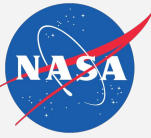




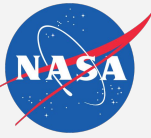
Initial Approach to Collect Small Unmanned Aircraft System Off-nominal Operational Situations Data

Jaewoo Jung, Charles Drew, Sreeja Nag, Edgar Torres, Abraham Ishihara, Minh Do, and Hemil Modi

Outline



- Why collect Unmanned Aircraft System (UAS) off-nominal operational situations data
- NASA UAS Traffic Management (UTM) project's off-nominal data collection approach
- What were collected
- Findings
- Next steps



Russian postal drone crashes into wall on maiden flight

<https://tinyurl.com/yaefsunb>

Major League Baseball responds after drone makes crash landing during San Diego Padres game

<https://tinyurl.com/n5bscpn>

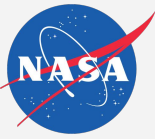
Stadium and team owners see drones as major league threat

<https://tinyurl.com/yd64zkx6>

Why America's drone problem may not be as bad as some think

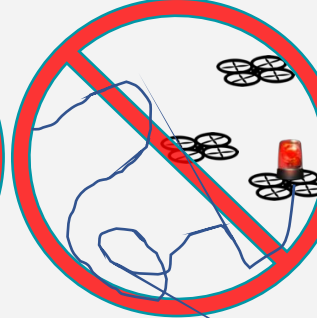
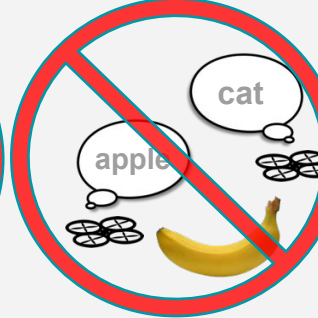
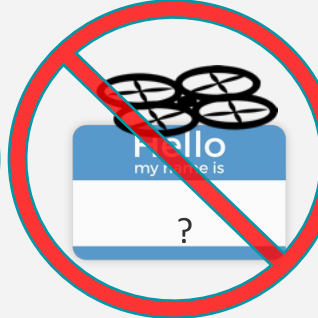
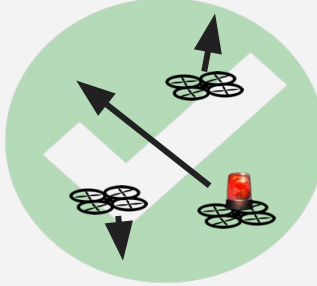
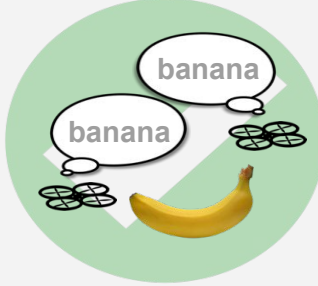
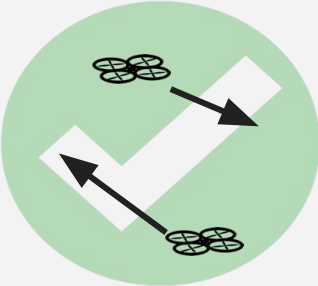
<https://tinyurl.com/yb6nkn3d>

Collecting Off-Nominal Operational Situations Data

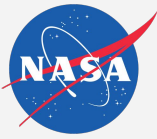


- Overarching goals:
 - Reduction in off-nominal situations incidence
 - Safe resolution of off-nominal situations
- Initial focus of the UAS Traffic Management (UTM) effort: Communications and Navigation, to ensure that
 - Unmanned Aircraft (UA) are under operational control of the remote pilot
 - UA remain within a defined area

UTM Principles



UTM Project Overview



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

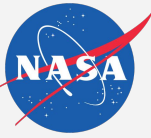
TCL 3 (Suburban)

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

TCL 4 (Urban)

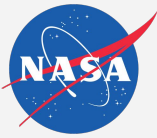
Beyond Visual Line of Sight
Intent Sharing
Strategic De-confliction
Geographic Containment
Detect and Avoid (DAA)
Vehicle-to-Vehicle (V2V)

TCL: Technical Capability Level



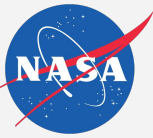
- Demonstrate the UTM TCL 2
 - Test scenarios across a wide range of UAS platforms and locations
 - Validate further the scalability of the UTM concept and architecture
- Off-nominal data collection
 - Variables added to Data Management Plan for digital data
 - Voluntary online report form developed for contextual data

