National Aeronautics and Space Administration

Effectiveness of Redundant Communications Systems in Maintaining Operational Control of Small Unmanned Aircraft

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UAS Traffic Management (UTM) Project

Outline

- NASA's Unmanned Aircraft System Traffic Management (UTM) progress
- Communications system test description
- Test reports summary
- Recommendations for urban operations

Unmanned Aircraft System Traffic Management (UTM)

- 3.9 million small Unmanned Aircraft System (UAS) by 2022
- UTM: air traffic management ecosystem for small UAS in low-altitude
- Complements FAA's air traffic management services

UTM Research Transition Team

- NASA, the FAA, and Industry coordination
  - Operational Concept and Scenario
  - Data Exchange and Information Architecture
  - Sense and Avoid
  - Communication and Navigation
- NASA conducting research to explore UTM capabilities that will accommodate rulemaking

UAS Traffic Management (UTM)

Research Transition Team (RTT) Plan

FAA and NASA collaborative efforts planned through September 2020

January 31, 2017

Parimal Kopardekar
NASA Ames Research Center
NASA Senior Technologist for Air Transportation System, and
Principal Investigator, Unmanned Aerial Systems Traffic Management (UTM)
UTM RTT Co-Lead

Date 3/2/17

Steve Bradford
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Date 3/3/17

UTM Progress

Technical Capability Level (TCL) 1: *multiple Visual Line of Sight (VLOS)*

UTM Progress

TCL1: *multiple VLOS*

TCL2: *multiple Beyond VLOS (BVLOS), sparsely populated area*

UTM Progress

TCL1: *multiple VLOS*

TCL2: *multiple BVLOS, sparsely populated area*

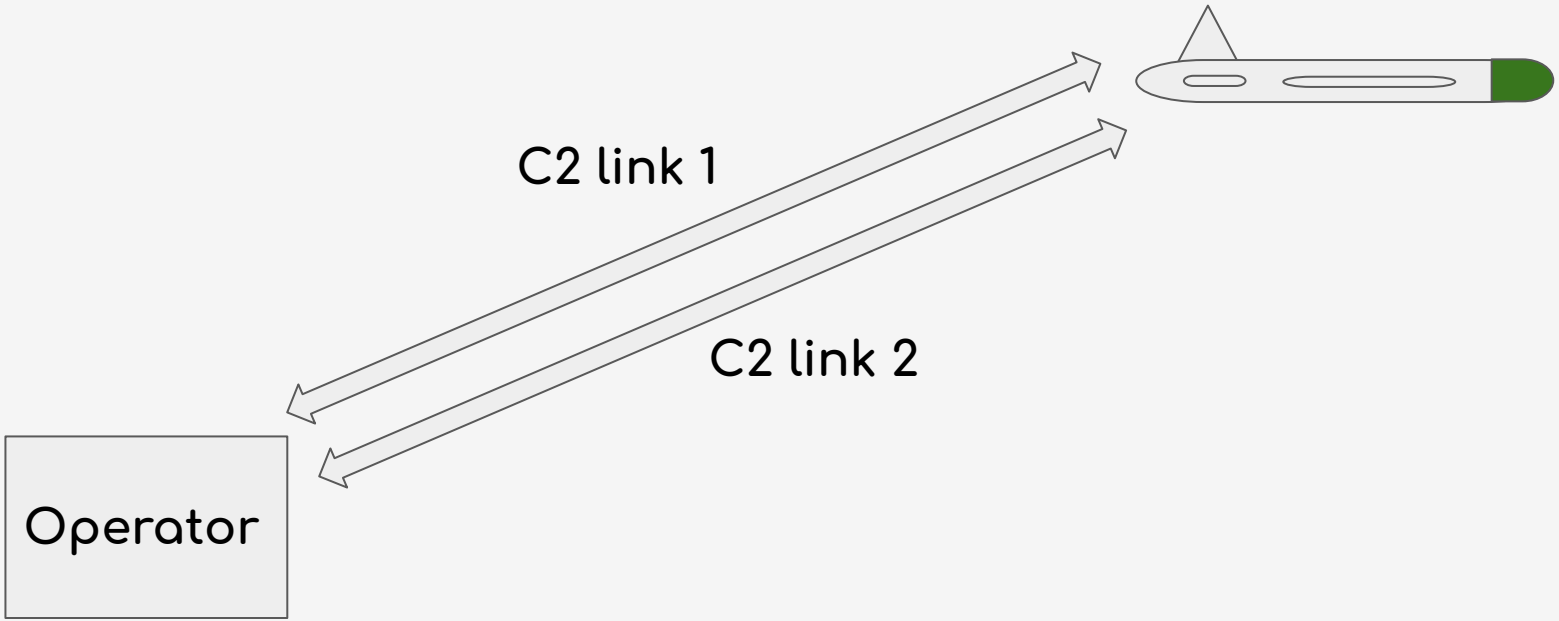
TCL3: *multiple BVLOS, moderately populated area*

