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

FY19 Annual Review

October 21, 2019

Mauricio Rivas
Project Manager

Vacant
Deputy Project Manager

Laurie Grindle
Associate Project Manager

Clint St. John
Deputy 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	Mauricio Rivas
9:30 – 10:15	Technical Performance	Clint St. John
10:15 – 10:30	Break	
10:30 – 11:15	Technical Performance	Clint St. John
11:15 – 12:00	Project Level Performance & Fiscal Year (FY) 20 Look Ahead, and Review Summary	Mauricio Rivas
12:00 – 1:00	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 FY20

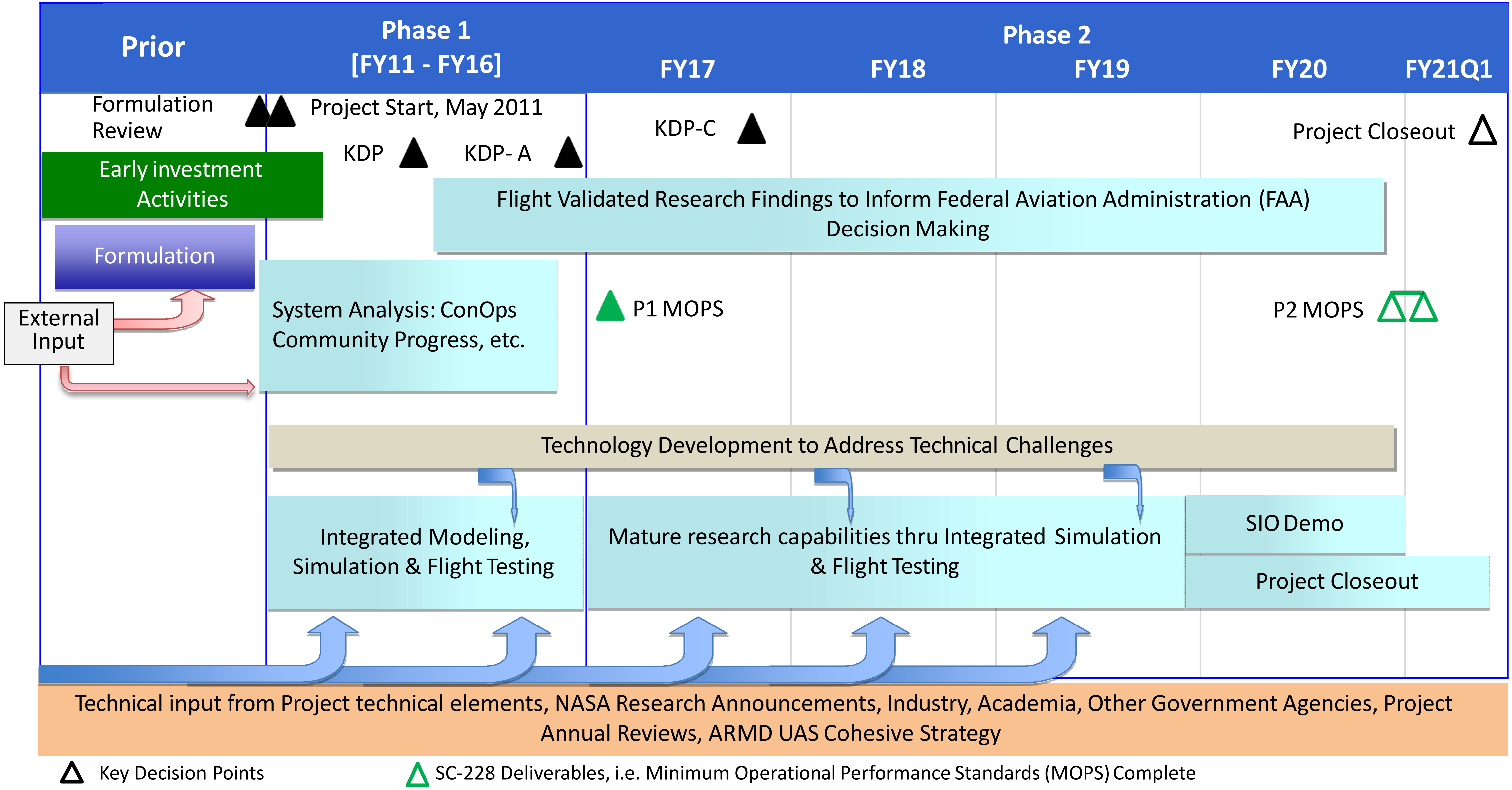
Outline

- UAS Integration in the NAS (UAS-NAS) Overview
  - FY19 Summary
  - UAS-NAS Project Background
- Technical Performance
- Project Level Performance & FY20 Look Ahead
- Review Summary

FY19 Summary

- Completed 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) and Critical Commitments (CC)
- Established three Cooperative Agreements (CA) with selected Industry Partners supporting the Systems Integration and Operationalization (SIO) activity and assisted the Partners through at least Preliminary Design Reviews (PDR) of their proposed Concept of Operations (ConOps)
- Advanced the DAA, SIO and C2 technical activities through the facilitation of the NASA/Federal Aviation Administration (FAA) UAS Integration Research Transition Team (RTT)
- Met FY19 Annual Performance Indicator (API)
- Managed Schedule and Milestones successfully

UAS-NAS Project Lifecycle
Timeframe for Impact: 2025



UAS Integration in the NAS Organizational Structure

Host Center

AFRC Director of Programs
Joel Sitz
Deputy Director
Laurie Grindle

Program Office

IASP Program Director
Dr. Ed Waggoner
Deputy Program Director
Lee Noble

Program External Interfaces

ExCom, Senior Steering Group, RTCA Steering Committee, UAS Aviation Rulemaking Committee

Project Support

Lead Resource Analyst – April Jungers, AFRC
Lead Proc Officer – Rosalia Toberman, AFRC
Scheduler – Irma Ruiz, AFRC
Risk and Outreach Lead – Jamie Turner, AFRC
Doc/Change Mgmt – Eleonor Barron, AFRC
SIO Support – Arya Abrego, AFRC
Admin Support – Sandra Rodriguez, AFRC
Resource Analyst – Amber Gregory, AFRC
Resource Analyst – Warcquel Frieson, ARC
Resource Analyst – Julie Blackett, GRC
Resource Analyst – Tanisha Baines, LaRC

Project Office

Project Manager (PM) – Mauricio Rivas, AFRC
Deputy PM – Vacant
Associate PM – Laurie Grindle, AFRC
Chief Engineer – William Johnson, LaRC
Deputy Chief Engineer – Clint St. John, AFRC

Staff Engineer – Doug Wada, AFRC
Senior Advisor for UAS Integration – Chuck Johnson
SIO Technical Manager – Kurt Swieringa, LaRC

Project External Interfaces

FAA, DoD, SARP, RTCA SC-228, RTCA SC-147, Industry, etc.

Aero Centers

Brad Flick – ARD, AFRC
Huy Tran – ARD, ARC
Greg Follen (Acting) – ARD, GRC
Mary DiJoseph – ARD, LaRC

Subprojects

Command and Control (C2) SPM
Mike Jarrell, GRC

C2 Subproject Technical Lead
Kurt Shalkhauser, GRC

Detect and Avoid (DAA) SPM
Jay Shively, ARC

DAA Subproject Technical Leads
Gilbert Wu, ARC; *Conrad Rorie, ARC*;
Tod Lewis, LaRC

Integrated Test and Evaluation (IT&E) SPM
Robert Navarro, AFRC

IT&E Subproject Technical Lead
Sam Kim, AFRC; Ty Hoang (Acting), ARC

ARD: Aeronautics Research Director, PM: Project Manager, SPM: Subproject Manager, SIO: Systems Integration and Operationalization
Green Italics: Personnel Changes

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 INDICATOR (API)**
UAS-NAS

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

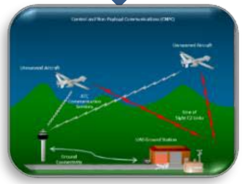
Provide research findings, utilizing simulation and flight tests, to support the development and validation of DAA and C2 technologies necessary for integrating UAS into the NAS

* Note: No API for FY20

ARMD Strategic Implementation 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-DAA; TC-C2; SIO

TC-DAA:
Detect and Avoid



TC-C2:
UAS Command & Control

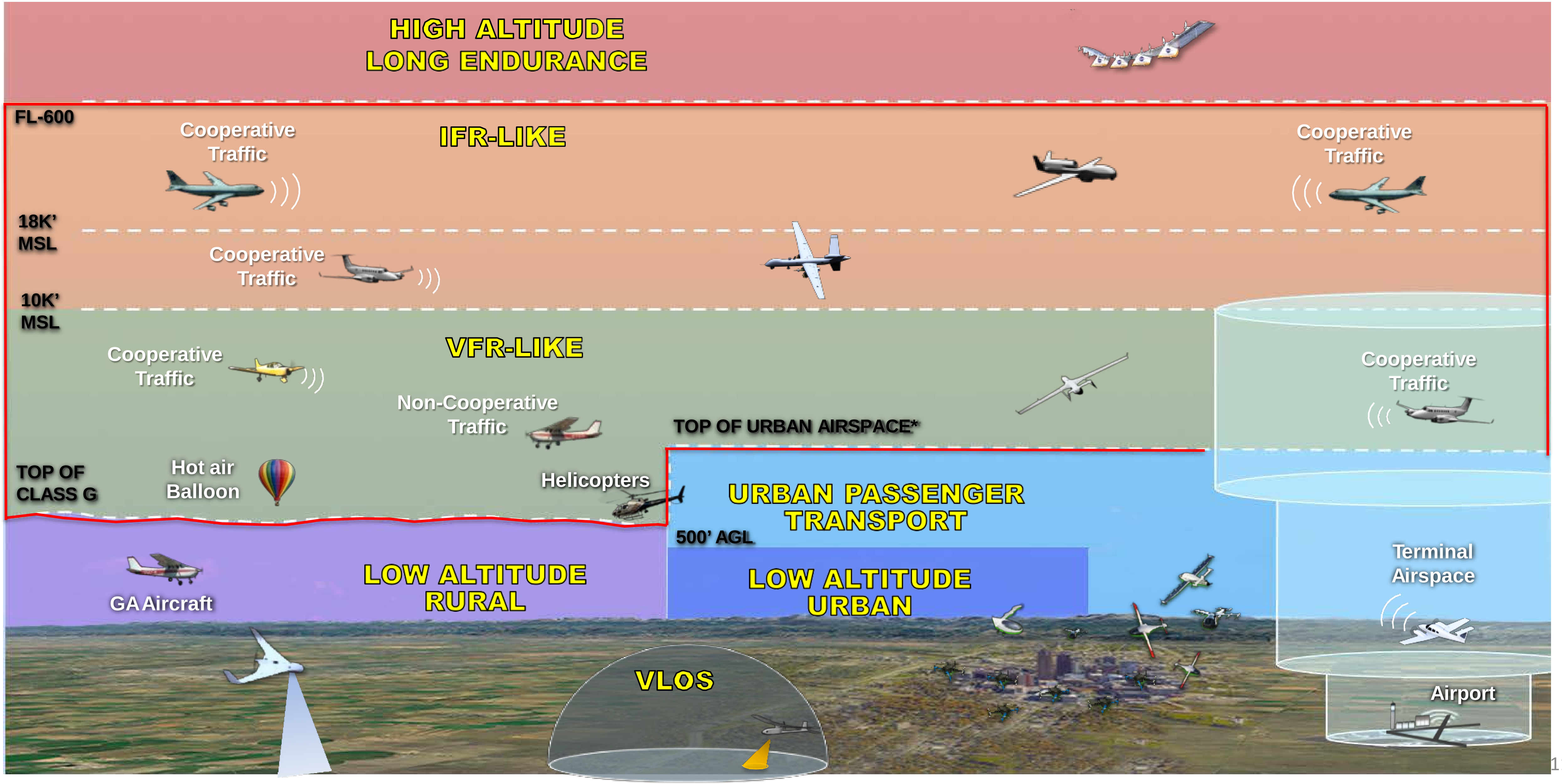
SIO:
Systems Integration and Operationalization

* 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

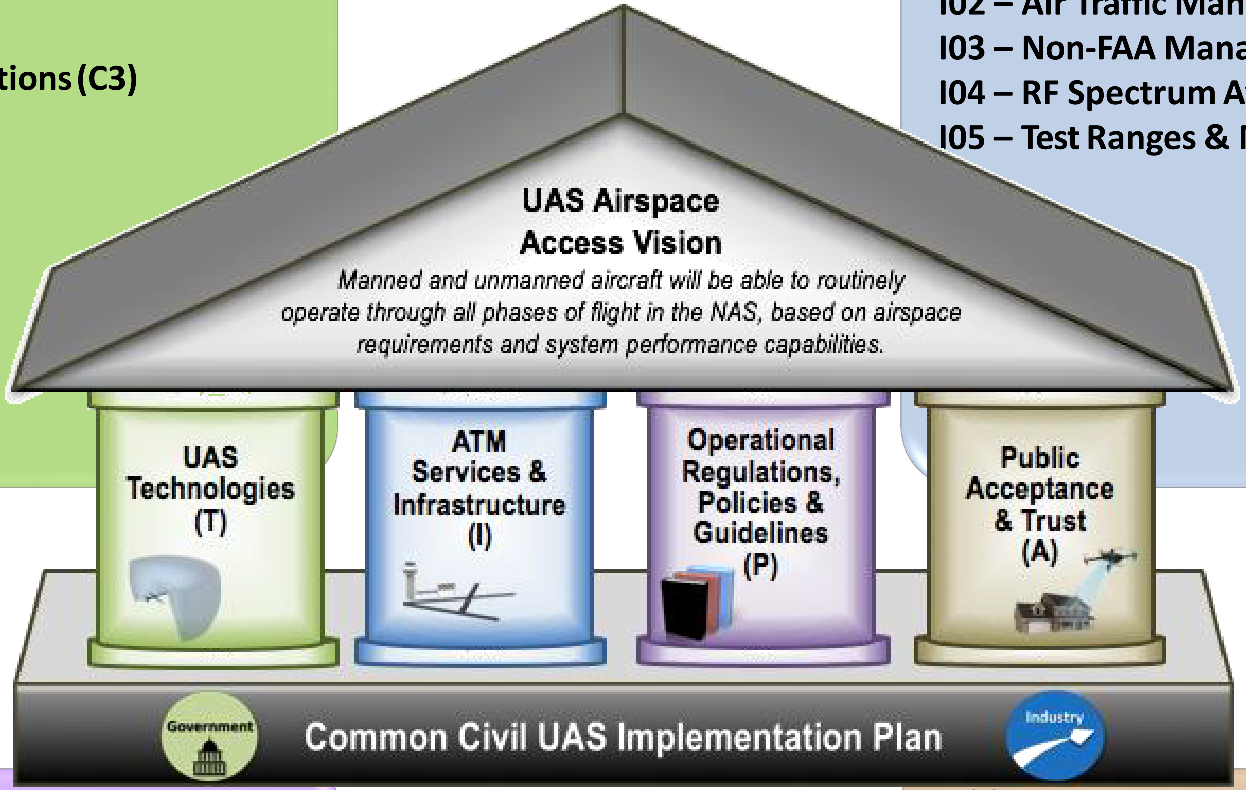
Operating Environments (OE)



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 – Air Traffic Management (ATM) Infrastructure
I03 – Non-FAA Managed Airspace Infrastructure
I04 – RF Spectrum Availability
I05 – Test Ranges & Modeling and Simulation Facilities

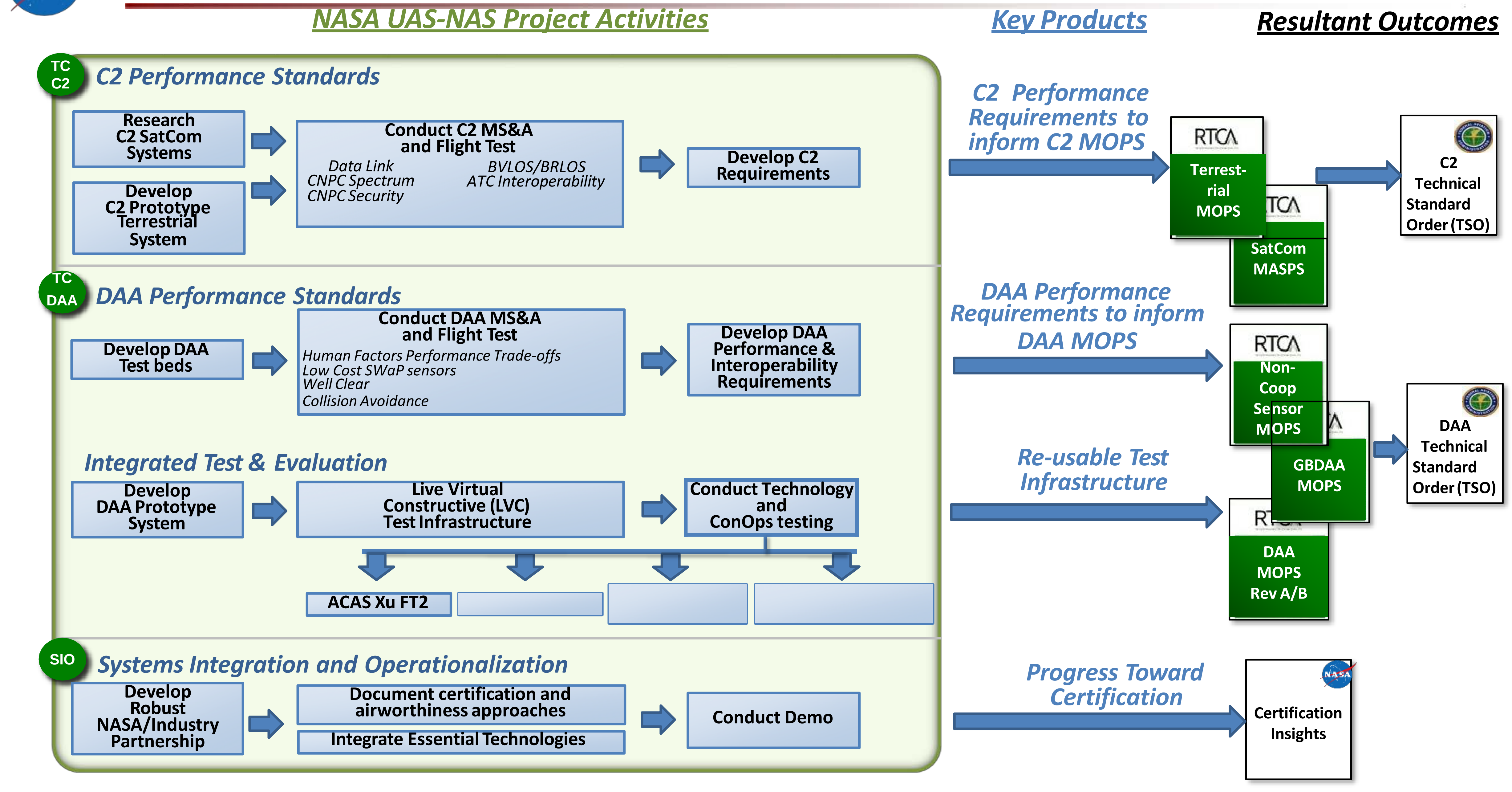


Operational Regulations, Policies & Guidelines:
P01 – ATM Regulations / Policies / Procedures
P02 – Airworthiness Regulations / Policies / Guidelines
P03 – Operating Rules / Regulations / Procedures
P04 – Safety Risk Mngmt & Methods of Compliance

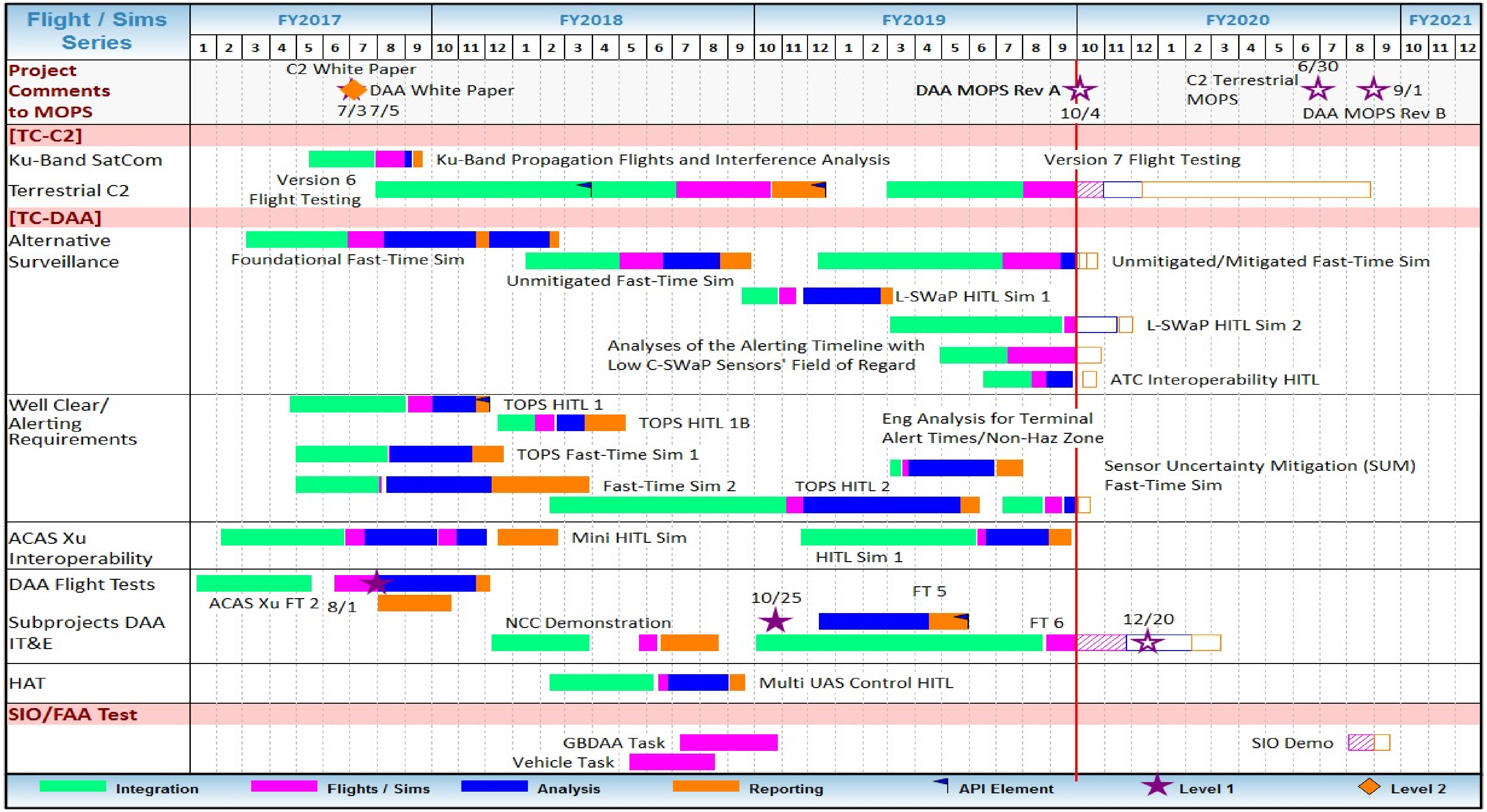
Public Acceptance & Trust:
A01 – Cybersecurity Criteria & Methods of Compliance
A02 – Legal & Privacy Rules / Guidelines
A03 – Noise Reduction
A04 – Physical Security Criteria & Methods of Compliance
A05 – Public Safety Confidence

