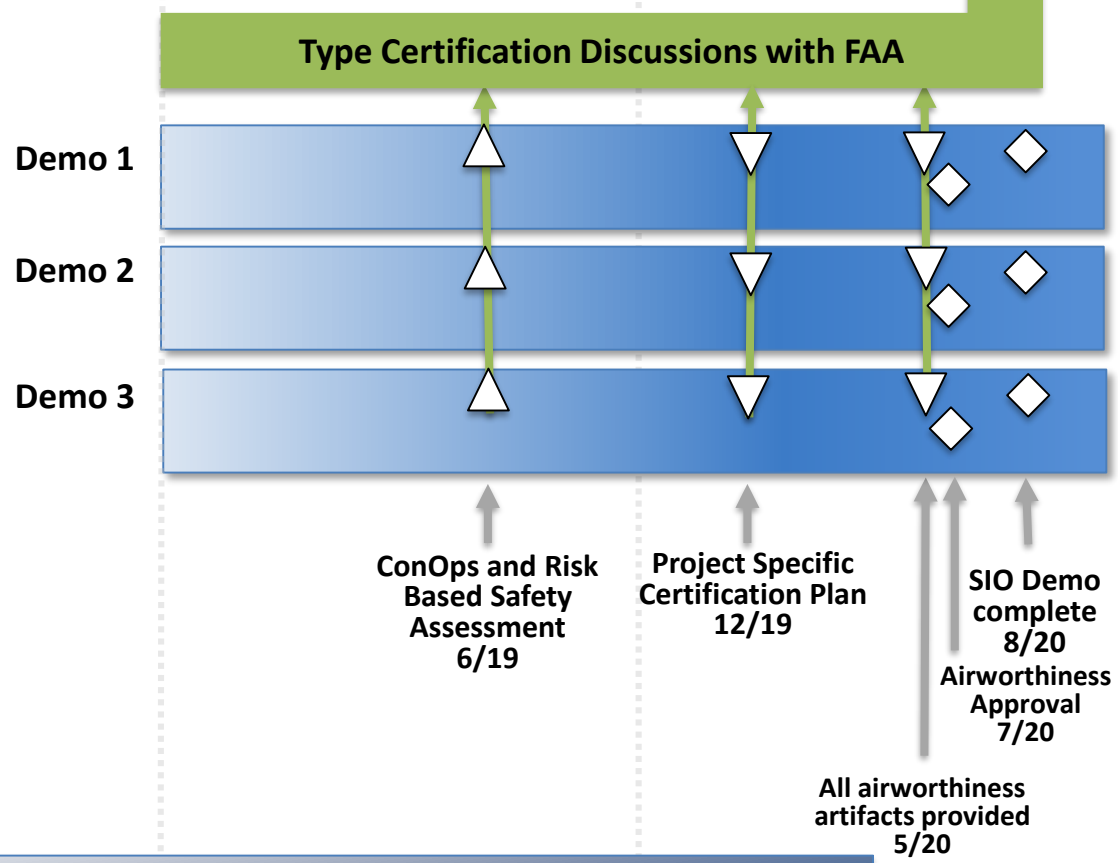
# Systems Integration and Operationalization (SIO)

*Timeline Not To Scale*




| Milestone | Type | Date |
|---|---|---|
| Cooperative agreements with Industry Partners signed | L2 | 9/30/18 |
| Baseline *Mission ConOps* and *Risk-Based Safety Assessment* documents complete | L3 | 7/30/19 |
| Airworthiness approvals for SIO demonstration | L2 | 7/30/20 |
| Documentation of type certification lessons learned and guidelines provided to Project Office | L3 | 7/30/20 |
| SIO demonstration complete | L2 | 8/31/20 |
| SIO *Final Report* provided to project office and submitted for review and export release | L3 | 9/18/20 |

☆ - ***L1 Milestone***
◇ - ***L2 Milestone***
△ - ***L3 Milestone***
▽ - ***Significant Event***

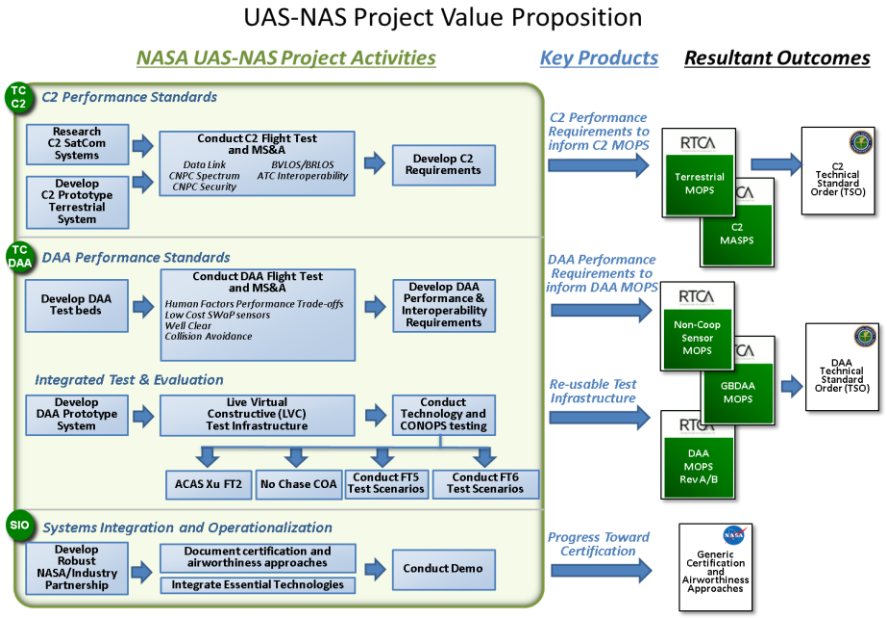



**SC-228 P1 MOPS and Draft Phase 2 MOPS**

# Technical Performance Summary

- TC-DAA
  - Completed No Chase COA flights in the NAS
  - Completed experiment designs, infrastructure preparations, and/or data collection for multiple experiments
  - Delivered data from simulations

- TC-C2
  - Conducted terrestrial based Version 6 radio systems development
  - Completed C-Band Satellite Communications (SatCom) Payload & Earth Station Concept Design
  - ConOps for Urban Air Mobility (UAM) C2 Study delivered




- SIO
  - Three partners identified
  - ConOps presented at SIO RTT planning meeting
  - Detailed schedules in work and resources being assigned

***Conducting experiments critical to C2 & DAA MOPS; SIO execution underway***

# Outline

- UAS-NAS Overview
- Technical Performance
- Project Level Performance & FY19 Look Ahead
  - Risk Summary
  - Resource Allocation and Utilization
  - Schedule Performance
  - Partnerships and Collaboration
  - FAA/NASA UAS Integration Research Transition Team
  - UAS-NAS and Urban Air Mobility (UAM)
  - International Participation and Collaboration
  - FY18 Accomplishments and FY19 Look Ahead
  - FY20 Closeout Planning
- Review Summary

# FY18 Risk Management Summary

- Data Redacted

# FY18 Top Risks

- Data Redacted

# Storm Clouds

- Data Redacted

# Resource Allocation against Baseline Budget

- Data Redacted

# Resource Utilization FY18
# Budget vs. Actuals Summary

- Data Redacted

# UAS-NAS FY18 Project Funding

- Data Redacted

# Schedule Performance

- Phase 2 Milestone Count
  - Completed 2 of 7 Level 1 Milestones
  - Completed 34 of 66 Level 2 Milestones
    - Experienced some delays to L2 milestones

Table Removed

- Causes of Level 2 Milestone Delays
  - DAA and C2 technical scope changes implemented to better align with community requirements
  - C2 Version 6 radio performance issues impacted delivery
  - SIERRA-B airworthiness and envelope expansion tests
  - FAA Spectrum Office RF authorization for No Chase COA
- Utilize continuous risk management to identify schedule impacts
- L2 Milestone delays did not impact downstream Level 1 or 2 Milestones

***Successful Milestone Management***

# Current Active Collaborations/Partnerships Status (1 of 3)

| Partner *(Project Area)* | Agreement In Place | Collaboration/ Partnership Role |
|---|---|---|
| Air Force Research Lab *(TC-DAA)* | Space Act *Mar-17 to Sep-18* | On-going collaboration with AFRL supporting use of Vigilant Spirit Control Station (VSCS) on DAA activities. AFRL has agreed to a NASA "leave behind" simulation capability after the agreement expires |
| *Bell (SIO Selectee)* | Cooperative Agreement *In Process* | Selectee for the SIO Demonstration. Mission is to conduct emergency medical supply delivery in Urban Areas with the Autonomous Pod Transport - 70 (APT70) electric VTOL |
| FAA UAS Integration *(Project Office, TC-DAA, TC-C2)* | RTT | Support by FAA leadership, management, and technical subject matter experts to validate work being done by the Project. On-going coordination of Research Transition Products (RTPs) within the UAS Integration RTT |
| FAA Aviation Safety (AVS) and NextGen (AUS) *(Project Office, TC-DAA, TC-C2)* | RTT | Coordination of RTPs within the UAS Integration RTT |
| FAA Air Traffic Organization (ATO) *(Project Office, TC-DAA, TC-C2)* | RTT / Controlled Airspace ARC | Primary organization managing the Controlled Airspace ARC where the project actively participates. Coordination of RTPs within the UAS Integration RTT |
| FAA UAS Test Sites *(Project Office)* | IDIQ Contract *Aug-15 to Sep-20* | Awarded Task 4 GBDAA (Gryphon Sensors LLC, Textron, UAVPro, FirebirdSE, Sunhillo, Dominion Energy, and Aviation Systems Engineering Company) and Task 5 Vehicle Task (Griffiss International Airport with the following subcontractors: Aurora, MTSI, NUAIR, AX Enterprize, Gryphon Sensors, Navmar Applied Sciences Corp.) Activities with the test sites are ongoing |

Purple text indicates changes since FY17 Annual Review

# Current Active Collaborations/Partnerships Status (2 of 3)

| Partner *(Project Area)* | Agreement In Place | Collaboration/ Partnership Role |
|---|---|---|
| General Atomics *(TC-DAA)* | Space Act *Sep-14 to Feb-20* | Ikhana equipped with avionics and Proof of Concept DAA system directly supported by UAS-NAS Project. General Atomics supported the No Chase COA flight |
| General Atomics *(SIO Awardee)* | Cooperative Agreement *In process* | Selectee for the SIO Demonstration. Mission is to inspect infrastructure in IFR-like airspace with the SkyGuardian unmanned aircraft |
| Honeywell *(TC-DAA)* | Cooperative Agreement *Oct-17 to Sep-20* | Partner for the DAA low SWaP non-cooperative sensor in support of data-buy. Agreement modification processed to include data-buy in support of FT5 |
| LinQuest *(TC-C2)* | Contract *Oct-17 to Sep-20* | Completed a conceptual system design study of the UAS C2 SatCom System, payload & earth station conceptual design, and Hosted Payload Study Report |
| NASA AOSP *(Project Office)* | NA | Coordination with Airspace Operations and Safety Program (AOSP) on UAS Traffic Management (UTM), SMART NAS, autonomy roadmapping, and other activities including collaborative effort on UAS integration strategies and LVC development |
| NASC *(TC-DAA)* | Contract *Sep-18 to Oct-19* | The NASC TigerShark is the test vehicle for FT6 |
| PAE-ISR *(SIO Awardee)* | Cooperative Agreement *Oct-18 to Aug-20* | SIO Demonstration awardee. Mission is to inspect infrastructure in VFR-like airspace with the Resolute Eagle unmanned aircraft |

Purple text indicates changes since FY17 Annual Review

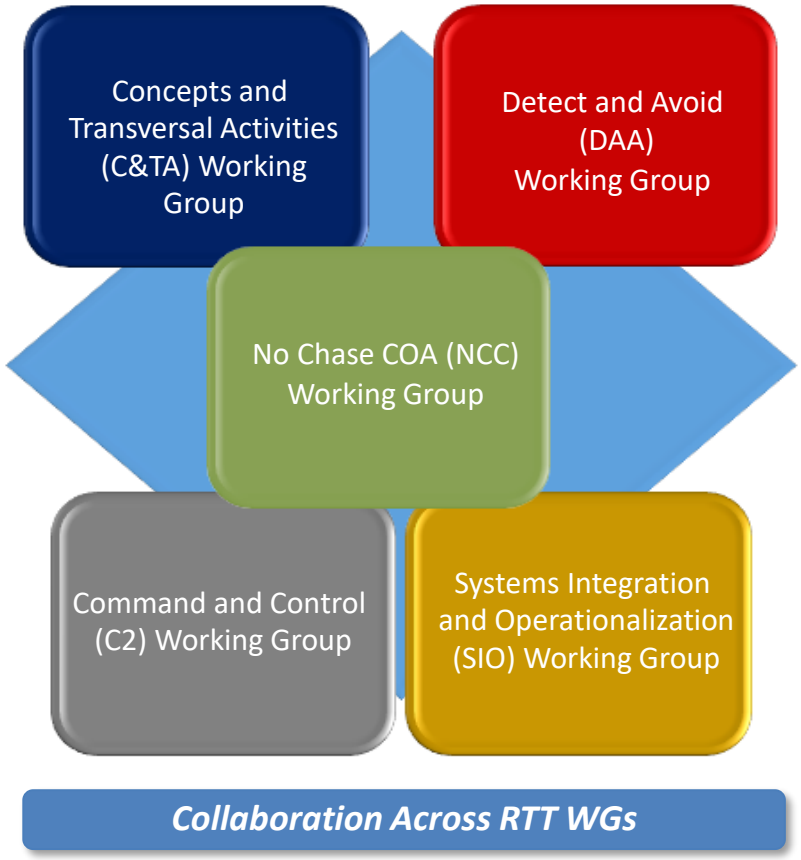
# Current Active Collaborations/Partnerships Status (3 of 3)

| Partner *(Project Area)* | Agreement In Place | Collaboration/ Partnership Role |
|---|---|---|
| Rockwell Collins (TC-C2) | Cooperative Agreement *Nov-11 to Oct-20* | Cost sharing agreement for CNPC radio development and flight test support for V6 radios in FY18 and V7 radios in FY19. FY20 support for final CNPC radio summary report |
| RTCA SC-228 (TC-C2, TC-DAA) | NA | On-going support to DAA and C2 working groups. NASA C2 CNPC radio testing is coordinated with SC-228 to support the development and validation of the C2 Link Systems MASPS and the CNPC Link System MOPS (terrestrial) DO-362A |
| RTCA SC-147 *(TC-DAA)* | NA | Close coordination on DAA standards required for success of P2 MOPS. Hosting workshops to ensure success of both working groups. Ad Hoc FAA/NASA working group established to coordinate ACAS Xu research |
| Science And Research Panel (SARP) *(TC-DAA)* | NA | Multi-UAS HITL results presented at the SARP special meeting on multi-UAS control. This work investigated the scalability of the Phase 2 well clear definition to multi-UAS control with clear applicability to other domains, e.g., UAM |

