Unmanned Aircraft Systems (UAS) Traffic Management (UTM) Project

UTM Conflict Management

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UTM RTT

UTM Technical Interchange Meeting
February 23rd, 2021

Outline

- Overview of Sense and Avoid (SAA) UTM RTT Subgroup
  - Progression of the State of the Art
  - Overview of the Conflict Management Model
- Activities and Findings
- Future Work Considerations
- Summary and Impact
- Publications

UTM RTT SAA Subgroup

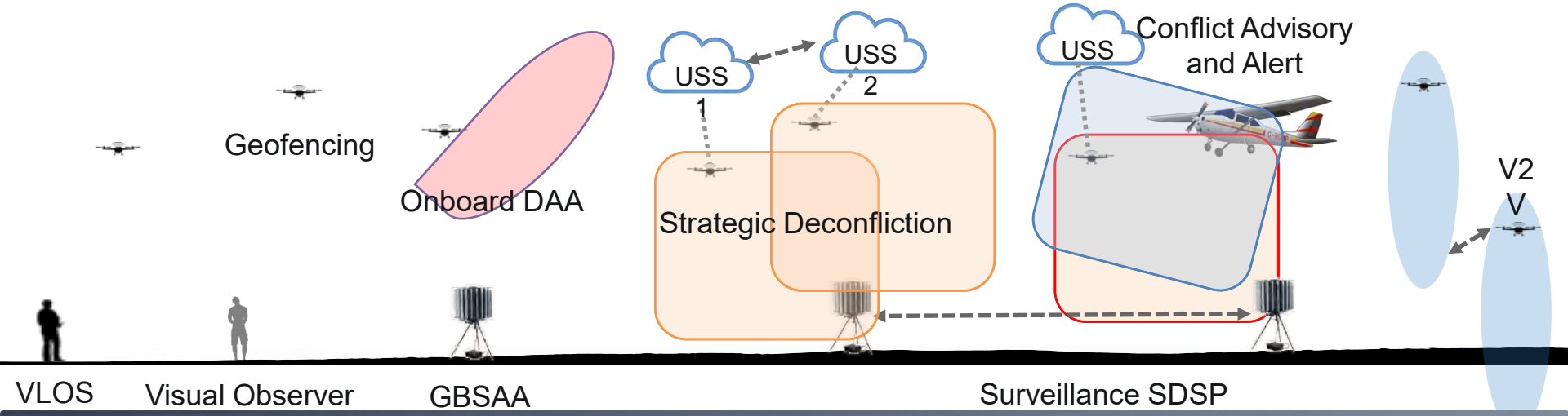
- The objective for this subgroup is to explore operator solutions to ensure that unmanned aircraft do not collide with other aircraft (unmanned [UA] or manned).
  - Scope was expanded to consider collision risk with ground and air hazards

- SAA subgroup kicked-off after TCL 1 concluded
  - 23 meetings including 3 joint meetings with the Communication and Navigation (C&N) subgroup
  - At peak more than 60 UTM community members interacted in the subgroup
  - Primary purpose was concept level discussion that informed the direction of NASA TCL evaluations, UPP evaluations and UTM ConOps

- One technical documentation package produced, associated with TCL 2, TCL 3, and TCL 4

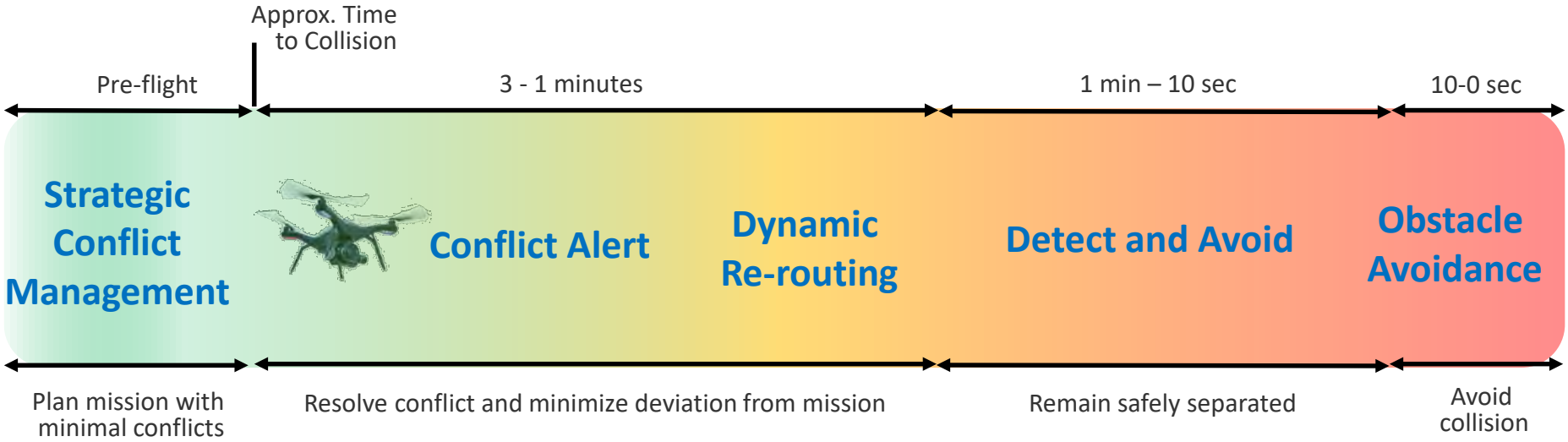
Progression of Conflict Management

- Small UAS have limited size, weight, and power
- Many detect and avoid technologies focuses on sensors or point solutions and do not holistically address collision risks to operations
- Integration, interoperability, and human factors tends to be an afterthought in development
- Completing a DAA system often falls on the UAS operator to “piece together” and test the necessary components to address the collision risk