The UAS Airspace Integration Pillars enable achievement of the Vision

UAS-NAS Project Value Proposition



Phase 2 Flight and Simulation Overview

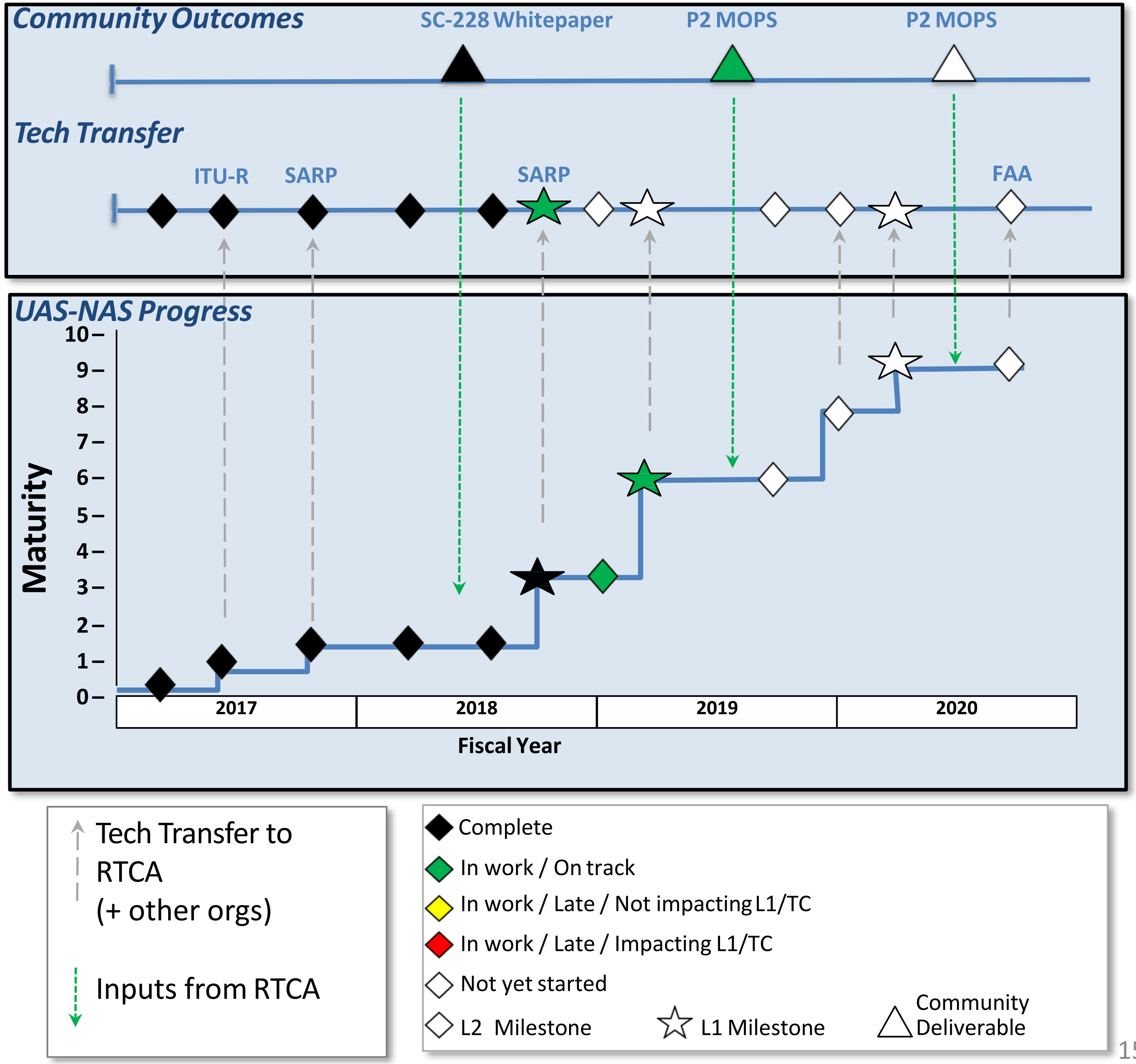


Red Status Line Date 9/30/19

Progress Indicator Definition

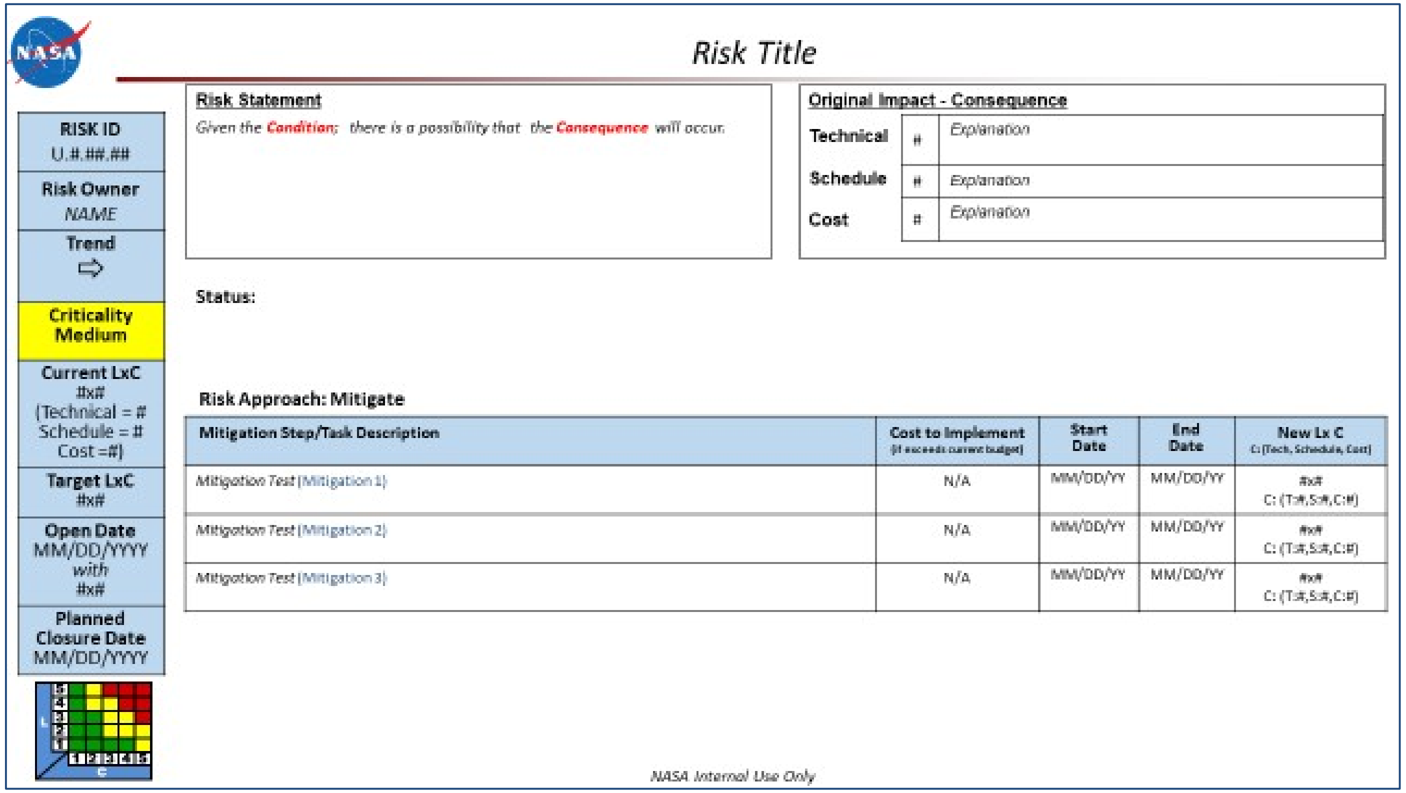
- Technical Challenge progress is tracked by means of Progress Indicators (PI)
  - Schedule Package (SP) L2 milestones are the data points for these plots
- Progress Indicators, i.e. lower portion of the plot, represent execution/data collection of Project SP activities
- Tech Transfer (i.e. upper portion 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

Technical Challenge (TC)
Technical Work Package (TWP)
Schedule Package (SP)
Task



UAS-NAS Risk Management Process

- Project utilizes a Continuous Risk Management (CRM) process to identify, analyze, plan, track, and control risks
  - To implement CRM process, the UAS-NAS Project holds monthly risk meetings and risk workshops
    - o Communication and Documentation
      - UAS-NAS Management Review Board (MRB)
      - IASP Risk Management Board



Risk Title

Risk Statement

*Given the **Condition**; there is a possibility that the **Consequence** will occur.*

Original Impact - Consequence

Technical	#	*Explanation*
Schedule	#	*Explanation*
Cost	#	*Explanation*

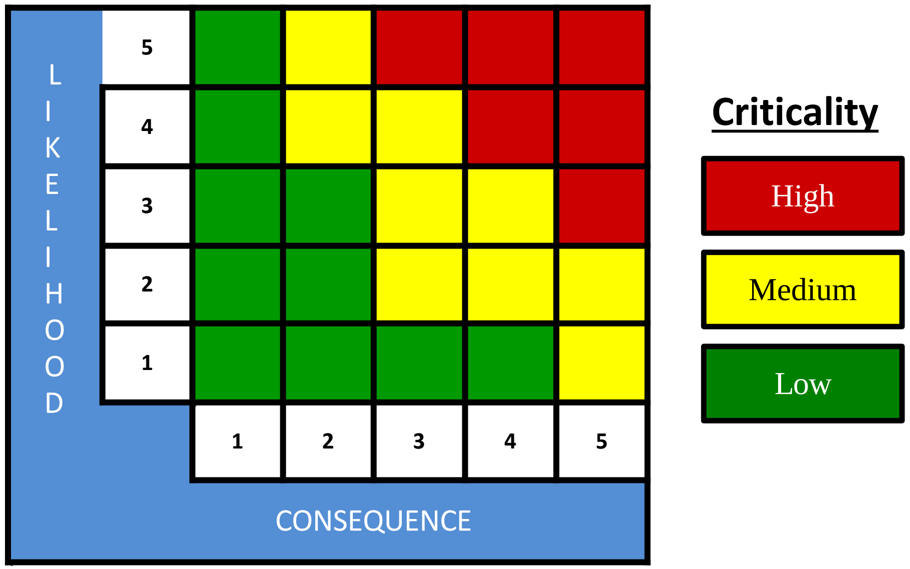
RISK ID U.#.##.##
Risk Owner *NAME*
Trend ⇨
Criticality Medium
Current LxC #x# (Technical = # Schedule = # Cost =#)
Target LxC #x#
Open Date MM/DD/YYYY *with* #x#
Planned Closure Date MM/DD/YYYY

Status:

Risk Approach: Mitigate

Mitigation Step/Task Description	Cost to Implement (if exceeds current budget)	Start Date	End Date	New Lx C C: (Tech, Schedule, Cost)
Mitigation Test (Mitigation 1)	N/A	MM/DD/YY	MM/DD/YY	#x# C: (T:#,S:#,C:#)
Mitigation Test (Mitigation 2)	N/A	MM/DD/YY	MM/DD/YY	#x# C: (T:#,S:#,C:#)
Mitigation Test (Mitigation 3)	N/A	MM/DD/YY	MM/DD/YY	#x# C: (T:#,S:#,C:#)

NASA Internal Use Only



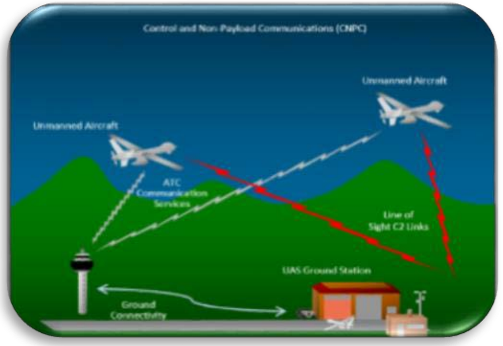
Outline

- UAS-NAS Overview
- Technical Performance
  - TC-DAA
  - TC-C2
  - SIO
- Project Level Performance & FY20 Look Ahead
- Review Summary

UAS-NAS Technical Efforts

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

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



SIO: Work toward routine commercial UAS operations in the National Airspace System (NAS) by integrating DAA and C2 technologies, obtaining approval to operate in the NAS for a flight demonstration in 2020, working toward type certification, and by sharing lessons learned with UAS community

Detect and Avoid

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

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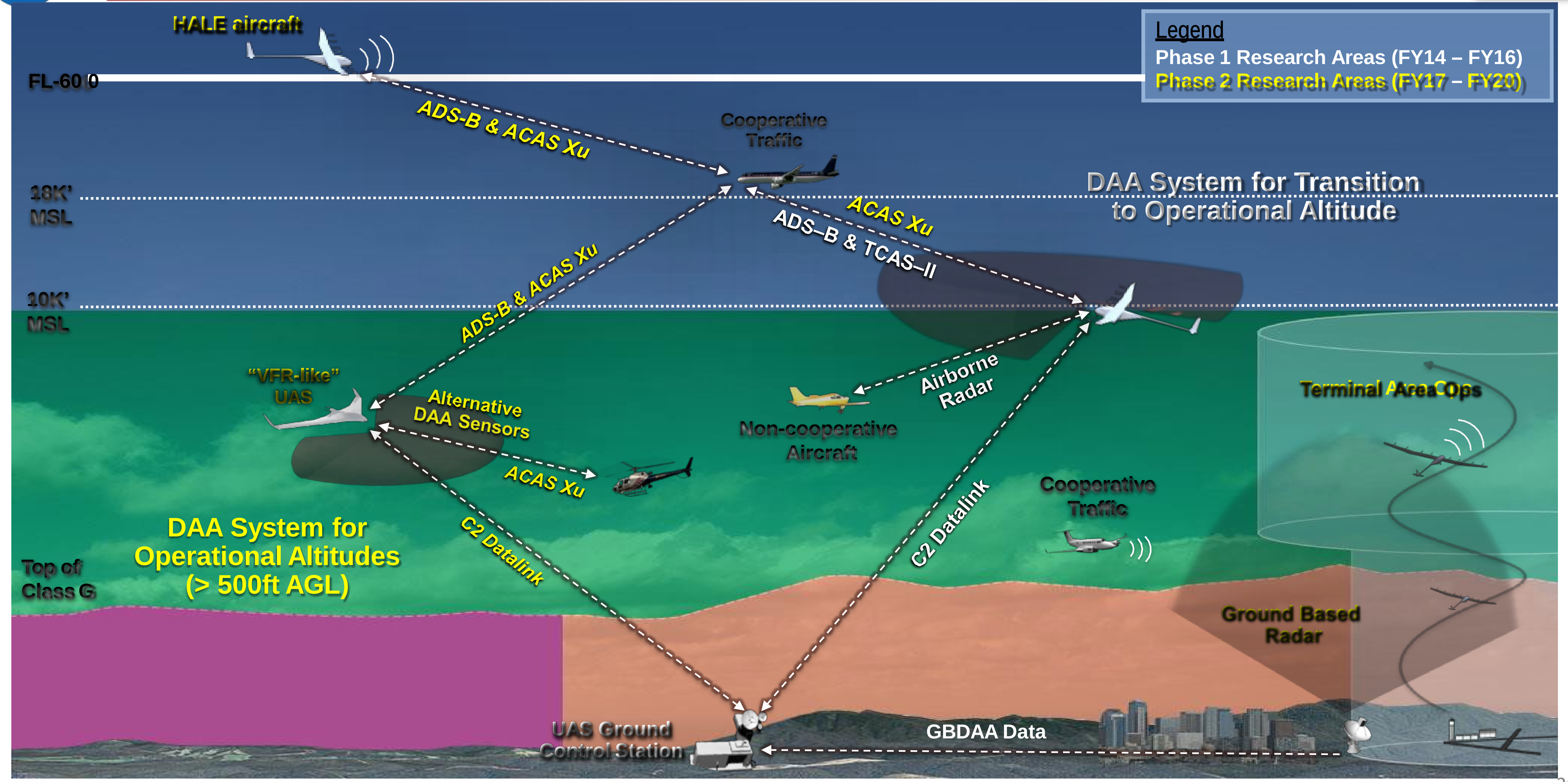
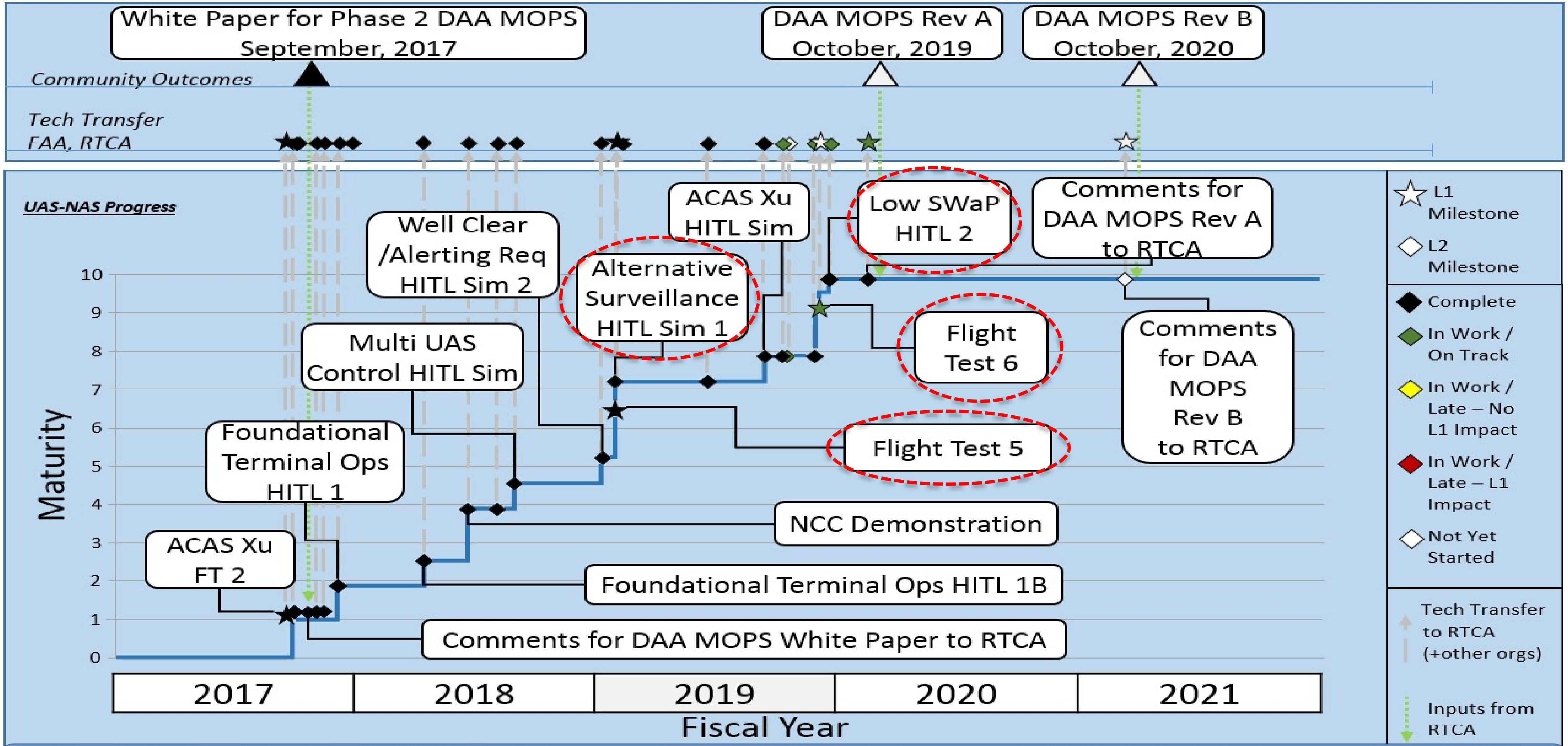
UAS Detect and Avoid (DAA) Operating Environments (OE)



TC-DAA: Progress Indicator

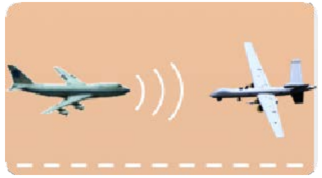
As of 9/30/19



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

Alternative Surveillance: **Human In The Loop (HITL) Sim 1** (TBEN-009, Center: ARC), **Low Size Weight and Power (SWaP) HITL 2** (TBEN-029, Center: ARC)

Integrated Events: **Flight Test 5** (TBEN-021, Centers: AFRC, ARC, LaRC), **Flight Test 6** (TBEN-022, Centers: AFRC, ARC, LaRC)



ACAS Xu Interoperability: **Airborne Collision Avoidance for Unmanned Aircraft (ACAS Xu) HITL Sim 1** (TBEN-019, Center: ARC)

Well Clear/Alerting Requirements: **HITL Sim 2** (TBEN-016, Center: LaRC), **Engineering Analysis for Terminal Alert Times/Non-Hazard Zone** (TBEN-030, Center: LaRC)

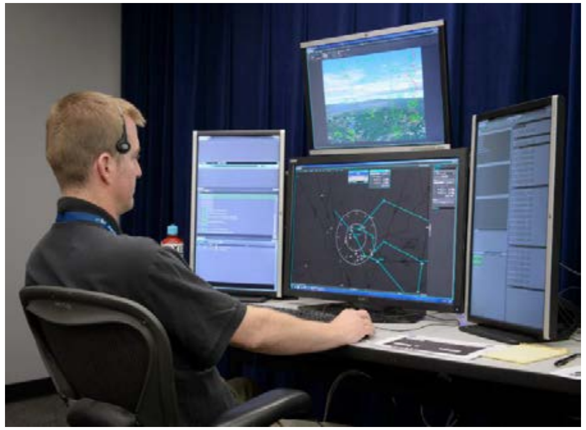
Human Automation Teaming: **Automatic Execution of Collision Avoidance and Return to Course Analysis** (TBEN-027, Center: ARC)

Ground Based Detect and Avoid: **Task Order 4 Ground Based Detect and Avoid (GBDAA)** (Virginia Tech Mid Atlantic Aviation Partnership UAS Test Site), **GBDAA Trade Study** – (SP D.1.100, Center: ARC)

Alternative Surveillance: HITL Sim 1

Research Objective

- Apply Phase 1 DAA alerting to non-cooperatives with Low Size Weight and Power (SWaP) detection range and DAA Well Clear (DWC) definitions
- Characterize pilot performance when provided with similar alerting time to Phase 1 but detection range of 3.5 nautical miles (nmi)
  - Compare two DWC candidates from fast time study
- Determine if changes to existing requirements are necessary



Technical Approach

- Twelve active-duty UAS pilot participants tasked to:
  - Remain DWC from other aircraft
  - Respond to scripted queries and electronic failures
- Four experimental trials per pilot (45 minutes each)
  - Two pre-filed mission routes
  - Six scripted DAA conflicts per trial
    - Five single-threat non-coop intruders
    - One cooperative intruder (Phase 1 criteria)
- Ownship: Generic RQ-7 Shadow model

Issues / Challenges

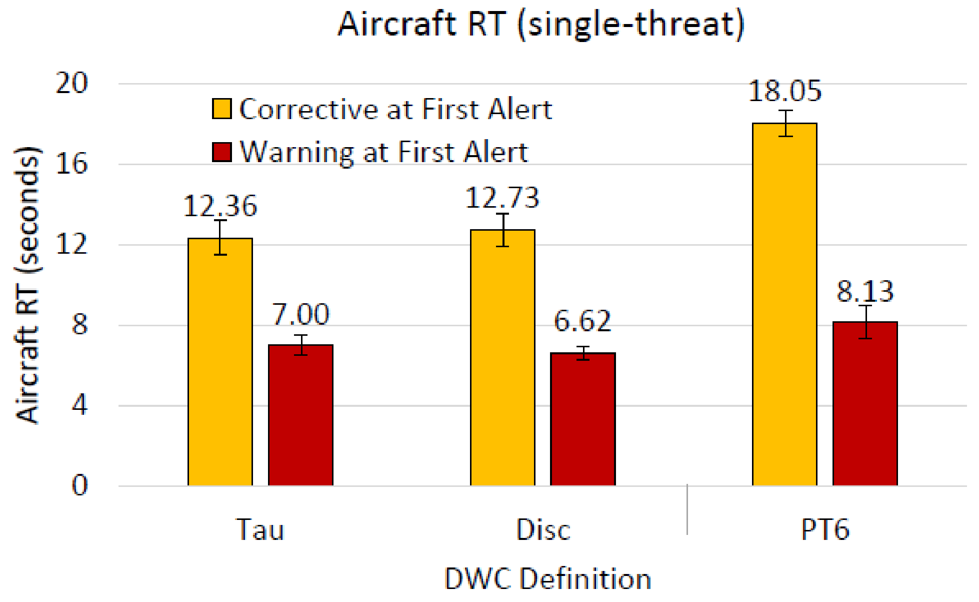
- Surveillance performance was based on nominal values that had not yet been agreed upon by RTCA or industry

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

Alternative Surveillance: HITL Sim 1

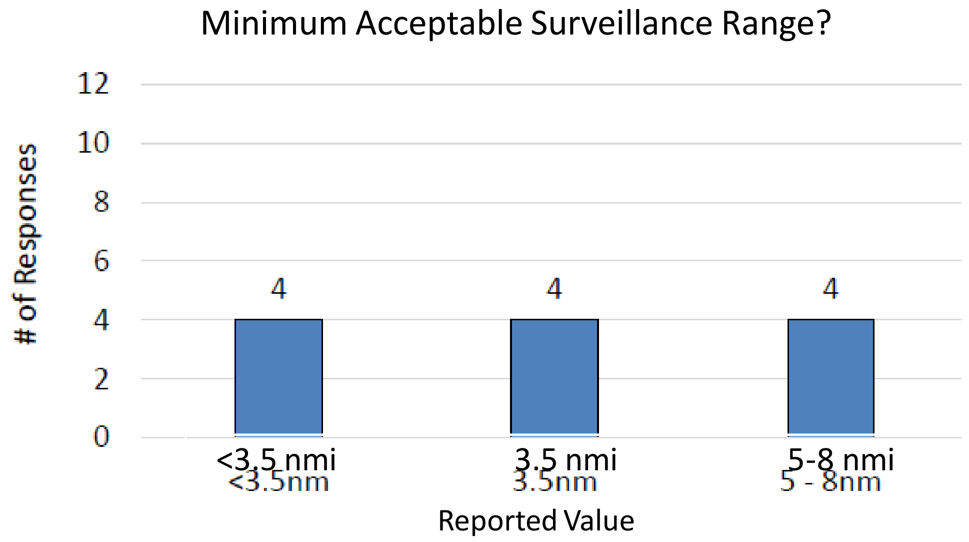
Highlights / Findings

- Objective metrics clearly indicate that pilots can maintain DWC with either DWC candidate at 3.5 nmi detection range
- Response times against Corrective alerts ~5 sec faster than observed in Phase 1 [Part Task 6 (PT6)]; no difference observed for Warning Alerts
- Potential challenges to reducing detection ranges below 3.5 nmi
  - Pilot acceptability (Two-thirds of pilots indicated that 3.5 nmi or more would be their minimum acceptable surveillance range)
  - May not be able to retain Corrective alerting