Purple text indicates changes since FY17 Annual Review

# FAA/NASA UAS Integration Research Transition Team

- Phase 2 collaboration between NASA and the FAA is being coordinated though a RTT that includes all FAA Lines of Business
- There are currently five Working Groups (WGs) within the UAS Integration RTT each with their own focus
  - C&TA WG: Developing commercial concepts of use for UAS Integration
  - DAA WG: Coordinating SC-228 related DAA research
  - C2 WG: Coordinating SC-228 related C2 research
  - NCC WG: Coordinating all aspects of the 2018 NCC Flight
  - SIO WG: Coordinating all aspects of the 2020 SIO demonstration



# Accomplishments/Next Steps for the UAS Integration RTT

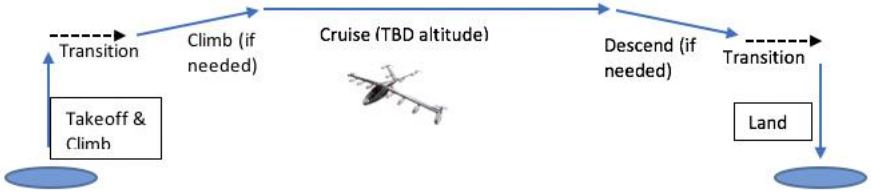
- 2018 Accomplishments
  - The Joint Management Plan (JMP) was signed February 5, 2018
  - All work under RTCA SC-228 for DAA and C2 were coordinated with the FAA lines of business
  - The NCC flight was successfully completed on June 12, 2018.
    - The FAA played a significant role in helping NASA with COA, operational, and frequency approvals
  - The C&TA WG provided input to NASA on potential SIO ConOps to assist in the CAN review process
    - The FAA provided three reviewers to assist in the SIO selection process.
  - A new SIO WG was established which will operate in a similar manner to the NCC WG as the 2020 demonstration approaches
- Next steps for the UAS Integration RTT
  - The NCC WG will be sunset at the next Executive Meeting
  - Continuation of Research Transition Product (RTP) delivery will occur throughout the duration of the Project
  - The FAA briefing of UAS Implementation Research Plan on September 27, 2018 may lead to future joint planning to help shape the ARMD UAS/autonomy research portfolio

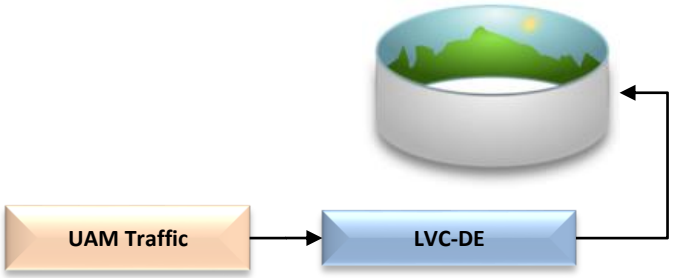
# UAS-NAS and Urban Air Mobility (UAM) Partnerships and Technology Transitions

- Complex UAS technology testing and standards verification and validation (V&V) experience
  - Vehicle and airspace interfaces and test techniques for emerging technologies such as DAA and C2
  - Experience in scenario development for UAM HITLs and Grand Challenge
  - Experience on standards V&V and FAA approvals

- Live Virtual Constructive Development
  - Development of LVC-DE environment that supports varying test infrastructure needs
  - Adaptable to external test ranges and future UAM partners
  - UAMPort (i.e. vertiport) visualizations and demonstrations

- Partnerships lessons learned
  - SIO implemented and baselined; “mini-Grand Challenge”
  - Explores unique NASA/industry partnership models




***Leveraging UAS-NAS technologies to assess the UAM concept and support research***

# International Participation and Accomplishments

- International Civil Aviation Organization (ICAO)
  - Accomplishments:
    - The Human In The System (HITS) outline was complete
    - Writing assignments were agreed upon and distributed
  - Next Steps:
    - The HITS team will write a chapter for the Remotely Piloted Aircraft Systems (RPAS) Panel's Remote Pilot Station (RPS) manual
      - Drafts are due March 1, 2019, Final to secretariat due July 1, 2020
    - The next HITS meeting will be at Ames
- European Organization for Civil Aviation Equipment (EUROCAE)
  - Accomplishments:
    - Participated in the development of the Operational Services Environment Description (OSED) for DAA related to European Classes A-C, D-G, and Very Low Level (VLL)
      - The OSEDs are an incremental step to creating international standards
      - The OSEDs for A-C and D-G are out for review
  - Next Steps:
    - OSED for VLL will be completed by the end of calendar 2018
    - Develop Minimum Aviation System Performance Standards (MASPS) and Minimum Operational Performance Standards (MOPS) to be submitted to ICAO for the development of global Standards and Recommended Practices (SARPS)

***International standards organizations accepting US standards accelerates the time to market for UAS manufacturers***

# FY18 Accomplishments


- Rania Ghatas: won best paper and received publication in their bound volume for her paper on “The Effects of Alert Scoring and Alert Jitter on a MOPS UAS DAA System” at the 5th ENRI International Workshop on ATM/CNS (EIWAC)
- Dr. Lisa Fern: former DAA Tech Lead was recognized by RTCA for her contributions to DO-365, “DAA MOPS Phase 1 and DO-365, MOPS for Air-to-Air Radar DAA Systems Phase 1”
- DAA team: NASA Group Achievement Award for their work that formed the basis of national standard, “DO-365: MOPS for DAA Systems”
- Laurie Grindle: NASA Outstanding Leadership Medal
- Robert Sakahara: NASA Exceptional Achievement Medal
- Cesar Munoz: won the best in session and best in track awards for his paper on Sensor Uncertainty Mitigation and Well Clear Volumes In Detect and Avoid Alerting Logic for Unmanned Systems (DAIDALUS), at the Digital Avionics Systems Conference 2018

# FY18 Accomplishments & FY19 Look Ahead

## FY18 Accomplishments

- TC: Detect and Avoid
  - Simulations: Terminal Ops HITL 1B; Multi-UAS HITL Simulation
  - Flight Tests: No Chase COA Flight Demonstration; Flight Test 5/6 Planning
- TC: Command and Control
  - C-band SatCom: Hosted Payload Study Report
  - UAM Study: UAS C2 System ConOps
- Systems Integration and Operationalization
  - Industry coordination and CAN release
  - Industry Partner selection and award
- FAA Test Sites
  - GBDAA task order 4 test activities
  - Vehicle and ConOps task order 5 test activities
- Project
  - Establishment of Research Transition Team

Ikhana Unmanned Aircraft

Picture Removed

DAPA Lite Radar

CNPC Version 6 radio

## FY19 Look Ahead

- DAA Simulations: ACAS Xu HITL, Terminal Area HITL, Fast Time Simulation
- Flight Tests: Data Collection for FT5 & FT6; CNPC Radio V6 & V7
- Submit Consolidated Input for DAA MOPS Rev A to RTCA

# FY20 Closeout Planning

- Project Completion date set for September 30, 2020
  - Two years left on Project; ramping down personnel in FY20 for DAA, IT&E and C2
- Notional Closeout requirements/content
  - Transition of technologies and relationships to appropriate ARMD projects/programs
  - Final project plan to address:
    - Description of research and/or technology advancement
    - Performance relative to goals and threshold requirements
    - Lessons learned
    - Dissemination and/or storage/archival approach utilized, and
    - Results of any independent assessments
    - Continuation of contract mechanisms and partner agreements
  - AFRC Project closeout checklist (additional items)
    - Systems decommissioning/disposal
    - Risk status
    - Funding/budget
- Schedule:
  - Update Project Plan (new section) – November 2018
  - IASP Terms of Reference – December 2019
  - Closeout Review Meeting – July 2020
  - Project Final Report – September 2020

# Outline

- UAS-NAS Overview
- Technical Performance
- Project Level Performance & FY19 Look Ahead
- Review Summary

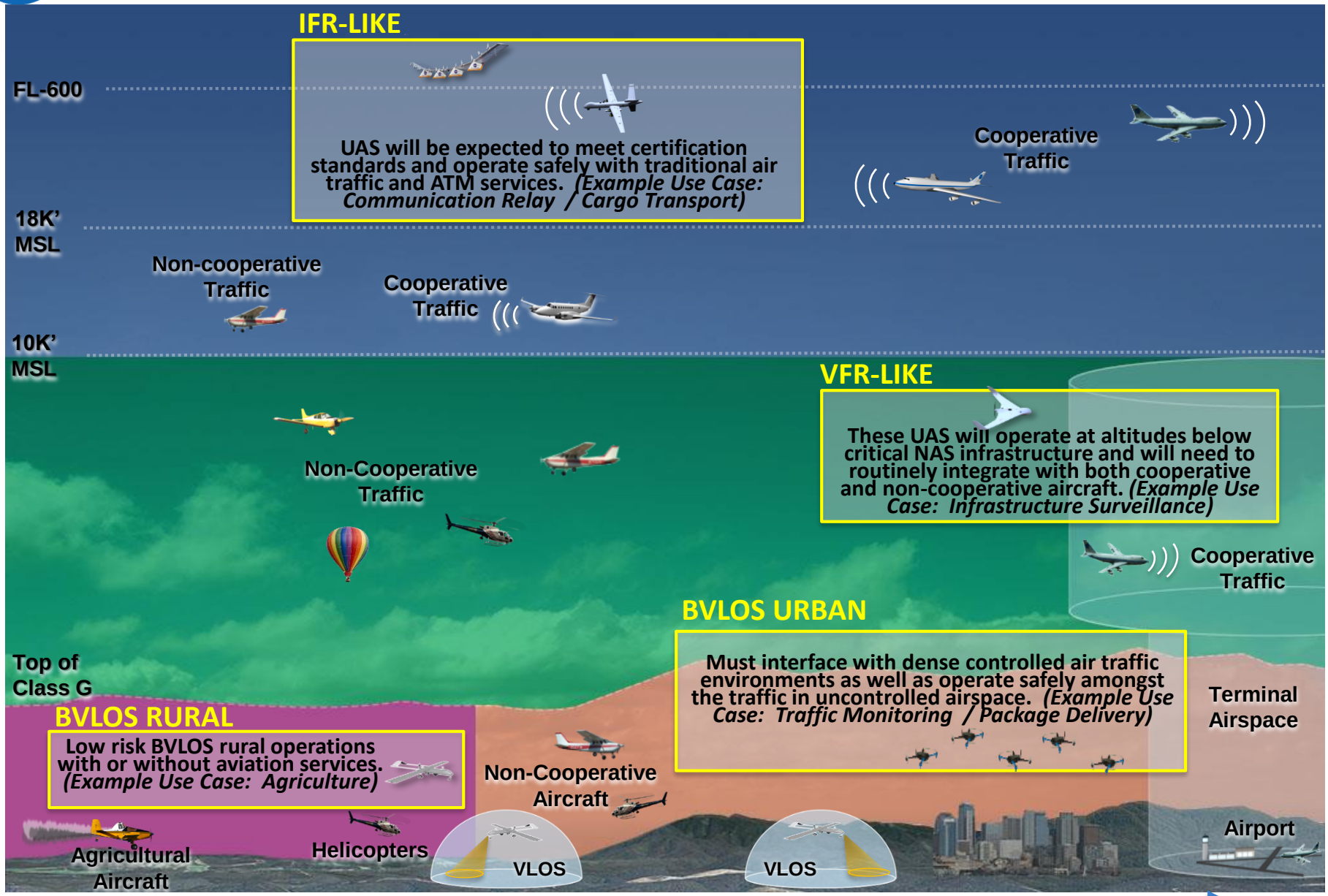
# FY18 Summary

- ✓ Successful completion of multiple Project Research Activities (simulations and flight tests) in support of Phase 2 Detect and Avoid (DAA) and Command and Control (C2) Technical Challenges (TC)
- ✓ Successfully advanced the Systems Integration and Operationalization (SIO) Demonstration through Cooperative Agreements (CA) with selected Industry Partners
- ✓ Established Research Transition Team (RTT) formally with the Federal Aviation Administration (FAA)
- ✓ Successful continuous risk management
  - ✓ Flight Test (FT) 5 and 6
- ✓ Effective Schedule and Milestone management

***Successfully executing technical portfolio***

# UAS-NAS Technical Performance
# Backup Slides

# Emerging Commercial UAS Operating Environments (OE)



# UAS-NAS Technical Challenge Autonomy Contributions

**AERONAUTICS STRATEGIC THRUST**

**Thrust 6:** Assured Autonomy for Aviation Transformation

**AERONAUTICS OUTCOME**

**Outcome (2015 – 2025):** Introduction of aviation systems with bounded autonomy, capable of carrying out function-level goals

**AERONAUTICS Research Theme**

Implementation and Integration of Autonomous Airspace and Vehicle Systems

**AERONAUTICS Overarching Technical Challenge**

4B. Select, develop, and implement applications of autonomy that are compatible with existing systems

4C. Develop framework for co-development of policies, standards, and regulations with development and deployment of increasingly autonomous systems

**UAS-NAS *Technical Content***

***TC-C2***

***TC-DAA***

***SIO***

TC-DAA Alignment:

- Development of requirements that can be leveraged for autonomous DAA guidance algorithm and alerting display
- Examples: removing the operator from the system and meeting the same requirements

TC-C2 Alignment:

- Development of requirements that support automatic and/or autonomous unmanned aircraft communication systems
- Examples: system wide removal of communication delays in time sensitive situations

SIO Alignment:

- Implement, test, evaluate and demonstrate selected applications of increasingly autonomous systems

# UAS-NAS Technical Challenge Autonomy Contributions

**AERONAUTICS STRATEGIC THRUST**

**Thrust 6:** Assured Autonomy for Aviation Transformation

**AERONAUTICS OUTCOME**

**Outcome (2015 – 2025):** Introduction of aviation systems with bounded autonomy, capable of carrying out function-level goals