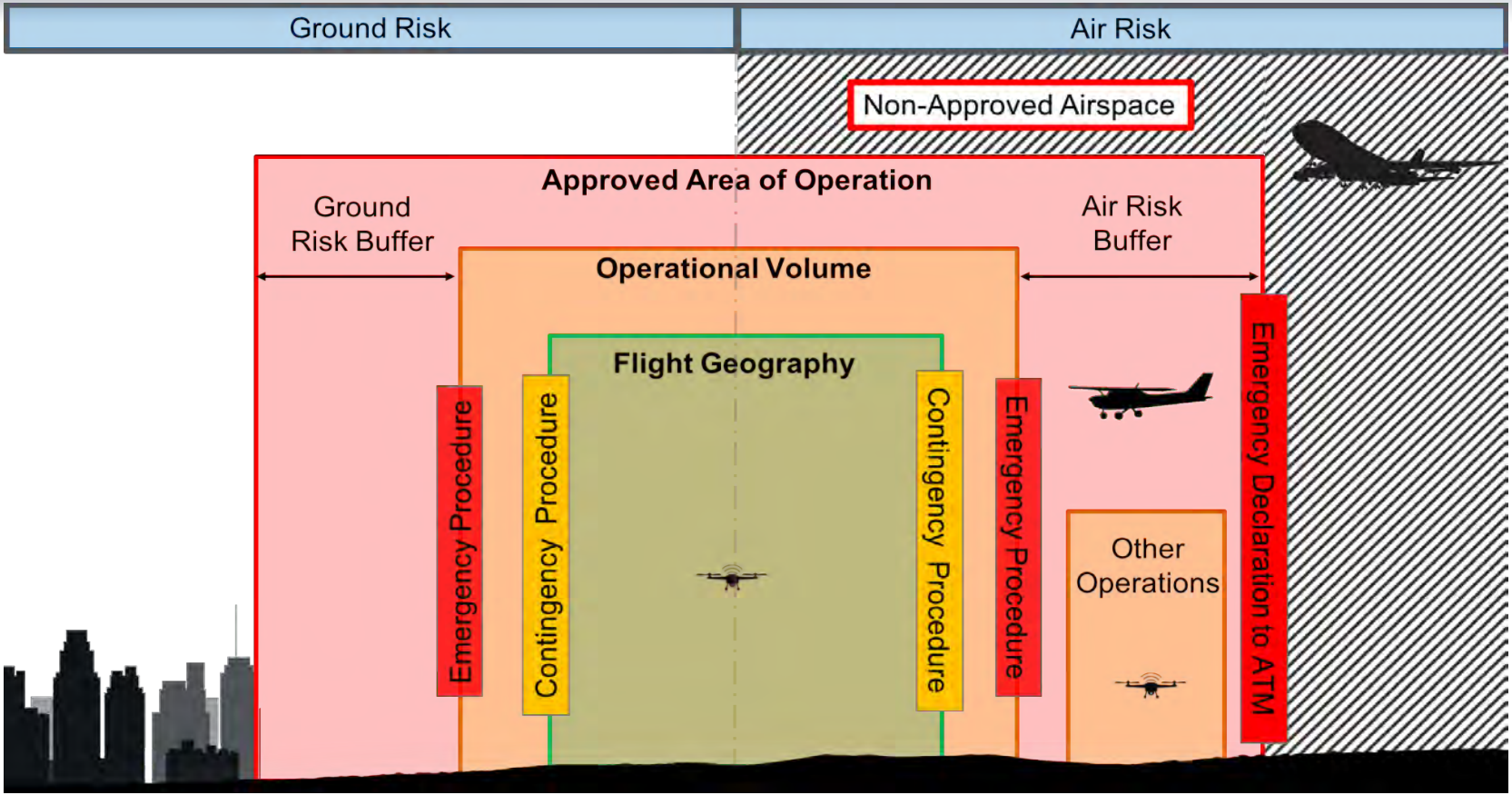


Desired State of UTM Conflict Management

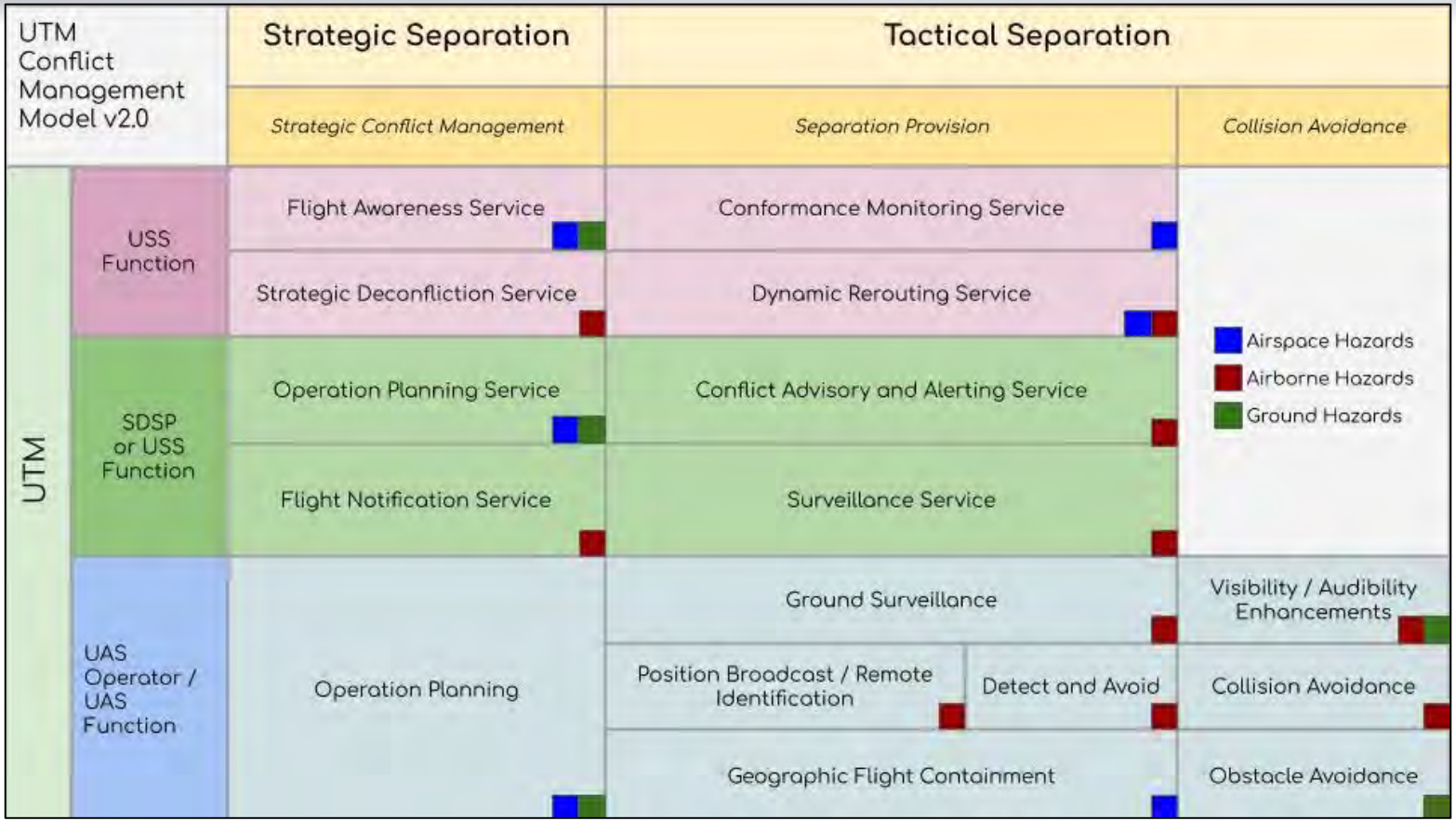
- Desired state is to treat conflict management mitigations as a continuum of independent and interoperable capabilities and services rather than disjoint sensors, algorithms, and functions
- Service and capabilities with overlapping time horizons and well understood objectives and ”sphere of control”
- Addresses air and ground hazards for transponding and non-transponding aircraft and static and dynamic obstacles while considering airspace constraints and other limitations

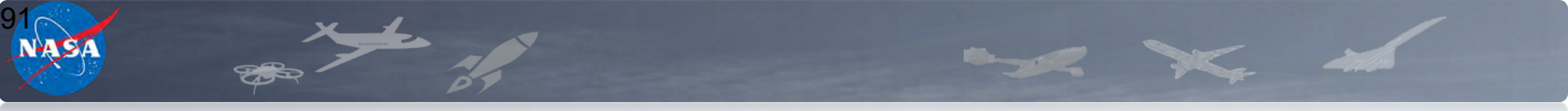


Contributing Hazards to Conflict Management in UTM



UTM Conflict Management Model





Conflict Management in the TCL Demonstrations

Risk Based Approach to Conflict Management

TCL1 (Remote)

- Visual Line of Sight
- Notice of Operation
- Position-Sharing (Optional)

TCL 2 (Rural)

- Beyond Visual Line of Sight
- Intent Sharing
- Strategic De-confliction
- Geographic Containment

TCL 3 (Suburban)

- Beyond Visual Line of Sight
- Intent Sharing
- Strategic De-confliction
- Geographic Containment
- Conflict Alert
- Detect and Avoid (DAA)
- Vehicle-to-Vehicle (V2V)

TCL 4 (Urban)

- Beyond Visual Line of Sight
- Intent Sharing
- Strategic De-confliction
- Geographic Containment
- Detect and Avoid (DAA)
- Vehicle-to-Vehicle (V2V)
- Obstacle Avoidance
- Dynamic Re-routing