Test Description

- Command and Control (C2) communications system: necessary to maintain operational control of UA
- Designed to evaluate effectiveness of redundant C2 communications system
- Four FAA-designated UAS test sites conducted the test during TCL3: Alaska, Nevada, New York, and North Dakota
- Test Site Operator to use redundancy configurations of their own choosing

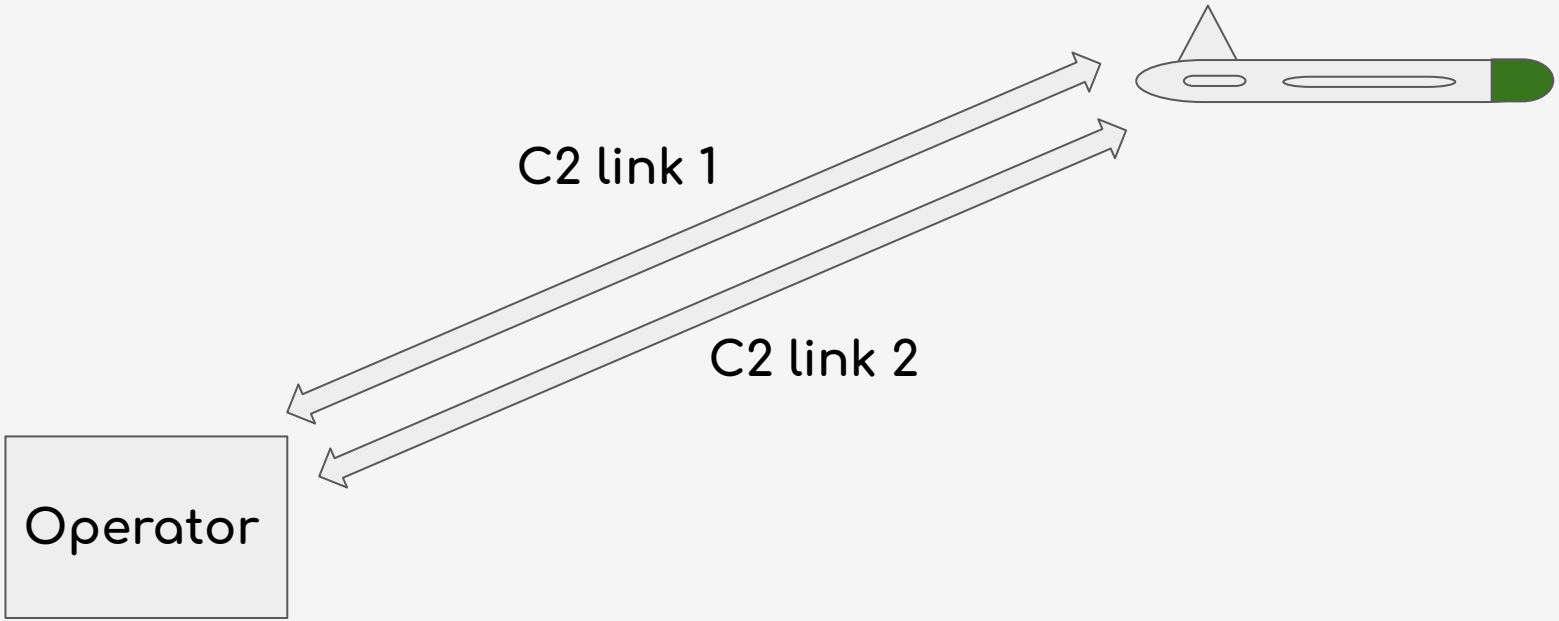
Test Instruction

1. Equip small UAS with more than one C2 communications system



