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

UTM Flight Testing at NASA LaRC

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Outline

• General objectives of the presentation
  – Provide insights
  – Lessons Learned
  – Describe next steps and follow-on work

• Characterization of UTM LaRC Flight Tests

• Review selected flight tests

• Summary

• List of
  – Team Members
  – Reports
  – Invention disclosures, licenses and patents
First live vehicle connected to the NASA UTM system 2015

Subsequent sUAS flight tests were performed to support an array of technical areas that included:

- Autonomous Detect/Sense and Avoid (ASAA, eg ICAROUS)
- Autonomous Contingency Management (ACM, eg Safe2Ditch)
- Vehicle to Vehicle (V2V) communication
- UTM traffic management system development and integration
- Assured range containment
- Autonomous powerline inspection
- Human Factors for UTM Operators
- Communication and Control (C2) links
- Degraded GPS
- Real-time ground risk assessment
- Autonomous merging and spacing
- Failure Modes Effects and Criticality Analysis (FMECA)

Integrated UTM TCL-4 Pathfinder test performed in 2019

- Provided integrated system evaluation
- ACM, ASAA, V2V, UTM traffic management system
- Human Factors assessment

ICAROUS: Integrated Configurable Architecture for Reliable Operation of Unmanned Systems
**Objectives**

1. Evaluate use of micro ADS-B receiver to provide ADS-B-in
2. Evaluate the utility of using ADS-B-in to provide effective sUAS autonomous traffic deconfliction
   - sUAS to sUAS
   - sUAS to general aviation (GA) aircraft
3. Assess performance of ICAROUS system to deconflict traffic
4. Assess effectiveness of reduced-power ADS-B for sUAS applications
5. Assess the well “clear definition” for sUAS
6. Acquire high-res, position-correlated video of sUAS and manned aircraft
   - Used to develop optical-based traffic detection algorithms

**Results**

1. Micro ADS-B unit provides effective input
   - Ghost targets observed due to Mode-C transponder rebroadcast
2. ICAROUS able to maintain well clear (2,000ft)
3. Low-power ADS-B feasible (~400mW vs 40W)
4. Low-cost/high-res cameras can support well-clear optical DAA (Sony Action cams)
UTM Safe2Ditch Testing

• Objectives
  – Perform efficacy testing of ACM concept
  – Assess autonomous machine vision verification of ditch site
  – Demonstrate autonomous re-routing based on ditch site state
  – Evaluate integration of S2D/ACM with overall system

• Results
  – ACM functions on sUAS can greatly mitigate ground risk
  – COTS cameras combined with state-of-the-art micro computers and algorithms enables autonomous ditch site verification
  – Geolocation of ground targets is adequate
    • Improved geolocation could support smaller ditch site usage
  – Integration of S2D with ICAROUS tested
    • Ditch site top of descent provided by S2D
    • ICAROUS provided route
    • Included geofencing around other vehicle’s airspace
• Objectives
  1. Characterize performance of a prototype commercially available sUAS airborne radar to detect and track sUAS as well as General Aviation (GA) non-cooperative aircraft
  2. Integrate radar output into ICAROUS and evaluate non-cooperative autonomous sense and avoid scenarios

• Results
  – Collaborative flight testing performed with Mid-Atlantic Aviation Partnership (MAAP)
    • MAAP BFD multi-rotor ownership
    • Liberty University C-172
    • NASA ICAROUS software and Tempest sUAS
    • Used Kentland Farms MAAP test site
  – Prototype radar able to detect and track targets most of the time
  – Substantial background clutter issues were observed
  – Prototype radar: Echodyne Echoflight radar
Objective: Flight test effort aimed at developing and assessing technologies essential for UTM operations
- Dedicated Short Range Communication (DSRC) V2V comm links
- Evaluation of 4G cellular to provide command and control for sUAS
- Collection of high-res position-correlated video for optical sense and avoid development (secondary)
- Fixed wing evaluation of Safeguard (secondary)

Results
- DSRC effective range is limited to less than a 1km as tested
  - High frequency (5.9 GHz) and low-power (26 dB)
- 4G cell comm is effective with some short-duration drop-outs
  - Tested in rural area
  - No link ~3% of the time
- Sony action cams sensors/lenses can enable effective optical detect and avoid
  - Overall system weight still a challenge for full 360 deg coverage
- Safeguard functioned adequately at fixed-wing speeds (20 m/s)
UTM TCL-4 Pathfinder

**Objectives**

1. ICAROUS/S2D contingency management and effects on UTM system
   - Evaluate Ground Control Station (GCS) operator situational awareness, workload, reactions to contingency operations using representative UTM interface
   - Assess the effect of Autonomous Sense and Avoid (ASAA)
   - Evaluate effect of airspace-constrained contingency management (ICAROUS routing/re-routing)
   - With high-density operations (simulated aircraft)
2. Evaluate Flight Alarm (FLARM) for sUAS ASAA
3. Long range cross-center operations
4. Botlink 4G characteristic data

**Results**

- FLARM is effective for sUAS ASAA
- ICAROUS can effectively perform sUAS traffic separation
- Human separation of sUAS traffic is a monotonous task
- HF results indicate vehicle intent is highly-desirable
Summary

• Insights
  – Many challenges exist towards ubiquitous sUAS operations
  – Both for on-ground and airborne aspects
  – The UTM project achieved progress in both
  – Fully-operational sUAS transportation system is required before UAM

• Lessons Learned
  – Separate technology development and testing is effective
  – Integration and testing of technologies is difficult
  – Integrated testing has extremely high value

• Next Steps
  – STEReO: Application of UTM technologies for disaster response
  – AAM HDV
    • Prototype UAM system development and test
    • Leverage technologies from UTM/SWS/ATM-X/TTT
    • Enable effective management of off-nominal scenarios
    • Coordination of dynamic re-routes throughout the UAM system
    • Operational credit for NASA/other technologies
    • sUAS Part-135 BVLOS advancement
# List of LaRC personnel

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List of additional 2020 reports


List of additional 2017, 2018 and 2019 reports

- 2019

- 2018

- 2017
  - Marco A. Feliú, Camilo Rocha, and Swee Balachandran. Verification-driven Development of ICAROUS Based on Automatic Reachability Analysis, International SPIN Symposium on Model Checking of Software (SPIN 2017), Santa Barbara, CA, USA, July 2017
Invention Disclosures, Licenses, and Patents

• Invention Disclosures and Open Source Releases

• Patents
  – Safe2Ditch: US Patent #10,403,153
• General objectives of the presentation
  – Provide insights
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