Example Variables for the Digital Data Collection



c2RssiAircraft_dBm	Command and Control (C2) link Received Signal Strength Indicator (RSSI) measured in dBm at aircraft
c2RssiGcs_dBm	C2 link RSSI measured in dBm at Ground Control Station (GCS)
c2NoiseAircraft_dBm	Sum of Thermal noise power and Radio Frequency (RF) interference power, measured in dBm at aircraft
c2NoiseGcs_dBm	Sum of Thermal noise power and RF interference power, measured in dBm at GCS
hdop_nonDim	HDOP: Horizontal dilution of precision of GPS constellation
vdop_nonDim	VDOP: Vertical dilution of precision of GPS constellation
numGpsSat_nonDim	Number of GPS satellites tracked by GPS receiver

Example Questionnaire from the Online Form



1. If you were the Pilot In Command (PIC), were you the...

- RC Pilot
- GCS Operator

~

8. What are the Aircraft & Associated Control Systems?

~

14. Which of the following occurred?

- Loss/Degradation of vehicle to GCS communication
- Loss/Degradation of GCS to vehicle communication
- GPS Satellite or other navigation system signal loss/degradation
- Other navigation system failure
- Lateral Deviation from flight geography
- Vertical Deviation from flight geography

~

Reporter Narrative

Off-nominal Operational Situations Data from the NC II



Data collected from 118 operations, 15 online forms received

Alaska



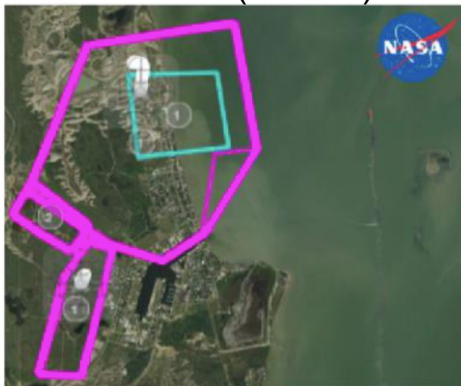
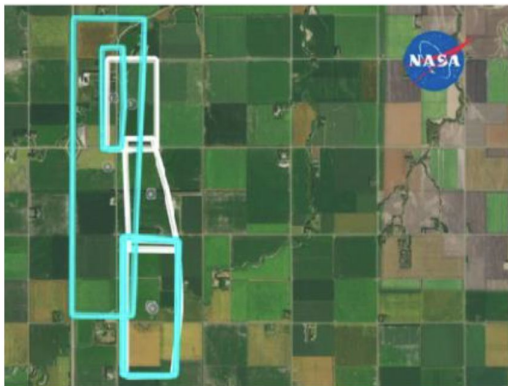
Nevada (top)
Texas (bottom)



New York

North Dakota

North
Dakota

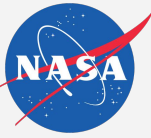


Virginia

Virginia

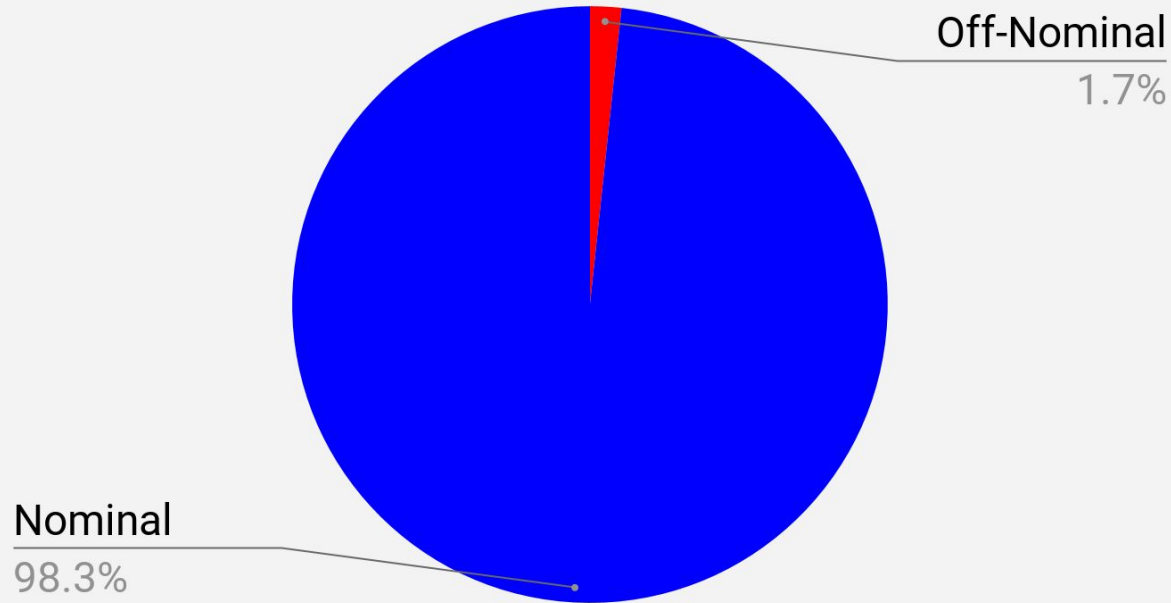
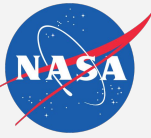