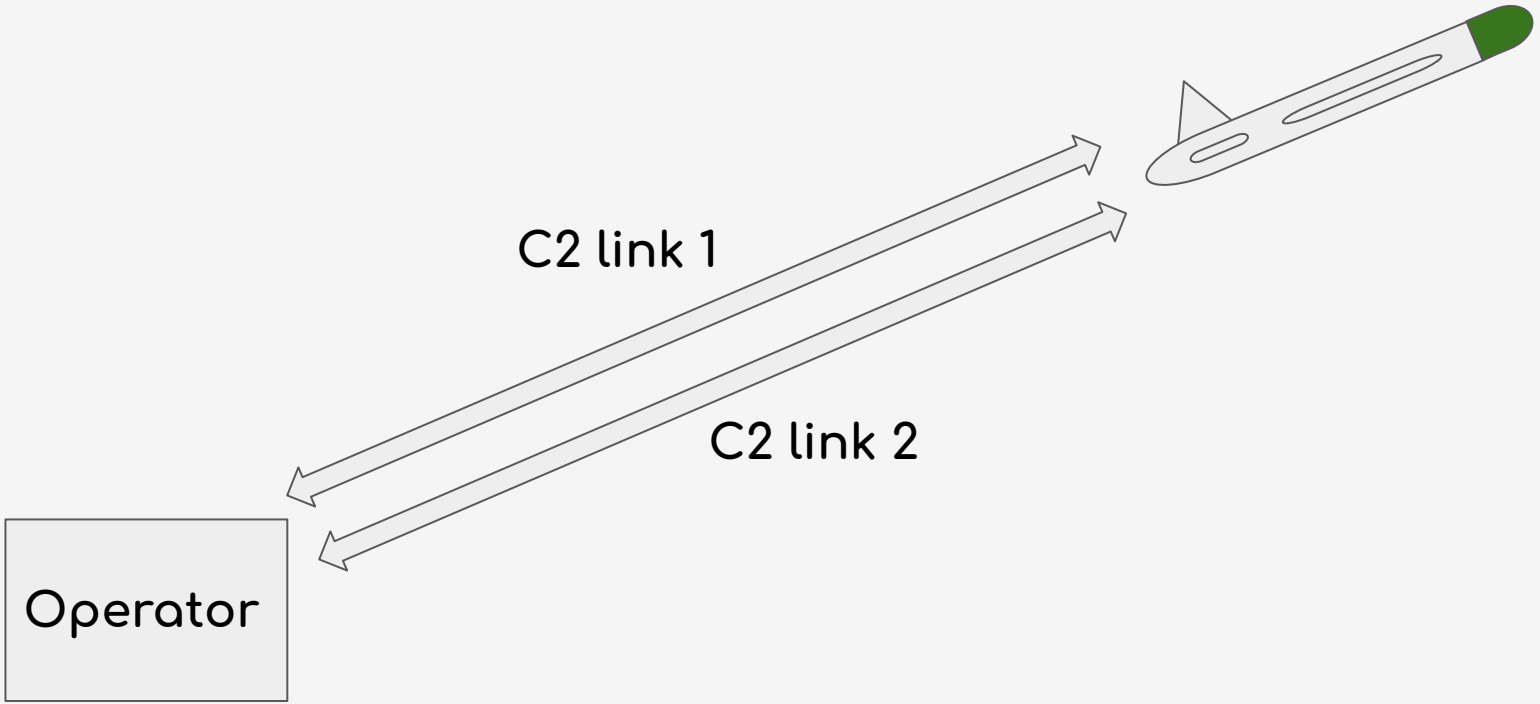
Test Instruction

2. Prepare a maneuver command (e.g. climb)



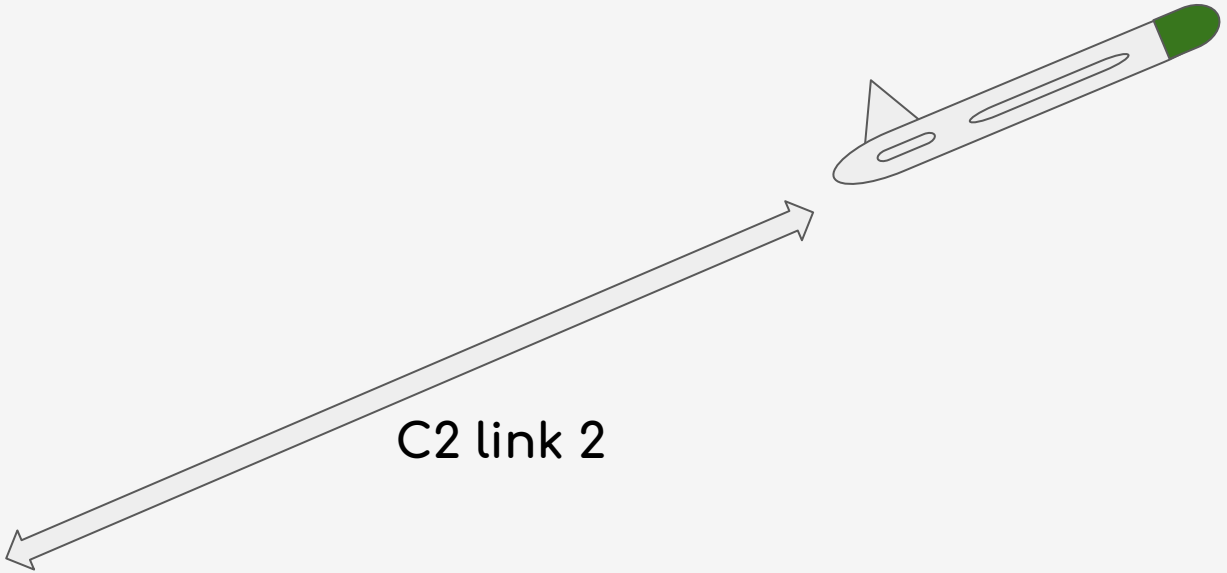
Test Instruction

3. Send the command and confirm execution



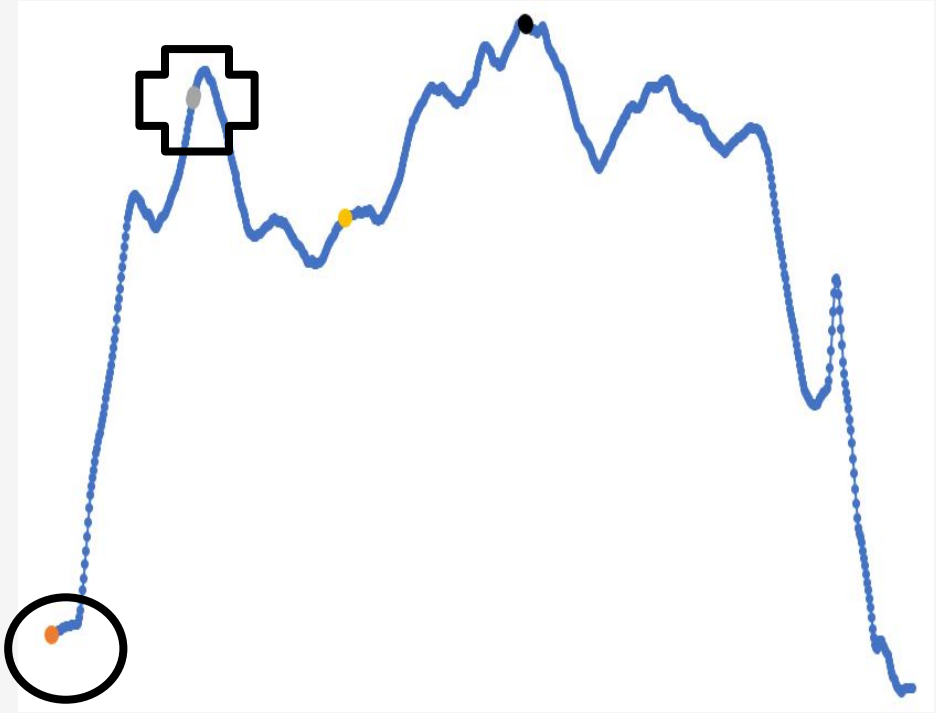
Test Instruction

4. Take one C2 system off-line and repeat #3

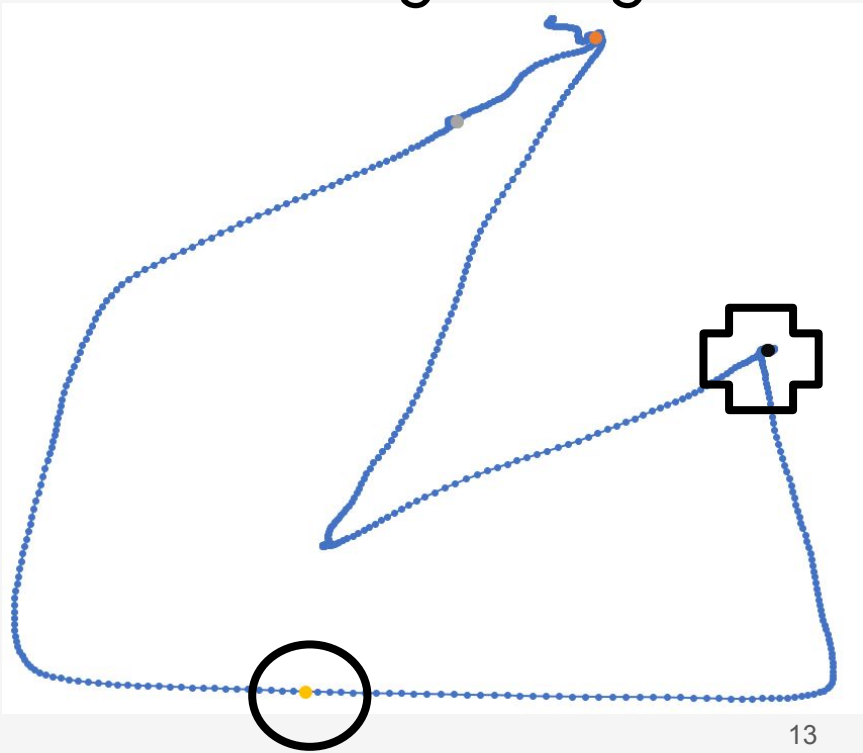


Example UA Track & Maneuver Command

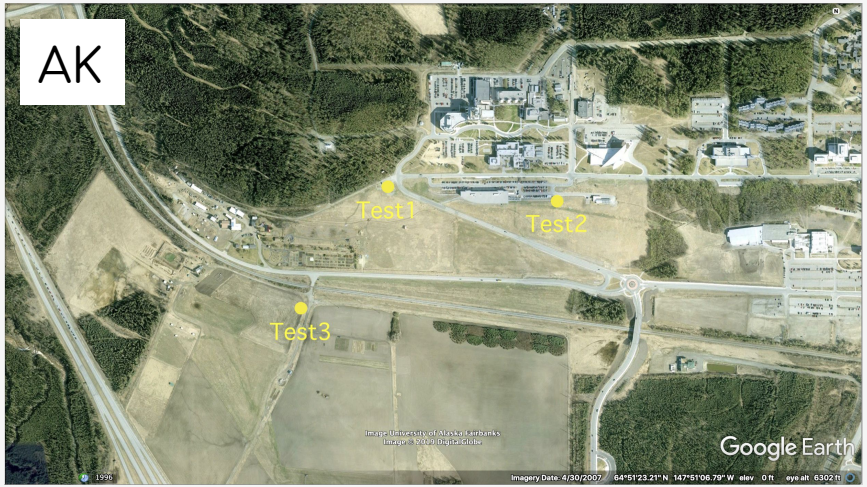
First maneuver: climb

