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UAS Reports (UREPs): Enabling Exchange of Observation Data Between UAS Operations

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Abstract

As the volume of small unmanned aircraft systems (UAS) operations increases, the lack of weather products to support these operations becomes more problematic. One early solution to obtaining more information about weather conditions is to allow operators to share their observations and measurements with other airspace users. This is analogous to reporting systems in traditional aviation wherein pilots (or aircraft) report weather phenomena they have observed or experienced to provide better situational awareness to other pilots. Given the automated nature of the small (under 55 lbs.) UAS platforms and operations, automated reporting of relevant information should also be supported. To promote automated exchange of these data, a well-defined data schema needs to be established along with the mechanisms for sending and retrieving the data. This paper examines this concept and offers an initial definition of the necessary elements to allow for immediate implementation and use.

1 Concept

A UAS Report (UREP) is similar in function to a Pilot Weather Report (PIREP) or Position Reports (AIREP) in the National Airspace System (NAS). UREPs are data that are provided to the UAS Traffic Management (UTM) System (see UTM description below) that can be shared with other stakeholders to provide better situational awareness. While a traditional PIREP is typically confined to weather phenomena, a UREP allows for reporting of weather phenomena as well as other observable airspace activity (i.e., other aviation operations that could affect UTM operations). Since the UTM System is highly automated, the submission and retrieval of UREPs is built to rely on automated processes. The Flight Information Management System (FIMS) component of the UTM System is envisioned as the owner of the UREP functionality, though it may ultimately reside elsewhere within the UTM System.

An operator may be able to manually enter a report based on observed phenomena, or that operator may implement an approach where sensors onboard an aircraft can trigger the submission of a UREP when certain conditions are sensed (winds, temperatures, precipitation, etc.). This submission will likely be mediated by a UAS Service Supplier (USS) to make the connection between the operator and the FIMS. In the other direction, the UTM System (via the FIMS) will be able to automatically provide UREP data based on parameters supplied by an operator (again, likely mediated by a USS). Submission of UREPs will typically be a voluntary activity so that operators can share relevant information with other operators in an indirect manner. In some cases, depending on the overall UTM concept, the reporting of UREPs may be required (extreme winds encountered, for example). This is similar to the PIREP system wherein certain observed phenomena are required to be reported.

While there are several use cases that could be identified, three major and immediate cases are described below.

1.1 Use Case: Manual Submission and Retrieval by an Operator

Operator A has a ground control station (GCS) with a portable weather station co-deployed. The weather station senses and reports a 25 knot wind gust. Operator A enters this information into the GCS that is connected to the Internet via a 4G cellular connection. The software in the GCS allows for submission of this information in the form of a UREP to Operator A's USS. The USS then submits that information on the operator's behalf to the FIMS. Operator B has a subscription set up with his USS to receive any new UREPs within 10 miles of Operator B's position. Operator B's USS receives the UREP data via the FIMS and then forwards it to Operator B since it fits his subscription filter.

Note that this process also supports the reporting of non-weather information. In this use case, for example, instead of wind gusts, Operator A could report observed hang glider activity. Notification of this airspace activity could prove valuable to other operators planning operations in the vicinity of the report.

1.2 Use Case: Automated Submission and Retrieval by UAS

An advanced Internet-connected UAS has a suite of weather sensors, including an icing sensor. While flying a mission, icing is detected on the aircraft surfaces. Using automated software on the operator's UAS and GCS, a UREP is created and sent to the USS, which then forwards it to the FIMS.

Another UAS has also Internet connectivity and has subscribed directly to its USS for any relevant alerts. The icing UREP is sent directly to the UAS. The UREP is easily parsed and the UAS makes an adjustment to its flight path to avoid the area of the report. This adjustment is communicated to the UAS operator and since the adjusted flight path is still within the operational limits of the mission, the UAS continues its flight.

1.3 Use Case: Historical Analysis

Researcher X is developing a new prediction algorithm for low-altitude winds. An operational area in California has received automated UREPs for the past 12 months. So as to refine the algorithm, Researcher X queries the FIMS for all UREPs which included a wind element that were received in the last 12 months. Since the data are well defined, parsing and processing the data are trivial aspects of this effort.

2 Background

In this section, a brief overview of UTM, PIREPs, and AIREPs is provided.