**AERONAUTICS Research Theme**

Testing and Evaluation of Autonomous Systems

**AERONAUTICS Overarching Technical Challenge**

5B. Test, evaluate & demonstrate selected small-scale applications of autonomy

**UAS-NAS *Technical Content***

***TC-C2***

***TC-DAA***

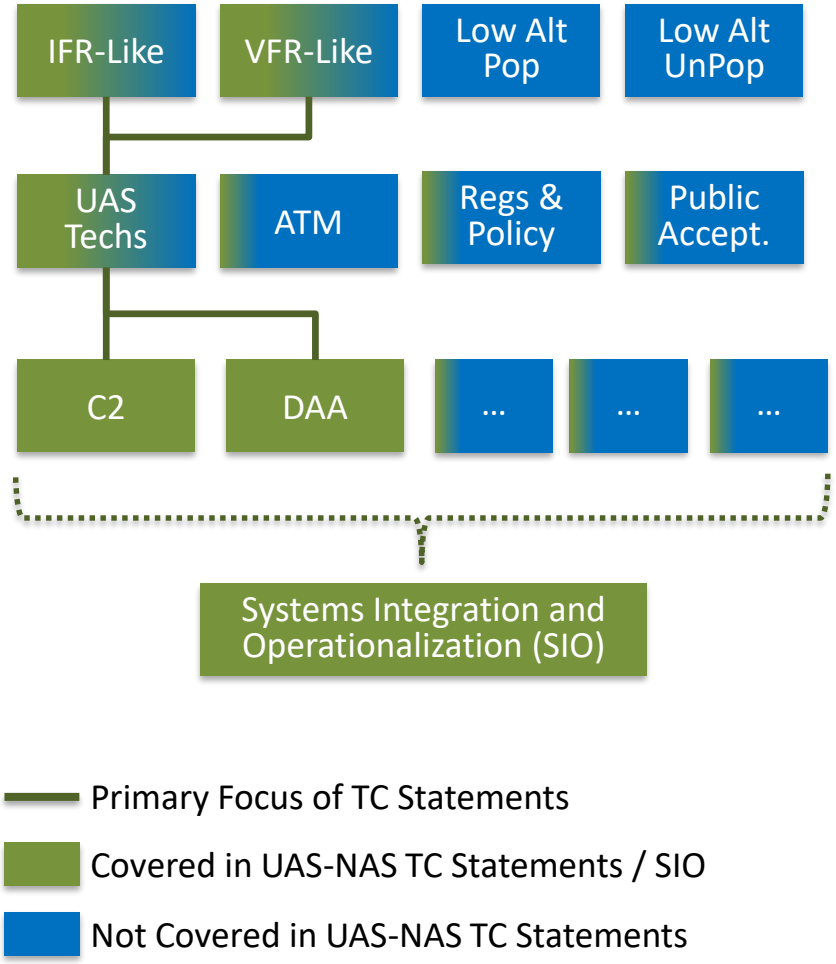
***SIO***

UAS-NAS Portfolio:

- Development of unmanned aircraft flight test methods and operational procedures relevant to small-scale applications of autonomy
  - Flight test of automatic and/or autonomous systems such as Airborne Collision Avoidance System (ACAS Xu)
  - Flight test of Detect and Avoid systems
  - Flight test of command and control radios
- Leverage NASA airworthiness safety processes to provide operational assessments for automatic and autonomous systems

# UAS Integration / Project Background

- Each OE has unique considerations with respect to each Pillar
- Program and Project core competencies focus on Integrated Vehicle technologies
- "IFR-Like" and "VFR-Like" OEs became the project focus due to considerations such as core competencies, Technology Readiness Level (TRL), other ARMD portfolio work, and community benefit
- Project Phase 2 TCs for DAA and C2 do not cover the broad needs for all OEs or UAS Vehicle Technologies
- SIO Demonstration effort developed around integration of DAA and C2 while including efforts towards closing UAS Vehicle technology gaps for project relevant OEs
- Project currently does not support other Program/Project TCs



# UAS Integration / Project Background

- NASA and FAA have determined DAA and C2 are highly significant barriers to UAS integration
- Project wrote TC statements that address the full barrier for DAA and C2 in the “VFR-Like” and “IFR-Like” Operating Environments
- Project identified the work required to complete the TCs and which aspects NASA should lead
- Project assessed and prioritized research to provide the greatest benefit to address the community barriers within resource allocations

***NASA well positioned to lead research addressing most significant barriers, DAA and C2, to UAS integration***

# TC-DAA Technical Baseline Elements (1/4)

| Technical Baseline Element Number | Technical Baseline Title | Reference SP Numbers |
|---|---|---|
| TBEN-005 | Alternative Surveillance and Well Clear/Alerting Requirements ConOps (Complete 1/19/18) | SP D.1.30, SP D.2.10 |
| TBEN-006 | Alternative Surveillance: Foundational Fast-time Simulation (FY17) (Complete 2/22/18) | SP D.1.40 |
| TBEN-007 | Alternative Surveillance: Display Requirements (Complete 2/13/18) | SP D.1.50 |
| TBEN-008 | Alternative Surveillance: Unmitigated Fast-time Simulation for Low SWaP Sensors Using Surveillance Volume and Uncertainties with Updated DAA Well Clear Definition (FY18) (Complete 9/27/18) | SP D.1.60 |
| TBEN-009 | Alternative Surveillance: HITL Simulation 1 | SP D.1.70, SP T.7.20 |
| TBEN-010 | Alternative Surveillance: Unmitigated/Mitigated Fast-time Simulation (FY19) | SP D.1.80 |

Current September 2018

# TC-DAA Technical Baseline Elements (2/4)

| Technical Baseline Element Number | Technical Baseline Title | Reference SP Numbers |
|---|---|---|
| ~~TBEN-011~~ | ~~Deleted September 28 2017 MRB, CR164: Alternative Surveillance: HITL Simulation 2~~ | ~~SP D.1.90, SP T.7.40~~ |
| TBEN-012 | Well Clear/Alerting Requirements: Foundational Terminal Operations HITL Simulation 1 (Complete 12/29/17) | SP D.2.30, T.7.10 |
| TBEN-013 | Well Clear/Alerting Requirements: Foundational Terminal Operations Fast-time Simulation 1 (Complete 12/20/17) | SP D.2.40 |
| TBEN-014 | Well Clear/Alerting Requirements: Fast-time Simulation 2 (Complete 3/27/18) | SP D.2.50 |
| ~~TBEN-015~~ | ~~Deleted September 28 2017 MRB, CR178: Well Clear/Alerting Requirements: Fast-time Simulation 3~~ | ~~SP D.2.60~~ |
| TBEN-016 | Well Clear/Alerting Requirements: HITL Simulation 2 | SP D.2.70 |
| TBEN-017 | Well Clear/Alerting Requirements: HITL Simulation 3 | SP D.2.80 |
| TBEN-018 | ACAS-Xu: Mini HITL Simulation (Complete 2/20/18) | SP D.3.20 |

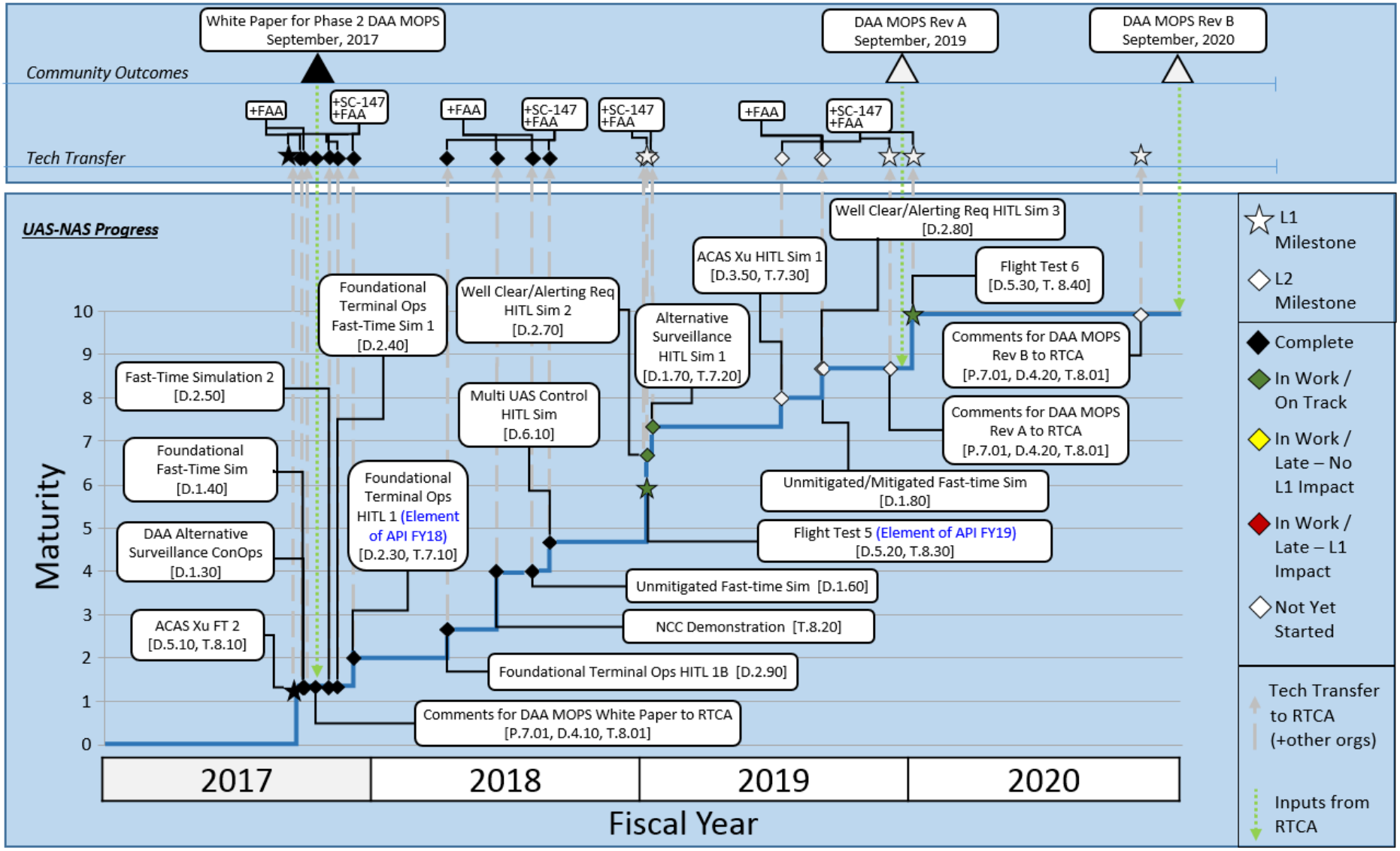
# TC-DAA Technical Baseline Elements (3/4)

| Technical Baseline Element Number | Technical Baseline Title | Reference SP Numbers |
|---|---|---|
| TBEN-019 | ACAS-Xu: HITL Simulation 1 | SP D.3.50, SP D.7.30 |
| TBEN-020 | Integrated Event: ACAS-Xu Flight Test 2 (Complete 10/23/17) | SP D.5.10, SP T.8.10 |
| TBEN-021 | Integrated Event: Flight Test 5 | SP D.5.20 |
| TBEN-022 | Integrated Event: Flight Test 6 | SP D.5.30, SP T.8.40 |
| TBEN-023 | No-Chase Certificate of Waiver or Authorization Flight Demonstration (Complete 8/20/18) | SP T.8.20 |
| TBEN-024 | Well Clear/Alerting Requirements: Foundational Terminal Ops HITL Simulation 1B (Complete 6/26/18) | SP D.2.90, T.7.50 |
| ~~TBEN-025~~ | ~~Deleted February 22, 2018 MRB, CR185: External Coordination: DAA-C2 Latency Sensitivity HITL Simulation~~ | ~~SP D.4.60, T.7.60~~ |

# TC-DAA Technical Baseline Elements (4/4)

| Technical Baseline Element Number | Technical Baseline Title | Reference SP Numbers |
|---|---|---|
| TBEN-026 | Human Automation Teaming: Multi UAS HITL | SP D.6.10 |
| TBEN-027 | Human Automation Teaming: Automatic Execution of CA and Return to Course Analysis | SP D.6.20 |

# TC-DAA: Progress Indicator



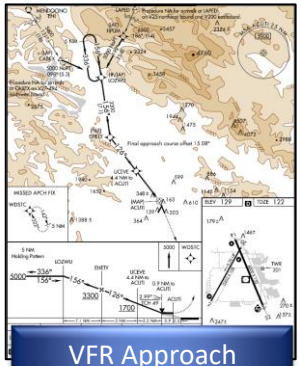
# Well Clear/Alerting Requirements: Foundational Terminal Operations HITL Simulation 1

## ✓ Research Objective:

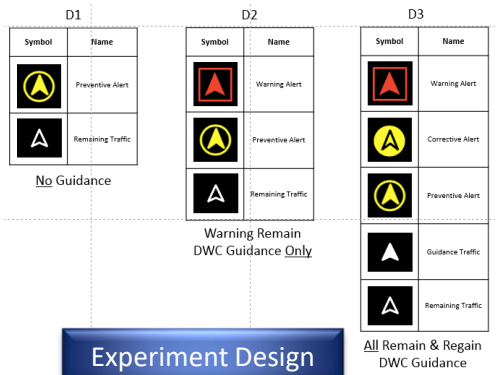
- Explore pilot performance and operational suitability issues associated with Class D terminal area operations

| Ownship Scenario | Description | Route Variations |
|---|---|---|
| **Instrument Approach** | • RNAV (GPS) Rwy 14 approach<br>• Non-precision approach; flown via GPS avionics | 1. Start point NW of CABEX<br>2. Start point NE of FIPUM |
| **Visual Approach** | • Approach conducted under IFR but through ATC-approved visual clearance<br>• Pilot must report either airport or a lead aircraft detected to start procedure | 1. Start point NW of KSTS<br>2. Start point NE of KSTS |
| **Traffic Pattern** | • Used to sequence (typically VFR) arrivals and departures<br>• Prop pattern=1150ft | 1. 45° entry into the downwind<br>2. Mid-field entry |

Scenario Design



VFR Approach




Experiment Design

- **Status:**
  - Experimental design, including Stakeholder/Partner Workshop, completed July 2017
  - Data collection completed October 2017
  - Results dissemination completed December 2017
  - Technical Baseline Element completed December 2017

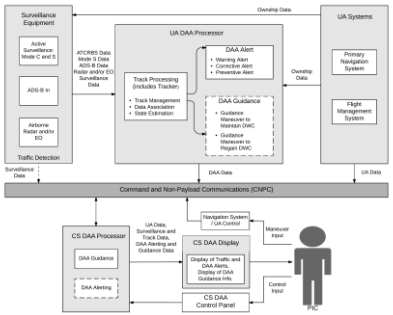
***Results accepted by SC-228; Shaping DAA MOPS development***

Technical Baseline Element Number: TBEN-012 (SP D.2.30, T.7.10)

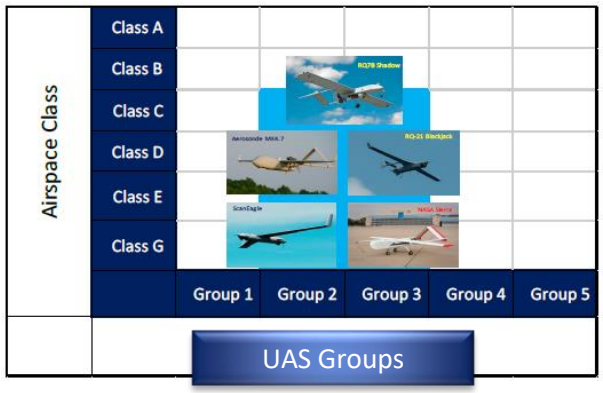
# Alternative Surveillance and Well Clear/Alerting Requirements ConOps