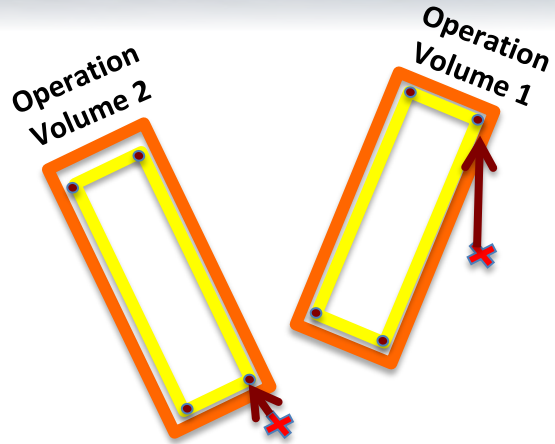
TCL 1 (August 2015)

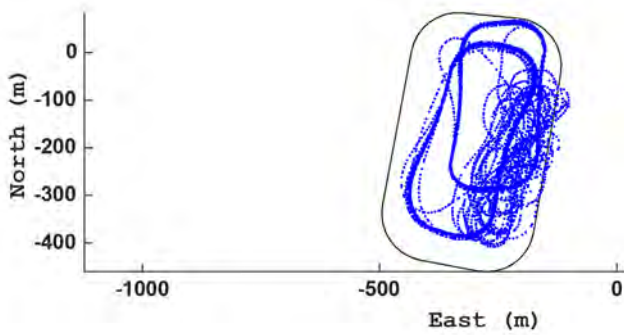
- **Conflict Management (CM) Approach:** Separation by Structure (Flight Notification)

- **Example CM Research Question:**
  - How well can a UA remain in its operational volume?

- **CM Lessons Learned:**
  - Lack of a common operating picture between UAS and UAS Operator and between UAS Operators resulted in overly conservative and undesirable behavior.
  - **Recommendation:** UTM will need to provide common strategic and tactical view of the airspace operations and conditions to the UAS Operator.

  - With varying atmospheric conditions and vehicle performance, UAS occasionally left operational volumes.
  - **Recommendation:** Operation Volumes should incorporate flight technical error, and atmospheric conditions. Additional mitigations are needed for aircraft geographic containment (e.g., conformance monitoring, geofencing, etc.)





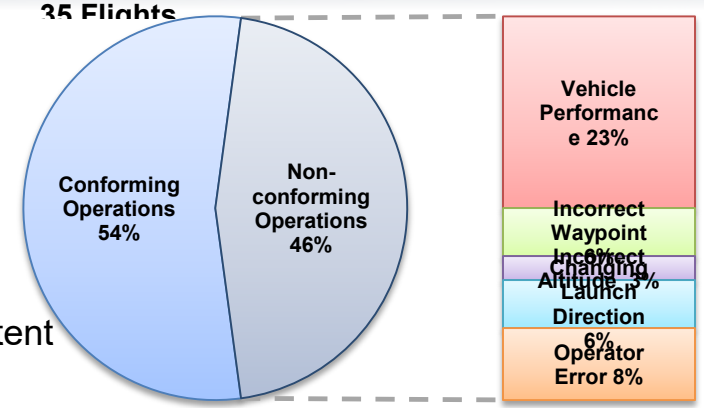
TCL 2 (October 2016 / May 2017)

- **Conflict Management (CM) Approach:** Strategic Deconfliction, Geographic Containment, & Conflict Advisory and Alert

- **Example CM Research Question:**
  - What key considerations for flying altitude stratified?

- **CM Lessons Learned:**
  - Measurement and reporting of vehicle altitude was not consistent among airspace users
  - **Recommendation:** Altitude reporting should be consistent or translatable across airspace users.

  - The sources of weather information for this flight test were inadequate to support BVLOS operations.
  - **Recommendation:** Initial routine BVLOS operations should not conduct altitude stratification unless there is accurate and timely information shared of the relative position of nearby UAS and improvements are made in the fidelity of the weather predictions along the flight path.

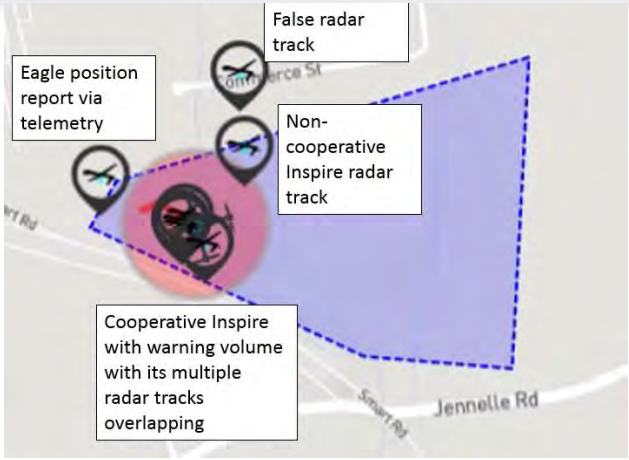


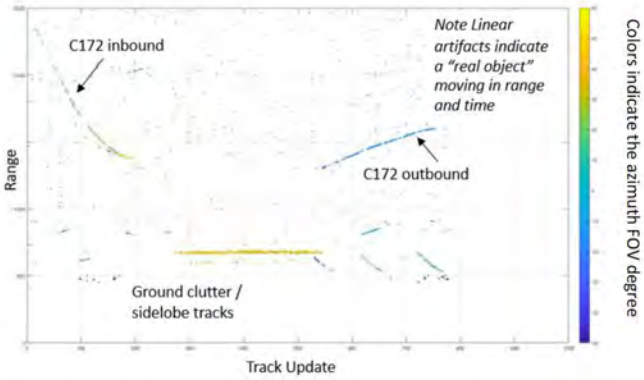
TCL 3 (May 2018)