Tech Transfer

- **Key Stakeholders:** RTCA Special Committee 228 (SC-228), FAA, & UAS Community
- **Importance to Stakeholder:** Low SWaP non-cooperative sensor detection range (timeline) is crucial to Phase 2 (P2) MOPS development
- **NASA Contribution:** Data (Pilot response times and acceptability) for Low SWaP detection range
- **Briefing:** SC-228 Face to Face March 2019
  - Push back from sensor manufacturers at SC-228 on 3.5 nmi detection range (may not be possible)
  - Additional studies initiated to investigate lower detection ranges



Integrated Events: Flight Test 5

Research Objective

- Initial integration testing and prototyping
- Validate the adequacy of Honeywell radar’s surveillance volume for supporting the DAA alerting and guidance
- Validate the adequacy of Honeywell radar’s sensor accuracy in supporting the DAA alerting and guidance
- Validate DAA alerting and guidance in the presence of realistic sensor, tracking and navigational errors in varying intruder maneuvers and offset encounters against non-cooperative intruders

Technical Approach

- Honeywell AStar manned helicopter equipped with Low SWaP sensor (single panel prototype) performing unmitigated DAA encounters with manned intruder(s)
- Sensor tracks stored onboard the aircraft for post-processing by DAA algorithm
- Helicopter equipped with non-cooperative and cooperative Automatic Dependent Surveillance – Broadcast (ADS-B In) sensors and a tracker to correlate multiple sensor tracks

Issues / Challenges

- Initial prototype sensor with limited field of regard (single panel no elevation scan)
- Limited elevation scan made it challenging to keep the intruder within the radar’s field of view
- Track correlation needed improvement to account for ownship’s rapid motion

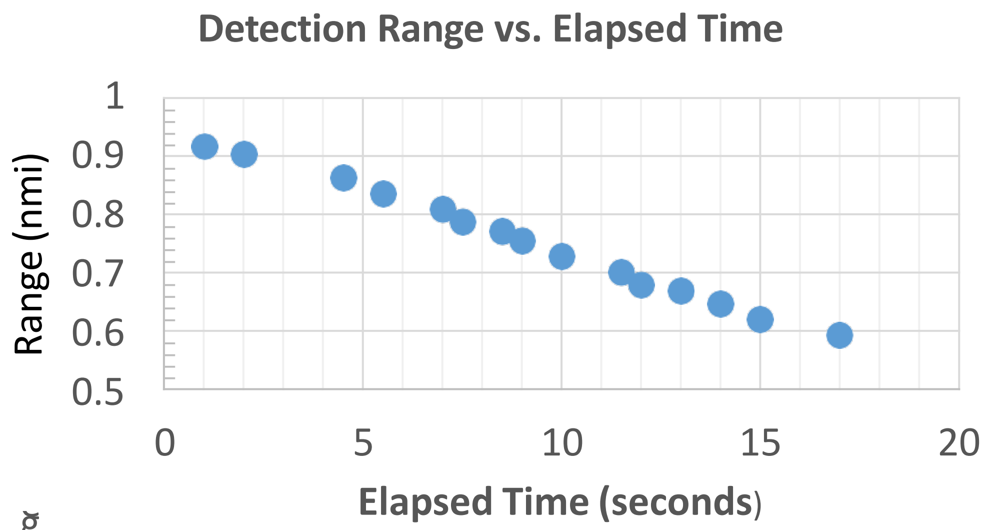
Integrated Events: Flight Test 5

Highlights / Findings

- Two dynamic targets generate a rapidly varying target return
  - Not having elevation scan to increase detection window limited the amount of power on target
- FT5 detection ranges not in line with minimum detection range identified from simulations and analysis

Tech Transfer:

- **Key Stakeholders:** RTCA SC-228 DAA Working Group, RTCA SC-147, FAA, & UAS Community
- **Importance to Stakeholder:** Stepping stone activity (initial integration and test) to full up system test which will provide DAA alerting and guidance in the presence of realistic sensor, tracking and navigational errors for Low SWaP non cooperative sensors
- **NASA Contribution:** Data buy and payload hardware for initial buildup
- **Briefing:** SC-228 Air to Air Radar (ATAR) Teleconference May 31, 2019



Alternative Surveillance: Low SWaP HITL 2 (in execution)

Research Objective

- Evaluate pilot & DAA system performance at shorter detection ranges than modeled in Low SWaP HITL 1
- Provide DAA data for human performance metrics to supplement FT6 results

Technical Approach

- Ten active-duty UAS pilot participants tasked to:
  - Remain DAA well clear from other aircraft
  - Respond to scripted queries and scripted system failures
- Four experimental trials per pilot (45 minutes each)
  - One pre-filled mission route (FT6 "Racetrack" route)
  - Five scripted DAA conflicts per trial
    - Four non-cooperative intruders
    - One cooperative intruder (Phase 1 criteria)
- Ownship: Generic RQ-7 Shadow model

Issues / Challenges

- This effort must account for two primary schedule constraints: the ACAS Xu HITL 1 and FT6

Technical Baseline Element Number: TBEN-029 (SP D.1.110)

Integrated Events: Flight Test 6 (in execution)

Research Objective

- Inform Phase 2 MOPS development of requirements for Low SWaP airborne non-cooperative surveillance system
- Inform Phase 2 MOPS development of DWC, alerting and guidance requirements
- Characterize pilot response data in a full-mission environment to validate Low SWaP HITL

Technical Approach

- Fly unmitigated, scripted encounters between UAS and manned intruder to characterize the performance of the Honeywell radar
- Fly mitigated encounters with the DAA algorithm in the loop to evaluate the effectiveness of the DWC definition
- Have subject UAS pilots execute DAA avoidance maneuvers using the Vigilant Spirit Control Station (VSCS) / Java Architecture for Detect and Avoid Extensibility and Modeling (JADEM) software in a simulated UAS mission in simulated airspace

Issues / Challenges

- Test Aircraft Availability for FT6 (Risk 5.2.07) (Resolved)
- Completion of FT6 by end of FY19 (Risk 1.2.07) (Resolved)
- DAPA-lite Radar Range (Risk 1.2.16)
- Honeywell Delivery Issues (Risks 1.2.17 & 1.2.18) (OBE)

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

DAA Risk Summary (1 of 2)

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DAA Risk Summary (2 of 2)

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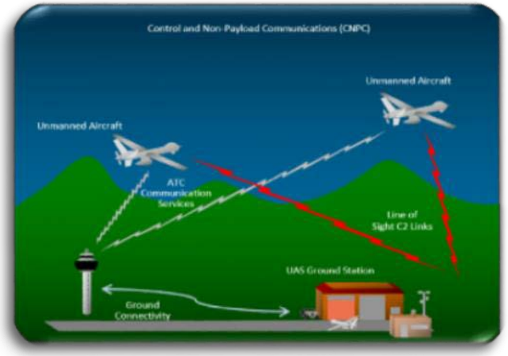
Command and Control

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



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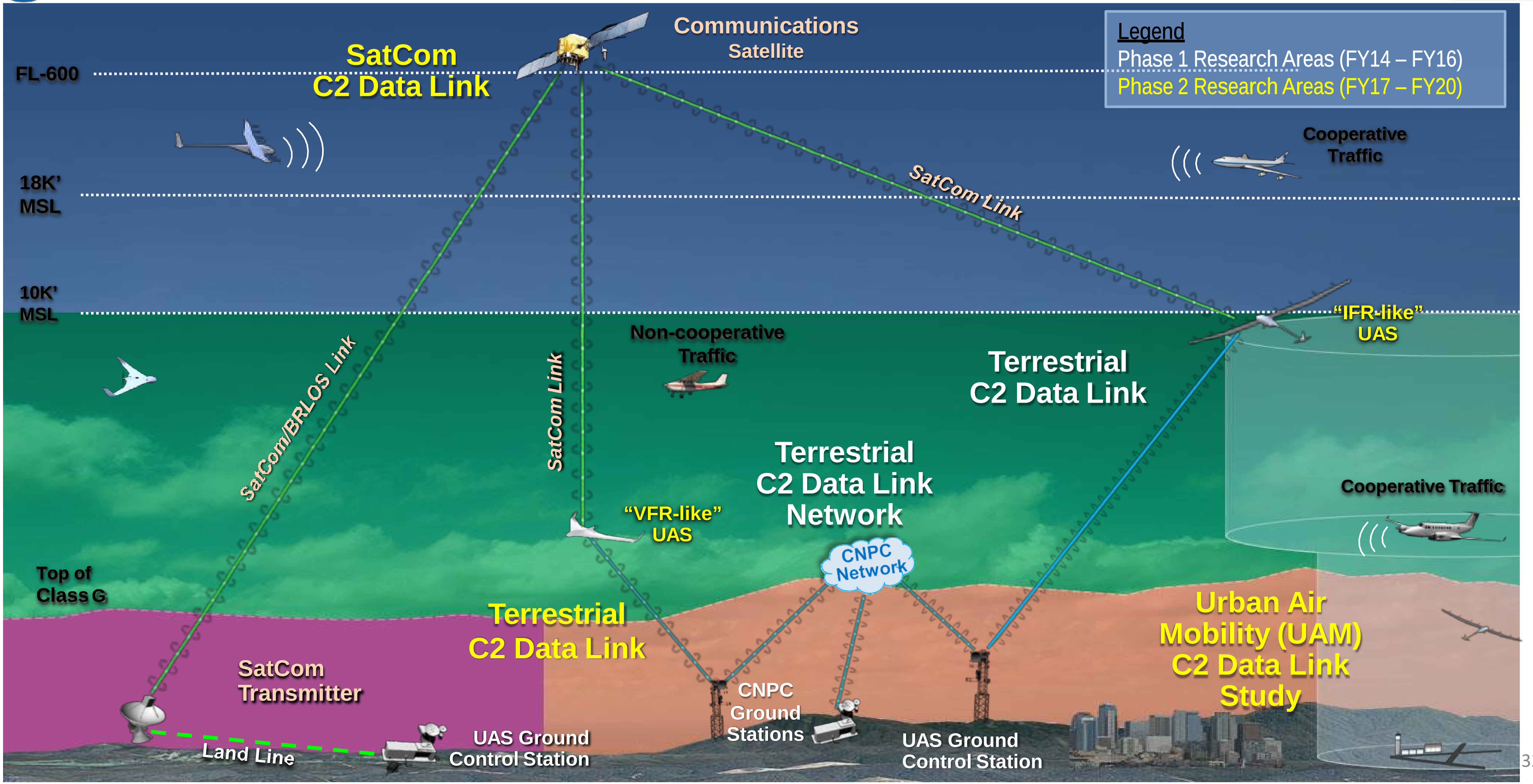
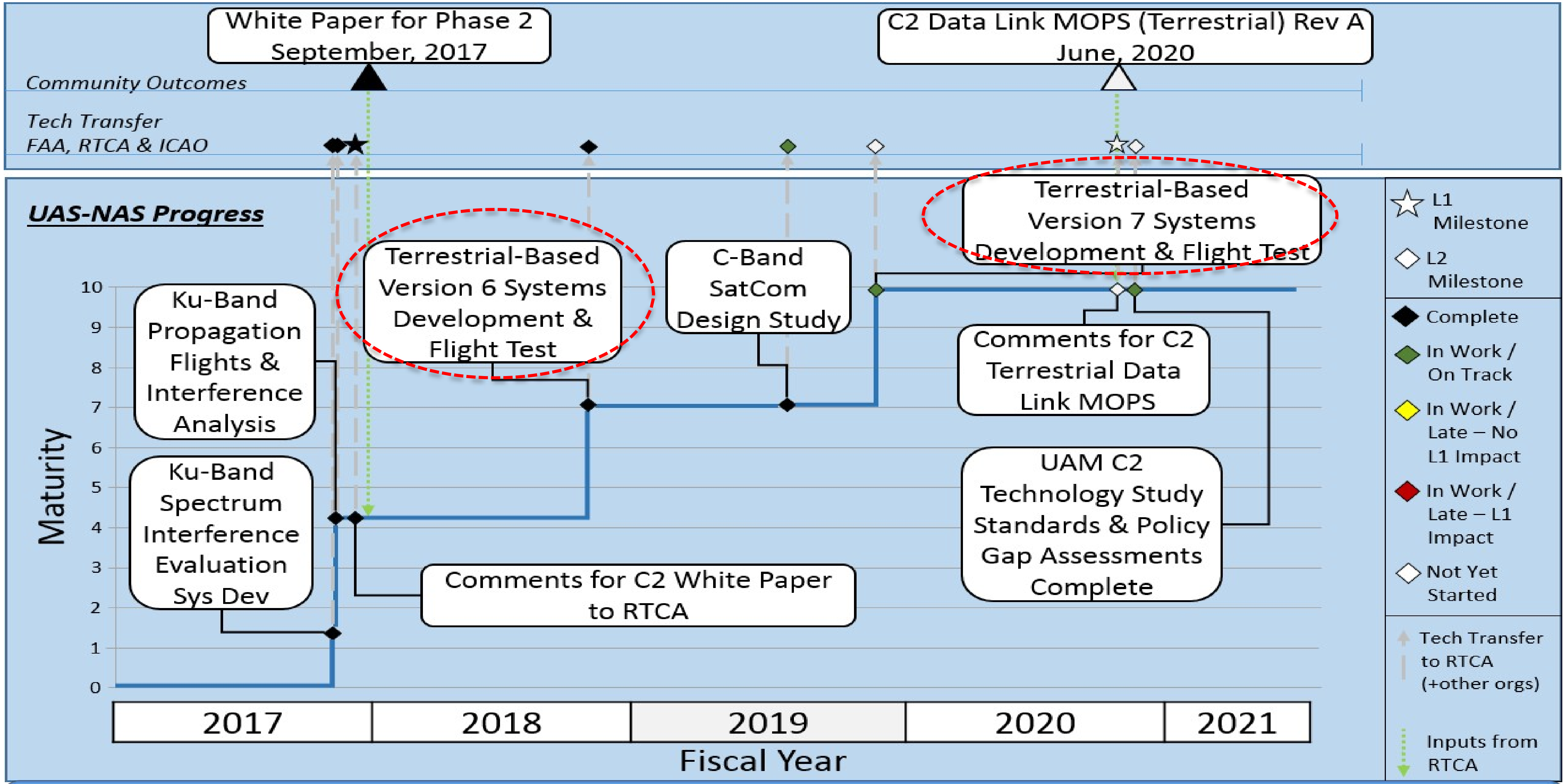
UAS Command and Control Operating Environments (OE)



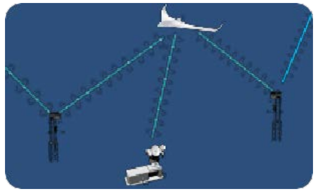
TC-C2: Progress Indicator

As of 9/30/19



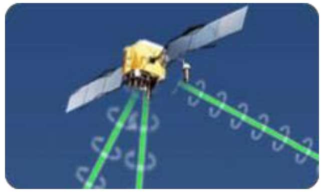
TC-C2: Develop Satellite (SatCom) and Terrestrial based Command and Control (C2) operational concepts and technologies in support of standards to enable the broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to leverage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

TC-C2 Technical Work



Terrestrial Based UAS Command and Control: **Terrestrial Based Version 6 Systems Development & Flight Test** (TBEN-004, Center: GRC), **Terrestrial Based Version 7 Systems Development & Flight Test** (TBEN-004, Center: GRC)

Urban Air Mobility Communications Technology Study: **UAM C2 Technology Study Standards & Policy Gap Assessments** – (SP C.7.10, Center: GRC)

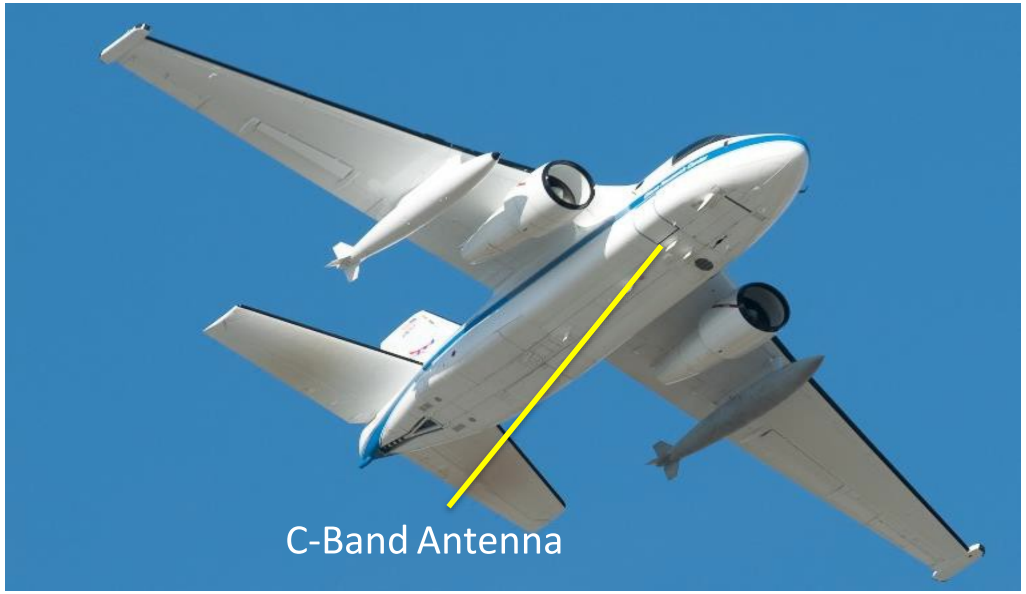


Satellite Based UAS Command and Control: **C-Band SatCom Design Study** – (TBEN-003, Center: GRC)

Terrestrial Based V6 Systems Development & Flight Test

Research Objective

- Develop and demonstrate/validate the MOPS being developed by RTCA SC-228 C2 Working Group for Command and Non-Payload Communications (CNPC) on a Low SWaP radio platform for mid-size UAS
- Demonstrate CNPC radio waveform on a path to FAA certification and commercialization, without International Traffic in Arms Regulations (ITAR) restrictions and independent of proprietary intellectual property implementation



Technical Approach

- Continued spiral development adding
  - New waveforms
  - C-Band only
- GRC S-3 (N601NA) modified for research flights
- Ground station updated to meet V6 requirements
- Flight tests consisted of orbits 5, 7, and 10 nmi from antenna
- Orbits were flown at 8500 and 9500 feet mean sea level

Issues / Challenges

- Learning curve of new team members from Collins Aerospace (continuity of personnel) and coordination of responsibilities within Collins Aerospace
- Design issues led to low receiver signal sensitivity that prevented testing of the radio to any acceptable/useful range
- Major increase in volume and level of NASA GRC lab testing to enable Collins Aerospace to diagnose the root cause of problems and formulate design corrections

Technical Baseline Element Number: TBEN-004 (SP C.6.10, C6.11)

Terrestrial Based V6 Systems Development & Flight Test

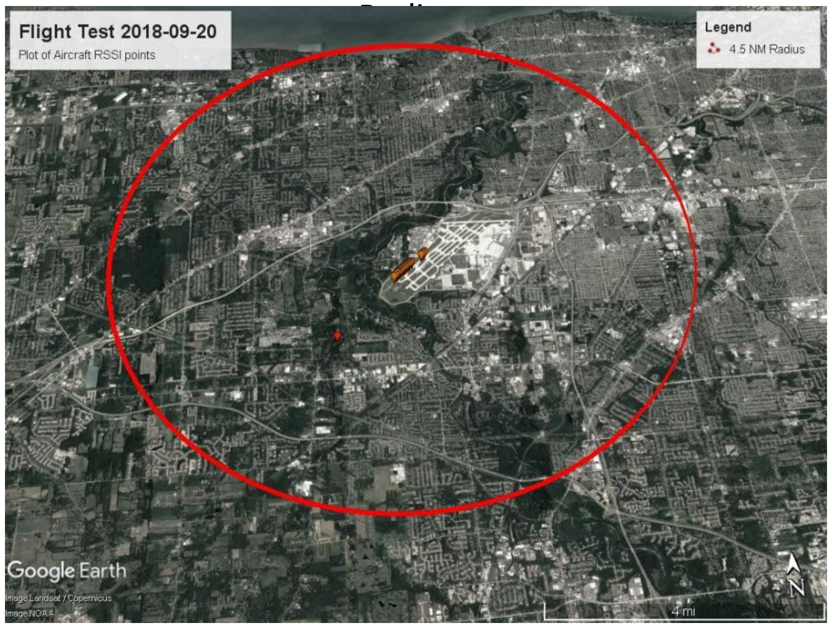
Highlights / Findings

- Poor receiver sensitivity performance resulted in a very limited distance range of radio operation compared to the previous 19-inch rack mounted generations
- After extensive testing at the GRC Lab, the radios were sent back to Collins Aerospace for evaluation and repair
- Repaired V6 radios taken to GRC for re-evaluation
- V6 radios evaluated in flight validated lab results of poor performance
- After major re-design and four iterations on V6 led to the development of the V7 radio

Tech Transfer

- **Key Stakeholders:** RTCA SC-228 C2 Working Group, FAA Spectrum Office, ICAO, Collins Aerospace
- **Importance to Stakeholder:** Definition, development, and validation of a civil UAS Terrestrial C2 system and the establishment of necessary spectrum band performance parameters
- **NASA Contribution:** Flight test data to inform the MOPS for a Low SWaP CNPC
- **Final Report:** Published December 2018

Low SWaP redesign of the Phase 1 Generation

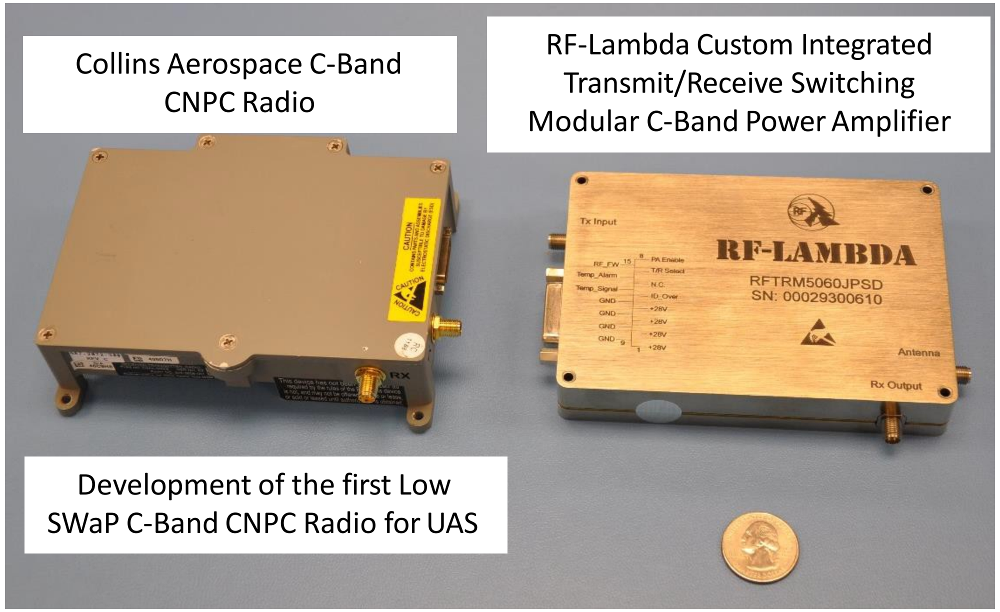


4.5 nmi range limit of V6 Radio centered around GRC

Terrestrial Based V7 Systems Development & Flight Test (in execution)

Research Objective

- Develop and demonstrate/validate the MOPS being developed by RTCA SC-228 C2 Working Group for CNPC on a Low SWaP radio platform for mid-size UAS
- Demonstrate CNPC radio waveform on a path to FAA certification and commercialization, without ITAR restrictions and independent of proprietary intellectual property implementation



Technical Approach

- Development of the first Low SWaP C-Band CNPC Radio via NASA/Collins Aerospace cost sharing cooperative agreement
- Development of a matching custom-built integrated Transmit/Receive Modular C-Band Transmit Amplifier built under contract by RF-Lambda to NASA specifications
- GRC S-3 and T-34s modified for research flights
- Radial range, network data flow & excess path loss tests on S-3
- Two aircraft flight configuration for interference testing

Issues / Challenges

- Major design review and collaborative challenge leading to a complete redesign of the V6 CNPC radio to correct deficiencies and add features for the V7 radio
- Expansion of baseline V7 flight testing campaign with modifications and reconfiguration of ground stations and test equipment to enable specific additional tests requested by RTCA SC-228 essential for MOPS support and validation: 1) Constant elevation angle aircraft to ground station 2) over hilly terrain 3) over water

Terrestrial Based V7 Systems Development & Flight Test (in execution)

Highlights / Findings

- Eight CNPC small-form-factor radios were received from Collins Aerospace
  - Radios tested in the UAS laboratory using GRC-custom semi-automated test system
- All performance parameters meet initial expectations and data quality is excellent for dissemination to RTCA SC-228 for review and support of C2 MOPS development