## ✓ Research Objective:

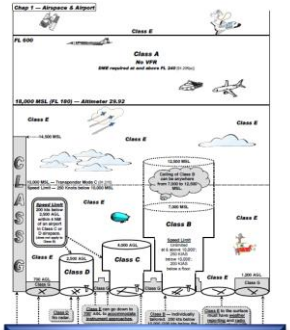
- Develop a ConOps describing the scope of DAA alternative surveillance and Well Clear Definition research to support the development of DAA Phase 2 MOPS and Non-Cooperative Sensor MOPS



Architecture



UAS Groups


Airspace Classes

- **Status:**
  - Alternative Surveillance ConOps completed November 2017
  - Well Clear/Alerting Requirements ConOps completed January 2018
  - Technical Baseline Element completed January 2018

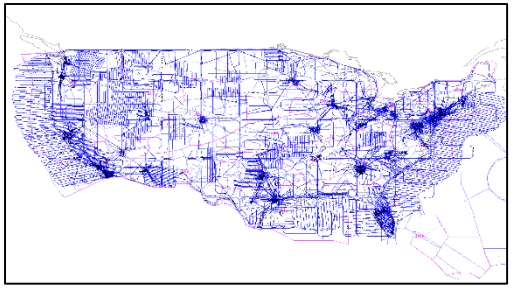
***Alternative Surveillance and Well Clear/Alerting Requirements ConOps shaped future Project research and approach for MOPS development***

Technical Baseline Element Number: TBEN-005 (SP D.1.30, SP D.2.10)

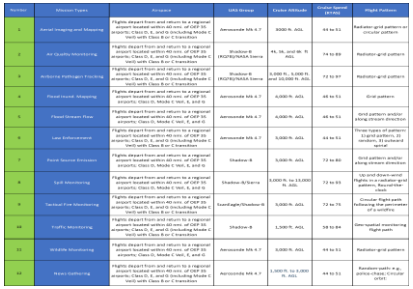
# Alternative Surveillance: Foundational Fast-time Simulation (FY17)

## ✓ Research Objective:

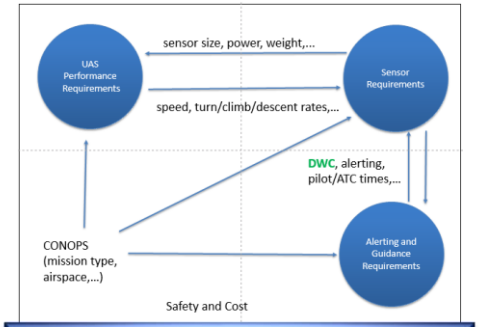
- Estimate the target performance of alternative surveillance within Phase 2 MOPS UAS operations in order to provide acceptable DAA alerting and guidance



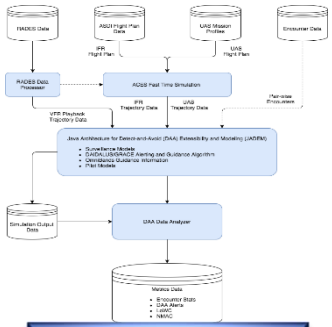
NAS Simulation



UAS Missions




Requirements Interrelationship



Architecture

- **Status:**
  - Experiment review completed July 2017
  - Data collection completed August 2017
  - Final results dissemination to SC-228 completed February 2018
  - Technical Baseline Element completed February 2018

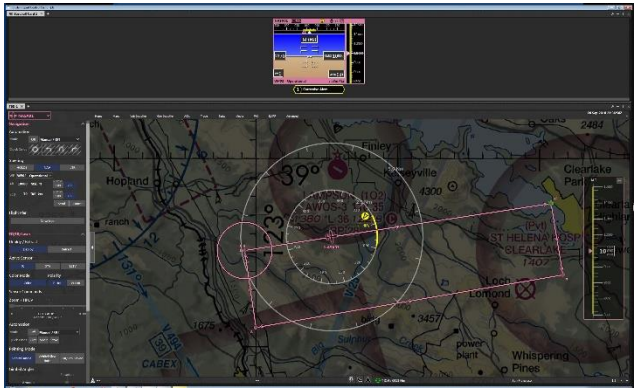
***Results accepted by SC-228; Shaping Alternative Surveillance MOPS Requirements***

Technical Baseline Element Number: TBEN-006 (SP D.1.40)

# Alternative Surveillance: Display Requirements

✓ **Research Objective:**

- Define DAA system display requirements for UAS with alternative surveillance systems within UAS operations associated with Phase 2 MOPS




- **Status:**
  - Definition of human factors issues completed February 2018
  - Definition of requirements completed February 2018
  - Definition of display options, as a list of display recommendations, completed February 2018
  - Technical Baseline Element completed February 2018

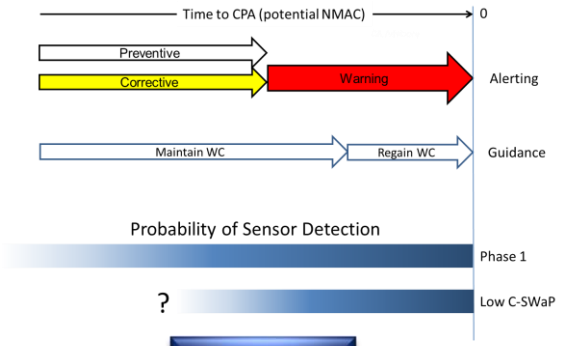
***Display recommendations support future human-in-the-loop simulation***

Technical Baseline Element Number: TBEN-007 (SP D.1.50)

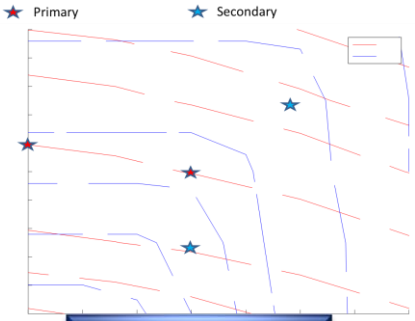
# Alternative Surveillance: Unmitigated Fast-time Simulation (FY18)

## ✓ Research Objective:

- Verify DAA alerting and surveillance performance with surveillance volume and uncertainties and updated DAA Well Clear definition within UAS operations associated with Phase 2 MOPS




Timelines




Candidate DWC


Hazard Zones

- **Status:**
  - Experiment Review completed March 2018
  - Data Collection completed June 2018
  - Data analysis completed August 2018
  - Results disseminated September 2018



Technical Baseline Element Number: TBEN-008 (SP D.1.60)

# Alternative Surveillance: HITL Simulation 1

- **Research Objective:**
  - Verify 1) UAS pilot performance of an DAA system with low size, weight, and power sensors, 2) interoperability of low size, weight, and power sensor requirements with DAA alerting, guidance, and display requirements, and identify modifications to alerting, guidance and display requirements for low size, weight, and power sensors as needed

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- **Status:**
  - Experiment design started April 2018
  - Experiment design completed September 2018
- **Next Steps:**
  - Data collection to be completed November 2018
  - Results dissemination to be completed January 2019



Technical Baseline Element Number: TBEN-009 (SP D.1.70, SP T.7.20)

# Alternative Surveillance: Unmitigated/Mitigated Fast-time Simulation (FY19)

- **Research Objective:**
  - Inform and verify draft for final DAA and Non-cooperative Sensor Phase 2 MOPS

- **Next Steps:**
  - Experiment plan to be completed March 2019
  - Data collection to be completed April 2019
  - Results dissemination to be completed August 2019

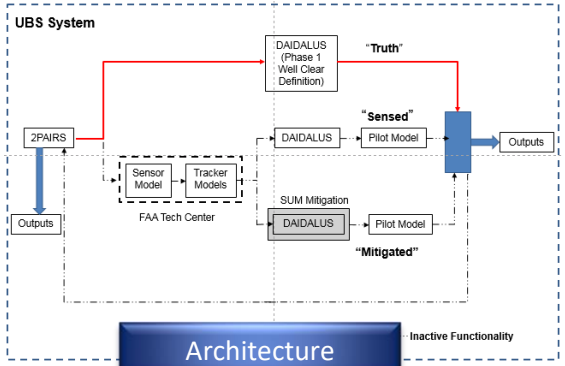


Technical Baseline Element Number: TBEN-010 (SP D.1.80)

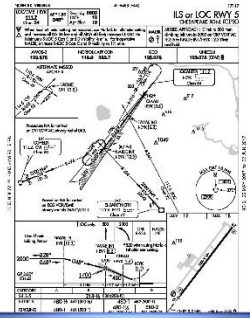
# Well Clear/Alerting Requirements: Foundational Terminal Operations Fast-time Simulation 1

## ✓ Research Objective:

- Collect empirical data to address well clear issues



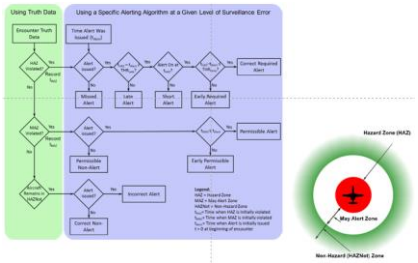

Architecture



Mission Profile

| | Geometry | Encounters |
|---|---|---|
| 1 | 45-degree Entry | 558 |
| 2 | Midfield Entry | 558 |
| 3 | Downwind | 15 |
| 4 | Extended Downwind | 45 |
| 5 | Turn to Base | 140 |
| 6 | Base | 31 |
| 7 | Base Entry | 31 |
| 8 | Turn to Final | 31 |
| 9 | 45-degree Departure | 54 |
| 10 | Straight Departure | 54 |

Test Matrix



Phase 1 DAA Metrics

- **Status:**
  - Experiment design and shakedown completed July 2017
  - Data collection completed August 2017
  - Results dissemination completed December 2017
  - Technical Baseline Element completed December 2017

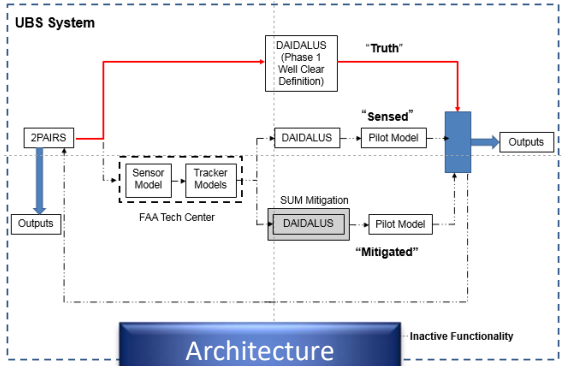
***Results accepted by SC-228; Shaping future simulations and DAA MOPS development***

Technical Baseline Element Number: TBEN-013 (SP D.2.40)

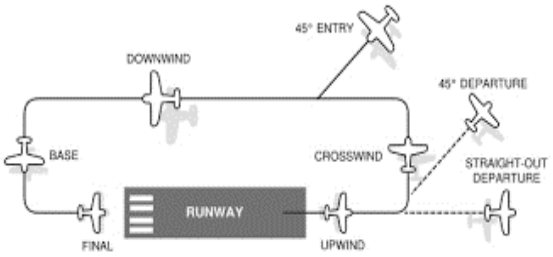
# Well Clear/Alerting Requirements: Fast-time Simulation 2

## ✓ Research Objective:

- Collect empirical data to address well clear issues




Architecture




Traffic Pattern

| | Geometry | Encounters |
|---|---|---|
| 1 | 45-degree Entry | 558 |
| 2 | Midfield Entry | 558 |
| 3 | Downwind | 15 |
| 4 | Extended Downwind | 45 |
| 5 | Turn to Base | 140 |
| 6 | Base | 31 |
| 7 | Base Entry | 31 |
| 8 | Turn to Final | 31 |
| 9 | 45-degree D | |
| 10 | Straight De | |

DAA Well Clear Parameters

| Tuning Thresholds | Phase 1 DAA Well Clear | Batch Simulations | | |
|---|---|---|---|---|
| | | Minimum | Maximum | Increment |
| $\tau_{mod}$ | 35 sec | [0, 15] | 35 | 10 |
| $HMD^*$ | 4000 ft | 2000 | 4000 | 500 |
| $h^*$ | 450 ft | 200 | 450 | 50 |

Test Matrix/Independent Variables

## • Status:

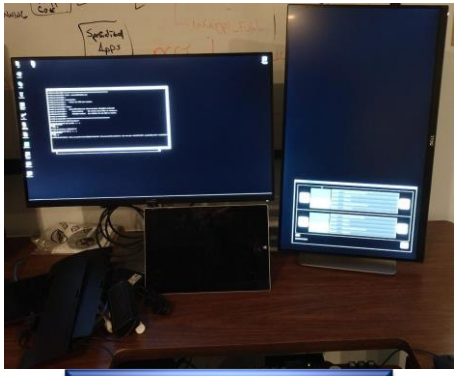
- Experiment design and shakedown completed July 2017
- Data collection completed August 2017
- Results dissemination completed March 2018
- Technical Baseline Element completed March 2018

***Results accepted by SC-228; Shaping future simulations and DAA MOPS development***

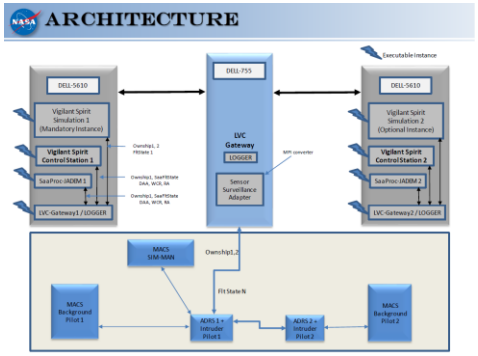
Technical Baseline Element Number: TBEN-014 (SP D.2.50)

# Well Clear/Alerting Requirements: Well Clear/Alerting Requirements: HITL Simulation 2

- **Research Objective:**
  - Verify 1) pilot performance of Class D and E terminal area operations and 2) DAA algorithm configurable parameters for Class D and E terminal area operations



Communication Tools




Architecture

- **Status**
  - Preliminary Experiment Review completed May 2018
  - Final Experiment Plan completed September 2018
- **Next Steps:**
  - Data collection to be completed November 2018
  - Results dissemination to be completed January 2019



Technical Baseline Element Number: TBEN-016 (SP D.2.70)