Findings



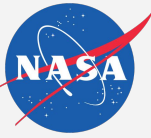
- Digital Data
 - Loss of Navigation
 - Loss of Command and Control (C2) link
- Online forms: Safety expert analysis

Loss of Navigation: Analysis of 118 Operations



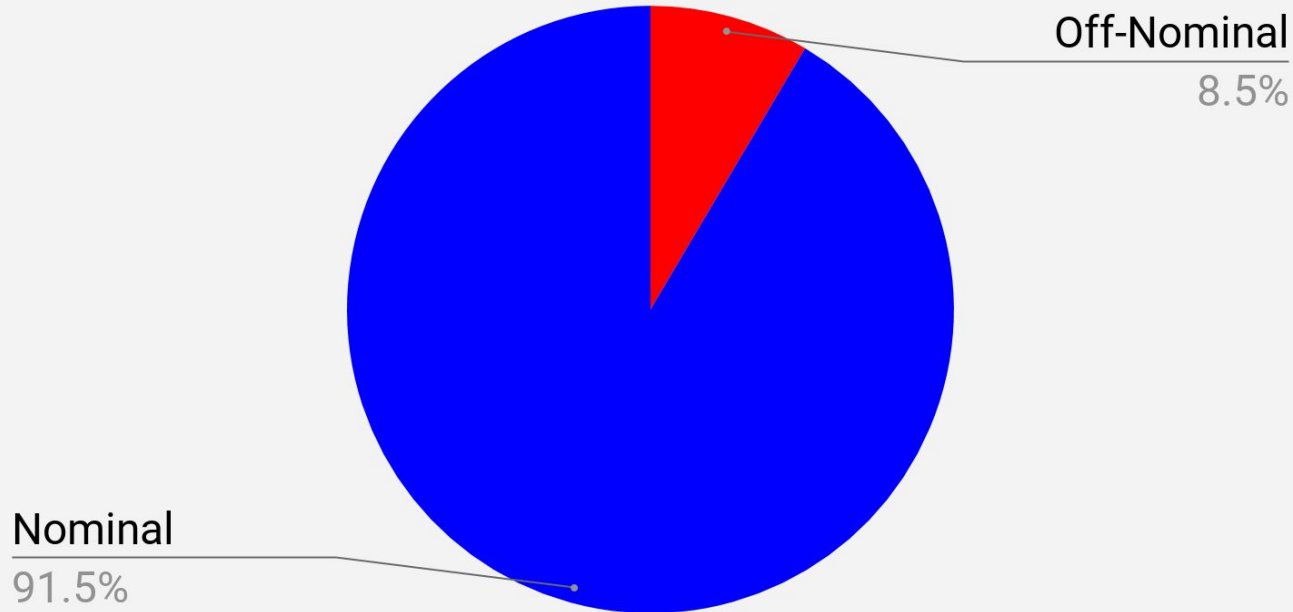
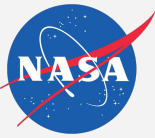
- Criteria: Number of GPS satellites ≤ 6 for more than 10 seconds
- GPS navigation system sufficient for the NC II environment
- Unobstructed view of the sky likely contributed to small incidence

Loss of Navigation: Going Forward



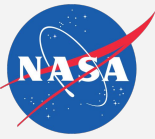
- Line-of-sight (LOS) necessary for navigation using Global Navigation Satellite System (GNSS) such as GPS
- Maintaining LOS may be difficult for low altitude operations in hilly terrain or urban area
- Non-GNSS navigation to cope with loss of LOS to GNSS satellites may be needed for operations in hilly terrain/urban area
 - Light Detection and Ranging (Lidar)
 - Radar