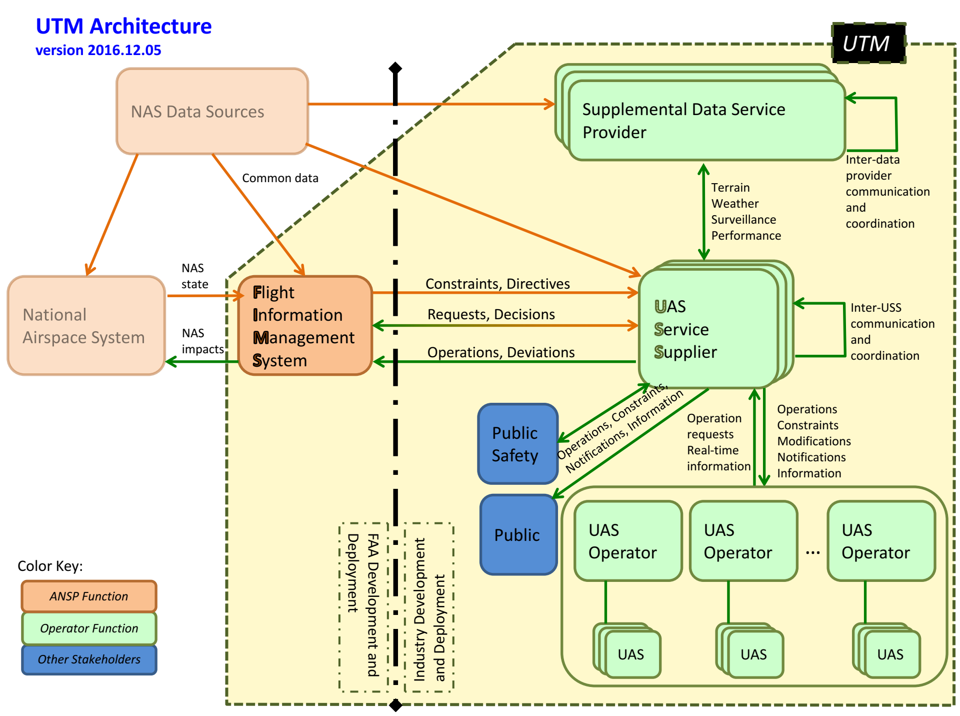
2.1 UTM

A more complete introduction to the concepts underlying UTM is provided in a NASA conference paper [NASA 2016]. This section is provided to ground the discussion within this paper. The UTM System is envisioned to support management of the low-altitude airspace for small UAS. UTM development is guided by five operating principles:

1. Only authenticated UAS and operators are allowed to operate in the airspace.
2. UAS stay clear of each other.
3. UAS and manned aviation stay clear of each other.
4. UAS, their operators or support systems have awareness of all airspace constraints and all static and dynamic objects on the ground (e.g. people, animals and structures) and UAS will stay clear of them.
5. Public safety UAS operations should be given priority over other UAS operations and manned aviation.

The general concept is supported by the following high-level architecture:

Figure 1. The overall UTM Architecture as of December 2016.



There is a delineation between the responsibilities of the Air Navigation Service Provider (ANSP) and Industry. The Flight Information Management System (FIMS) is a central, cloud-based component that acts both as a bridge to the traditional NAS and as a broker of information between UTM System stakeholders. Connections to the FIMS are allowed from USSs who meet minimum requirements that may be related to functionality, quality of service, and/or liability. These USSs then support missions by UAS operators. Note that an operator may also function as a USS; the operator and USS roles are functionally separated but are not necessarily physically separated. Connections and communications are Internet-based, built on industry standards and protocols.

Many operations may be completed without communication with the FIMS, being supported solely by communication between the operator and one or more USSs. Communication with the FIMS may only be required when operations must notify or request approvals from the ANSP. Also note that the FIMS may provide other functionality in the UTM System including authentication and authorization services, emergency notifications, and other services.

Operations are typically defined as airspace volume reservations. Thus, an operator will likely plan a trajectory or area-based operation, which is then translated into a series of four-dimensional volumes that the vehicle plans to occupy. These volumes may be specified by the operator or by the USS based on the planned operation. As needed, the operational plan may be shared via the USS-to-USS and/or the USS-to-FIMS communication channels depending on the final UTM concept. Supplemental data (weather, terrain, surveillance, etc.) may be provided by other entities.