# Well Clear/Alerting Requirements: Well Clear/Alerting Requirements: HITL Simulation 3

- **Research Objective:**
  - Verify 1) pilot performance of Class E and G terminal area operations with no operating Airport Traffic Control Tower and 2) DAA algorithm configurable parameters for Class E and G terminal area operations with no operating Airport Traffic Control Tower

---

- **Next Steps:**
  - Experiment Design to be completed March 2019
  - Data collection to be completed July 2019
  - Results dissemination to be completed October 2019



Technical Baseline Element Number: TBEN-017 (SP D.2.80)

# ACAS-Xu: Mini HITL Simulation

## ✓ Research Objective:

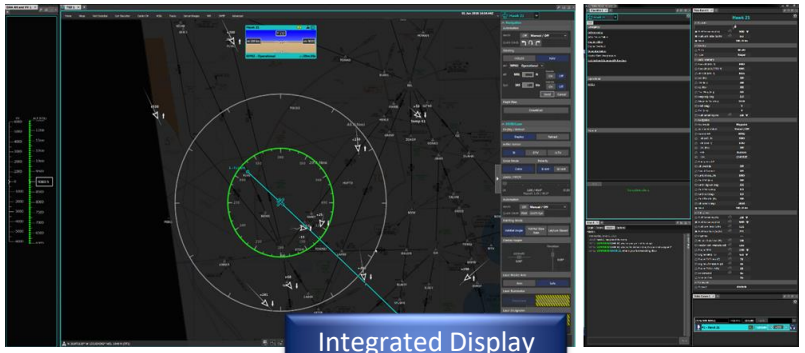
- 1) Determine that the Ames Research Centers Human Autonomy Teaming Laboratory components are installed properly and up to date for Project Phase 2 research (Primary) and 2) provide data on alerting, display and/or guidance Phase 1 DAA MOPS (Secondary)

| Pilot # | Trial 1 | Trial 2 | Trial 3 | Trial 4 |
|---|---|---|---|---|
| P01 | D1_Integrated_T1 | D1_Integrated_T2 | D1_Standalone_T2 | D1_Standalone_T1 |
| P02 | D2_Standalone_T1 | D2_Standalone_T2 | D2_Integrated_T2 | D2_Integrated_T1 |
| P03 | D3_Integrated_T2 | D3_Integrated_T1 | D3_Standalone_T1 | D3_Standalone_T2 |
| P04 | D1_Standalone_T1 | D1_Standalone_T2 | D1_Integrated_T2 | D1_Integrated_T1 |
| P05 | D2_Integrated_T2 | D2_Integrated_T1 | D2_Standalone_T1 | D2_Standalone_T2 |
| P06 | D3_Integrated_T1 | D3_Integrated_T2 | D3_Standalone_T2 | D3_Standalone_T1 |
| P07 | D1_Standalone_T2 | D1_Standalone_T1 | D1_Integrated_T1 | D1_Integrated_T2 |
| P08 | D2_Integrated_T1 | D2_Integrated_T2 | D2_Standalone_T2 | D2_Standalone_T1 |
| P09 | D3_Standalone_T2 | D3_Standalone_T1 | D3_Integrated_T1 | D3_Integrated_T2 |
| P10 | D1_Integrated_T2 | D1_Integrated_T1 | D1_Standalone_T1 | D1_Standalone_T2 |
| P11 | D2_Standalone_T2 | D2_Standalone_T1 | D2_Integrated_T1 | D2_Integrated_T2 |
| P12 | D3_Standalone_T1 | D3_Standalone_T2 | D3_Integrated_T2 | D3_Integrated_T1 |
| P13 | D1_Integrated_T1 | D1_Integrated_T2 | D1_Standalone_T2 | D1_Standalone_T1 |
| P14 | D2_ | | | Integrated_T1 |
| P15 | D3_ | | | Standalone_T2 |

Test Matrix

| D1: Caution Only | | | D2: Warning Aural | | | D3: Warning Aural + Symbol | | |
|---|---|---|---|---|---|---|---|---|
| Symbol | Name | Aural Alert Verbiage | Symbol | Name | Aural Alert Verbiage | Symbol | Name | Aural Alert Verbiage |
| N/A | N/A | N/A | | DAA Warning Alert | "Traffic, Maneuver Now" x2 | | DAA Warning Alert | "Traffic, Maneuver Now" x2 |
| | Corrective DAA Caution Alert | "Traffic, Avoid" | | Corrective DAA Caution Alert | "Traffic, Avoid" | | Corrective DAA Caution Alert | "Traffic, Avoid" |
| | *Preventive DAA Alert | "Traffic, Monitor" | | *Preventive DAA Alert | "Traffic, Monitor" | | *Preventive DAA Alert | "Traffic, Monitor" |
| | Guidance Traffic | N/A | | Guidance Traffic | N/A | | Guidance Traffic | N/A |
| | None (Target) | N/A | | None (Target) | N/A | | None (Target) | N/A |

Alerting Logic



Integrated Display

- **Status:**
  - Experimental design including Stakeholder input completed January 2017
  - Data Collection completed August 2017
  - Results dissemination completed February 2018
  - Technical Baseline Element completed February 2018

***Laboratory components installation acceptable; DAA results accepted by SC-228***

Technical Baseline Element Number: TBEN-018 (SP D.3.20)

# ACAS-Xu: HITL Simulation 1

- **Research Objective:**
  - Investigate highest priority interoperability issues related to the impact of ACAS Xu integrated DAA Remain Well Clear and collision avoidance alerting and guidance on pilot performance

- **Next Steps:**
  - Experimental design including Stakeholder input to be completed January 2019
  - Data Collection to be completed May 2019
  - Results dissemination to be completed July 2019
  - Technical Baseline Element to be completed July 2019



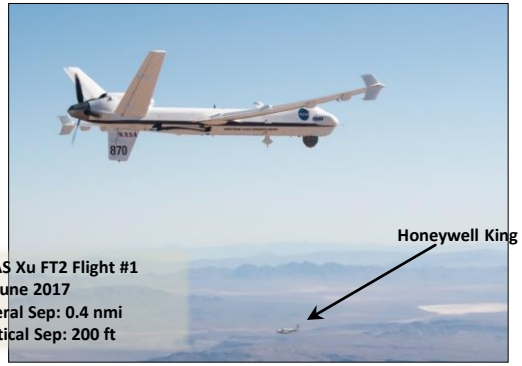
Technical Baseline Element Number: TBEN-019 (SP D.3.50, T.7.30)

# Integrated Flight Test: ACAS-Xu Flight Test 2

✓ **Research Objectives:**

- Continue collaboration with the FAA TCAS Program Office-led partnership to mature the ACAS Xu software in support of ACAS Xu MOPS development (draft FY18, final FY20)
- Demonstrate system behavior integrated on prototype avionics and UAS
- Compare DAA alerts and guidance between ACAS Xu and NASA algorithms
- Evaluate interoperability between ACAS Xu and NASA's DAA algorithms alerting and guidance


Team





Lab

- **Status:**
  - Flight test completed August 2017 (12 flight tests / 56 flight hours, 241 flight cards / test points)
  - Flight test data made available to FAA and contractor team following each flight
  - Comparison of ACAS-Xu and DAIDALUS Detect and Avoid Systems briefing completed November 2017
  - Public release of Flight test report completed October 23, 2017

***Flight Test Data Supported ACAS Xu MOPS Development***

Technical Baseline Element Number: TBEN-019 (SP D.5.10, T.8.10)

# Integrated Event: Flight Test 5

- **Research Objective:**
  - Collect data to characterize the performance of the low size, weight ,and power radar and to support development of the sensor model

Removed Picture


Honeywell Helicopter

Test Area

- **Status:**
  - Contract modification with Honeywell completed September 2018
- **Next Steps:**
  - Data Collection to start October 2018
  - Data Delivery from Honeywell to be completed December 2018
  - Results to be disseminated March 2019



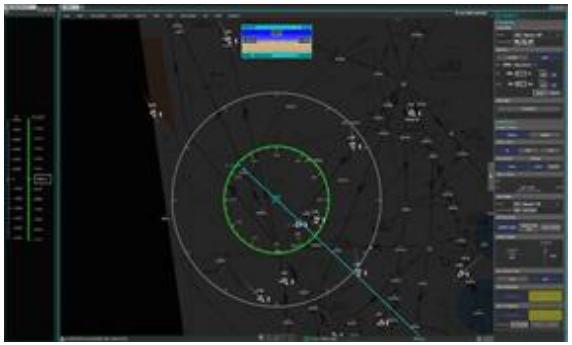
Technical Baseline Element Number: TBEN-021 (SP D.5.20, SP T.8.30)

# Integrated Event: Flight Test 6

- **Research Objective:**
  - Conduct a flight test providing data to support development, verification, and validation of the RTCA SC-228 Phase 2 Detect and Avoid and Alternative Surveillance MOPS

Removed Picture

NASC TigerShark



DAA Mitigated Encounters with Intruders

- **Status:**
  - Navmar Applied Sciences Corp awarded contract September 2018
- **Next Steps:**
  - Phase 2 CDR to be completed November 2018
  - System Checkout flights to be conducted May 2019
  - Radar Characterization flights to be conducted June 2019
  - FT6 Mission Flights to be conducted July 2019
  - Results to be disseminated March 2020



Technical Baseline Element Number: TBEN-022 (SP D.5.30, SP T.8.40)

# Well Clear/Alerting Requirements: Foundational Terminal Ops HITL Simulation 1B

## ✓ Research Objective:

- Explore pilot performance and operational suitability issues associated with Class D terminal area operations
  - Implement two candidates for a terminal area DAA well clear (DWC) definition
  - Further investigate the efficacy of the DAA Corrective alert in the terminal area
  - Compare pilot and system performance to previous studies

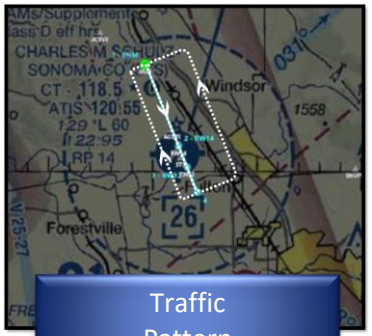
DWC Candidate (Within-Subjects):

| | No Tau | Tau |
|---|---|---|
| Horizontal Threshold* | 1500ft | 1500ft |
| Vertical Threshold | 450ft | 450ft |
| modTau | N/A | 15sec |

*HMD in Tau definition

DWC Candidates


Vigilant Spirit Control Station




Traffic Pattern

## • Status:

- Experiment design completed December 2017
- Data collection completed February 2018
- Results dissemination completed May 2018
- Technical Baseline Element completed May 2018

***Results support definition of Terminal Area Well Clear***



Technical Baseline Element Number: TBEN-024 (SP D.2.90)

# Human Automation Teaming: Multi UAS HITL

- **Research Objective:**
  - Investigate highest priority issues related to integration of the DAA system with multi-UAS control operations; Examine viability of 1:N and M:N operations with DAA

5 UA Condition


Sensor Task Example – Traffic Accident

- **Status:**
  - Experiment design review complete June 2018
  - Data collection complete June 2018
- **Next Steps**
  - Results dissemination to be completed October 2018



Technical Baseline Element Number: TBEN-026 (SP D.6.10, T.7.70)

# Human Automation Teaming: Automatic Execution of CA and Return to Course Analysis

- **Research Objective:**
  - Initial implementation of a Human Machine Interface to support effective auto-RA execution and return to course to inform SC-228 MOPS requirements development; Risk reduction for HITL testing of auto-RA and return to course in FY19

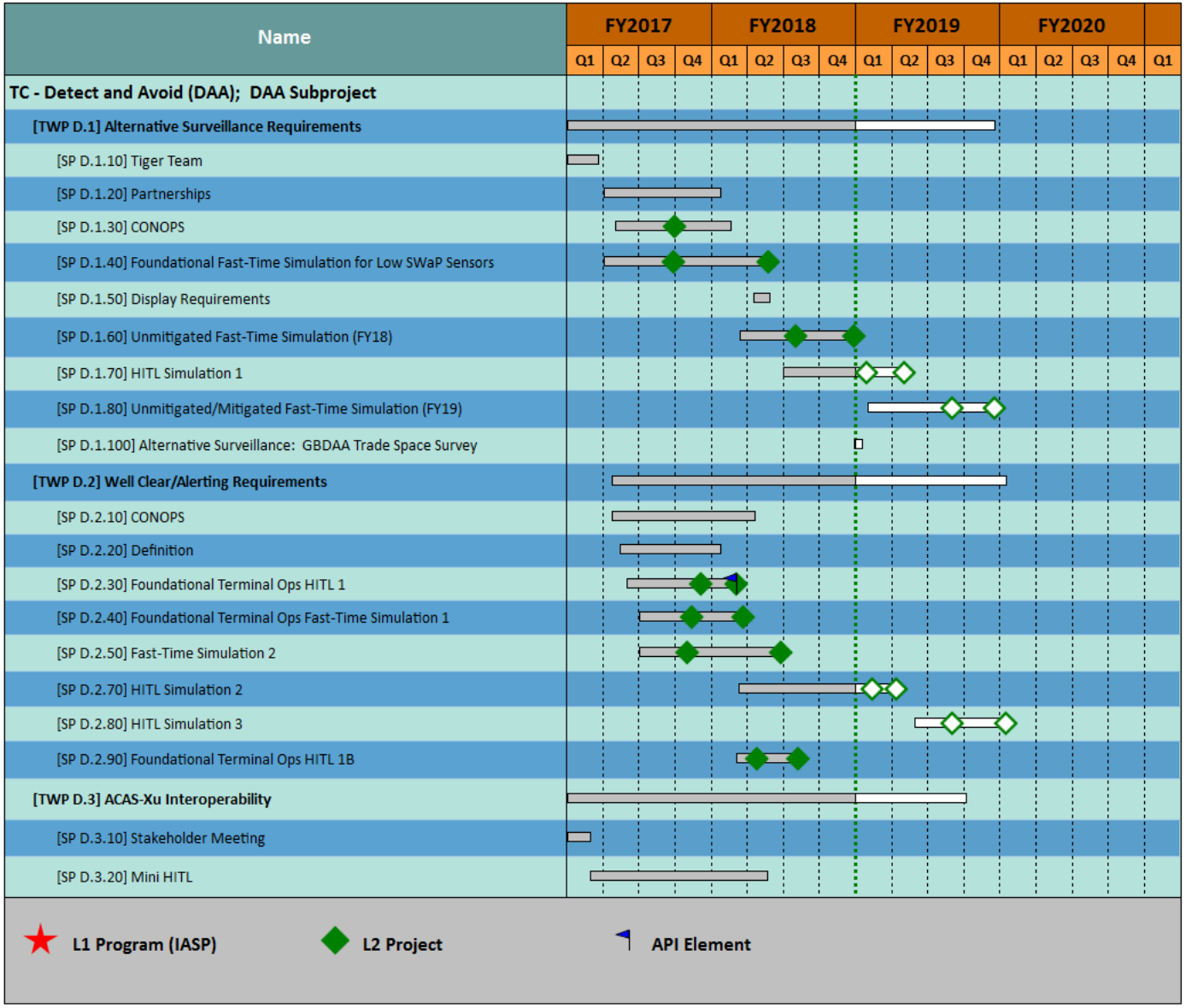
---

- **Status:**
  - Automation Workshop 2 complete May 2018
- **Next Steps**
  - Pilot-in-the-loop Engineering analysis to be completed January 2019
  - Recommendations for automation collision avoidance execution and return to course requirements presentation to be completed March 2019