Loss of C2 Link: Analysis of 47 operations

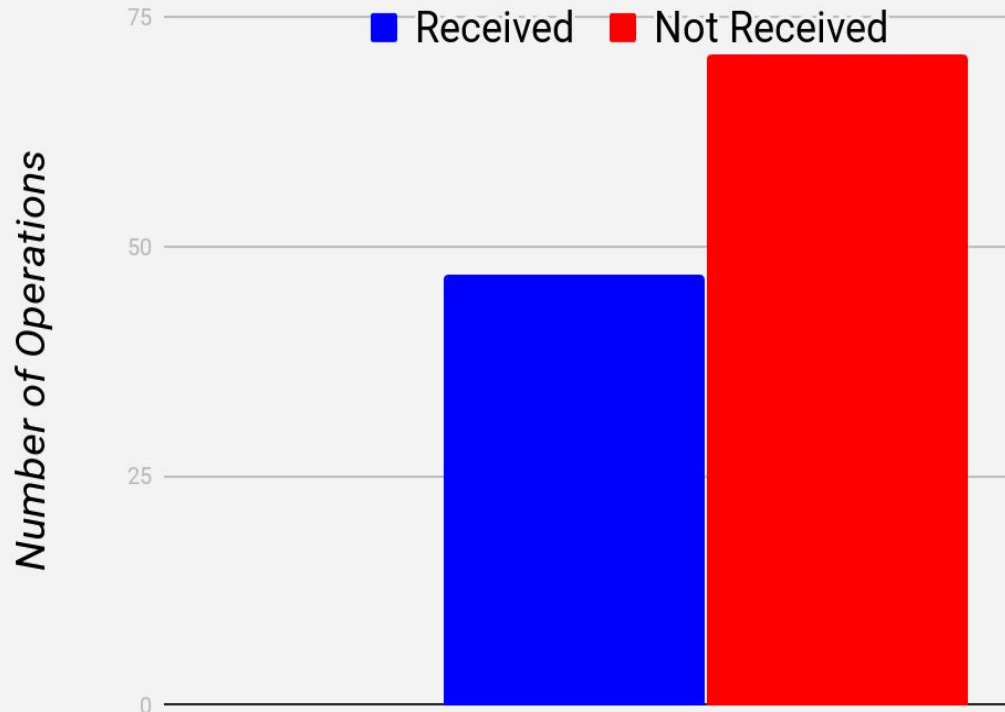


- Signal strength ≤ -90 dBm for more than 10 seconds
- Communications systems used in the NC II sufficient to cover up to 4300 feet separation between GCS and UA
- Unobstructed radio line of sight likely contributed to small incidence

Loss of C2 Link: Going Forward

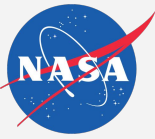


Data for Loss of C2 Identification



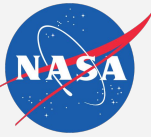
- Lack of data, 71 operations:
 - Not monitoring performance
 - Not aware of performance parameter to monitor
 - Different performance parameter to monitor
- Further engagement with the operator community
- Development of De-facto standard

Online Form: Safety Expert Analysis



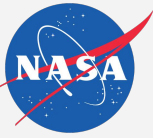
Event	Count
GPS or other navigation system signal loss/degradation	2
Other navigation system failure	4
Loss/Degradation of GCS to vehicle communication	3
Loss/Degradation of vehicle to GCS communication	3

Online Form: Events and Trends (lack of)



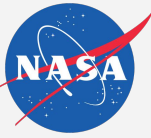
- 9 originated from the Remote-Control Pilot, 4 from the GCS Operator
- Distribution of events among aircraft types was unremarkable
- Due to the low number of reports, no significant trends emerged and uncertain what might be potential underlying common contributors to off-nominal situations

Online Form: Going Forward



- Number of potential improvements to the report form identified
- Future form will display different sets of questions to match operator role
- Questions that were deemed too specific, such as the version of autopilot software and GCS software, will be removed

Next Steps



- Digital(What)/Contextual(Why) Data Fusion to further increase insights into off-nominal operational situations
- Data collection mechanism improvements
 - Ingestion
 - Filtering
 - Validation
- Online-form improvements
- 2018 National Campaign Data Collection

Questions?