- **Conflict Management (CM) Approach:** Strategic Deconfliction, Geographic Containment, & Conflict Advisory and Alert, DAA, V2V

- **Example CM Research Questions:**
  - Do onboard sensors have suitable performance to support conflict management?

- **CM Lessons Learned:**
  - Using airborne and ground radar to support separation showed that a low SWaP airborne radar does not provide sufficient range to support the recommended well clear definition, had high false alerts, and is better suited to support collision avoidance.
  - DSRC raised situation awareness and at close proximity (~.5 km or less) yields reliable data to support collision avoidance under slow closure rates
  - **Recommendation:** Testing multiple layered mitigations to address hazards resulted in a raised situation awareness and achieving the needed increased range of surveillance. Continued evaluation is needed to address the technology interoperability and the data fusion between tracking aircraft with multiple





TCL 4 (Summer 2019)

- **Conflict Management (CM) Approach:** Layered Conflict Management

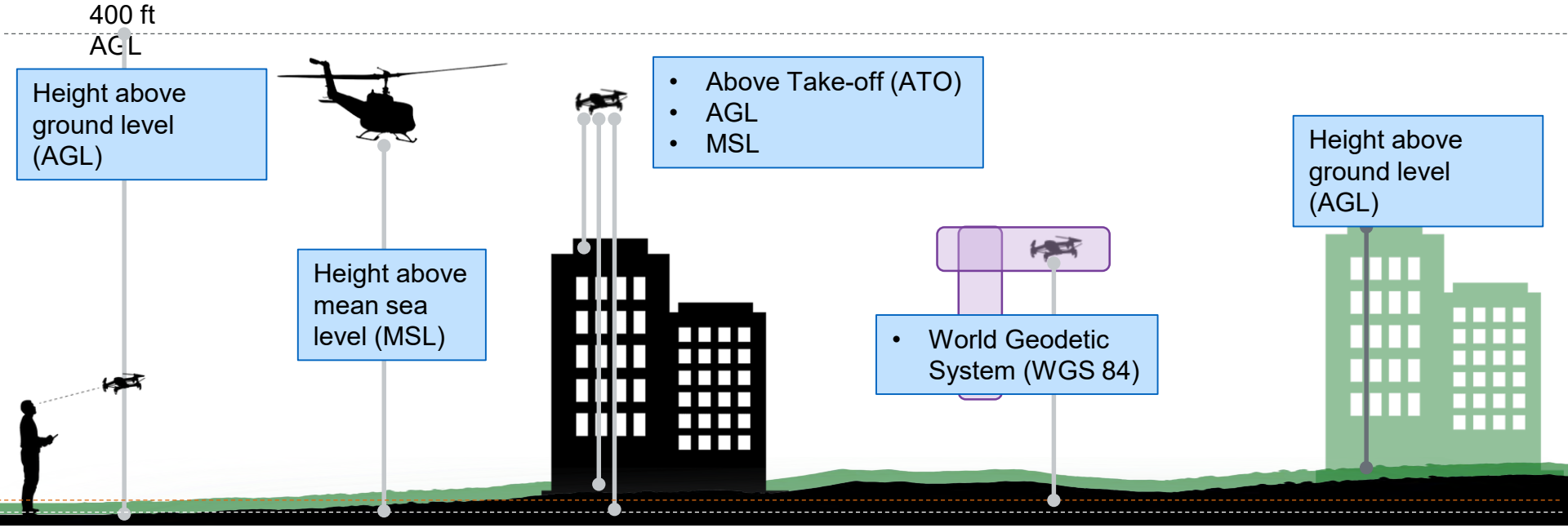
- **Example CM Research Questions:**
  - What factors impact conflict management in urban environments?

- **CM Lessons Learned:**
  - UAS and onboard mitigations lacked appropriate reliability. Single point failures of nominal systems (e.g., motors) or safety mitigation systems (e.g., parachute) created hazardous conditions for people on the ground
  - Urban environments contained numerous hazardous conditions:
    - Diverse micro-climates
    - High concentration of use of unlicensed RF (e.g., Wifi)
    - Multi-pathing and GPS degradation
  - **Recommendation:** Maturation of vehicle reliability, health monitoring, and contingency management systems (e.g., automated safe landing) are needed to support urban operations. UTM services can better support hazard awareness in urban