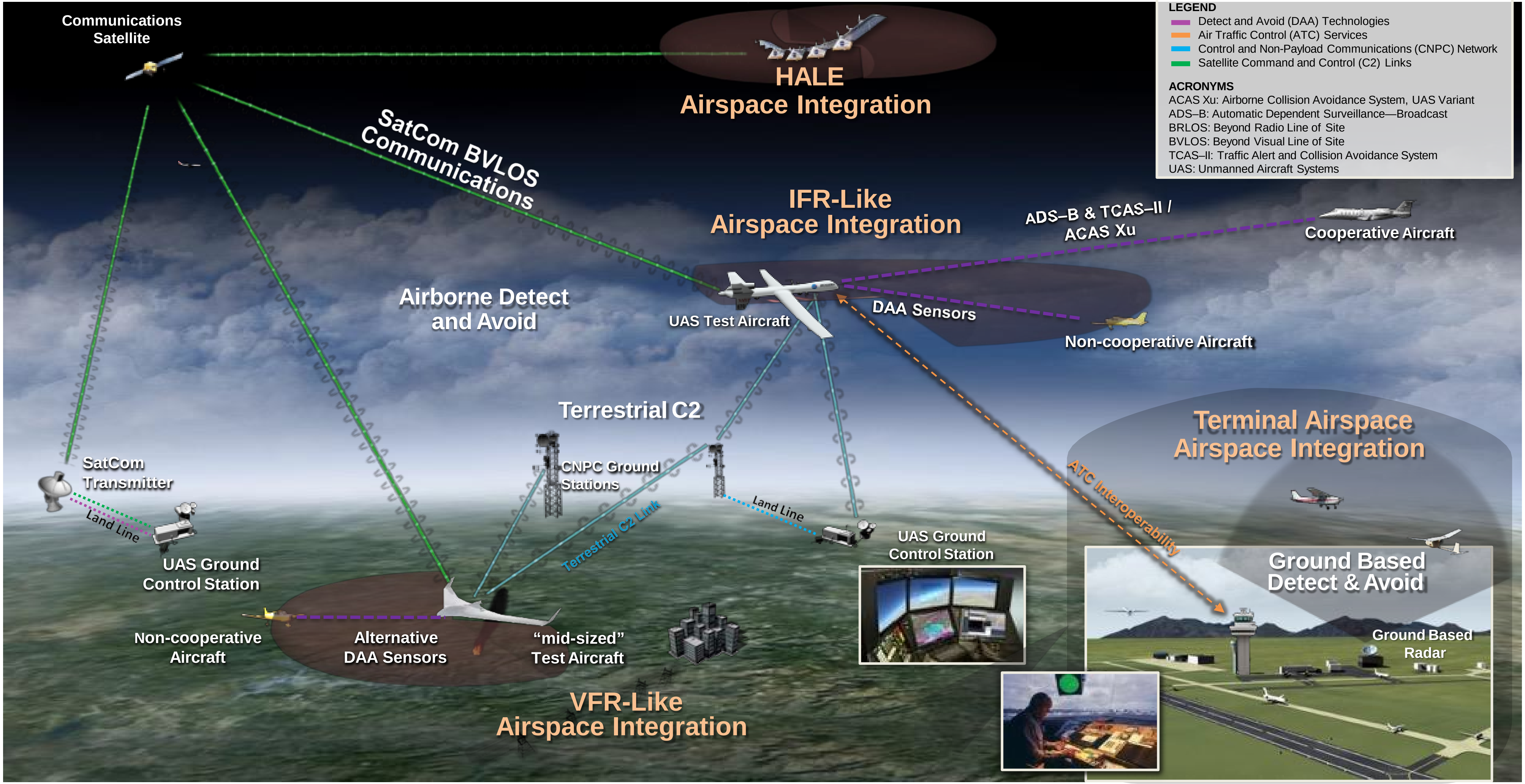
Tech Transfer

- **Key Stakeholders:** RTCA SC-228 C2 Working Group, FAA Spectrum Office, ICAO, Collins Aerospace
- **Importance to Stakeholder:** Definition, development, and validation of a civil UAS Terrestrial C2 system and the establishment of necessary spectrum band performance parameters
- **NASA Contribution:** Flight test data to inform the MOPS for a Low SWaP CNPC
- **Flight Test Results:** Briefing scheduled for RTCA SC-228 C2 Face to Face October 2019, Final V7 Flight Test Report will be completed in December 2019

C2 Risk Summary

- Data redacted

UAS-NAS Project – SIO Operational View Representation



LEGEND

- Detect and Avoid (DAA) Technologies
- Air Traffic Control (ATC) Services
- Control and Non-Payload Communications (CNPC) Network
- Satellite Command and Control (C2) Links

ACRONYMS

ACAS Xu: Airborne Collision Avoidance System, UAS Variant
ADS–B: Automatic Dependent Surveillance—Broadcast
BRLOS: Beyond Radio Line of Site
BVLOS: Beyond Visual Line of Site
TCAS–II: Traffic Alert and Collision Avoidance System
UAS: Unmanned Aircraft Systems

SIO Technical Work

General Atomics

Mission: Infrastructure inspection in Southern California
Altitudes: above 10,000 feet MSL
Vehicle: SkyGuardian (~12,000 lbs)

PAE-ISR

Mission: Infrastructure inspection in rural area
Altitudes: 1,000 to 3,000 feet AGL
Vehicle: Resolute Eagle (~180 lbs)

Bell

Mission: Medical supply transportation in DFW area
Altitudes: 500 to 1,000 feet AGL
Vehicle: Autonomous Pod Transport (APT) -70 (~300 lbs)

- Data redacted

SIO Accomplishments

Goals / Objectives:

- Partner with industry to work toward routine commercial UAS operations in the NAS
  - Integrate DAA and C2 technologies
  - Obtain approval for a flight demonstration in the National Airspace System in 2020
  - Work toward UAS type certification
    - Type certification efforts are not expected to be complete by the end of the SIO activity, but progress will be made
  - Share lessons learned with the UAS community

Tech Transfer

- **Key Stakeholders:** RTCA SC-228 DAA & C2 Working Groups, FAA, & UAS Community
- **Importance to Stakeholder:** Gaps and lessons learned in working towards certification
- **NASA Contribution:** Compilation of shareable gaps and lessons learned in working towards certification
- **Report:** To be complete September 2020

Schedule

	Milestone	Date
✓	Cooperative Agreements Signed (L2)	01/19
✓	Kickoff Meeting Slides – Received from all partners	02/19
✓	Concept of Operations – Received from all partners	05/19
✓	Operational Risk Assessment (L3) – Received from all partners	07/19
•	System Test/Acceptance Plan	10/19
•	Project Specific Certification Plan	12/19
•	Flight Demonstration Plan	05/20
•	System Design Document	05/20
•	All Airworthiness Approvals (L3)	07/20
•	Certification Lessons Learned Report Complete (L3)	07/20
•	Flight Demonstrations Complete (L2)	08/20
•	SIO Final Report (L3)	09/20

SIO Accomplishments

- Data redacted

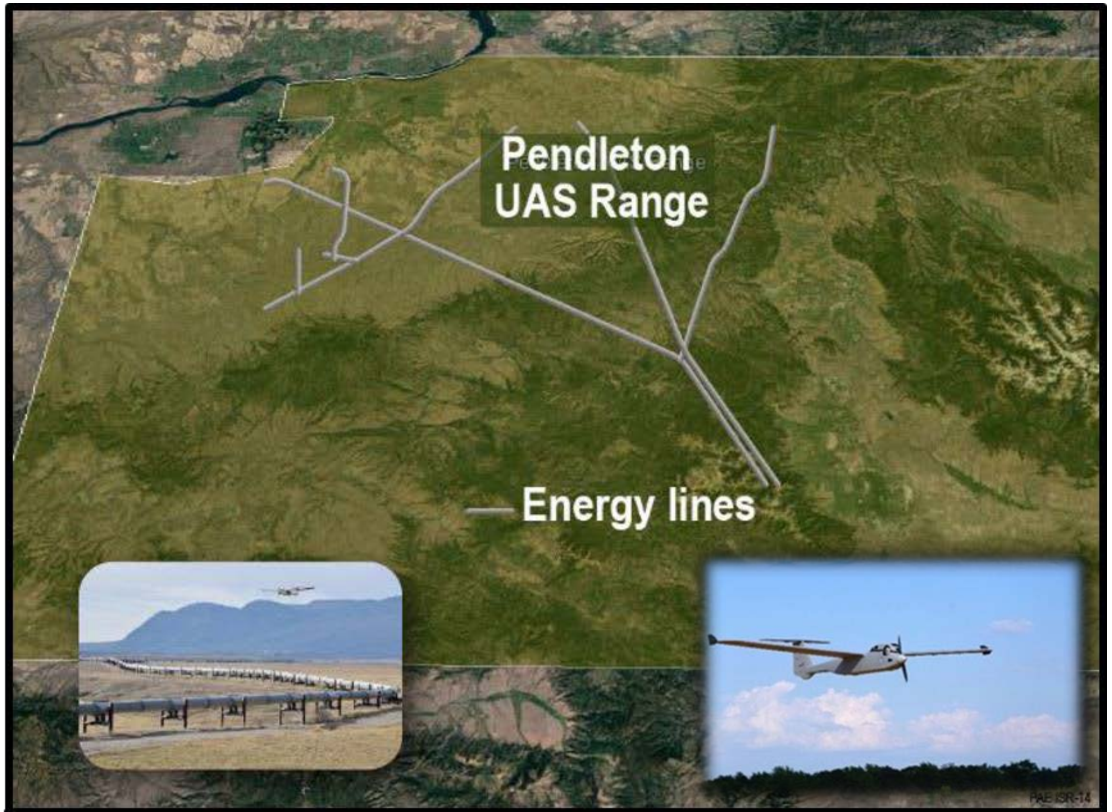
SIO Accomplishments

PAE ISR Key Accomplishments:

- Agreement Signed (September 27, 2018)
- Kickoff Meeting (October 17, 2018)
- Baseline Mission ConOps Document (February 8, 2019)
- PDR (June 26, 2019)

Issues / Challenges

- Current Low SWaP DAA sensor range may not be sufficient for BVLOS operations (safety cases are being evaluated as part of SIO)
- RTCA SC-228 MOPS compliant C2 radios are not commercially available and experimental spectrum approval for existing radios do not appear to be a viable option for the SIO demonstrations
- DAA system will be an engineering prototype that will likely require further development after SIO concludes (visual observers will likely be required to mitigate risk)
- Desire to operate UAS without Air Traffic Control (ATC) coordination; however, RTCA SC-228 MOPS do not support those operations



Location: Pendleton UAS Range (PUR)

- Part of the Pan-Pacific UAS Test Range Complex
- Low risk rural environment
- Northwest Pipeline: 110 miles of pipeline within Pendleton UAS Test Range

SIO Accomplishments

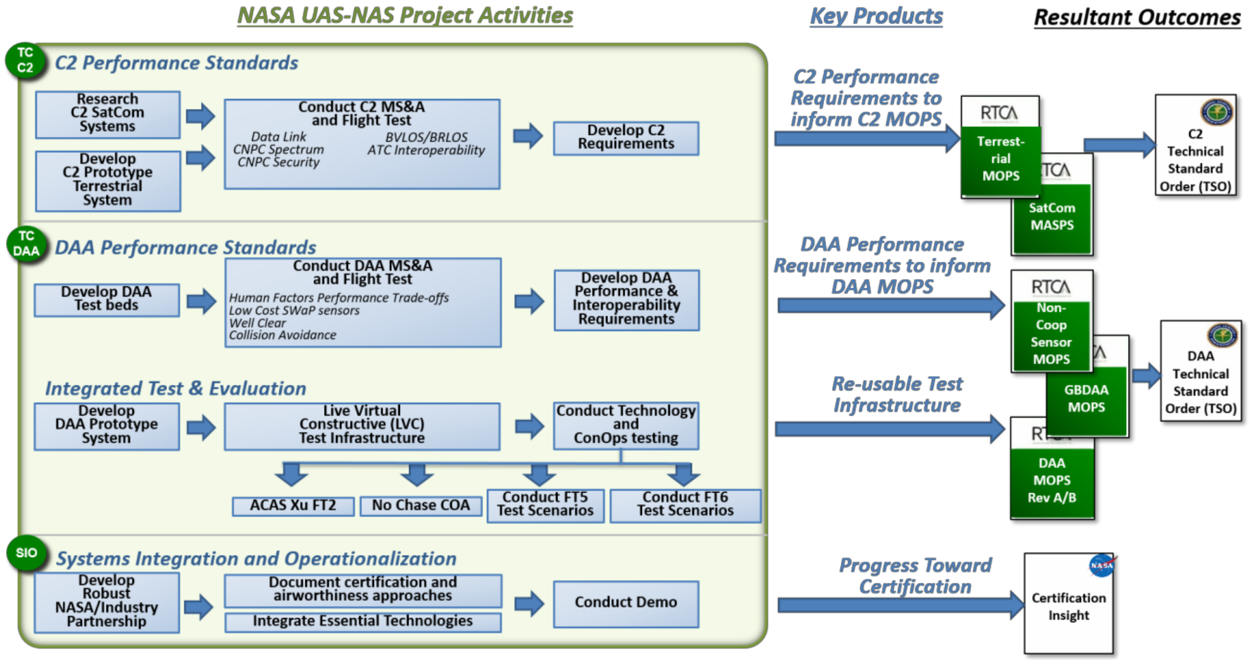
- Data redacted

SIO Risk Summary

- Data redacted

Technical Performance Summary

- TC-DAA
  - FT5 completed
  - FT6 underway to inform DAA and Human Systems Integration (HSI) operation in Low SWaP sensor scenarios
  - Low SWaP HITLs performed to explore DAA acceptability to pilots
  - ACAS Xu HITL performed to inform integration with DAA



- TC-C2
  - Terrestrial based V6 Flight Test complete
  - Terrestrial based V7 radio systems flight test conducted to inform feasibility of Low SWaP systems
  - Completed C-Band SatCom Earth Station Concept Design Study
  - Urban Air Mobility (UAM) C2 Study delivered

- SIO
  - Three partners working towards 2020 demonstrations
  - Design reviews and safety cases presented
  - Working demonstration plans with FAA

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

Outline

- UAS-NAS Overview
- Technical Performance
- Project Level Performance & FY20 Look Ahead
  - Risk Summary
  - Resource Allocation and Utilization
  - Schedule Performance
  - Partnerships and Collaboration
  - FAA/NASA UAS Integration Research Transition Team
  - FY19 Accomplishments and FY20 Look Ahead
  - FY20/FY21 Closeout Planning
- Review Summary

UAS-NAS Active Risk Summary

- Data redacted

Storm Clouds

- Data redacted

Resource Allocation Against Baseline Budget

- Data redacted

Resource Utilization FY19
Budget vs. Actuals Summary

- Data redacted

UAS-NAS FY19 Project Funding

- Data redacted

Schedule Performance

- Phase 2 Milestone Count
  - Completed 3 of 7 Level 1 Milestones
  - Completed 58 of 76 Level 2 Milestones
    - Experienced delays to L2 milestones
- Causes of Level 2 Milestone Delays
  - The 35 days of government shutdown delayed the completion of several L2 milestones
  - FT6 integration efforts slipped to the right due to Cooperative Agreement partner's delays
  - Report milestones slipped due to delays in the Export Control process
  - DAA and C2 technical scope changes implemented to better align with community requirements
- Utilize continuous risk management to identify schedule impacts
- L2 Milestone delays did not impact the MOPS L1 or L2 Milestones

- Tables Removed

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)*	Memorandum of Understanding (MOU)	On-going collaboration with AFRL supporting use of Vigilant Spirit Control Station (VSCS) on DAA activities. AFRL agreed to a NASA "leave behind" simulation capability after the agreement's expiration. After the Project SAA expired, DAA leveraged existing MOU between NASA Ames and AFRL for this collaboration.
Bell (SIO Awardee)	Cooperative Agreement *Oct-18 to Aug-20*	Mission includes demo of emergency medical supply delivery in Urban Areas using Bell's Autonomous Pod Transport - 70 (APT70) electric VTOL. Completed Critical Design Review and operational risk assessment and ConOps.
Collins Aerospace *(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. Started the V7 test flights August 2.
EUROCAE, ICAO *(TC-DAA, TC C2)*	NA	Collaborate on the development of a Remotely Piloted Aircraft System (RPAS), a Remote Pilot Station (RPS) manual, and DAA and C2/C3 Operational Services Environment Description (OSED), MASPS, and MOPS to inform global Standards and Recommended Practices (SARPs).
FAA Aviation Safety (AVS), Air Traffic Organization (ATO), Spectrum Engineering Office (AJP), and NextGen (AUS) *(Project Office, TC-DAA, TC-C2, SIO)*	Research Transition Team (RTT)	Supported by FAA leadership, management, and technical subject matter experts. Stakeholder forum to validate work being done by the Project. On-going coordination of Research Transition Products (RTPs) within the UAS Integration RTT. Coordination of RTPs within the UAS Integration RTT.

Purple text indicates changes since FY18 Annual Review

Current Active Collaborations/Partnerships Status (2 of 3)

Partner *(Project Area)*	Agreement In Place	Collaboration/ Partnership Role
FAA UAS Test Sites *(Project Office)*	IDIQ Contract *Aug-15 to Sep-20*	Task Order (TO) 4 for Ground Based Detect and Avoid (GBDAA) radar characterization. TO is concluding in October 2019 and involved support from Gryphon Sensors LLC, Textron, UAVPro, FirebirdSE, Sunhillo, Dominion Energy, and Aviation Systems Engineering Company. TO5 for Vehicle Integration Task, concluded in August 2019 with the establishment of an IT Security Authority to Operate (ATO), this TO involved activity at Griffiss International Airport with the following subcontractors: Aurora, MTSI, NUAIR, AX Enterprize, Gryphon Sensors, Navmar Applied Sciences Corp.
General Atomics *(SIO Awardee)*	Cooperative Agreement *Jan-19 to Aug-20*	Mission includes inspection of ground infrastructure from IFR-like airspace with the SkyGuardian unmanned aircraft. Completed Operational Risk Assessment, ConOps, and CDR.
Honeywell *(TC-DAA)*	Cooperative Agreement *Oct-17 to Sep-20*	Partner for the DAA low SWaP non-cooperative sensor. Agreement modification processed to include data-buy in support of FT5. Ongoing cooperative agreement for Flight Test 6.
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. Presented C-Band SatCom study update at the RTCA SC-228 WG face-to-face meeting on July 25.
MIT-LL *(SIO)*	Contract *Oct-20 to Sep-20*	The objective of this activity is to provide the SIO industry demonstrations, and by extension the UAS community at large, the requisite data and tools to perform the airspace safety assessment that will enable airspace operational approval.

Purple text indicates changes since FY18 Annual Review

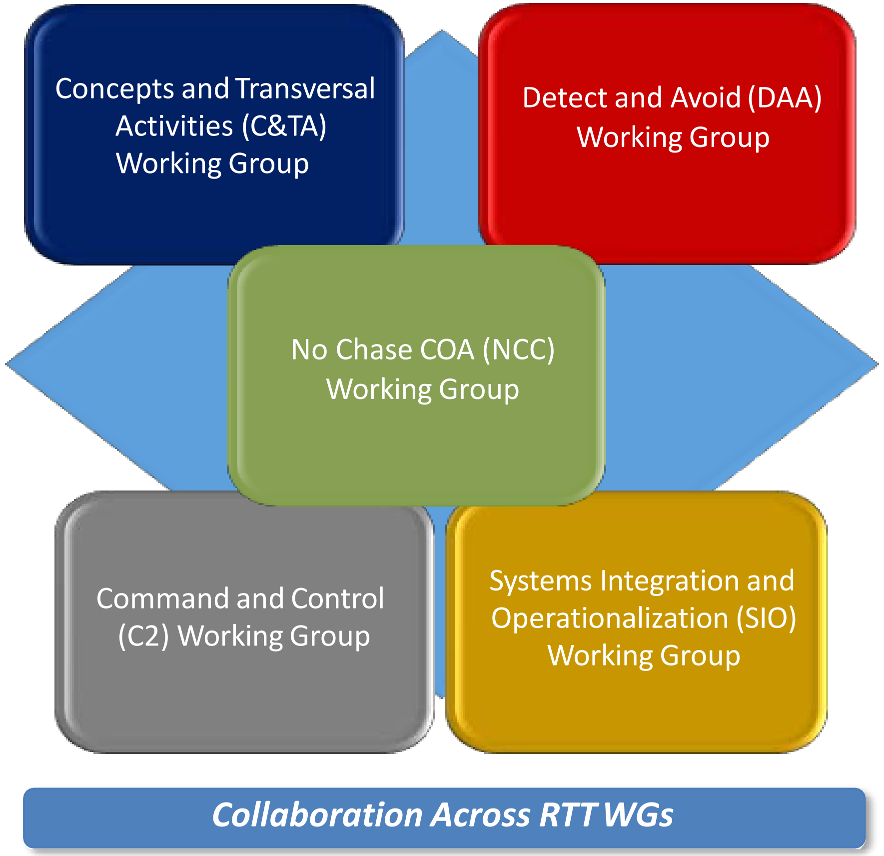
Current Active Collaborations/Partnerships Status (3 of 3)

Partner *(Project Area)*	Agreement In Place	Collaboration/ Partnership Role
NASA AOSP *(Project Office)*	NA	Coordination with Airspace Operations and Safety Program (AOSP) on UAS Traffic Management (UTM), autonomy roadmapping, and other activities including collaborative effort on UAS integration strategies and LVC development.
Navmar Applied Sciences Corp. (NASC) *(TC-DAA)*	Contract *Sep-18 to Jan-20*	The NASC TigerShark is the test vehicle for FT6. The vehicle is at AFRC supporting flight testing. Extended contract through January 2020 to support FT6 Flight Test Report completion date.
PAE-ISR *(SIO Awardee)*	Cooperative Agreement *Oct-18 to Aug-20*	Mission is to inspect infrastructure in VFR-like airspace with the Resolute Eagle unmanned aircraft. Completed Operational Risk Assessment and ConOps.
RTCA SC-228 (TC-C2, TC-DAA)	NA	On-going support to DAA and C2 working groups. NASA C2 CNPC radio testing 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. NASA DAA Low SWaP radar research to support the development and validation of the DAA MOPS.
RTCA SC-147 *(TC-DAA)*	NA	Close coordination on DAA standards required for success of P2 MOPS. NASA simulation of alerting logic and presentation of alerts. 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 FY18 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
  - DAA WG: Coordinating SC-228 related DAA research
  - C2 WG: Coordinating SC-228 related C2 research
  - SIO WG: Coordinating all aspects of the 2020 SIO demonstration
  - NCC WG: Coordinating all aspects of the 2018 NCC Flight – Sunset RTPs completed in 2018
  - C&TA WG: Developing commercial concepts of use for UAS Integration – On hiatus until needed



Accomplishments/Next Steps for the UAS Integration RTT

- 2019 Accomplishments
  - The Joint Management Plan (JMP) was updated to reflect all changes and signed by Nick Lento and Laurie Grindle June 14, 2019
  - All work under RTCA SC-228 for DAA and C2 were coordinated with the FAA lines of business
  - The FAA assigned Peter White as the FAA/SIO Co-Lead (with Kurt Swieringa SIO Technical Manager)
  - The C&TA WG was put on hiatus after providing inputs for the SIO ConOps and will be reactivated if needed
  - Numerous WG RTPs were successfully closed and the associated deliverables were documented in a report delivered to the RTT Executive Leadership

- Next steps for the UAS Integration RTT
  - Continuation of Research Transition Products (RTP) delivery will occur throughout the duration of the Project
  - The pace of coordination with the FAA for the 2020 SIO Demonstrations will increase until the flights are completed to ensure their success
  - Considerations will be given to the impacts of the UAS-NAS Project close out on the shifting SC-228 timeline

FY19 Awards

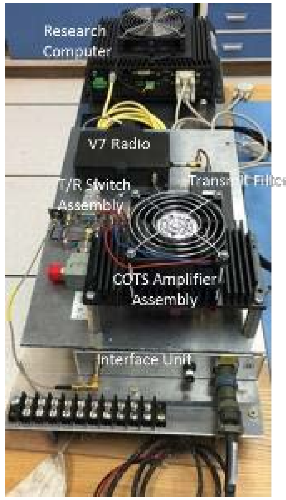
- No Chase COA team received the 2019 Aviation Week Laureate Award for Commercial Aviation in the Unmanned Systems category
- 2019 AFRC Group Achievement Award to UAS-NAS IT&E Team
- ARC received Team Award for IT&E, HSI and M&S
- Jay Shively received the ARC 2019 Mentor of the Year Award

FY19 Accomplishments & FY20/FY21 Look Ahead

- FY19 Accomplishments
  - TC: Detect and Avoid
    - Simulations: HITL Sim 1, ACAS Xu HITL Sim 1, HITL Sim 2
    - Flight Tests: FT5
  - TC: Command and Control
    - V6 flight test completed
    - Delivered Baseline UAM C2 Seed Requirements
  - Systems Integration and Operationalization
    - Three cooperative agreements awarded
    - Administrator Bridenstine visited General Atomics and Bell
  - FAA Test Sites
    - Wrapped up work on GBDAA task order 4 (Virginia Tech) and Vehicle and ConOps task order 5 (NY)
  - Research Transition Team
    - Completed NCC WG
    - Stood up SIO WG

- FY20/FY21 Look Ahead
  - Flight Tests: Complete Data Collection for DAA FT6 and C2 V7
  - Submit Consolidated Input to RTCA: for C2 MOPS and DAA MOPS Rev A and B
  - Project Closeout

DAPA Lite Radar



CNPC V7 Radio

FY20/FY21 Closeout Planning

- Phase 1
  - Relevance
  - Phase 1 System Level Assessments
  - Phase 1 Progress on Technical Challenges
  - Lessons Learned
  - Summary Comments
- Phase 2
  - Relevance
  - Phase 2 System Level Assessments
  - Phase 2 Progress on Technical Challenges and Critical Commitments
    - Closeout activities (e.g., S-3 decommission)
  - Lessons Learned
  - Summary Comments
- General
  - Internal and External Communications
  - Project & Funding Life Cycle
  - Contracts & Partnerships
  - Independent Assessments
  - Risk Process
- Project Completion date set for December 31, 2020
  - One year + left on Project; ramping down personnel in FY20 for DAA, IT&E and C2
- Schedule:
  - IASP Terms of Reference – TBD
  - Project Final Report – September 2020
  - Closeout Review Meeting – November 2020