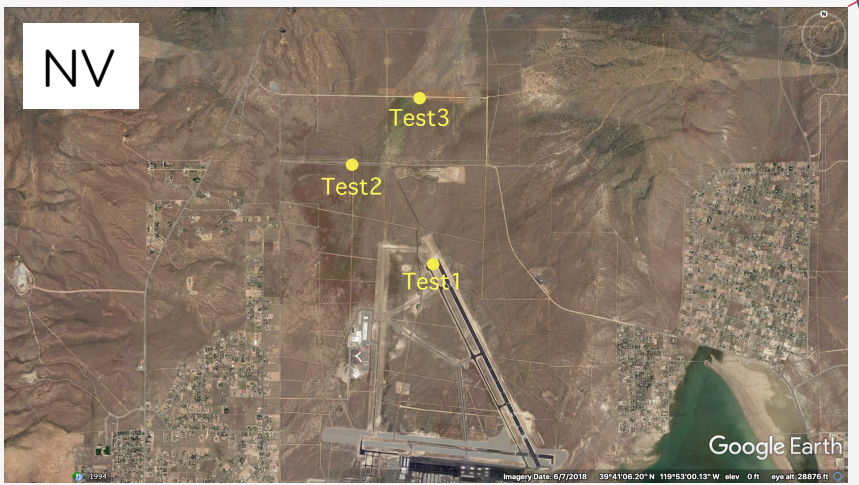


Second maneuver: heading change



Test Locations





Test UAS & Communications Technology

- UAS (7 total)
  - 2 quadcopters
  - 2 fixed-wings
  - 1 hexacopter
  - 1 octocopter
  - 1 helicopter
- Communications technologies
  - Radio modem
  - Wi-Fi
  - Long Term Evolution cellular (LTE)
  - Satellite communication (SatCom)

Redundancy Configurations

Test site	AK	AK	NV	ND	ND	NY	ND
UAS	Quad copter	Quad copter	Fixed wing	Fixed wing	Hexa copter	Octo copter	Heli copter
Comm. system 1	Radio	LTE	Radio	Radio	LTE	Wi-Fi	Radio
Comm. system 2	Radio	Radio	Radio	SatCom	Radio	LTE	Radio

Test Execution and Remarks

Test Site	Transition to redundant communications system	Test Site Operator remark
AK	1) one radio manually disconnected, 2) LTE link failed without intervention	Both cases having a secondary C2 improved reliability in maintaining the operator control
NV	One radio signal turned off	The operator was able to maintain control with transition
NY	UA flown outside Wi-Fi range	No issues occurred, the operator maintained control
ND	1) one radio manually disconnected, 2) UA flown outside radio range	The operator's control of UA maintained

UTM Next Step

TCL1: *multiple VLOS*

TCL2: *multiple BVLOS, sparsely populated area*

TCL3: *multiple BVLOS, moderately populated area*

TCL4: *high density BVLOS, urban area*

"wi-fi" is licensed under CC0 1.0

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Recommendation for Urban Operations