TCL 4 Testing at Reno, NV

TCL 4 Testing at Corpus Christi, TX

TCL 4 Return of the Altitude Issues



TCL 4 Return of the Altitude Issues

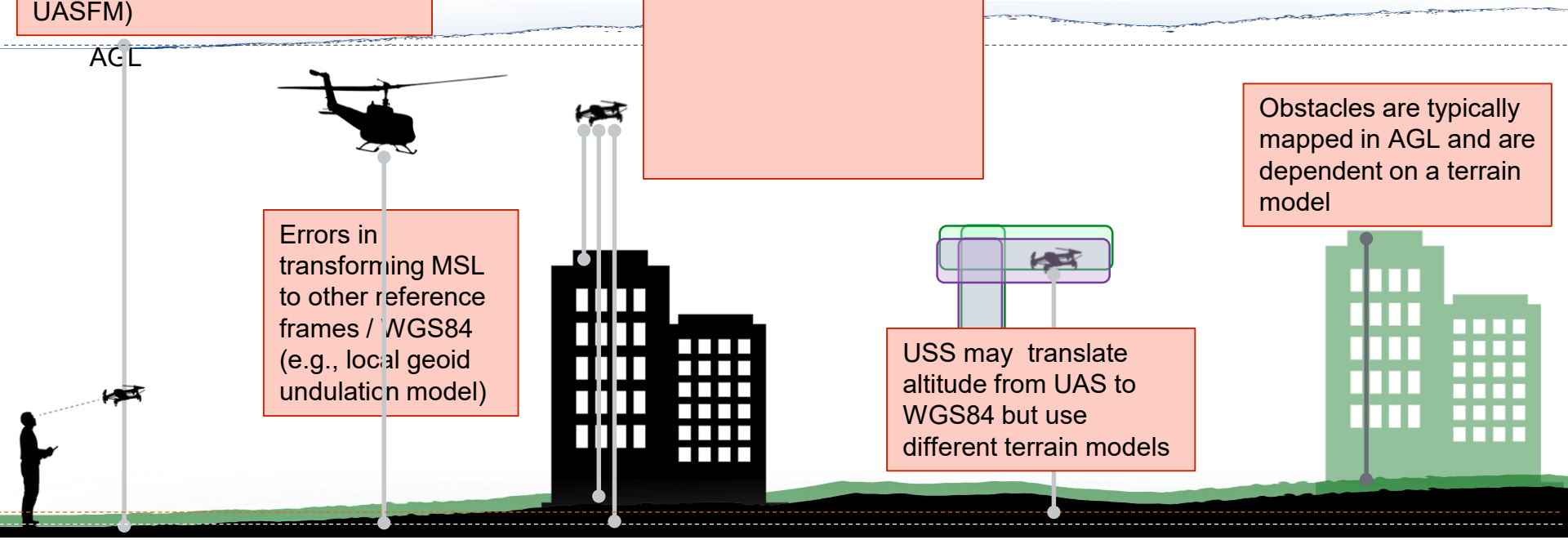
Airspace boundaries may not account for terrain (e.g., UASFM)

AGL

Errors in transforming MSL to other reference frames / WGS84 (e.g., local geoid undulation model)

Obstacles are typically mapped in AGL and are dependent on a terrain model

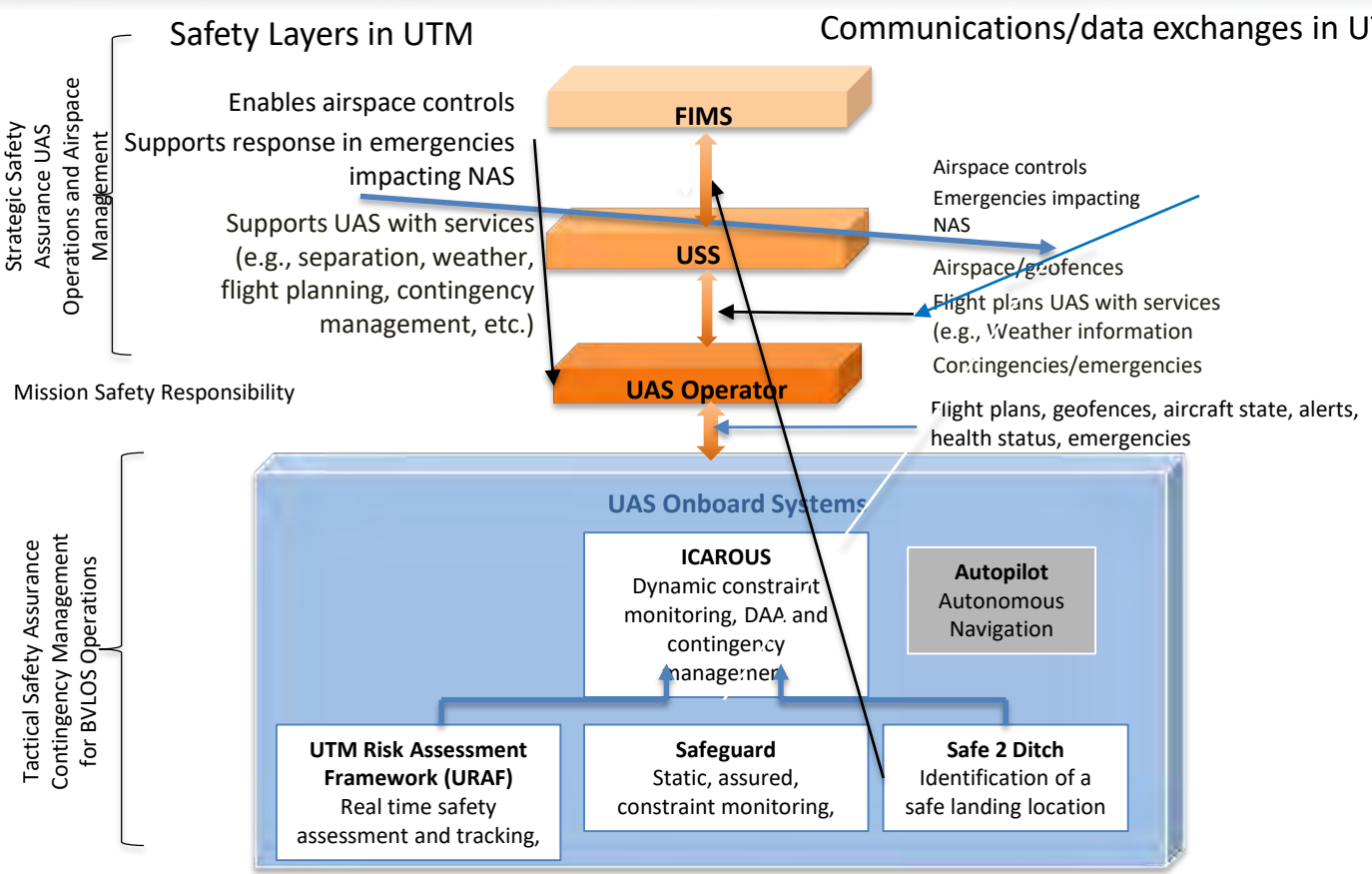
USS may translate altitude from UAS to WGS84 but use different terrain models