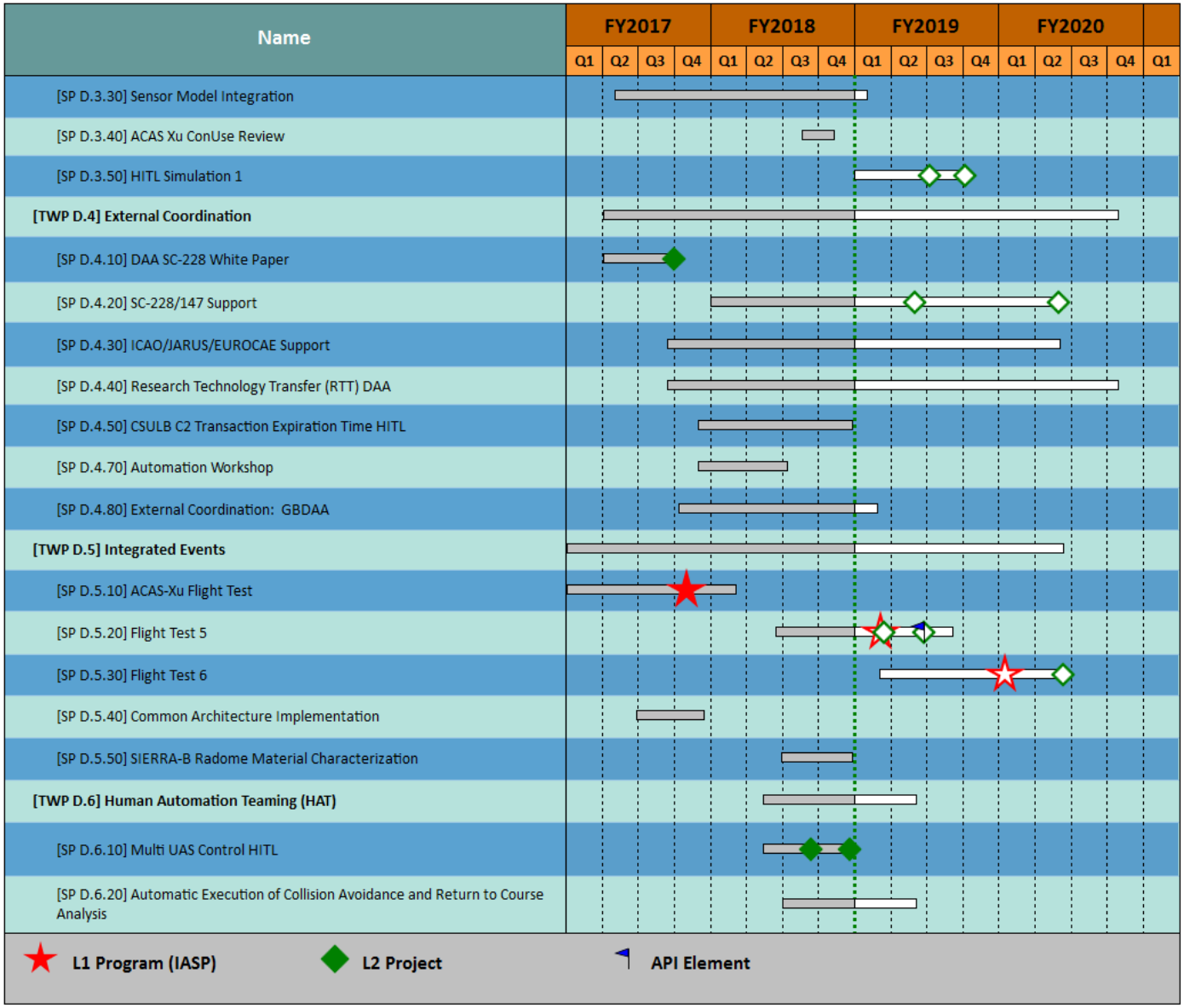
Technical Baseline Element Number: TBEN-027 (SP D.6.20)

# TC-DAA (1 of 3)



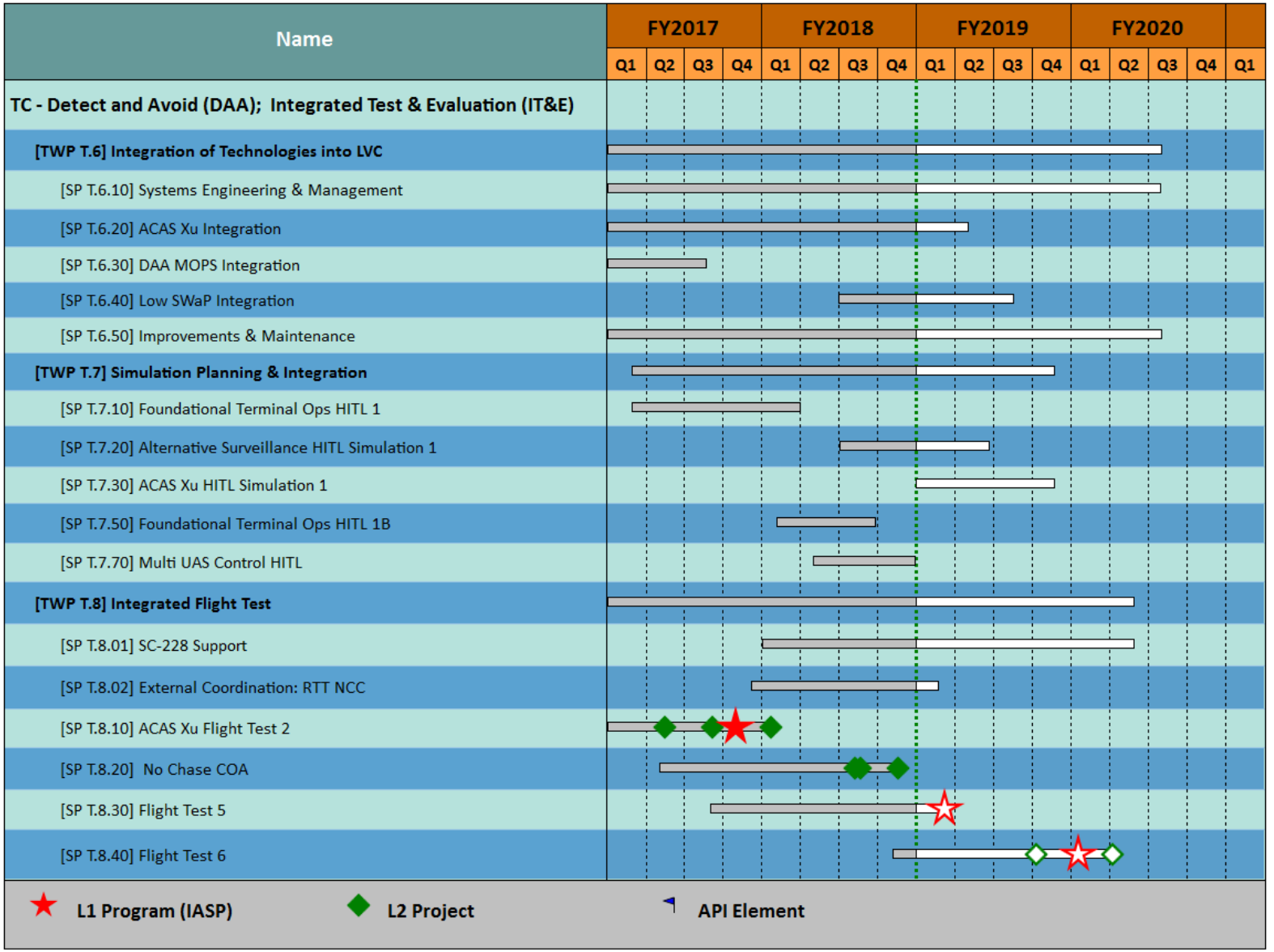

***Green Status Line Date 9/30/18***

# TC-DAA (2 of 3)




***Green Status Line Date 9/30/18***

# TC-DAA (3 of 3)

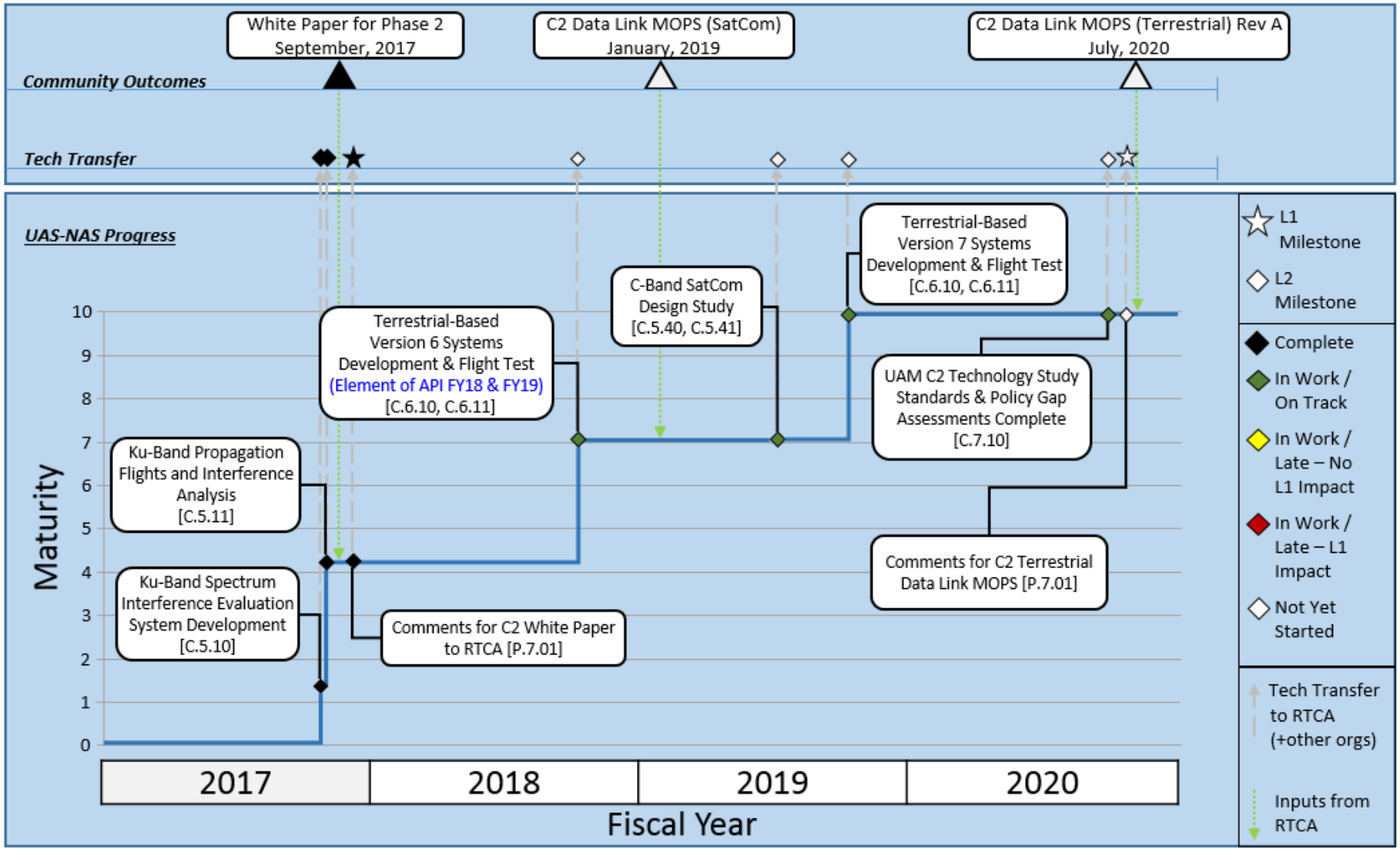



*Green Status Line Date 9/30/18*

# TC-C2 Technical Baseline Elements

| Technical Baseline Element Number | Technical Baseline Title | Reference SP Numbers |
|---|---|---|
| TBEN-001 | Ku-Band Spectrum Interference Evaluation System Development (Completed 7/25/17) | SP C.5.10 |
| TBEN-002 | Ku-Band Propagation Flights and Interference Analysis (Completed 9/20/17) | SP C.5.11 |
| TBEN-003 | C-Band Design Study, Verification & Validation Planning | SP C.5.40, SP C.5.41 |
| TBEN-004 | Terrestrial C2 Radio Evaluation System Development and Test and Evaluation | SP C.6.10, SP C.6.11 |
| TBEN-028 | UAS Urban Air Mobility C2 Study | SP C.7.10 |

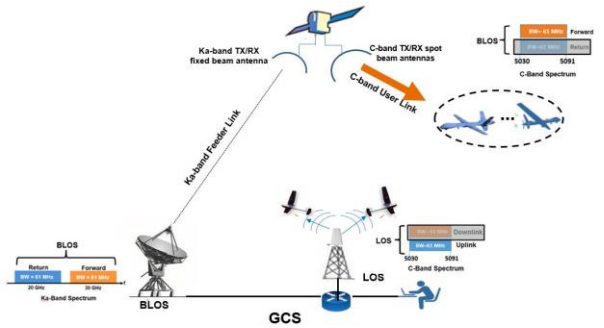
# TC-C2: Progress Indicator



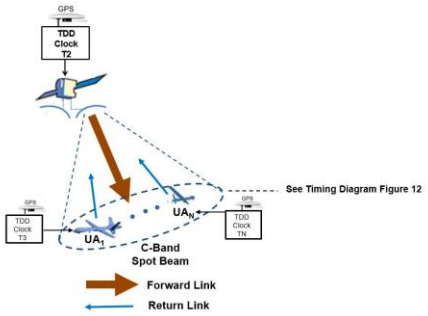

Technical Transfer Recipients: RTCA SC-228 C2 Working Group, FAA Spectrum Office and ICAO

# C-Band Design Study, Verification & Validation Planning

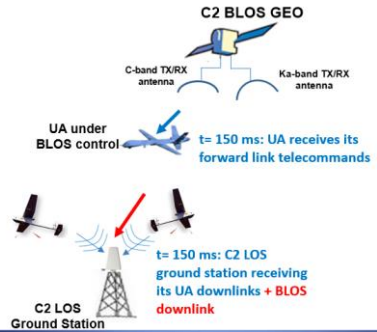
- **Research Objective:**
  - Transfer research data for the development and validation of standards for C-Band SatCom C2 data link