Outline

- UAS-NAS Overview
- Technical Performance
- Project Level Performance & FY20 Look Ahead
- Review Summary

FY19 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) and Critical Commitments (CC)

- ✓ Successfully established three Cooperative Agreements (CA) with selected Industry Partners supporting the Systems Integration and Operationalization (SIO) activity and assisted the Partners through at least Preliminary Design Reviews (PDR) of their proposed Concept of Operations (ConOps)

- ✓ Advanced the DAA, SIO and C2 technical activities through the facilitation of the NASA/Federal Aviation Administration (FAA) UAS Integration Research Transition Team (RTT)

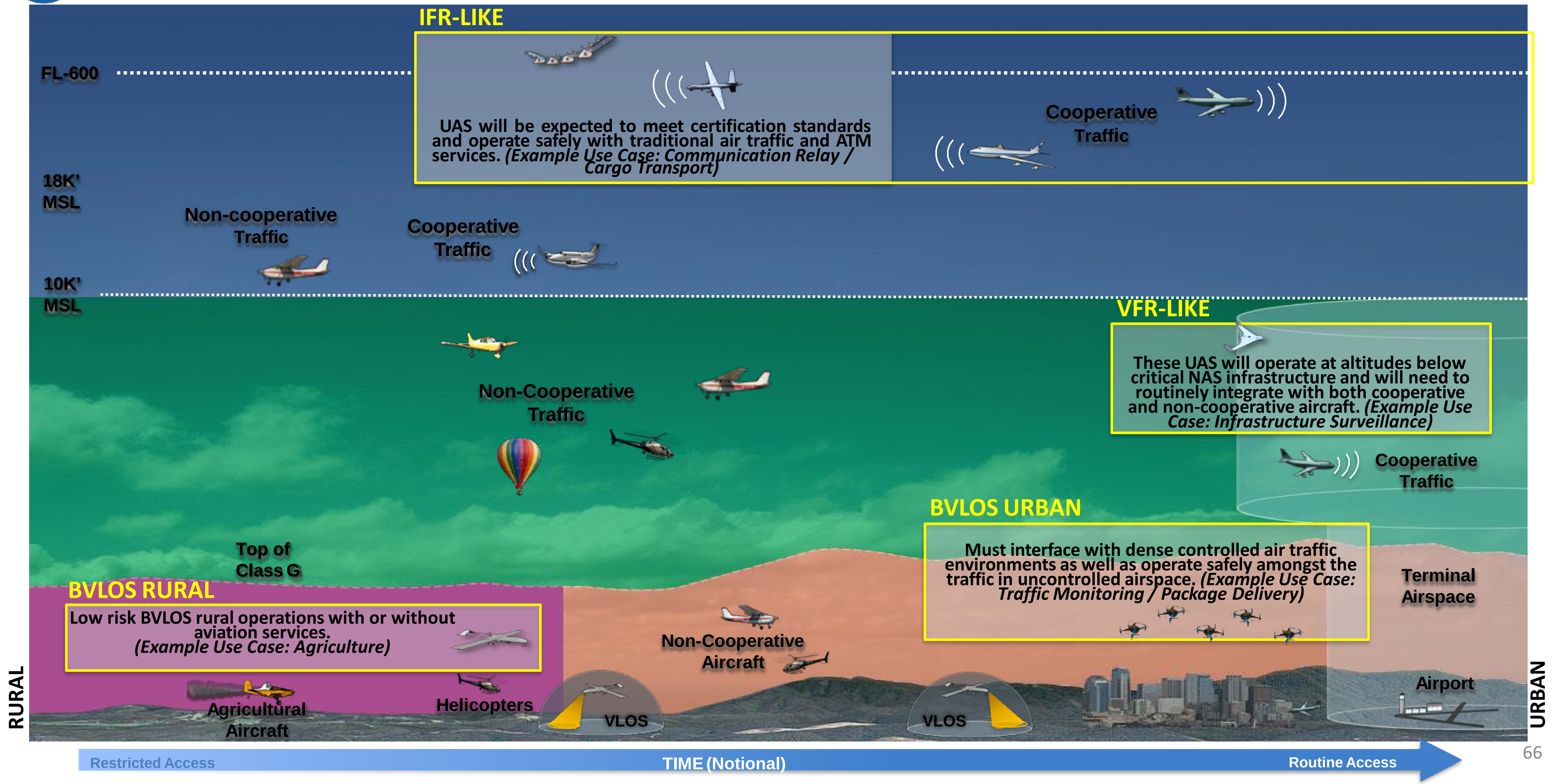
- ✓ Met FY19 Annual Performance Indicator (API)

- ✓ 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

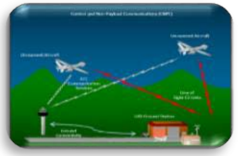
Implementation and Integration of Autonomous Airspace and Vehicle Systems

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

<u>TC-DAA Alignment</u>:

- 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

<u>TC-C2 Alignment</u>:

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

<u>SIO Alignment</u>:

- 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

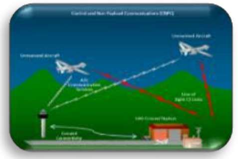
AERONAUTICS RESEARCH THEME

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

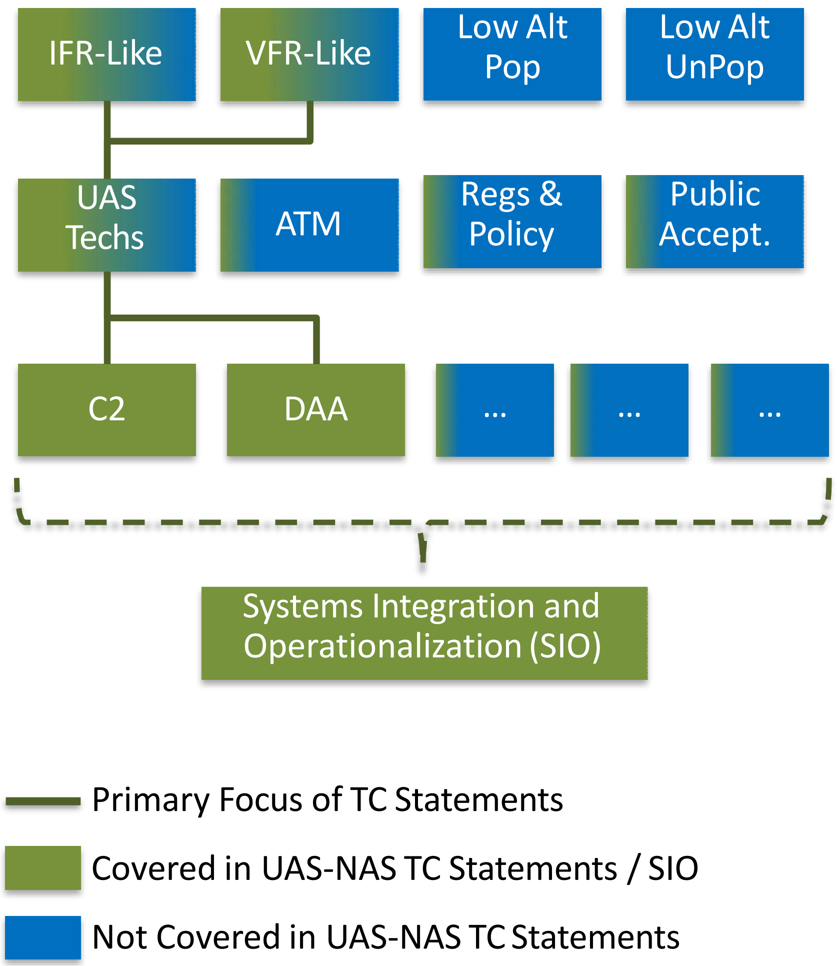
SIO

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 (Completed 1/19/18)	SP D.1.30, SP D.2.10
TBEN-006	Alternative Surveillance: Foundational Fast-time Simulation (FY17) (Completed 2/22/18)	SP D.1.40
TBEN-007	Alternative Surveillance: Display Requirements (Completed 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) (Completed 9/27/18)	SP D.1.60
TBEN-009	**Alternative Surveillance: HITL Simulation 1 (Completed 3/6/19)**	**SP D.1.70, SP T.7.20**
TBEN-010	*Alternative Surveillance: Unmitigated/Mitigated Fast-time Simulation (FY19) (Scheduled to Complete 10/23/19)*	*SP D.1.80*

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 (Completed 12/29/17)	SP D.2.30, T.7.10
TBEN-013	Well Clear/Alerting Requirements: Foundational Terminal Operations Fast-time Simulation 1 (Completed 12/20/17)	SP D.2.40
TBEN-014	Well Clear/Alerting Requirements: Fast-time Simulation 2 (Completed 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 Sim 2 (Completed 06/11/19) [Backup]**	**SP D.2.70**
~~TBEN-017~~	**~~Well Clear/Alerting Requirements: HITL Simulation 3~~**	**~~SP D.2.80~~**
TBEN-018	ACAS-Xu: Mini HITL Simulation (Completed 2/20/18)	SP D.3.20

TC-DAA Technical Baseline Elements (3/4)

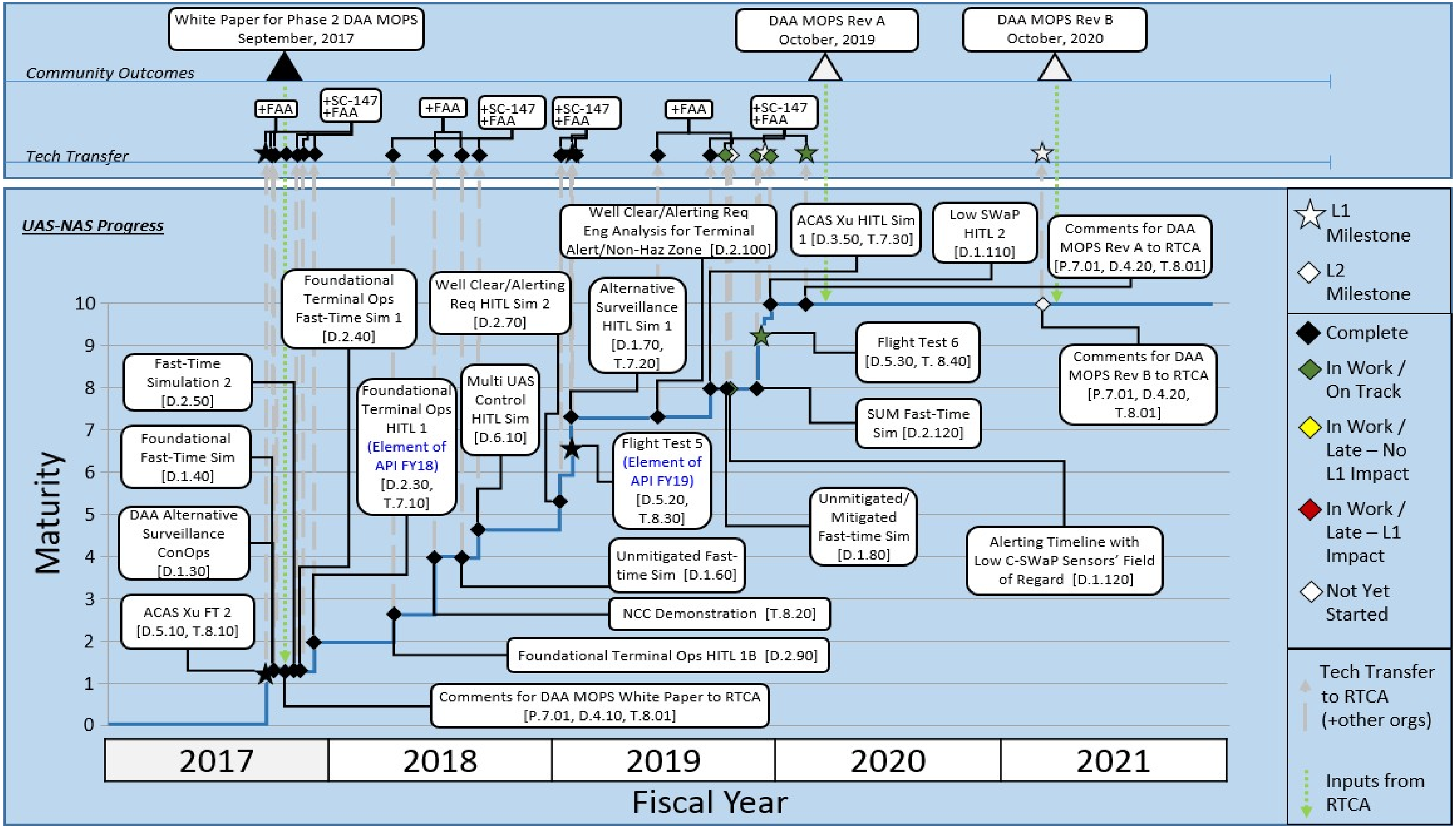
Technical Baseline Element Number	Technical Baseline Title	Reference SP Numbers
TBEN-019	**ACAS-Xu: HITL Simulation 1 (Completed 09/16/19) [Backup]**	**SP D.3.50, SP D.7.30**
TBEN-020	Integrated Event: ACAS-Xu Flight Test 2 (Completed 10/23/17)	SP D.5.10, SP T.8.10
TBEN-021	**Integrated Event: Flight Test 5 (Completed 05/30/19)**	**SP D.5.20**
TBEN-022	*Integrated Event: Flight Test 6 (Scheduled to Complete on 11/25/19)*	*SP D.5.30, SP T.8.40*
TBEN-023	No-Chase Certificate of Waiver or Authorization Flight Demonstration (Completed 8/20/18)	SP T.8.20
TBEN-024	Well Clear/Alerting Requirements: Foundational Terminal Ops HITL Simulation 1B (Completed 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 (Completed 9/20/18)	SP D.6.10
TBEN-027	**Human Automation Teaming: Automatic Execution of CA and Return to Course Analysis (Completed 5/9/19) [Backup]**	**SP D.6.20**
TBEN-029	*Alternative Surveillance: Low SWaP HITL 2 (Scheduled to Complete on 12/2/19)*	*SP D.1.110*
TBEN-030	**Well Clear/Alerting Requirements: Results Dissemination for Well Clear/Alerting Requirements Engineering Analysis for Terminal Alert Times/Non-Hazard Zone (Completed 8/2/19) [Backup]**	**SP D.2.100**
TBEN-031	*Alternative Surveillance: Analyses of the Alerting Timeline with Low SWaP Sensors' Field of Regard (Scheduled to Complete on 10/28/19)*	*SP D.1.120*
TBEN-032	*Well Clear/Alerting Requirements: Sensor Uncertainty Mitigation (SUM) Fast-Time Simulation (Scheduled to Complete on 10/15/19)*	*SP D.2.120*

TC-DAA: Progress Indicator

As of 9/30/19



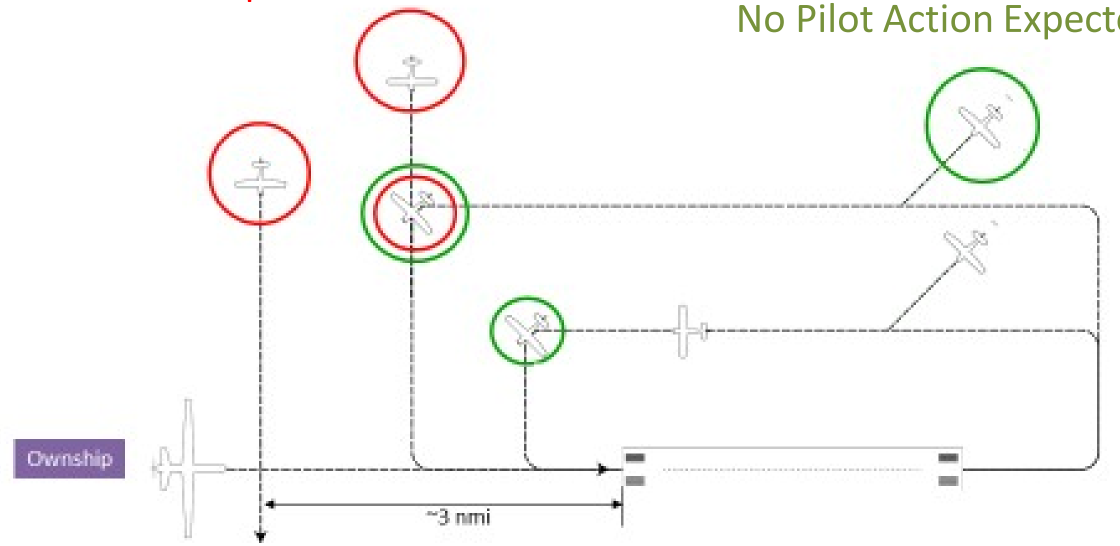
Well Clear/Alerting Requirements: HITL Simulation 2

Research Objective

- Verify pilot performance of Class D and E terminal area operations
- Verify DAA algorithm configurable parameters for Class D and E terminal area operations

Pilot Action Expected

No Pilot Action Expected



Technical Approach

- Vary dimensions and shape of DAA Terminal Area (DTA)
- Vary the DWC switching methodology for transition from the En Route DWC to the Terminal DWC.
- Characterize alerting performance and subject pilot response as a function of DTA
- Assess pilot preference/performance regarding intruder alerting throughout the airport environment

Issues / Challenges

- Number of subjects limited to 9 from originally planned 15
- RTCA request to add Ownship-Centric DWC switching to the planned Intruder-Centric switching conditions resulted in a complex test matrix
  - There was insufficient room in the test matrix to test multiple terminal warning alert times

Well Clear/Alerting Requirements: HITL Simulation 2

Highlights / Findings

- Given the conflicting list of pros and cons it is possible that two or more of these DTA examples should be included in the MOPS
- DAA Terminal Area (DTA) should be cylindrical
- Terminal Warning Alert time is too short at 30 seconds
- No clear choice for switching method between ownship-centric or intruder-centric

Tech Transfer

- **Key Stakeholders:** SC-228, FAA, UAS Community
- **Importance to Stakeholder**: Guides development of DAA configurable parameters for terminal area operations
- **NASA Contribution:** Data (DTA shape, DWC switching methodology) for DAA configurable parameters.
- **Briefing:** SC-228 Face to Face, June 2019
  - Additional engineering analysis elements identified (see SP D.2.100) to choose a new alert time and make recommendations on all items in DAA MOPS Table 2-23

Feature	Intruder Cylinder	Intruder Prism	Ownship Cylinder
Alerting on 45 Entry			
Alerting on Extended Base			
Alerting on Transit			
Alerting given Nominal Separation			
Alerting on Downwind			
Alerting on Turn to Base			
Aircraft Response Time			
Maneuvering			
Separation			
Subjective: Alert Timing/Distance			

Well Clear/Alerting Requirements: Engineering Analysis for Terminal Alert Times/Non-Hazard Zone

Research Objective

- Determine alert times and a non-hazard zone definition that result in alerting behavior that is appropriate for the DTA
  - Warning Alert Late Threshold
  - Warning Alert Minimum Average Time of Alert
  - Warning Alert Early Threshold
  - Warning Non-Hazard Zone

Technical Approach

- Utilize data from TOPS 2 HITL to determine
  - Minimum Average Time of Alert
  - Late Alert Threshold
- Perform Terminal Alerting Engineering Analysis to determine
  - Early Alert Threshold
  - Non-Hazard Zone

	Alert Type →	Warning Alert
	Alert Level →	Warning
Hazard Zone Alert Times	Minimum Average Time of Alert (Seconds)	30 (TBR)
	Late Threshold (THR_{Late}) (Seconds)	TBD
	Early Threshold (THR_{Early}) (Seconds)	TBD
Non-Hazard Zone	τ^*_{mod} (Seconds)	TBD
	DMOD and HMD*(NM)	TBD
	VMOD (Feet)	450

Technical Baseline Element Number: TBEN-030 (SP D.2.100)

Well Clear/Alerting Requirements: Engineering Analysis for Terminal Alert Times/Non-Hazard Zone

Highlights / Findings

- Minimum Average Time of Alert determined: 45 seconds
- Late Alert Threshold determined: 30 seconds
- Early Alert Threshold determined: 70 seconds
- Non-Hazard Zone not determined
  - To be resolved in consultation with SC-228 SMEs
  - Larger than Early Alert Threshold

Tech Transfer

- **Key Stakeholders:** RTCA SC-228 DAA Working Group, RTCA SC-147, FAA, & UAS Community
- **Importance to Stakeholder:** Informs requirements for MOPS development in the transition to the terminal area
- **NASA Contribution:** Data from HITL simulation and engineering analysis to inform MOPS development in the transition to the terminal area
- **Briefing:** RTCA SC-228 Display/Alert/Guidance Working Group Meeting July 01, 2019

Alert Type →		Warning Alert
Alert Level →		Warning
Hazard Zone Alert Times	Minimum Average Time of Alert (Seconds)	45
	Late Threshold (THR_{Late}) (Seconds)	30
	Early Threshold (THR_{Early}) (Seconds)	70
Non-Hazard Zone	τ^*_{mod} (Seconds)	75 (TBR)
	DMOD and HMD*(Feet)	2000 (TBR)
	VMOD (Feet)	450 (TBR)

ACAS Xu Interoperability: ACAS Xu HITL Sim 1

Research Objective

- Assess ACAS Xu Run 5 in a HITL setting to measure pilot & system performance
  - DAA alerting and guidance
  - RA alerting and guidance
  - Incorporate realistic sensor noise
  - Compare pilot & DAA system performance to Phase 1
- Leverage the findings of the ACAS Xu Engineering Analysis to determine how to display visual and aural RA alerts

Technical Approach

- Sixteen active UAS pilot participants tasked to:
  - Manually respond to DAA and RA guidance from Xu
  - Coordinate with center controller as appropriate
  - Navigate UAS along pre-filed flight path (navigation only)
  - Respond to scripted messages and system failure events
- Two display configurations: Integrated vs. Standalone
- Four experimental trials per pilot (6 scripted encounters per trial)
- Ownship: Generic MQ-9 model

Issues / Challenges

- Unintended DAA Alerting and Guidance ACAS Xu Behavior in HITL Simulation (U.4.7.01)
- ACAS Xu HITL Simulation 1 (U.4.7.05)

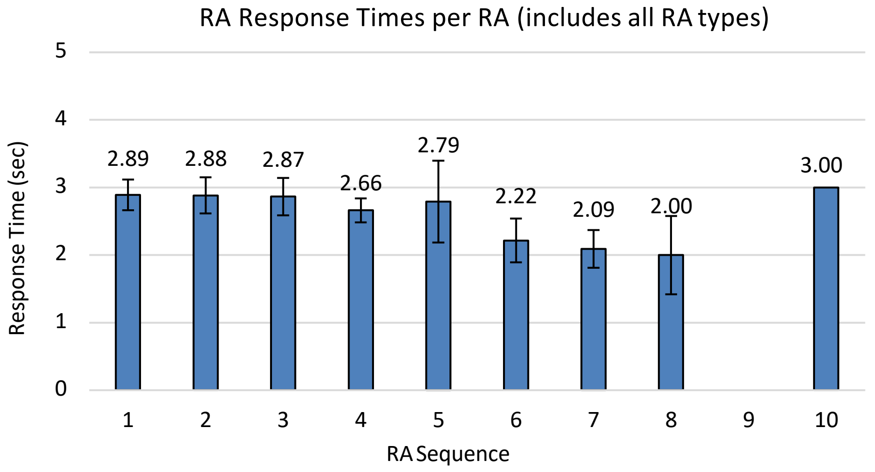
ACAS Xu Interoperability: ACAS Xu HITL Sim 1

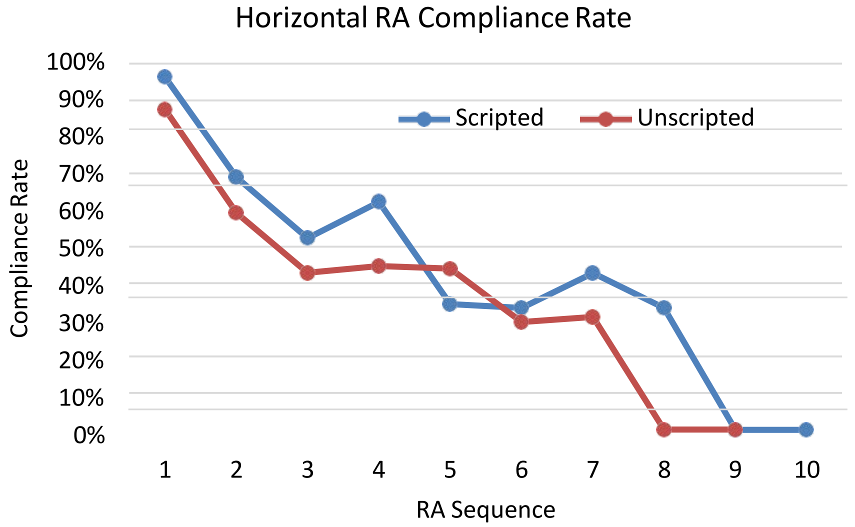
Highlights / Findings

- Pilots were able to comply with RAs within (or near) the required limit:
  - Avg. response time to first RA = **2.89 sec** (TCAS requirement = 5sec)
  - Avg. response time to subsequent RA(s) = **2.69 sec** (TCAS requirement = 2.5sec)
  - Faster response times due to *auto-fill behavior* - VSCS auto-populated the new target heading or altitude and pilot simply had to press send if they approved
- Multiple horizontal RAs (i.e., target headings) were common per RA encounter
  - Results showed that pilot compliance rate dropped off substantially from the 1st RA to subsequent RAs
- No significant effect of display configuration (Standalone vs Integrated)