UASFM Alt | Manned Indicated Altitude | UAS Indicated Altitude | USS Operation Volume | Obstructions

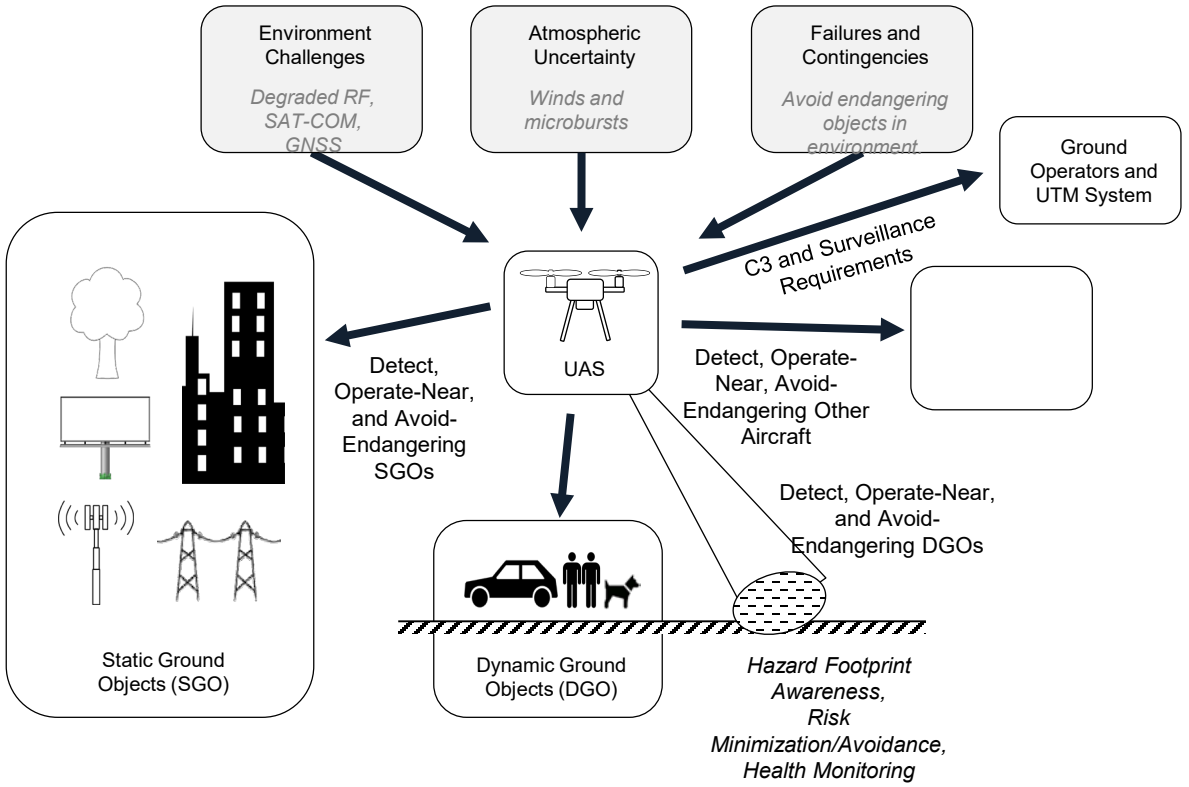
NASA Reference Technologies evaluating Conflict Management

DAA Reference Implementation



Vehicle Autonomy Requirements for Urban Operations (SAFE50)