Notional UAS C2 Network



Link Synchronization



Potential Interference Scenario

- **Status:**
  - Contract awarded and Kickoff meeting completed June 2017
  - Conceptual System Design Study completed January 2018
  - Hosted Satellite Payload Study completed July 2018
- **Next Steps:**
  - Satellite payload design to be completed November 2018
  - Earth station design to be completed April 2019
  - Verification and Validation Plan to be completed July 2019
  - C-Band SatCom final report to be completed April 2020

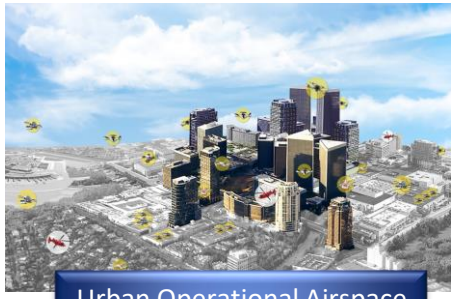
Technical Baseline Element Number: TBEN-003 (SP C.5.40, SP C.5.41)

# UAS Urban Air Mobility C2 Study

- **Research Objective:**
  - Study the unique C2 challenges related to UAS to satisfy the perceived needs of the Urban Air Mobility emerging market

| | Manned | | Unmanned | |
|---|---|---|---|---|
| | Phase 1 | Phase 2 | **Phase 3** | Phase 4 |
| Pilot | Expert Pilot | Skilled Pilot | **Ground Pilot** | No Pilot |
| Autonomy | None | Limited | **Partial** | Full |
| C2 | None | Low | **Medium** | High |

UAM Operational Phase



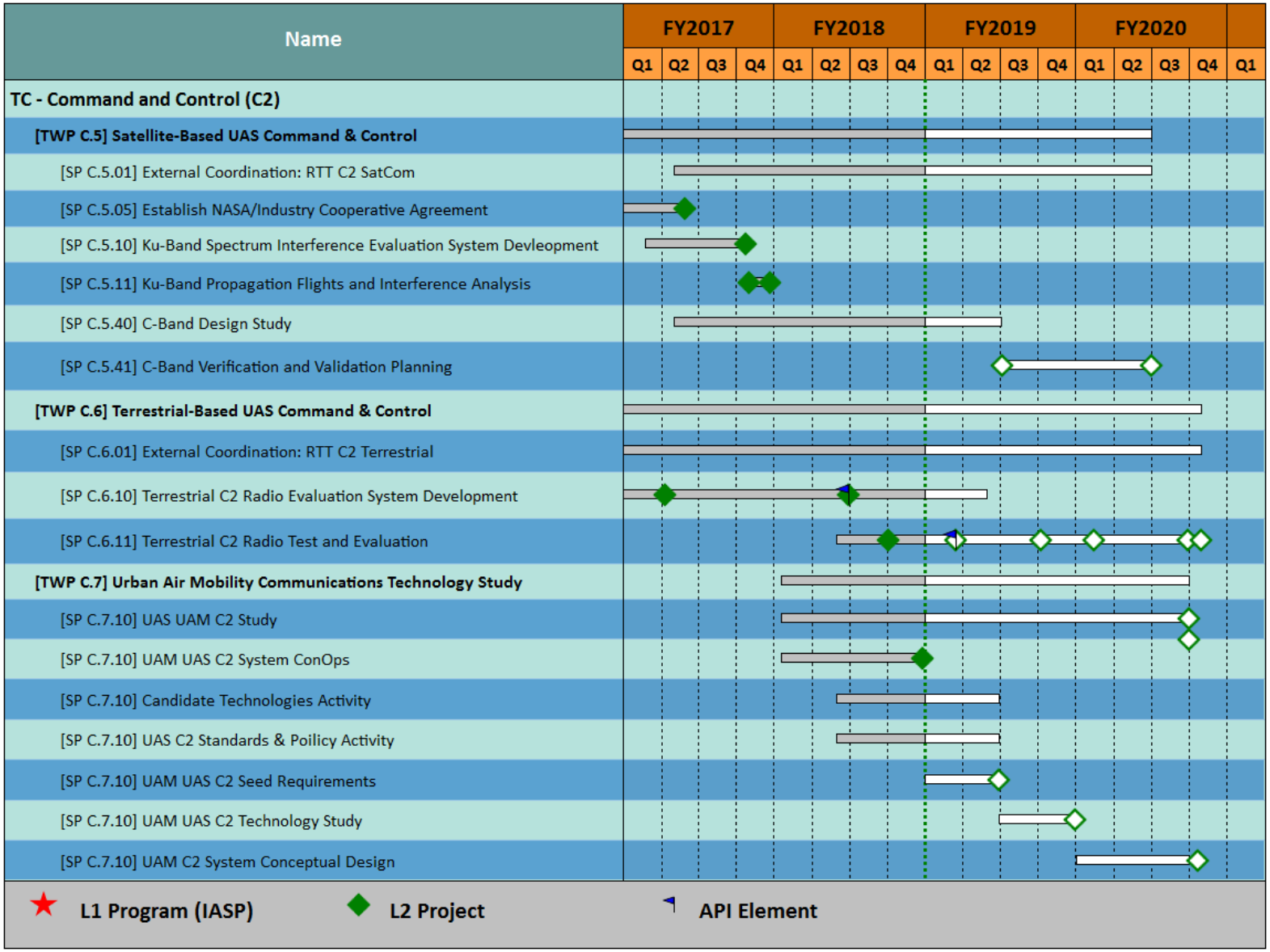
Urban Operational Airspace

Urban C2 Communications Environment

- **Status**
  - Baseline ConOps completed September 2018
- **Next Steps:**
  - Final Candidate Technologies for Study Criteria to be completed March 2019
  - Final Standards & Policies for Study Criteria to be completed March 2019
  - Baseline UAM C2 Seed Requirements to be delivered March 2019
  - UAM UAS C2 Technology Study to be completed September 2019
  - UAS C2 Standards & Policies Gap Assessment to be completed June 2020

Technical Baseline Element Number: TBEN-028 (SP C.7.10)

# TC-C2




*Green Status Line Date 9/30/18*

# NASA, FAA, and Industry Relationship for SIO

Maximum contribution from NASA

## NASA

- Command and Control (C2) and Detect and Avoid (DAA)
- UAS Airworthiness
- Subject matter expertise
- Type certification lessons learned


UAS-NAS RTT (SC-228)

DAA/C2, Airworthiness Criteria

**SIO**

FAA role

## FAA

- Approval to fly in the NAS
- Type Certification guidance
- Procedural, policy, and regulatory changes

Certification, Operational Approval

## Industry

- Airworthy vehicle with integrated C2 and DAA equipage
- Other gap filling technologies required for missions
- Specific Type Cert Basis

Minimum contribution from Industry

Systems Integration and Operationalization (SIO) Partnership

# Project Level Performance
# Backup Slides

# Active Risk Status

- Data Redacted

# Top Risk

- Data Redacted

# Active Risks

- Data Redacted

# FY18 Closed Risks

- Data Redacted

# UAS-NAS Risk Summary Card

- Data Redacted

# IASP Risk 02: UAS-NAS Project Focus Changes Due to External Influences

- Data Redacted

# UAS-NAS FY18 Project Funding

- Data Redacted

# Resource Allocation FY18 Budget

- Data Redacted

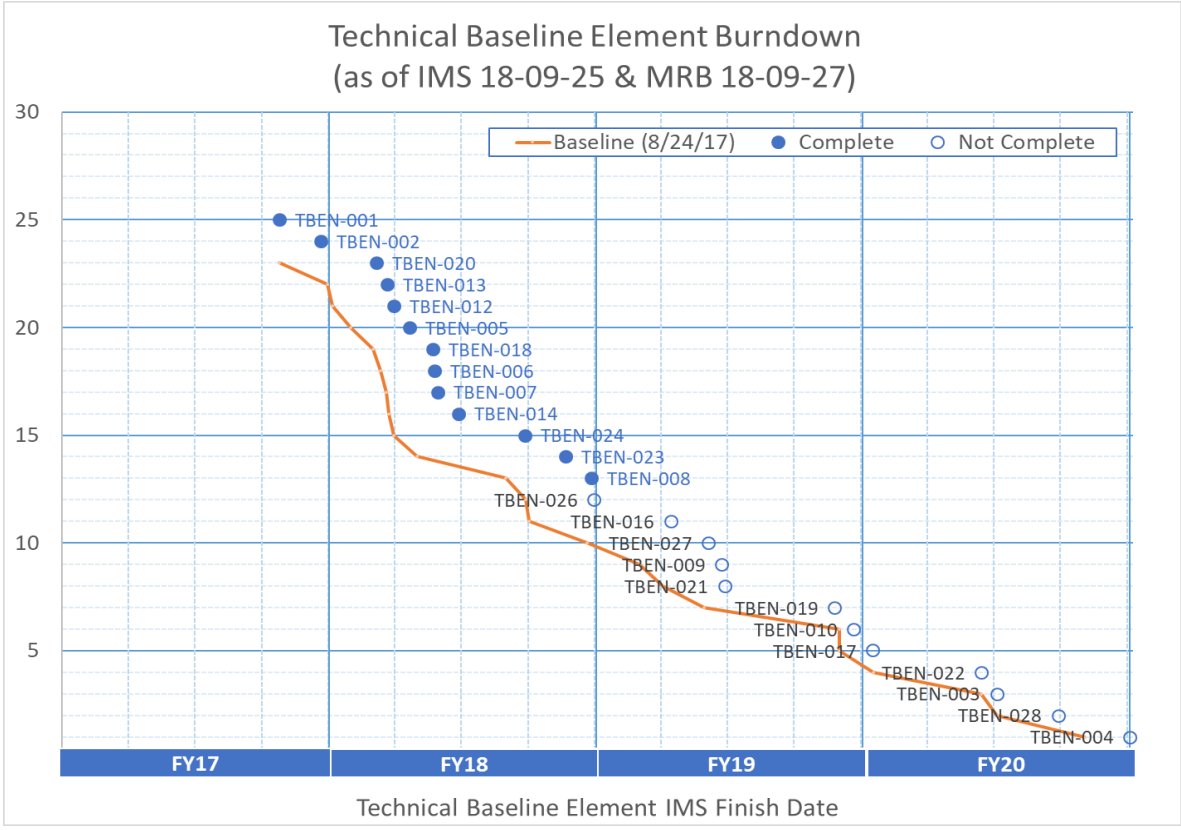
# MRB Technical Baseline Summary
# September 27, 2018

- August 23, 2018 MRB
  - TBEN-021 modified for FT5 re-plan

- Technical Baseline Elements Completed Since August 23, 2018 MRB
  - [SP D.1.60] Results Dissemination for Unmitigated Fast-time Simulation Study of Surveillance Volume and Alerting Timelines for Low SWaP Sensors to SC-228

- Technical Baseline Element Summary
  - 25 Approved
  - 13 Completed
  - 12 Open

| TC | 8/24/17 Baseline | Current MRB Approved Total | Total Completed | Total Remaining |
|---|---|---|---|---|
| C2 | 4 | 5 | 2 | 3 |
| DAA | 19 | 20 | 11 | 9 |
| Total | 23 | 25 | 123 | 12 |



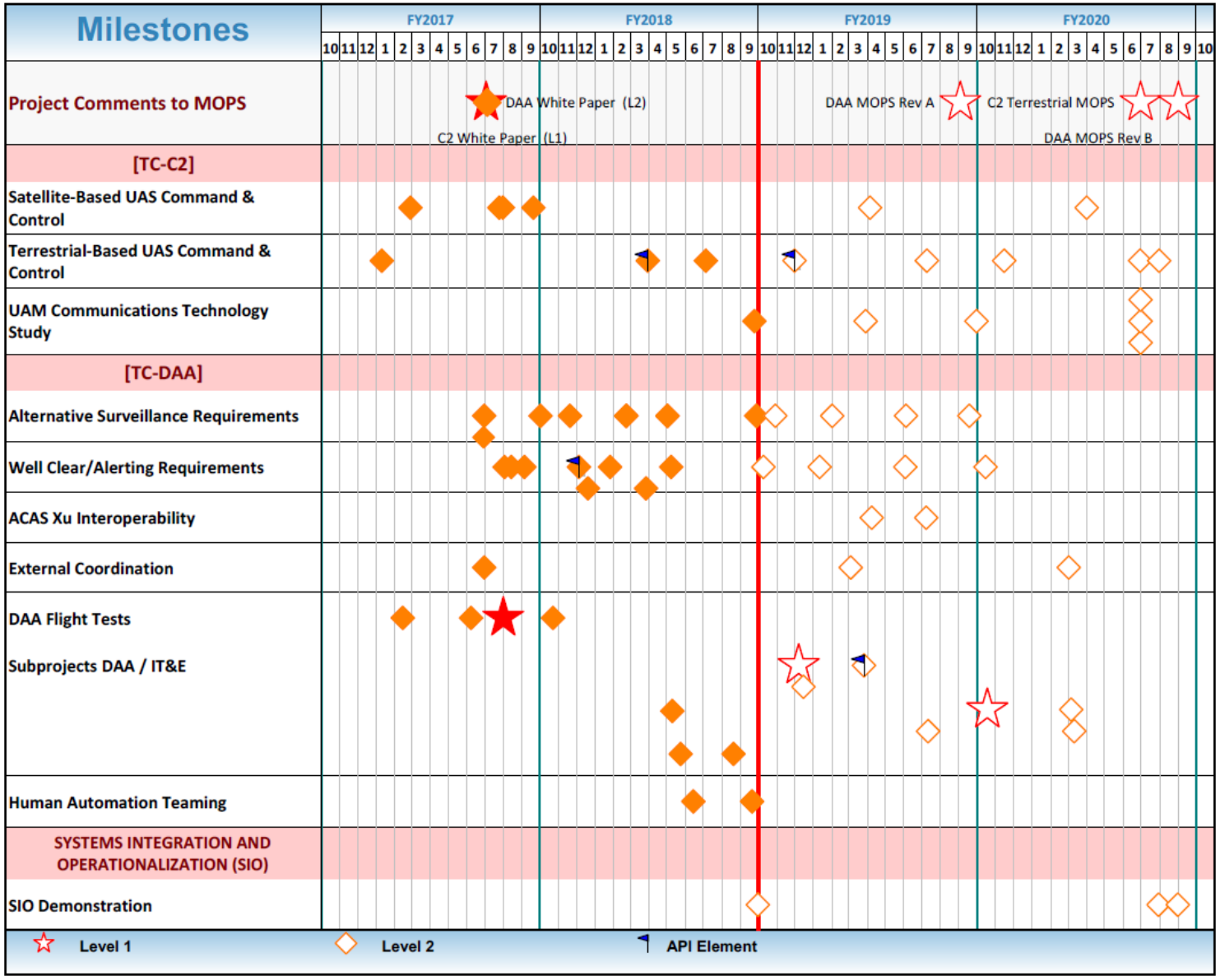
# FY18 Project Deliverables (1 of 2)