Tech Transfer

- **Key Stakeholders:** RTCA SC-228 DAA Working Group, RTCA SC-147 ACAS Xu Working Group, FAA, & UAS Community
- **Importance to Stakeholder:** Insight into interoperability issues related to the integration of Remain Well Clear (RWC) and Collision Aerospace Avoidance display, alerting, and guidance
- **NASA Contribution:** Analyzed data and recommendations related to the integration of RWC and ACAS Xu
- **Briefing:** Joint SC-228/SC-147 meeting, September 16, 2019

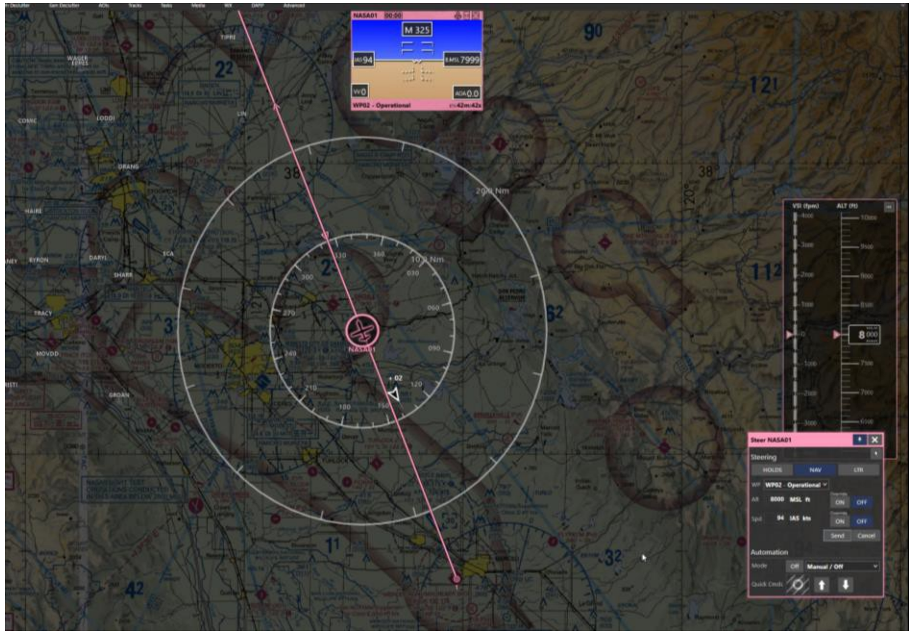




Human Automation Teaming: Automatic Execution of Collision Avoidance and Return to Course Analysis

Research Objective

- Two-part study to examine the display of ACAS Xu Resolution Advisories (RAs)
- Part 1: Investigate the effects of different display configurations on pilot responses to different types of ACAS Xu RAs:
  - *Vertical-only RAs* – provides a target vertical speed (identical to TCAS II)
  - *Horizontal-only RAs* – provides a target heading (unique to ACAS Xu)
  - *Blended RAs* – a combination vertical + horizontal RA (unique to ACAS Xu)
- Part 2: Gather pilot feedback on how to automate the Collision Avoidance (CA) and Return-to-Course (RTC) functions



Technical Approach

- Part 1: Varied how to present different RA types:
  - RA Text Box (“With Text” vs. “No Text”)
  - Modified Aural Alerts (“Basic” / “Advanced”)
- Part 2: Automation Level
  - Manual (identical to Part 1)
  - Automated Collision Avoidance (CA)
  - Automated CA & RTC
  - Automated CA & RTC+ (added a dedicated aural alert to indicate automation activation)

Issues/Challenges

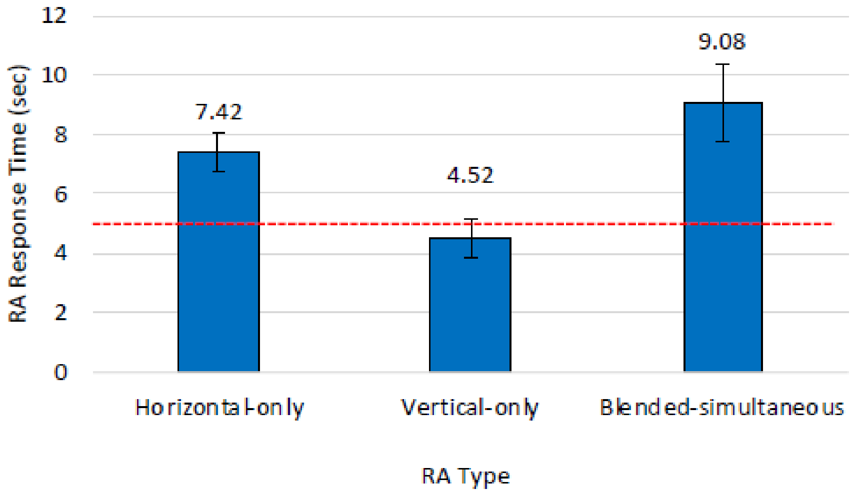
- Human Automation Teaming (U.4.7.04)
- Creating a system that could generate RAs *without* using the actual ACAS Xu logic (it was still being integrated by IT&E)
- Developing automatic-response concepts that would both execute as intended and model occasionally ‘fail’ so as to test pilots’ responses to automation failure

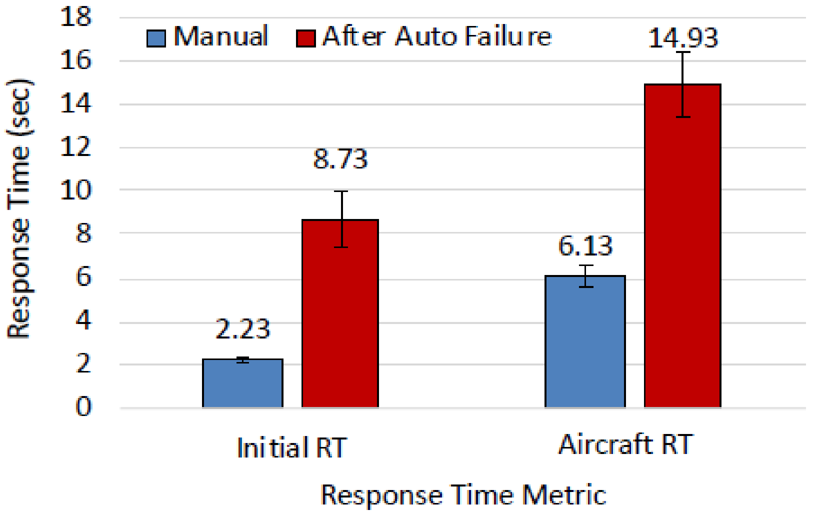
Technical Baseline Element Number: TBEN-027 (SP D.6.20)

Human Automation Teaming: Automatic Execution of Collision Avoidance and Return to Course Analysis

Highlights / Findings

- Part 1
  - Pilots failed to meet the 5 second response time requirement from TCAS II when responding to horizontal-only and blended RAs
  - Text box not considered a requirement by pilots in this study
  - Pilots self-rated as being highly accepting of horizontal and vertical RA guidance presentation
- Part 2
  - Pilots understood the value of automation but noted areas for improvement
  - General consensus was that they needed more information regarding the state of the system
  - Pilots found the disengagement process cumbersome





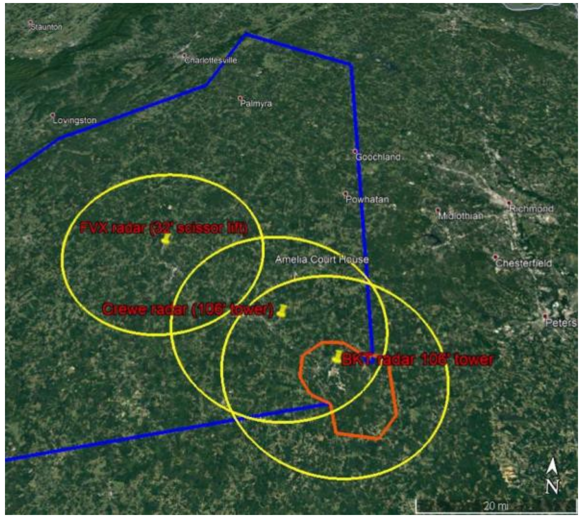
Tech Transfer

- **Key Stakeholders:** RTCA SC-228 DAA Working Group, RTCA SC-147, FAA, & UAS Community
- **Importance to Stakeholder:** Informs SC-228 MOPS requirements for automatic ACAS Xu CA and return to course
- **NASA Contribution:** Data to inform MOPS requirements
- **Briefing:** RTCA SC-228 / RTCA SC-147 June 2019 Face to Face meeting

Ground Based Detect and Avoid (Task Order 4)

Research Objective

- Develop a viable GBDAA Concept of Operations (ConOps) and architecture intended to meet GBDAA MOPS
- Identify any differences in requirements between DO-365 and a GBDAA system necessary for the standard
- Assess the GBDAA system performance against the RTCA MOPS
- Characterize the surveillance volume and performance of the ground based radar system
- Deliver ground based radar surveillance models for NASA simulations
- Demonstrate a path to implement the GBDAA System via a 14 CFR 91.113 Waiver



Technical Approach

- A network of three Gryphon Sensors R1400 radars were emplaced in operational area located in central Virginia
- Three flight campaigns were conducted to fully test the GBDAA sensors and components
- Encounters were flown utilizing general aviation aircraft to collect data

Issues / Challenges

- Spectrum approval for planned small Unmanned Aircraft System (sUAS) ownship C2 system
- Non-ITAR tracker development

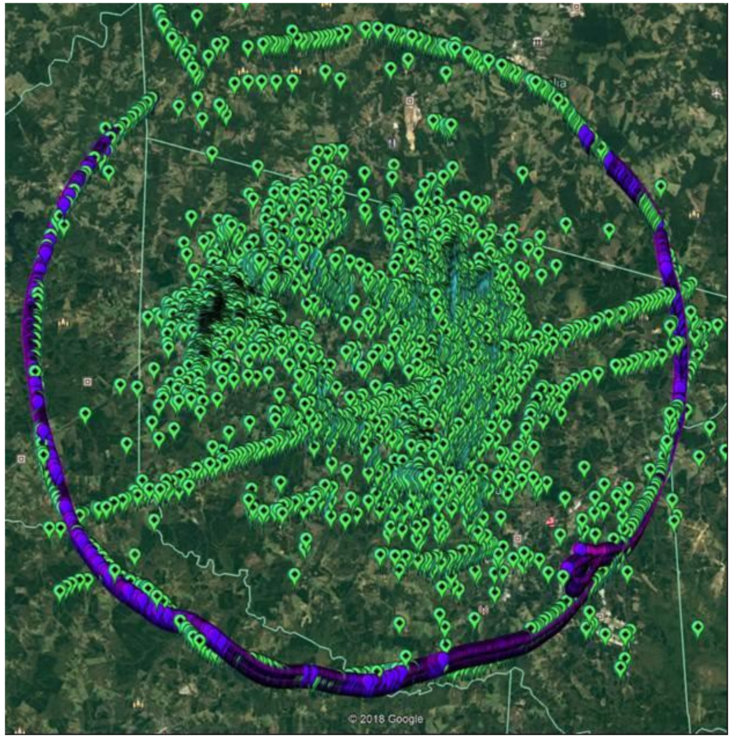
Ground Based Detect and Avoid (Task Order 4)

Highlights / Findings

- The results of this testing were compared to the DO-365, DO-366 and draft Ground Based Radar System (GBRS) MOPS
- The gaps between the current system and the minimum requirements for a waiver were identified
- Overall the GBRS failed to meet the MOPS, due to track continuity, track accuracy, and the number of false tracks
  - Areas of improvements were identified (ex. implementation of a better tracker and classifier)
- Several MOPS requirements were identified as having issues with testability

Tech Transfer

- **Key Stakeholders:** RTCA SC-228 DAA Working Group, FAA, & UAS Community
- **Importance to Stakeholder:** Data to assess draft MOPS
- **NASA Contribution:** Funded MAAP UAS Test site evaluation of a representative architecture against draft MOPS requirements
- **Final Report:** Ground radar characterization report provided December 21, 2018 (both ITAR and non-ITAR versions)



Campaign 1								
Day	Test Card	Radar	MOPS Performance					
			Track Continuity	Split Tracks	Horizontal Error	Vertical Error	Horizontal Velocity	Vertical Velocity
Tue.	1.4	BKT						
		CRW						
	1.5	BKT						
		CRW						
	1.6	BKT						
		CRW						
	1.7	BKT						
		CRW						
	1.8	BKT						
		CRW						
	1.9	BKT						
		CRW						
	1.1	BKT						
		CRW						
Wed.	1.3	BKT						
		CRW						
		FVX [1]						
	1.2	BKT						
		CRW						
		FVX [1]						
	2.3	BKT						
		CRW						
		FVX [1]						
	2.4	BKT [1]						
		CRW						
		FVX [1]						
Thur.	4.14-4.24	ALL [1]						
	2.1	FVX						
	2.2	FVX						
	3.1	CRW [1]						
		FVX [1]						
	3.2	FVX [1]						
	5.1	BKT [1]						
		CRW						
	5.2	BKT [1]						
		CRW						

GBDAA Trade Study

Research Objective

- Conduct a survey of the current Ground Based Detect and Avoid (GBDAA) landscape
- Inform future GBDAA requirements and research

designworks

Ground Based Detect and Avoid Industry Review

Final

REPORT DATE: 11 October 2018

This work is being performed under SJSU Research Foundation Account Number 21-1614-5736
to HF Designworks, Inc.

Technical Approach

- Conduct research on or interviews/visits
  - Requirements related documentation
  - System vendors
  - Technologists
  - FAA, US Army, US Air Force representatives
  - FAA approved UAS test sites

Issues / Challenges

- None

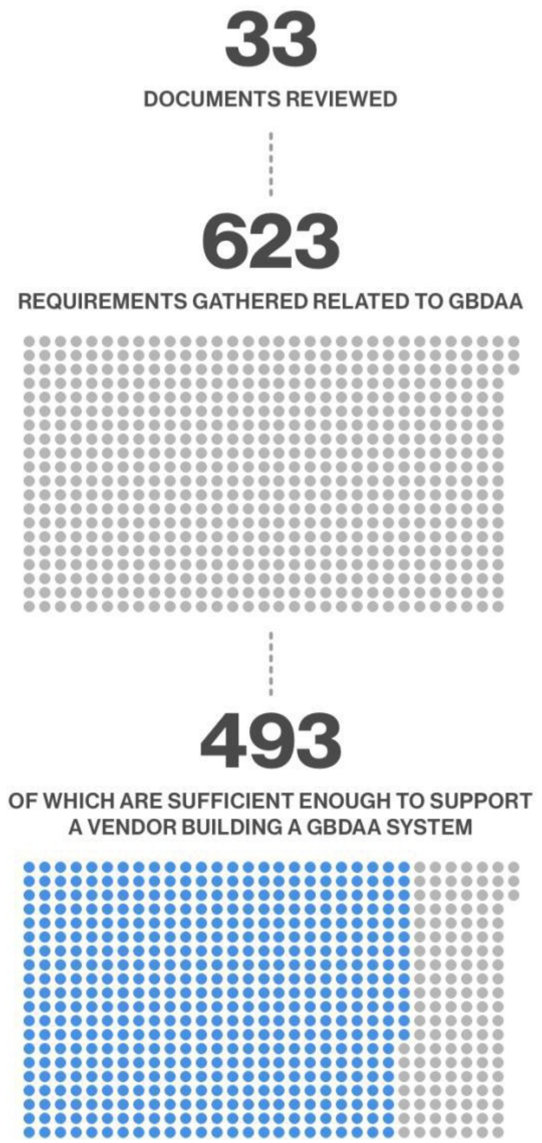
Ground Based Detect and Avoid

Highlights / Findings

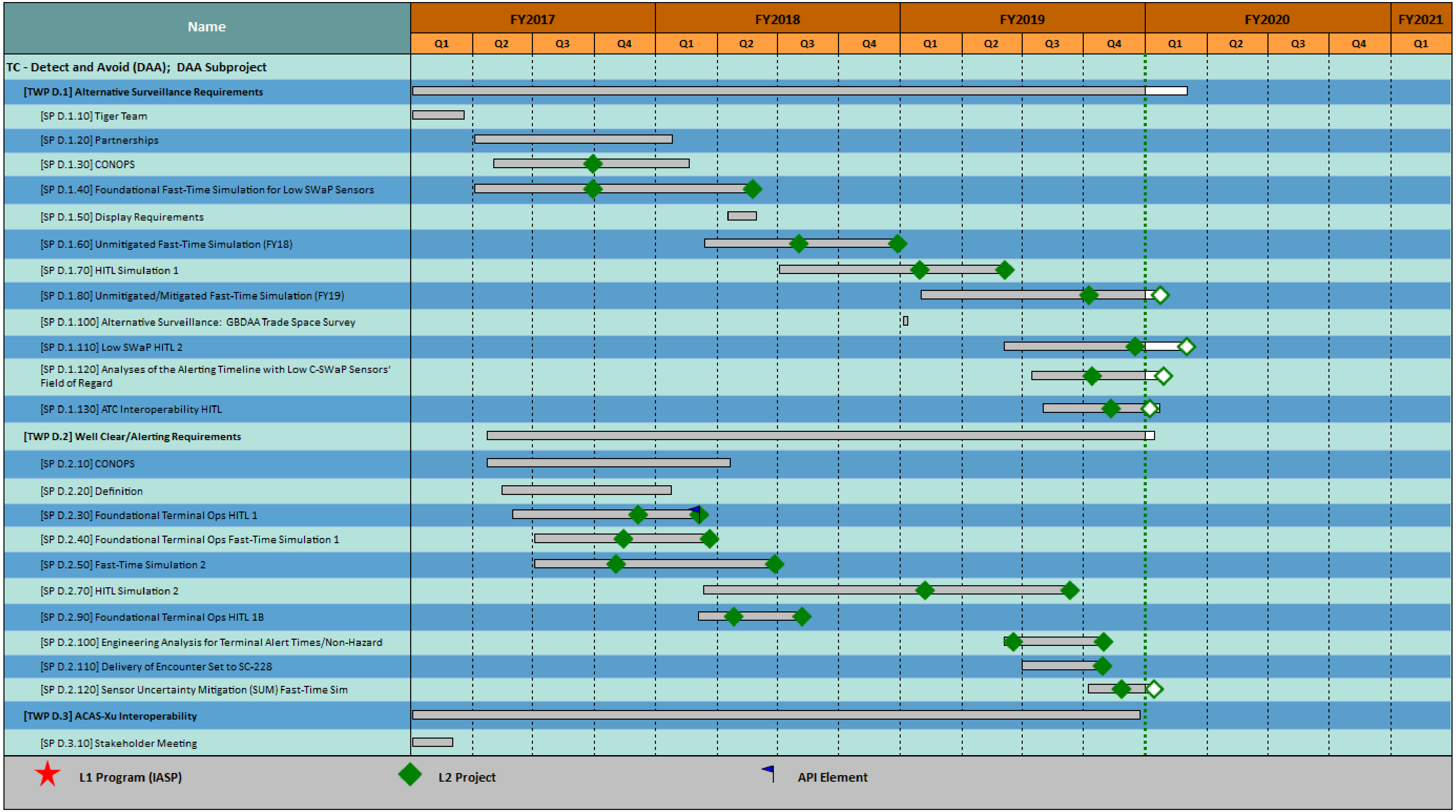
- No standard repository in which vendors can go to find the necessary requirements for building a GBDAA system.
- Several gaps in the requirements were identified related to avoidance procedures and alerting

Tech Transfer

- **Key Stakeholders:** RTCA SC-228 DAA Working Group, FAA, & UAS Community, FAA UAS Test Sites, GBDAA System Vendors
- **Importance to Stakeholder:** Development of GBDAA MOPS
- **NASA Contribution:** Compiled report of requirements and state of technologies and test
- **Final Report:** October 11, 2018

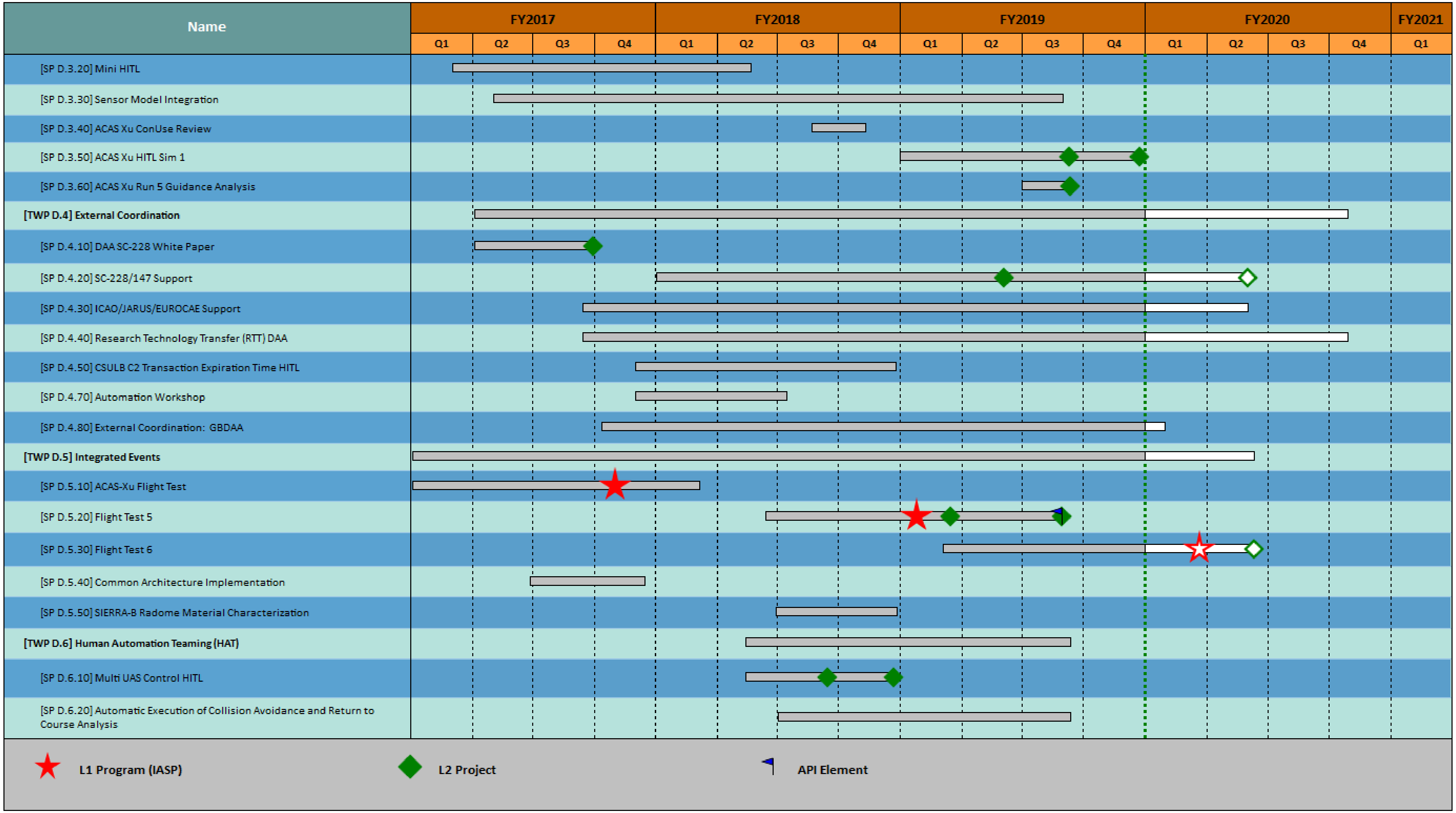


TC-DAA (1 of 3)