- Focused on autonomy requirements necessary for TLC 4 operations in urban environments
- Urban operations challenges include:
  - Navigation
  - Communication
  - Situation awareness
  - Collision and Obstacle avoidance
  - Vehicle reliability and health monitoring
  - Risk management
- Conflict management mitigations must factor in constraints to be effective



Example Lessons Learned from NASA Testing

- **Transponder-based Technology:**
  - ADS-B-in using a micro-ADS-B receiver and Flight Alarm (FLARM) have adequate performance to support for airborne sense and avoid sUAS to cooperative aircraft (e.g., general aviation)
  - Low-power ADS-B also show promise for supporting sUAS and general aviation deconfliction
- **Conflict Resolution Algorithms:**
  - Algorithms included in ICAROUS provide well clear assurance for defined targets
    - Continuously translating targets
    - Dynamically maneuvering targets
- **Multi-sensor Data Fusion:**
  - Best practices should be developed for sensor fusion to support effective airborne sense and avoid
    - Observations of ghost tracks, split tracks, and DAA mitigations to incorrect target can have implications on unexpected behavior that could lead to collisions.
- **Non-Transponder-based Technology**:
  - Low-cost prototype airborne radars may be able to provide well clear assurance from GA and sUAS traffic but are susceptible to clutter and false targets
  - Electro-optical systems from low-cost high-resolution cameras can support effective image object detection and collision avoidance within limited range.
    - While the performance is adequate and can support DAA with manned aircraft (visibility permitting) the SWaP requirements were not as amenable for many sUAS platforms

Summary and Impact Of Work

Research

Research Transition Team Working Groups
- Sense and Avoid

Concept and Software Development
- UAS Service Supplier
- Supplemental Data Service Providers
- UAS Operator Client
- DAA Reference Implementation

Field Testing and Technology Evaluation
- TCL Field Demonstrations
- Targeted Technology Evaluations

Simulation and Analysis
- Urban Operations Studies

Products

Software Prototypes
- NASA USS
- UAS Operator Client

ICDs and APIs
- USS-USS Specification
- Weather and Surveillance SDSP ICD
- V2V Communication Specification

Concept Documents
- UTM CONOPS and Use Cases
- UTM Conflict Mitigation Model
- Hazard Identification and Analysis
- Requirements for Urban Operations

Reference Technology Implementations
- Integrated Detect and Avoid System

Outcomes

Fielded Systems
- FAA-NASA UTM Pilot Project and Operational Evaluation

UAS Rule Making
- UTM Implementation Plan

Industry Guidance and Standards
- ASTM DAA Standard
- ASTM UTM Specification
- ASTM Surveillance SDSP
- IEEE V2V Specification

International Harmonization
- JARUS Specific Operational Risk Assessment (e.g. UTM Annex)

Future Considerations

- **FAA and Industry**
  - FAA BEYOND program will focus on BVLOS and DAA/UTM requirements
  - Conflict management topics will be further developed in UTM Implementation plan and updates to the UTM CONOPS
  - ASTM and IEEE standards (UTM, DAA, Surveillance SDSP, V2V, etc.) will continue to evolve to consider interoperability between conflict management systems

- **NASA**
  - **Advanced Air Mobility High Density Vertiport Subproject** – conflict management near vertiport operations
  - **Scalable Traffic management for Emergency Response (STEReO) –** Layered conflict management in constrained disaster response scenarios (e.g., TFR for a wildfire)
  - **System Wide Safety** (In-time Safety Management Systems) – Integration of conflict management with health monitoring and UTM services (e.g., SDSPs)
  - **Air Traffic Management eXploration Urban Air Mobility** – Onboard / Service-based conflict management interoperability

Publications

- M. Johnson, J. Larrow, UAS Traffic Management Conflict Management Model. (https://utm.arc.nasa.gov/documents.shtml), June 2020.
- C. Ippolito, K. Krishnakumar. Concept of Operations Towards Fully Autonomous UAS Operations over Urban Environments. AIAA InfoTech@Aerospace, 2019.
- C Ippolito, K. Krishnakumar. An Autonomy Architecture for Autonomous Urban Environment Operations. AIAA InfoTech@Aerospace, 2019.
- Brendan Duffy, Swee Balachandran, María Consiglio, Louis Glaab, César Muñoz, Kyle Smalling, Nicholas Rymer, David Bradley, David Hare, Richard Grube, Matthew Coldsnow, Scott Sims, Jeffrey Hill, and Mahyar Malekpour, Sense and Avoid Characterization of the ICAROUS Architecture , Technical Memorandum, NASA/TM-2020-220591, May 2020.
- Brendan Duffy, Swee Balachandran, Andrew Peters, Kyle Smalling, María Consiglio, Louis Glaab, Andrew Moore, and César Muñoz, Onboard Autonomous Sense and Avoid of Non-Conforming Unmanned Aerial Systems, Proceedings of the 39th Digital Avionics Systems Conference (DASC 2020), Virtual Conference, US, 2020.
- Maria Consiglio, Brendan Duffy, Swee Balachandran, Louis Glaab, César Muñoz, Sense and Avoid Characterization of the Independent Configurable Architecture for Reliable Operations of Unmanned Systems. ATM2019, June 17-21, 2019, Vienna, Austria.

- See NASA UTM website for full list of publications: (https://utm.arc.nasa.gov/documents.shtml)