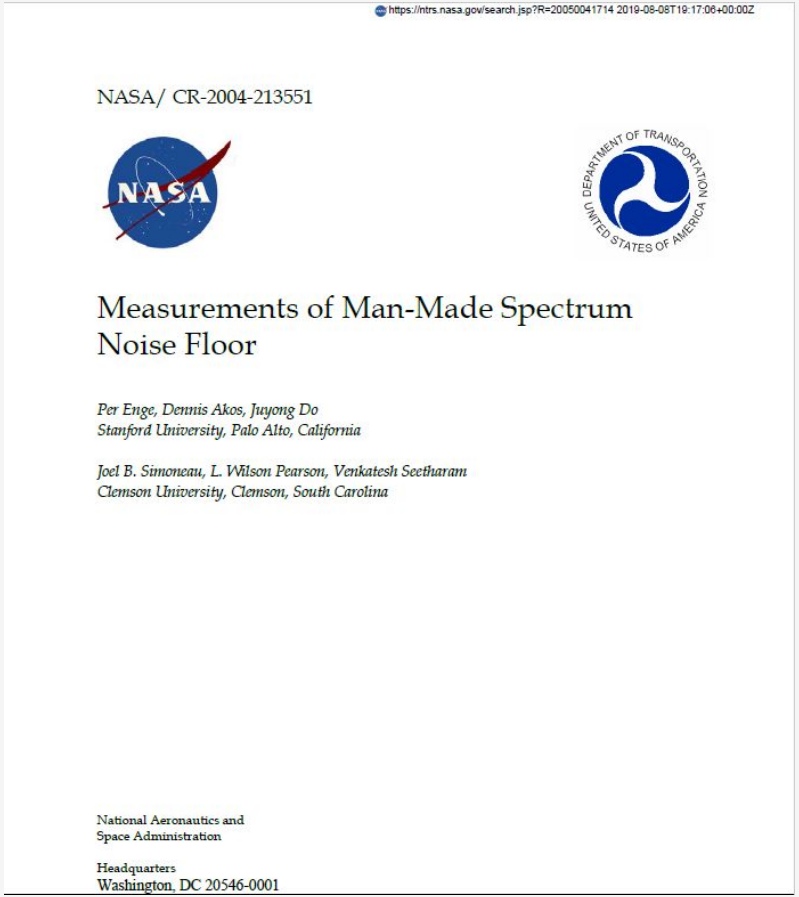
1. Do not use C2 systems that use the Industrial, Scientific, and Medical (ISM) radio bands for redundancy

Tested Redundancy Configuration

UAS	Quad copter	Quad copter	Fixed wing	Fixed wing	Hexa copter	Octo copter	Heli copter
Comm. system 1	Radio	LTE	Radio	Radio	LTE	Wi-Fi	Radio
Comm. system 2	Radio	Radio	Radio	SatCom	Radio	LTE	Radio

Recommendation for Urban Operations

2. Verify the RF characteristics of operation area and examine the radio interference level during operation



NASA/ CR-2004-213551

Measurements of Man-Made Spectrum Noise Floor

Per Enge, Dennis Akos, Juyong Do
Stanford University, Palo Alto, California

Joel B. Simoneau, L. Wilson Pearson, Venkatesh Seetharam
Clemson University, Clemson, South Carolina

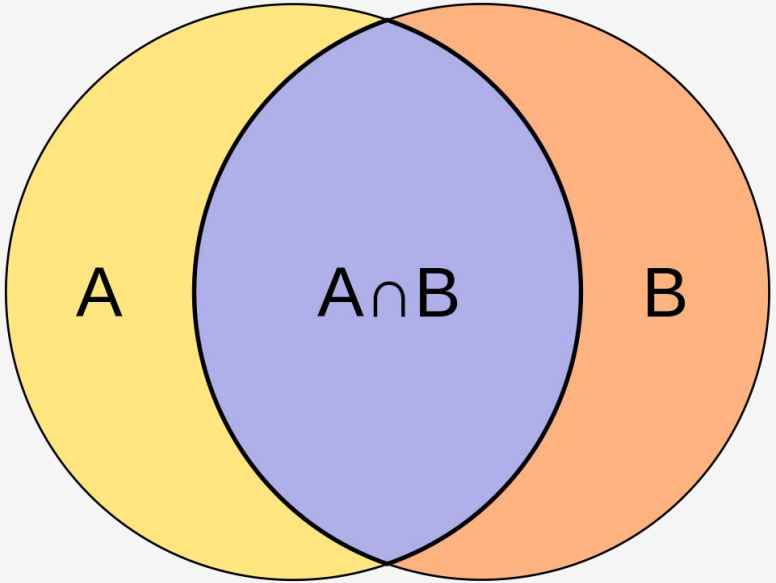
National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