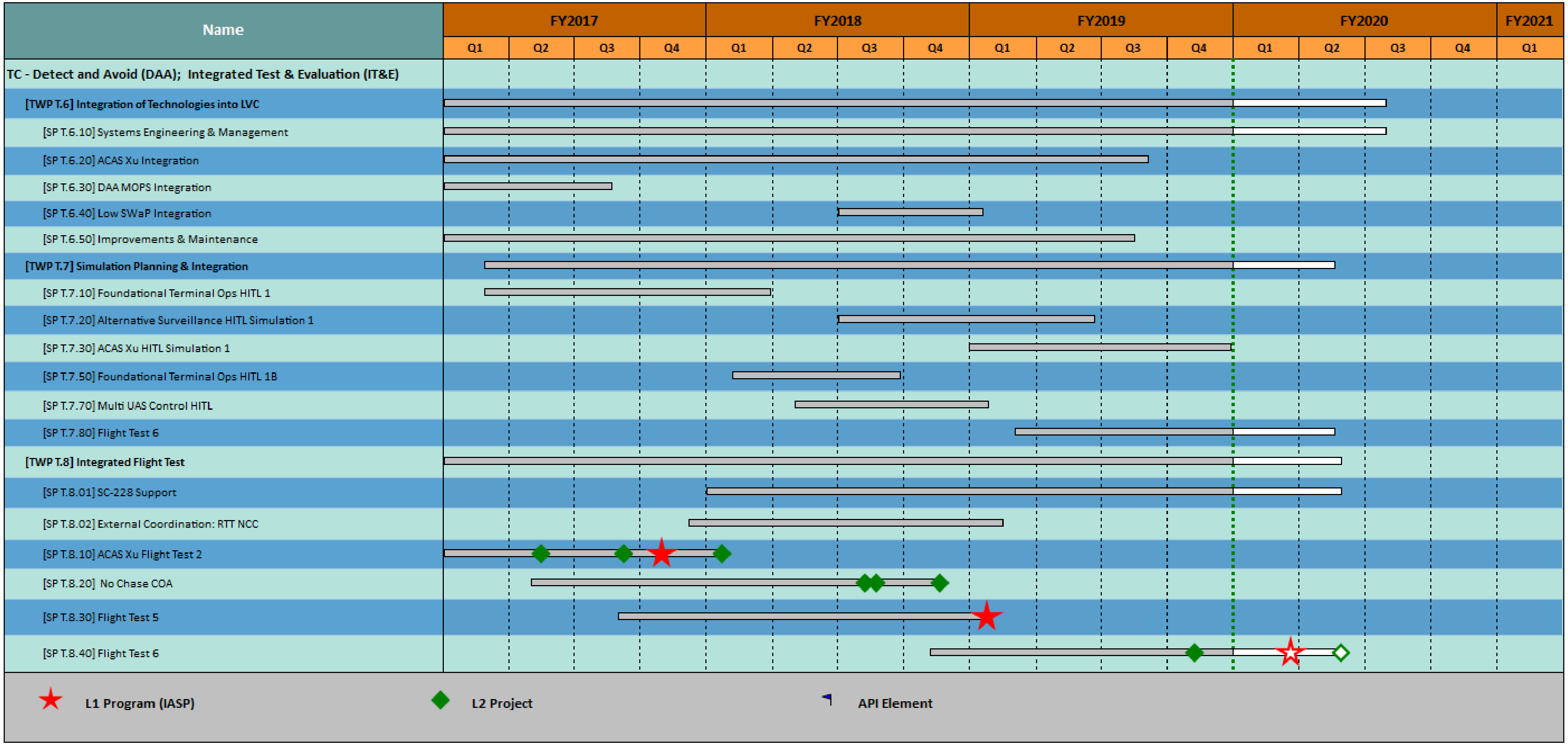
Green Status Line Date 9/30/19

TC-DAA (2 of 3)



Green Status Line Date 9/30/19

TC-DAA (3 of 3)



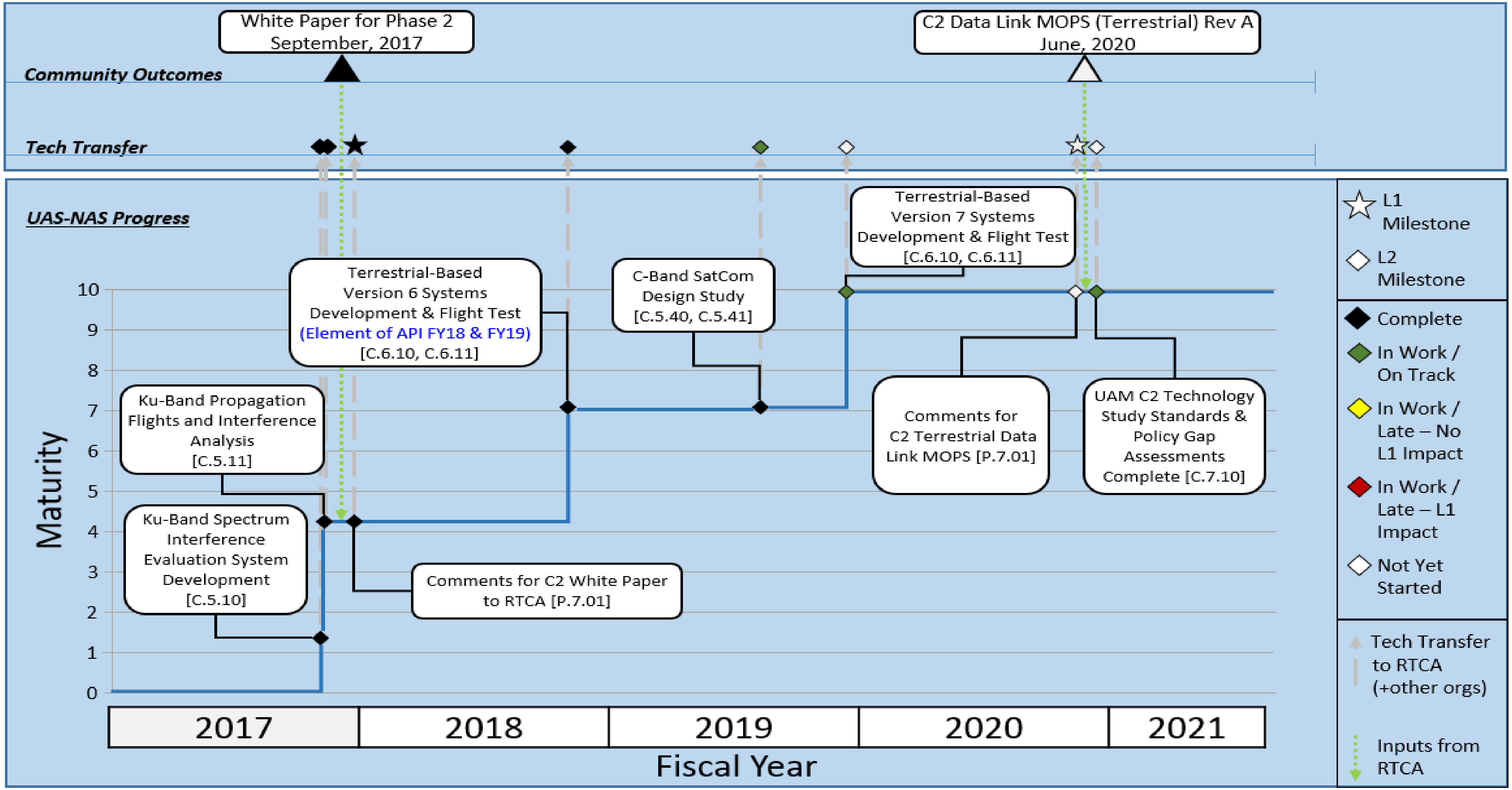
Green Status Line Date 9/30/19

TC-C2 Technical Baseline Elements (1/1)

Technical Baseline Element Number	Technical Baseline Title	Reference SP Numbers
TBEN-001	Satellite-Based UAS Command & Control: Ku Interference Evaluation System Development Complete (Completed 7/15/17)	SP C.5.10
TBEN-002	Satellite-Based UAS Command & Control: Deliver Ku Interference Final Report Delivered to SC-228 C2 WG (Completed 9/20/17)	SP C.5.11
TBEN-003	**C-Band Design Study: Earth Station Design Complete (Completed 4/2/19)[Backup]** *C-Band Design Study: C-Band SatCom Final Report (Scheduled to Complete 4/1/20)*	SP C.5.40, SP C.5.41
TBEN-004	**Terrestrial-Based UAS Command & Control: Version 7 Firmware Delivery for Terrestrial C2 Radio (Completed 2/27/19)** *Terrestrial-Based UAS Command & Control: Terrestrial-Based UAS Command & Control Final Report (Scheduled to Complete 8/27/20)*	SP C.6.10, SP C.6.11
TBEN-028	*UAS UAM C2 Study (Scheduled to Complete 7/23/20) [Backup]*	SP C.7.10

TC-C2: Progress Indicator

As of 9/30/19



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

UAM C2 Technology Study Standards & Policy Gap Assessments

Research Objective

- Study the unique C3 challenges related to UAS to address the perceived needs of the Urban Air Mobility (UAM) emerging market and identify requirements, standards, and technology gaps

Technical Approach

- UAM C3 Concept of Operations (L2)
- UAM C3 Seed Requirements (L2)
- Candidate Technologies Study (L3)
  - Identify current and near term technologies related to future C3 UAM operations
- UAS C3 Standards & Policy Activity(L3)
  - Identify current standards that apply to future C3 UAM operations.
- UAM UAS-C2 Technology Study (L2)
- UAM C3 Gap Assessment (L2)

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

National Aeronautics and Space Administration

Document #: UAM-003
Effective Date: May 24, 2019

John H. Glenn Research Center
21000 Brookpark Road, Cleveland, Ohio 44135

Urban Air Mobility Command, Control, and Communication Systems (C3)

Standards

Prepared by: Israel Greenfeld, Michael Jarrell, Michael Cauley, Dennis Iannicca, Jessica Reinert, Daniel Young, Gregory Kubat, William Bishop, Steven Bretmersky, Donna Clements

UAM C2 Technology Study Standards & Policy Gap Assessments

Highlights / Findings

- C3 Standards
  - Outlines major regulatory communication standards organizations
  - Includes international communication standards organizations
- C3 Candidate Technologies and Components
  - Technologies divided into families
  - Components divided into categories with several examples
- C3 Seed Requirements
  - High level requirements based on UAM Concepts of Operations
- C3 Gap Assessment
  - Requirements, standards, and technology gaps

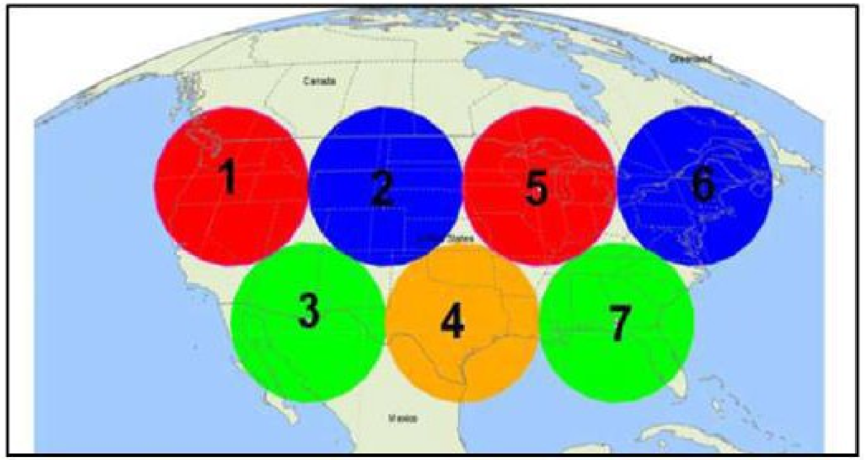
Tech Transfer

- **Key Stakeholders:** RTCA SC-228 C2 Working Group, FAA, & UAS Community
- **Importance to Stakeholder:** Compile requirements information needed for the UAM operational environment
- **NASA Contribution:** Documents compiling the seed requirements, standards, candidate technologies, and gap assessment
- **Final Report:** Scheduled to be delivered July 23, 2020

C-Band SatCom Design Study

Research Objective

- Determine the feasibility of terrestrial-based (LOS) and a satellite-based (BLOS) UAS C2 System sharing the same allocated FAA C-Band spectrum
- Finalize the design study of the beyond line of sight (BLOS) earth station (air and ground) terminals
- Detail the necessary equipment and design specifications based on representative hardware configurations
- The design approach and performance specifications of these reference designs should be considered conservative, with minimal technical risk



C-Band Frequency Reuse with:

1. Spot beams 1 & 5
2. Spot beams 2 & 6
3. Spot beams 3 & 7

Technical Approach

- Effort to date documented in the report *Initial C2 Payload and Earth Station Conceptual Design of the UAS C2 SatCom System*
- Delivered on April 20, 2018 by LinQuest to NASA GRC
- Provided a conceptual design of the BLOS earth stations along with an initial set of physical layer performance requirements
- The initial performance requirements were used to derive the initial forward and return link and capacity budgets.
- This report details the necessary equipment and design specifications based on representative hardware configurations

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

Issues / Challenges

- Spectrum sharing of terrestrial and satellite systems
  - Synchronization, coordination, and timing
- UA terminal projected to be largest portion of Life Cycle cost
- Must fit within a constrained size, weight, and power UA platform
- Must meet FAA airworthiness requirements

C-Band SatCom Design Study

Highlights / Findings

- Identifies a reference design and specifications for a ground station capable of providing C2 of UA in the NAS
- UA terminal also presented as reference design

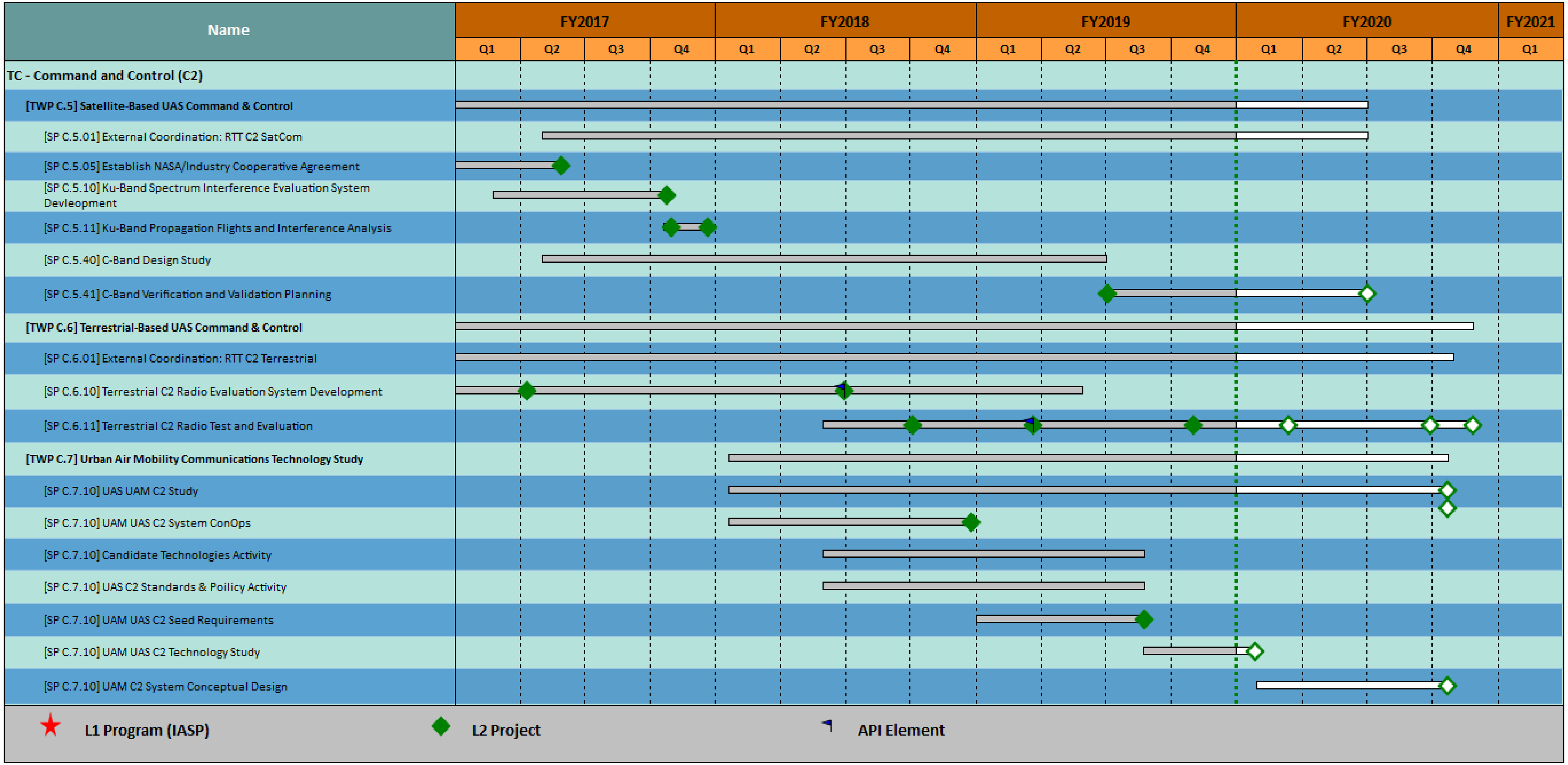
Tech Transfer

- **Key Stakeholders:** RTCA SC-228 C2 Working Group, FAA Spectrum Office, ICAO
- **Importance to Stakeholder:** Results from study will lead to the development of design parameters with the C-Band frequency allocation and broader determination of the operational feasibility of a C-Band satellite based C2 system
- **NASA Contribution:** The research and compilation of the design requirements in a final report
- **Final Report:** Scheduled to be delivered to NASA GRC April 1, 2020

Component	Unit weight (lbs.)	Unit Power (W)
Protocol Server	11.3	196.3
Network Hub	239.1	2,410
8 to 1 Converter	0.5	-
IFL Cabling	7.4	-
BUC/TWTA	60	1,400
6.3 meter (dia) antenna	9,000	21,811
LNA	24.8	100
Tracking Receiver	25	45
1 to 16 Splitter	.5	-
Ground Station Total	**9,368**	**25,962**

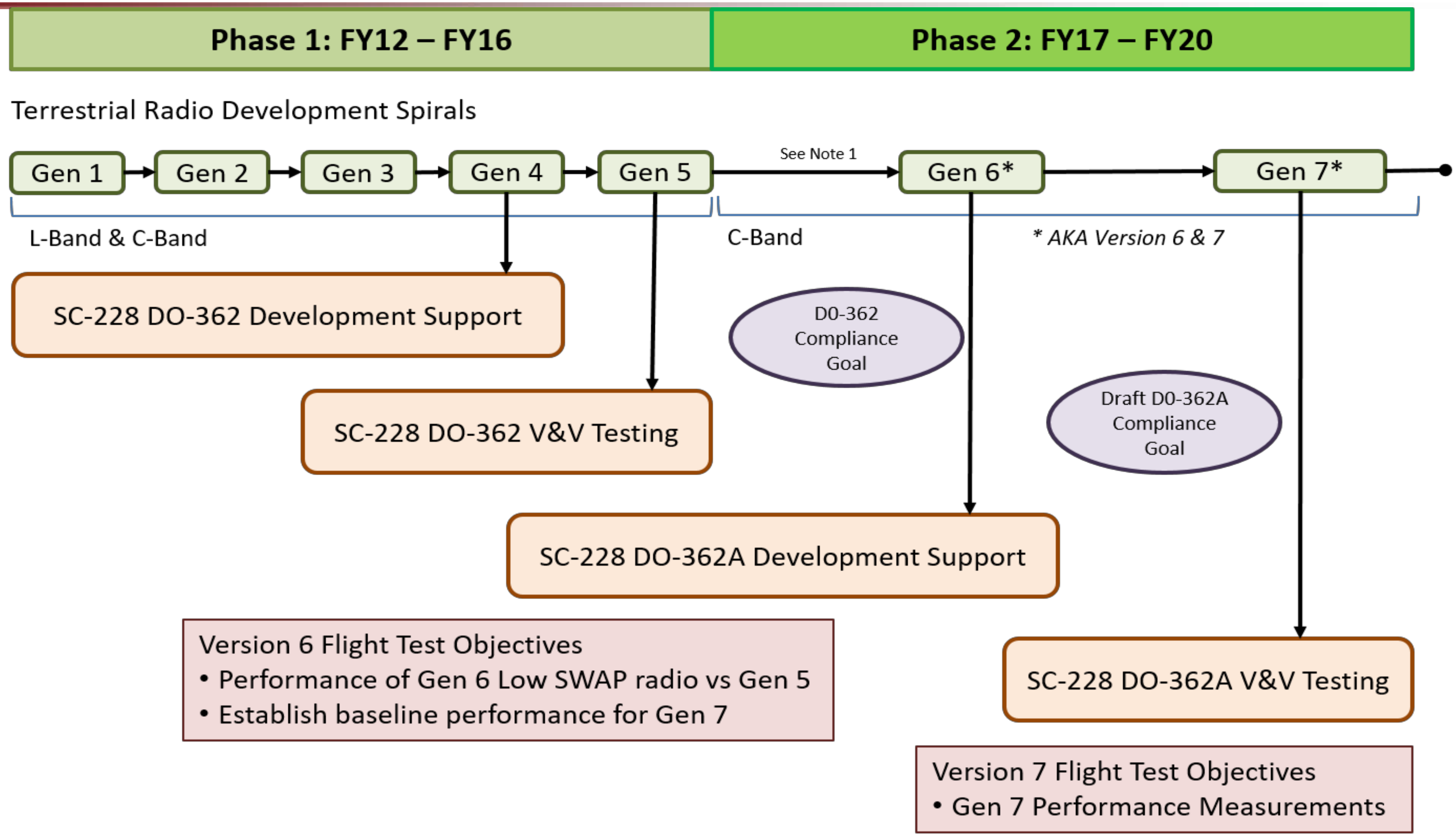
Component	Unit weight (lbs.)	Unit Power (W)
Satellite Modem	16.0	196
Block Upconverter	9.3	85
Low Noise Block Converter	1.8	8.4
Reference Oscillator	2.2	11.8
Transmit/Receive Switch	0.1	0.5
Tracking Antenna	11.6	32
Power/Control Interconnects	6.1	
RF Interconnects	4.1	
Airborne Station Total	**51.2**	**333.7**

TC-C2



Green Status Line Date 9/30/19

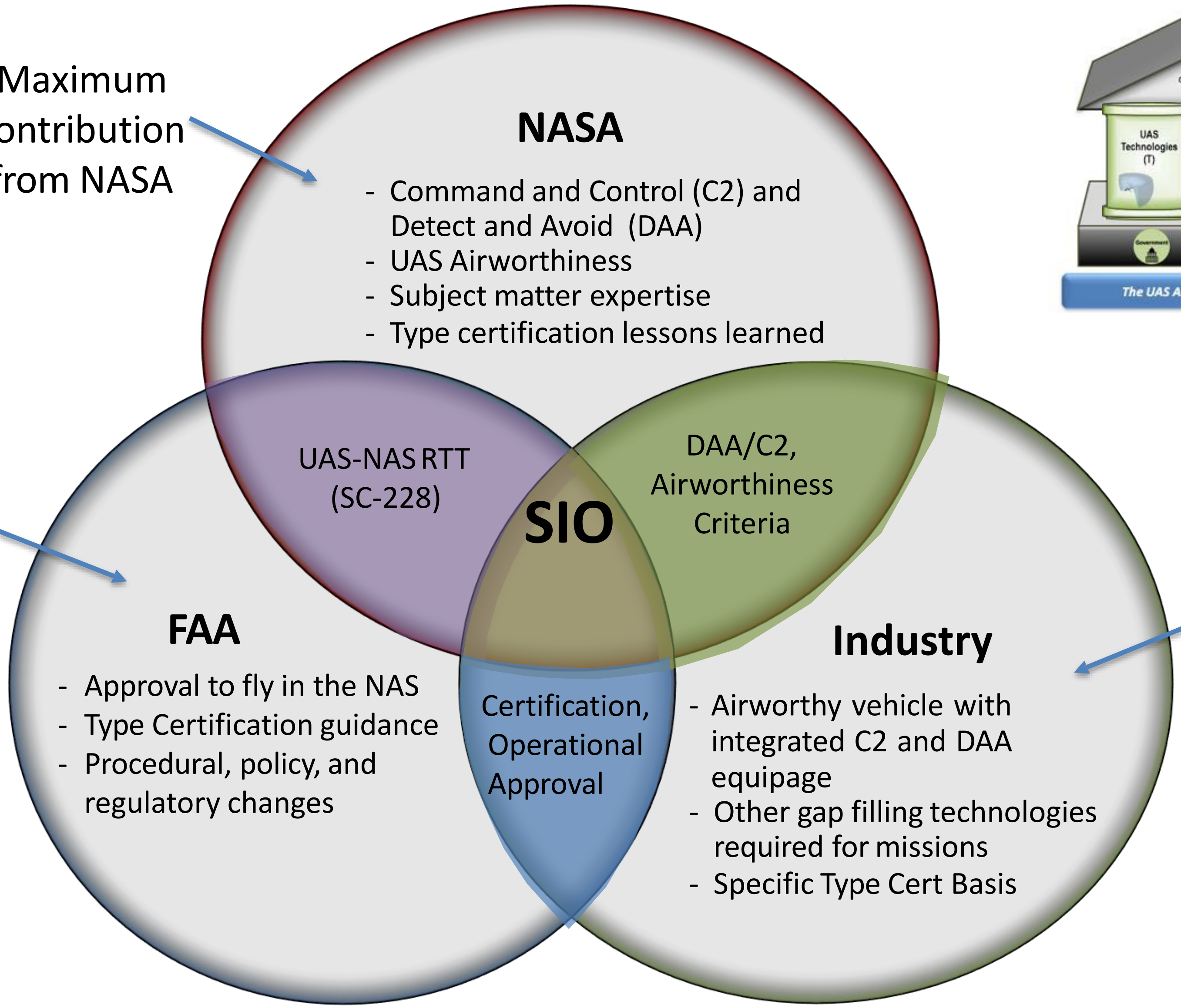
UAS C2 Terrestrial Radio Task Overview



Note 1: Gen 6 C-Band Radio is a total redesign using a new Rockwell team with no traceability to Gen 5 C-Band.

- Complete hardware redesign to a SDR Low SWAP package based on Rockwell's successful BNSF L-Band radio.
- Complete firmware/software non-ITAR redesign to achieve the functionality and performance of the ITAR-restricted Gen 5.