| FY18 Project Deliverables | Technical Challenge | Date | Type of Deliverable |
|---|---|---|---|
| ACAS Xu Flight Test 2 Flight Test Report | TC-DAA | Oct-17 | Report |
| Foundational Terminal Ops Fast-Time Batch Simulation 1 Data Analysis | TC-DAA | Nov-17 | Briefing |
| C-Band Cost/Benefit Assessment | TC-C2 | Nov-17 | Report |
| UAS-NAS Terminal Operations Human in the Loop 1 Test Report | TC-DAA | Dec-17 | Report |
| Concept of Operations for UAS Detect-and-Avoid in Terminal Operations | TC-DAA | Jan-18 | Paper |
| LinQuest Conceptual System Design Study of UAS C2 SatCom | TC-C2 | Jan-18 | Report |
| Low C-SWaP Well Clear Trade Study | TC-DAA | Feb-18 | Briefing |
| Comparative Analysis of ACAS-Xu and DAIDALUS Detect-and-Avoid Systems | TC-DAA | Mar-18 | NASA TM |
| Experiment Out-Brief: Well Clear/Alerting Requirements Foundational Terminal Ops HITL 1 | TC-DAA | Mar-18 | Briefing |
| Terminal Operations HITL 1B Primary Results | TC-DAA | Mar-18 | Briefing |
| Warning Alert HITL Experiment Report | TC-DAA | Mar-18 | Briefing |
| Terminal Area DAA Well-Clear Definition Results | TC-DAA | Mar-18 | Briefing |
| Payload & Earth Station Conceptual Design | TC-C2 | Apr-18 | Report |
| An Interoperability Concept for Detect and Avoid and Collision Avoidance Systems: Results from a Human-in-the-Loop Simulation | TC-DAA | May-18 | Paper |
| An Exploratory Evaluation of UAS DAA Operations in the Terminal Environment | TC-DAA | May-18 | Paper |
| Well Clear Trade Study for Unmanned Aircraft System Detect And Avoid with Non-Cooperative Aircraft | TC-DAA | May-18 | Paper |

# FY18 Project Deliverables (2 of 2)

| FY18 Project Deliverables | Technical Challenge | Date | Type of Deliverable |
|---|---|---|---|
| En Route Detect and Avoid Well Clear in Terminal Area Landing Pattern | TC-DAA | May-18 | Paper |
| A Recommended DAA Well-Clear Definition for the Terminal Environment | TC-DAA | Jun-18 | Paper |
| Sensitivity Analysis of Detect and Avoid Well Clear Parameter Variations on UAS DAA Sensor Requirements | TC-DAA | Jun-18 | Paper |
| Analysis of Influence of UAS Speed Range and Turn Performance on Detect and Avoid Sensor Requirements | TC-DAA | Jun-18 | Paper |
| UAS-NAS Terminal Operations Human in the Loop 1B Test Report | TC-DAA | Jun-18 | Report |
| Hosted Satellite Payload Study Report | TC-C2 | Jul-18 | Report |
| No Chase COA Flight Test Report | TC-DAA | Aug-18 | Report |
| Impact of the Transaction Expiration Time (TET) on ATC Performance and Acceptability | TC-DAA | Aug-18 | Report |
| UAM C2 Baseline ConOps | TC-C2 | Sep-18 | Report |
| Trade Off between Alerting Timeline and Surveillance Volume | TC-DAA | Sep-18 | Briefing |
| Sensor Uncertainty Mitigation and Dynamic Well Clear Volumes in DAIDALUS | TC-DAA | Sep-18 | Report |
| PAE ISR Cooperative Agreement Signed | SIO | Sep-18 | Agreement |
| Honeywell Cooperative Agreement Modification Signed | TC-DAA | Sep-18 | Agreement |
| NASC Contract Signed | TC-DAA | Sep-18 | Agreement |

# Phase 2 Milestone Summary

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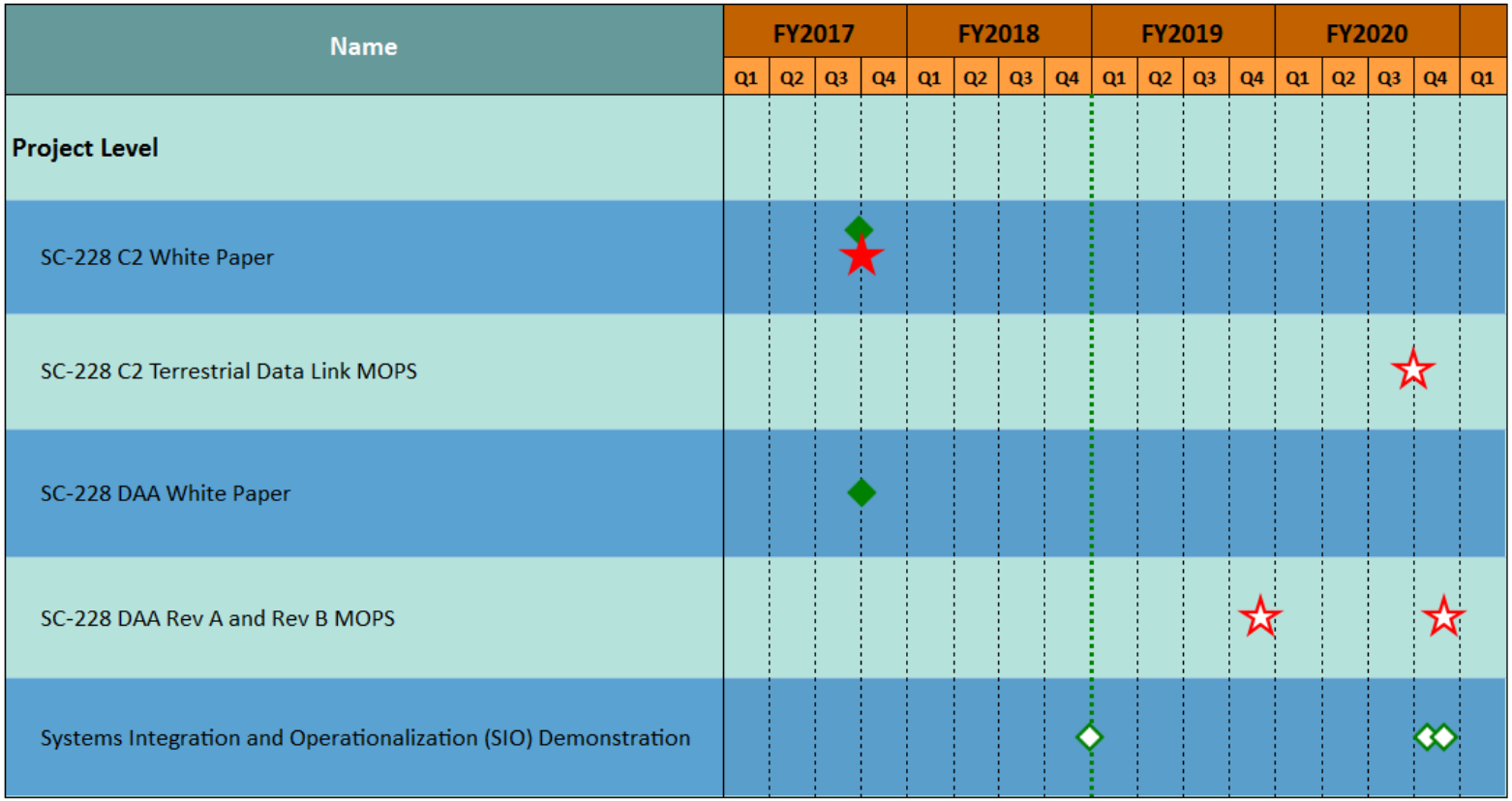
# Project Office




*Green Status Line Date 9/30/18*

# Acronyms

| | |
|---|---|
| A/A | Air-to-Air |
| ACAS | Airborne Collision Avoidance System |
| ACAS-Xu | Version of ACAS for Unmanned Aircraft |
| ADS-B | Automatic Dependent Surveillance - Broadcast |
| AFRC | Armstrong Flight Research Center |
| AFRL | Air Force Research Lab |
| AGL | Above Ground Level |
| AOSP | Airspace Operations and Safety Program |
| API | Annual Performance Indicator |
| APM | Associate Project Manager |
| APT | Autonomous Pod Transport |
| AR | Annual Review |
| ARC | Ames Research Center or Aviation Rule Making Committee |
| ARD | Aeronautics Research Director |
| ARMD | Aeronautics Research Mission Directorate |
| ATC | Air Traffic Controller |
| ATM | Air Traffic Management |
| ATO | Air Traffic Organization-FAA Organization or Authority to Operate |
| AVS | Aviation Safety-FAA Organization |

# Acronyms

| | |
|---|---|
| BRLOS | Beyond Radio Line of Sight |
| BVLOS | Beyond Visual Line of Sight |
| C2 | Command and Control |
| C3 | Command, Control and Communication |
| CA | Collision Avoidance or Cooperative Agreement |
| CAN | Cooperative Agreement Notice |
| CAS | Collision Avoidance System |
| CDR | Critical Design Review |
| CE | Chief Engineer |
| Cert | Certification |
| CMB | Change Management Board |
| CNPC | Control and Non-Payload Communications |
| CNS | Communication, Navigation and Surveillance |
| COA | Certificate of Authorization or Waiver |
| Comm | Communications |
| CONOPS | Concept of Operations |
| COTS | Commercial off the Shelf |
| CRM | Continuous Risk Management |
| CS | Civil Servant |
| C-SWaP | Cost – Size, Weight, and Power |

# Acronyms

| | |
|---|---|
| C&TA | Concepts & Transversal Activities |
| DAA | Detect and Avoid |
| DAIDALUS | Detect and Avoid Alerting Logic for Unmanned Systems |
| DAPA | Digital Active Phased Array |
| DoD | Department of Defense |
| DPM | Deputy Project Manager |
| DWC | Definition Well Clear |
| EUROCAE | European Organization for Civil Aviation Equipment |
| FAA | Federal Aviation Administration |
| FT | Flight Test |
| FTE | Full Time Equivalent |
| FY | Fiscal Year |
| FYE | Fiscal Year End |
| GA | General Aviation |
| GA-ASI | General Atomics Aeronautical Systems Inc. |
| GBDAA | Ground Based Detect and Avoid |
| GCS | Ground Control Station |
| Gen | Generation |
| GRC | Glenn Research Center |
| HALE | High Altitude Long Endurance |
| HAT | Human Autonomy Teaming |
| HF | Human Factors |

# Acronyms

| | |
|---|---|
| HITL | Human-in-the-loop |
| HITS | Human in the System |
| HQ | Headquarters |
| IASP | Integrated Aviation Systems Program |
| lb. | Pounds |
| ICAO | International Civil Aviation Organization |
| IDIQ | Indefinite-Delivery, Indefinite-Quantity |
| IFR | Instrument Flight Rules |
| IMS | Integrated Master Schedule |
| IRP | Independent Review Panel |
| IT&E or ITE | Integrated Test and Evaluation |
| KDP | Key Decision Point |
| L1 | Level 1 |
| L2 | Level 2 |
| LaRC | Langley Research Center |
| LVC-DE | Live Virtual Constructive Distributed Environment |
| MASPS | Minimum Aviation System Performance Standards |
| MOPS | Minimum Operational Performance Standards |
| MRB | Management Review Board |
| M&S | Modeling and Simulation |

# Acronyms

| | |
|---|---|
| MS&A | Modeling, Simulation, and Analysis |
| MSL | Mean Sea Level |
| N2 | 2nd upgrade to the original NBS |
| NAS | National Airspace System |
| NASA | National Aeronautics and Space Administration |
| NASC | Navmar Applied Sciences Corporation |
| NCC | No Chase COA |
| NextGen | Next Generation |
| NRA | NASA Research Announcement |
| OE | Operating Environment |
| OSED | Operational Services Environment Description |
| OUSD | Office of the Under Secretary of Defense |
| OV-1 | Operational View |
| P1 | Phase 1 |
| P2 | Phase 2 |
| PDR | Preliminary Design Review |
| PER | Preliminary Experiment Review |
| PI | Progress Indicator |
| PIL | Pilot in the loop |
| PM | Project Manager |

# Acronyms

| | |
|---|---|
| PO | Project Office |
| PP | Project Plan |
| PRP | Performance Review Panel |
| RADAR | Radio Detection and Ranging |
| RF | Radio Frequency |
| RFI | Request for Information |
| RFP | Request for Proposal |
| RPAS | Remotely Piloted Aircraft Systems |
| RPS | Remote Pilot Station |
| RT | Research Theme |
| RTP | Research Transition Products |
| RTT | Research Transition Team |
| SAA | Sense and Avoid or Space Act Agreement |
| SARP | Science and Research Panel |
| SatCom | Satellite Communications |
| SC | Special Committee |
| SIERRA-B | Sensor Integrated Environmental Remote Research Aircraft |
| Sim | Simulation |
| SIO | Systems Integration and Operationalization |
| SME | Subject Matter Expert |

# Acronyms

| | |
|---|---|
| SP | Schedule Package |
| SPM | Subproject Manager |
| SWaP | Size, Weight and Power |
| TB | Technical Baseline |
| TBE | Technical Baseline Element |
| TBEN | Technical Baseline Element Number |
| TC | Technical Challenge |
| TCAS | Traffic Alerting and Collision Avoidance System |
| TOPS | Terminal Operations |
| ToR | Terms of Reference |
| TRL | Technology Readiness Level |
| TSO | Technical Standard Order |
| UA | Unmanned Aircraft |
| UAM | Urban Air Mobility |
| UAS | Unmanned Aircraft Systems |
| UAS-NAS | Unmanned Aircraft Systems Integration in the National Air Space System |
| UAV | Unmanned Aircraft Vehicle |
| UCAT | Urban Air Mobility (UAM) Coordination Assessment Team |
| UTM | UAS Traffic Management |
| V | Version |

# Acronyms

| | |
|---|---|
| VFR | Visual Flight Rules |
| VLL | Very Low Level |
| VLOS | Visual Line of Sight |
| VSCS | Vigilant Spirit Control Station |
| VTOL | Vertical Take off and Landing |
| V&V | Verification and Validation |
| WC | Well Clear |
| WG | Working Group |
| WYE | Work Year Equivalent |