Recommendation for Urban Operations

3. Monitor availability, quality, and reliability of communications service used by the redundant system

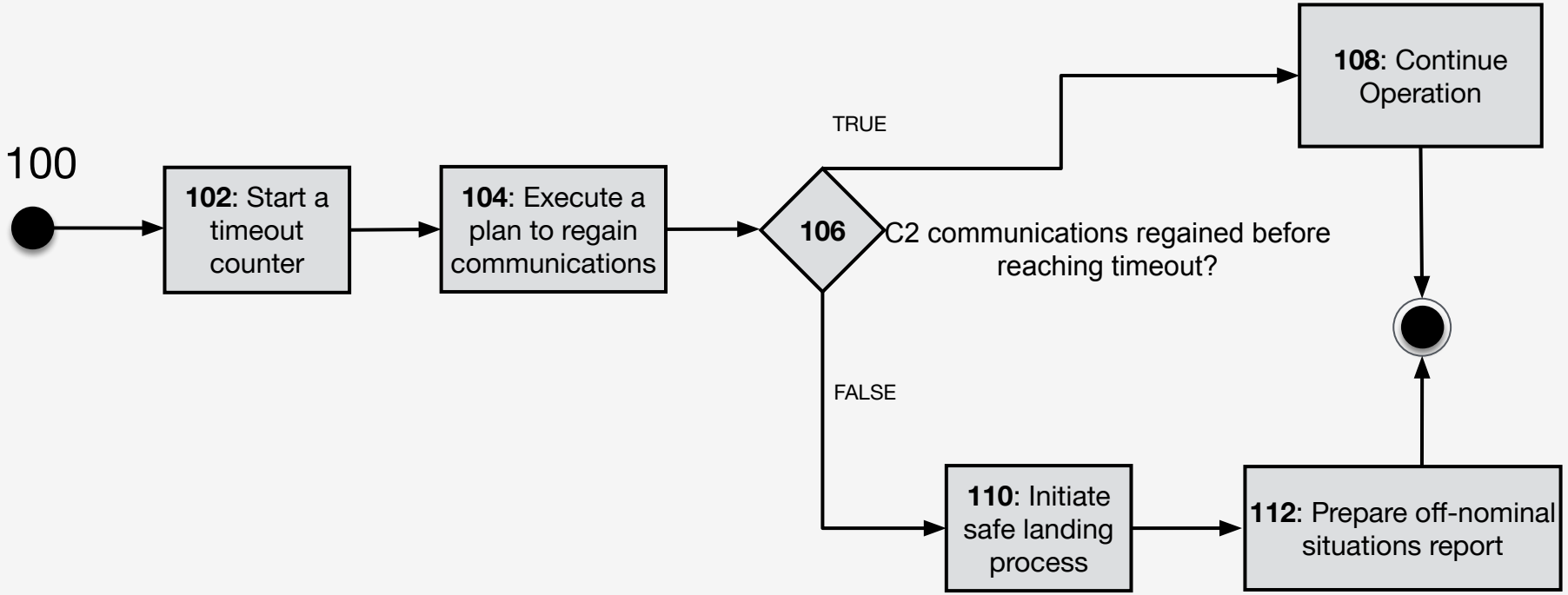
- Know before operation
  - Minimum data transfer rate
  - Maximum tolerable latency
- Monitor
  - Data transfer rate
  - Latency



The intersection of two sets in a Venn diagram, by Stephan Kulla, the Creative Commons CC0 1.0 Universal Public Domain Dedication

Recommendation for Urban Operations

4. Adopt a standard set of contingency steps to manage the loss of C2 in a consistent manner



Conclusion

- Tested redundant C2 communications system effective in maintaining operational control of sUAS over moderately populated area
- Operators must prepare C2 communications system that reflects urban environment
- The insights from the test to support the FAA's UAS integration effort