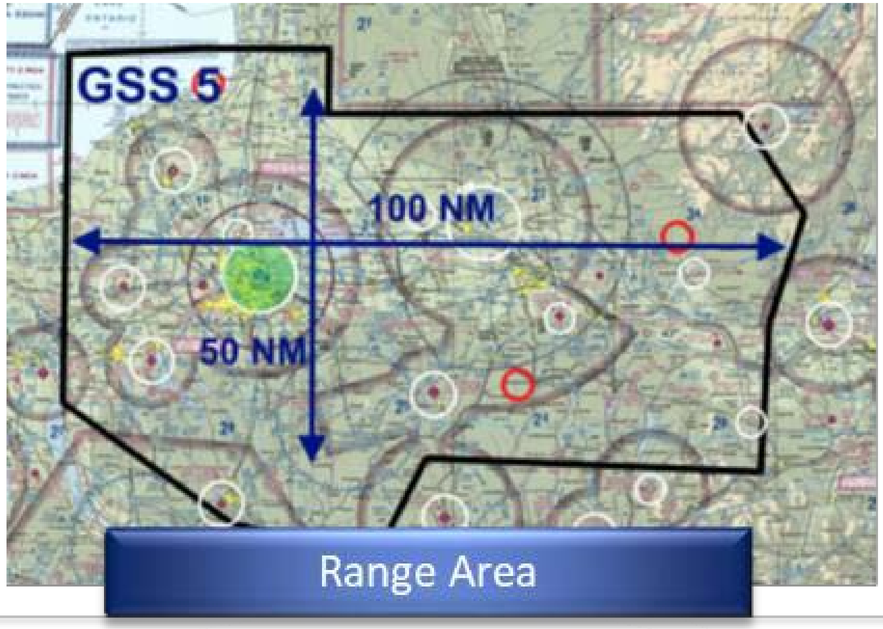
NASA, FAA, and Industry Relationship for SIO



Systems Integration and Operationalization (SIO) Partnership

Research Objective

- ConOps analysis, optimization and design
- Command and Control, including cyber resilience
- Ground-Based Detect and Avoid
- Transition between Airborne Detect and Avoid (ABDAA) & GBDAA
- Surfaced-Based Operational Autonomy
- Auto ATC Voice Communications
- Automation augmentation to permit the defined solutions/ConOps



Technical Approach

- Nominal and off-nominal (lost link) autonomous descent with auto-ATC voice communication through VFR-like environments into controlled airspace (low altitude urban) and landing
- Nominal and off-nominal autonomous clearance off the active runway to a safe location
- Nominal and off-nominal autonomous rerouting around a dynamic airspace obstruction (simulated weather)

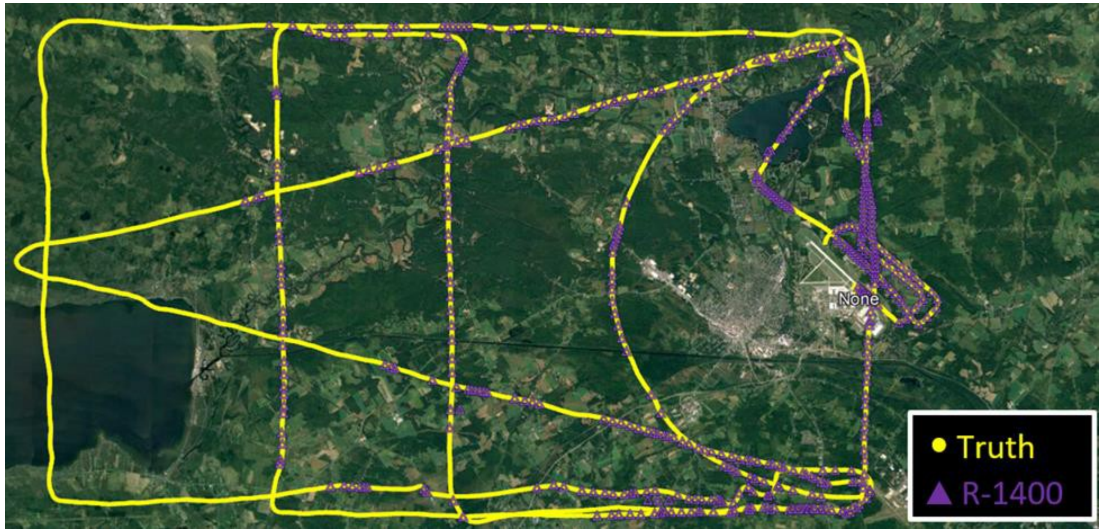
Issues / Challenges

- While TO5 included an adaptation of an airborne weather radar to work cooperatively with an optical tracker to identify airborne targets, time and funding limits did not allow cooperative ABDAA and GBDAA testing in this project

FAA UAS Test Site Vehicle Technology Demonstration (Task Order 5)

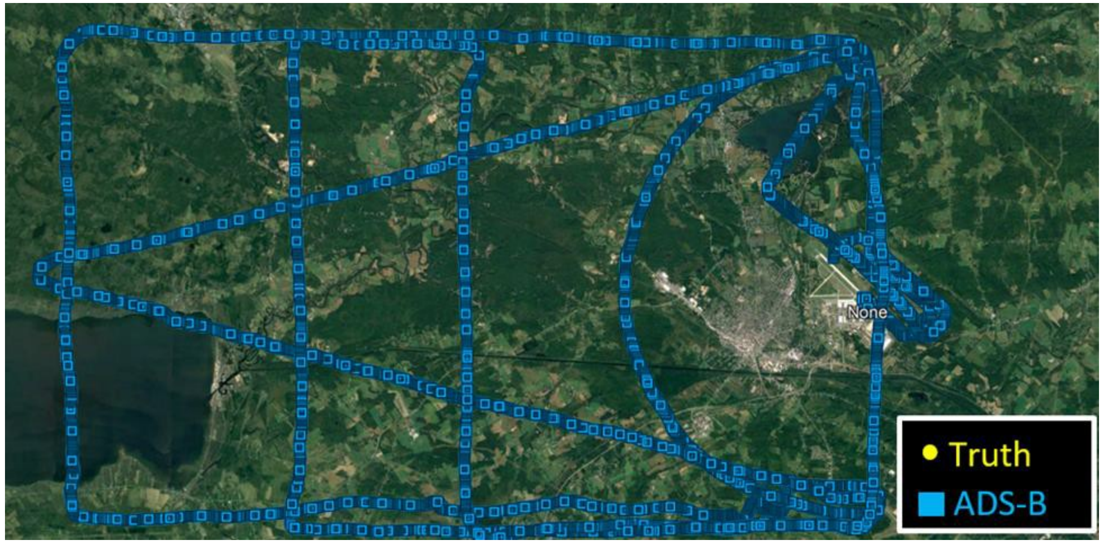
Highlights / Findings

- The R1400 sensors demonstrated mixed performance in terms of tracking both GA and UAS targets consistently throughout coverage volumes. It is likely that the close proximity of target detections resulted in only a single track for both targets at times
- Auto ATC Voice Communications shows promise. Two of three trials unsuccessful due to different ATC noise characteristics, inability of system to separate out ACT transmissions intended for two aircraft



Tech Transfer

- **Key Stakeholders:** FAA, RTCA SC-228, & UAS Community
- **Importance to Stakeholder:** Data to assess draft MOPS
- **NASA Contribution:** Funded New York UAS Test site evaluation of a representative architecture against draft MOPS requirements
- **Final Report:** Released April 2019



Project Level Performance
Backup Slides

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Risks Accepted/Closed in FY19

- Data redacted

Risks Accepted/Closed in FY19

- Data redacted

UAS-NAS Top Risk Summary

- Data redacted

UAS-NAS Risk Summary Card

- Data redacted

UAS-NAS FY19 Project Funding

- Data redacted

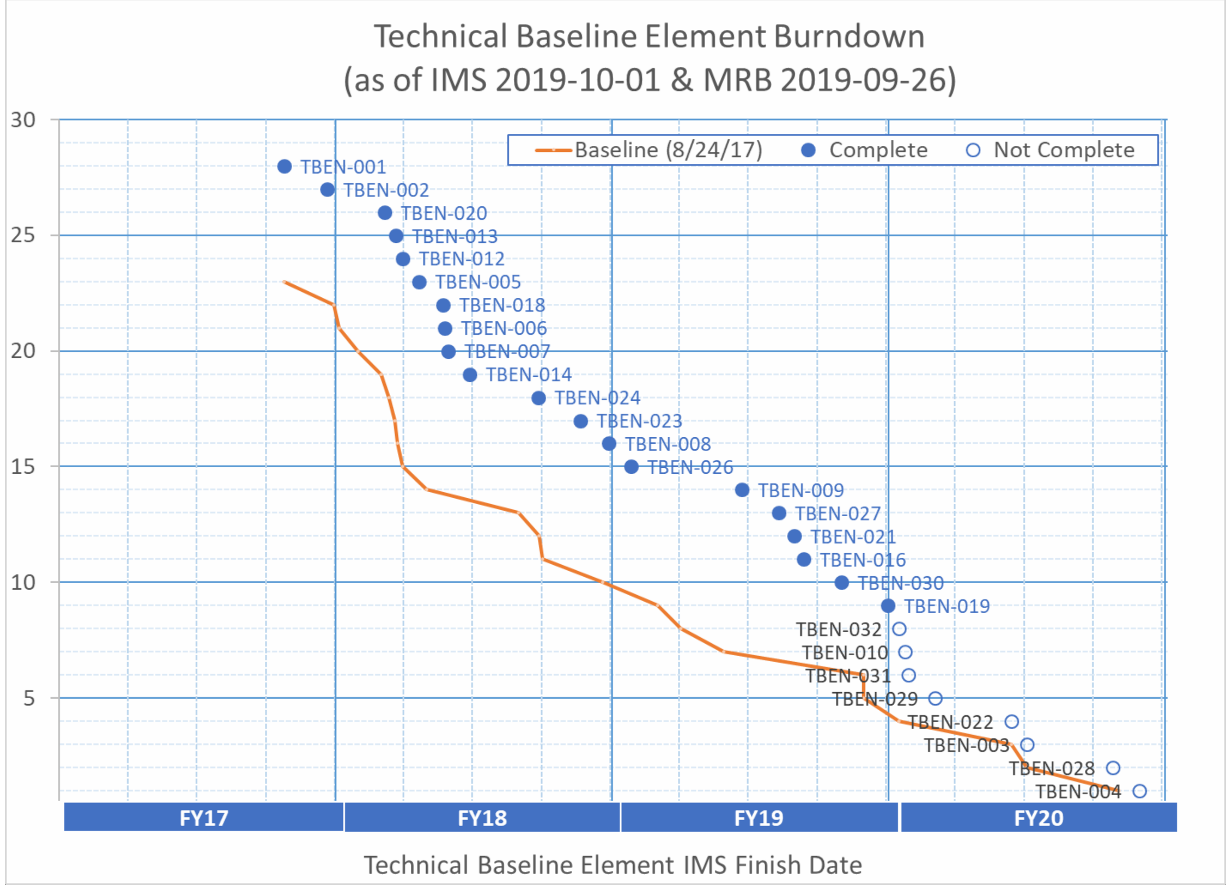
Resource Allocation FY19 Budget

- Data redacted

MRB Technical Baseline Summary
September 26, 2019

- August 22, 2019 MRB
  - No changes to Technical Baseline
- Technical Baseline Elements Completed Since August 22, 2019 MRB
  - TBEN-019 (ACAS Xu HITL 1)
- Technical Baseline Element Summary
  - 28 Approved
  - 20 Completed
  - 8 Open
- Technical Baseline document ready for Project Manager signature at today's MRB

TC	8/24/17 Baseline	Current MRB Approved Total	Total Completed	Total Remaining
C2	4	5	2	3
DAA	19	23	18	5
Total	23	28	20	8



FY19 Project Deliverables (1 of 3)

FY19 Project Deliverables	Technical Challenge	Date	Type of Deliverable
GBDAA Trade Space Study Final	TC-DAA	Oct-18	Report
Multi-UAS Control HITL Test Report	TC-ITE	Oct-18	Report
Linquest HPL-Performance Spec Final	TC-C2	Nov-18	Paper
C-Band SatCom System Conceptual Satellite Payload Design Complete	TC-C2	Nov-18	Brief
Evaluation of Ultem 1010 and Ultem 9085 3D printed Filaments for Radome Applications at 24.56Hz	TC-DAA	Dec-18	Report
V6 Terrestrial Based UAS Command and Control and Non-Payload Communications Generation	TC-C2	Dec-18	Report
Detect and Avoid Alerting performance with Limited Surveillance Volume for Non-Cooperative Aircraft	T-DAA	Jan-19	Report
Encounter-Based Simulation Architecture for Detect-and Avoid Modeling	TC-DAA	Feb-19	Report
UAM Communication ConOps	TC-C2	Feb-19	Report
Well Clear/Alerting Requirements: Results Dissemination to Fast-Time Simulation 2	TC-DAA	Mar-19	Briefing
Low Swap HITL Test Report	TC-IT&E	Mar-19	Report
FT6 Experiment Review	TC-DAA	Apr-19	Report
C-Band SatCom System Earth Station Design Complete	TC-C2	Apr-19	Report
Comparison of Two Terminal Area DAA Well Clear	TC-DAA	May-19	Report
Detect and Avoid System in the Context of Multiple unmanned Aircraft Systems Operations	TC-DAA	May-19	Report

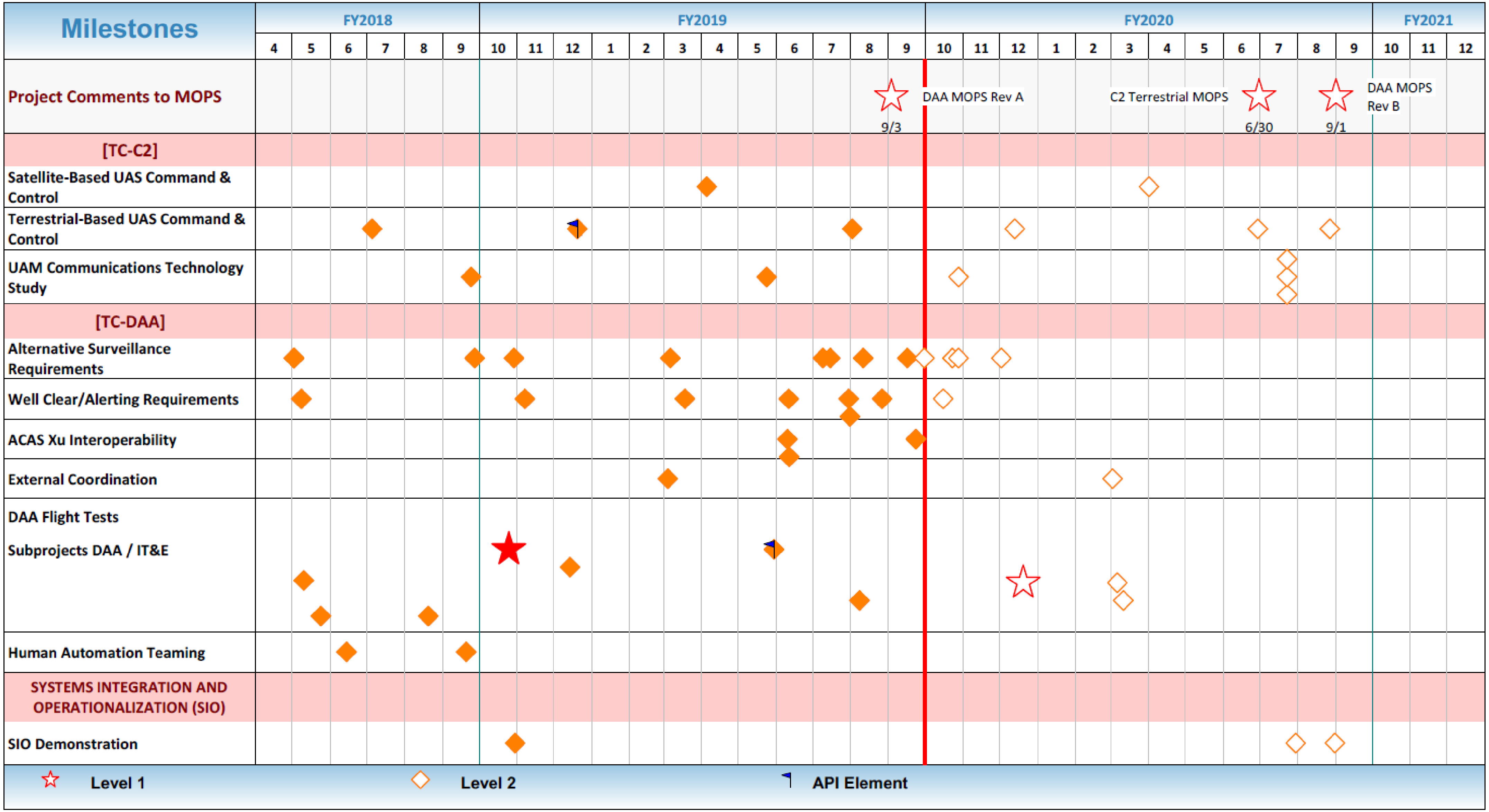
FY19 Project Deliverables (2 of 3)

FY19 Project Deliverables	Technical Challenge	Date	Type of Deliverable
Terminal operations HITL 2 (TOPS2)	TC-DAA	May-19	Brief
Low-SWaP Radar/DAA Flight Test Status	TC-DAA	May-19	Report
Deliver Baseline UAM C2 Seed Requirements	TC-C2	May-19	Brief
Urban Air Mobility Command, Control, and Communication Systems (C3) Seed Requirements	TC-C2	May-19	Report
Urban Air Mobility Command, Control, and Communication System (C3) Candidate Technologies & Components	TC-C2	May-19	Report
Urban Air Mobility Command, Control, and Communication Systems (C3) Standards	TC-C2	May-19	Report
Integrated Events: FT5 (Honeywell/Platform Astar Helicopter)	TC-DAA	May-19	Paper
Recommendation for Automation CA Execution and Return to Course Presented to SC-228	TC-DAA	May-19	Brief
LVC and Testbed Integration Using DDS Infrastructure	TC-IT&E	May-19	Paper
Bell Baseline Mission ConOps Document Complete	TC-SIO	May-19	Paper
Bell Baseline Risk-based Safety Assessment Document Complete	TC-SIO	Jun-19	Paper
Results Dissemination for Well Clear/Alerting Requirements HITL Sim 2	TC-DAA	Jun-19	Brief

FY19 Project Deliverables (3 of 3)

FY19 Project Deliverables	Technical Challenge	Date	Type of Deliverable
ACAS-Xu Run 5 Guidance Analysis Delivery of Results	TC-DAA	Jun-19	Paper
Terminal Area Test Vector Development	TC-DAA	Jun-19	Brief
Alternative Surveillance Fast Time Simulation with Sensor Uncertainties and Mitigation	TC-DAA	Jun-19	Brief
Hosted Satellite Payload Study Final	TC-C2	Jul-19	Report
Well Clear/Alerting Requirements: Delivery of Encounter Set to SC-228	TC-DAA	Jul-19	Brief
Results Dissemination for Well Clear/Alerting Requirements Engineering Analysis for Terminal Alert Times/Non-Hazard Zone	TC-DAA	Aug-19	Report
Results Dissemination for ACAS Xu HITL Sim 1	TC-DAA	Sep-19	Report
Alternative Surveillance: Low SWaP HITL 2 Start of Data Collection	TC-DAA	Sep-19	Report
Results Dissemination for ATC Interoperability HITL	TC-DAA	Sep-19	Report

Phase 2 Milestone Summary



Red Status Line Date 9/30/19

Project Office

Green Status Line Date 9/30/19

Ongoing UAS Activity

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Acronyms

A/A	Air-to-Air
ABDAA	Airborne Detect and Avoid
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
AJP	Spectrum Engineering Office-FAA Organization
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
ATAR	Air-to-Air Radar
ATC	Air Traffic Controller
ATM	Air Traffic Management
ATO	Air Traffic Organization-FAA Organization or Authority to Operate

Acronyms

AUS	UAS Integration Office-FAA Organization
AVS	Aviation Safety-FAA Organization
BLOS	Beyond Line of Sight
BRLOS	Beyond Radio Line of Sight
BUC	Block Up Converter
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
CC	Critical Commitment
CDR	Critical Design Review
CE	Chief Engineer
Cert	Certification
CFR	Code of Federal Regulation
CMB	Change Management Board
CNPC	Control and Non-Payload Communications
CNS	Communication, Navigation and Surveillance
COA	Certificate of Authorization or Waiver
Comm	Communications

Acronyms

CONOPS	Concept of Operations
COTS	Commercial off the Shelf
CRM	Continuous Risk Management
CS	Civil Servant
C&TA	Concepts & Transversal Activities
DAA	Detect and Avoid
DAIDALUS	Detect and Avoid Alerting Logic for Unmanned Systems
DAPA	Digital Active Phased Array
DDS	Data Distribution Services
DFW	Dallas Fort Worth
DMOD	Distance Modification
DoD	Department of Defense
DPM	Deputy Project Manager
DTA	DAA Terminal Area
DWC	Definition Well Clear
ECD	Expected Closure Date
EOY	End of Year
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
FDC	Flight Demonstration Capabilities
FRAC	Final Review and Comment

Acronyms

FT	Flight Test
FTE	Full Time Equivalent
FY	Fiscal Year
FYE	Fiscal Year End
GA	General Aviation or General Atomics
GA-ASI	General Atomics Aeronautical Systems Inc.
GBDAA	Ground Based Detect and Avoid
GBRS	Ground Based Radar System
G&C	Guidance and Control
GCS	Ground Control Station
Gen	Generation
GRC	Glenn Research Center
HALE	High Altitude Long Endurance
HAT	Human Autonomy Teaming
HF	Human Factors
HITL	Human-in-the-loop
HITS	Human in the System
HMD	Horizontal Missed Distance
HPL	Hosted Payload
HQ	Headquarters
HSI	Human Systems Integration

Acronyms

IASP	Integrated Aviation Systems Program
ICAO	International Civil Aviation Organization
IDIQ	Indefinite-Delivery, Indefinite-Quantity
IFL	Interfacility Link
IFR	Instrument Flight Rules
IMS	Integrated Master Schedule
IPP	Integration Pilot Program
IRP	Independent Review Panel
ITAR	International Traffic in Arms Regulations
IT&E or ITE	Integrated Test and Evaluation
ITU-R	International Telecommunication Union Radio Communication Sector
JADEM	Java Architecture for Detect and Avoid Extensibility and Modeling
JMP	Joint Management Plan
KDP	Key Decision Point
L1	Level 1
L2	Level 2
LaRC	Langley Research Center
lbs	Pounds
LITES II	Langley Research Center (LaRC) Information Technology Enhanced Services
LNA	Low Noise Amplifier
LOS	Line of Sight

Acronyms

LVC	Live Virtual Constructive
LVC-DE	Live Virtual Constructive-Distributed Environment
MAAP	Mid-Atlantic Aviation Partnership
MASPS	Minimum Aviation System Performance Standards
MOC	Mobile Operations Center
MOPS	Minimum Operational Performance Standards
MOU	Memorandum of Understanding
MPMB	Mission Portfolio Management Board
MRB	Management Review Board
MS&A	Modeling, Simulation, and Analysis
MSL	Mean Sea Level
MTSI	Modern Technologies Solutions Incorporated
N2	2nd upgrade to the original NASA Budgetary Structure
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASC	Navmar Applied Sciences Corporation
NCC	No Chase COA
NextGen	Next Generation
NMAC	Near Mid Air Collision
nmi	Nautical Mile
NRA	NASA Research Announcement

Acronyms

OBE	Overcome by Events
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
PO	Project Office
PP	Project Plan
PPBE	Planning Programming Budgeting and Execution
PRP	Performance Review Panel
PT6	Part Task 6
PUR	Pendleton UAS Range
RA	Resolution Advisory or Resource Analyst
RADAR	Radio Detection and Ranging
RF	Radio Frequency

Acronyms

RFI	Request for Information
RFP	Request for Proposal
RPAS	Remotely Piloted Aircraft Systems
RPS	Remote Pilot Station
RT	Research Theme
RTC	Return to Course
RTP	Research Transition Products
RTW	Remain Well Clear
RTT	Research Transition Team
SAA	Sense and Avoid or Space Act Agreement
SARP	Science and Research Panel
SARPs	Standards and Recommended Practices
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
SP	Schedule Package
SPM	Subproject Manager
SRR	Systems Requirements Review

Acronyms

SUM	Sensor Uncertainty Mitigation
SWaP	Size, Weight and Power
TB	Technical Baseline
TBD	To Be Determined
TBE	Technical Baseline Element
TBEN	Technical Baseline Element Number
TBR	To Be Refined
TC	Technical Challenge
TCAS	Traffic Alerting and Collision Avoidance System
THR	Threshold
TOPS	Terminal Operations
ToR	Terms of Reference
TRL	Technology Readiness Level
TSO	Technical Standard Order
TWP	Technical Work Package
TWTA	Traveling Wave Tube Amplifier
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

Acronyms

UCAT	Urban Air Mobility (UAM) Coordination Assessment Team
UTM	UAS Traffic Management
V	Version
VFR	Visual Flight Rules
VLL	Very Low Level
VLOS	Visual Line of Sight
VMOD	Vertical Missed Distance
Vs.	Versus
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