2.2 PIREPs

From the FAA's order on Flight Services (JO 7110.10Y) [FAA 2015], a PIREP includes:

- Height and coverage of cloud bases, tops, and layers.
- Flight visibility.
- Restrictions to visibility and weather occurring at altitude.
- Air temperature and changes to temperature with altitude or range.
- Direction and speed of wind aloft.
- Duration and intensity of turbulence.
- Extent, type, and intensity of icing.
- Weather conditions and Cloud Cover through mountain passes and over ridges and peaks.
- Location, extent, and movement of thunderstorms and/or tornadic activity.
- Excessive winds aloft, LLWS, and other phenomena bearing on safety and efficiency of flight.

The encoding of PIREPs is also specified in JO 7110.10Y [FAA 2015]. The details are left to that document and the documents that it references, but previously published examples [Rios 2015] are provided here to aid in understanding:

```
UA /OV ILI047045/TM 0013/FL210/TP SF34/TA M23/IC MOD RIME
```

This first PIREP is routine (UA) and reported at 47 degrees and 45 nmi from ILI (ILI047045) at 0013Z. The pilot was at flight level 210 in a Saab 340 turboprop (SF34). The pilot reported an air temperature of 23C (M23) and moderate rime icing (MOD RIME).

```
UUA /OV OMN115095/TM 0027/FL360/TP B737/TB SEV
```

The second PIREP was urgent (UUA) and reported at 115 degrees and 95 nmi from OMN (OMN115095) at 0027Z. The pilot was at flight level 360 in a Boeing 737. The report contains only one element: severe turbulence (TB SEV). Severe turbulence reports necessitate the tagging as urgent. For further discussion on PIREPs, the reader is directed to the FAA documentation.

2.3 AIREPs

From the FAA's order on Flight Services (JO 7110.10Y) [FAA 2015], AIREPs are defined as "messages from an aircraft to a ground station. AIREPs are normally comprised of the aircrafts position, time, flight level, ETA over its next reporting point, destination ETA, fuel remaining, and meteorological information."

These are typically automated messages from larger, internationally traveling operations. Position reports are required for Instrument Flight Rules (IFR) flights flying in a non-radar environment. AIREPs use similar information encoding techniques to PIREPs with some differences. Here are a few examples pulled from NOAA's Aviation Weather Center website [NOAA 2016]:

```
ARP UAL1520 3538N 7132W 1411 F350 MS58 310/047KT
```

Note that all AIREPs begin with "ARP" which stands for "aerodrome reference point." This is followed by the aircraft call sign (UAL1520), location in latitude, longitude notation with implicit decimals (35.38N 71.32W) and the time in UTC (14:11). The report includes the flight level (350) to provide the final dimension of the 4D position for the report. The MS58 indicates a temperature of -58C. The final datum is a wind report: 47 knot winds from a direction of 310.

```
ARP UAL1627 4000N 07415W 1416 F220 TB NEG RM B738 OV WHITE CONT
LGT-MOD RPTD FL240-380
```

This AIREP includes the callsign and 4D position information as in the previous example. It includes a negative turbulence (TB NEG) report. Note that a negative turbulence report is often more useful than it sounds, especially in cases where there was forecasted turbulence. Following the turbulence report, there is a remarks (RM) section wherein the encoding is more like a traditional PIREP and is likely reported by the pilot directly rather than from an automated sensing and reporting mechanism. In this case the remark notes the aircraft type, a waypoint over which the remark refers and then light to moderate continuous turbulence activity between flight levels 240 and 380.

3 UREP Description

Since communication to and from the FIMS is achieved through JavaScript Object Notation (JSON) data payloads, the UREP will be defined with a JSON schema. Ideally, a UREP will be easily translatable to a PIREP for potential future use by traditional aviation data feeds. As such, all of the weather-reporting information in a UREP is taken from existing PIREP formatting. For airspace activity, we propose using the aviation standard fix/radial/distance to point out activity. However, in most cases for a UREP, the 'fix' will be an arbitrary longitude/latitude pair. The "point out" will also include other relevant information such as vehicle type, vehicle state (climbing, hovering, etc.), course, speed, etc. Each UREP may contain one or more instances of an aircraft sighting (point out) and at most one instance of each weather element (phenomena). It must contain certain information about the reporter and report. These required fields that must accompany each UREP include: Submit time (the time that the UAS operator sends the report) Measured time (the time that the reported event(s) occurred) Location (longitude and latitude in WGS 84) Altitude (in feet Mean Sea Level (MSL) WGS 84) Source (vehicle, observer, ground sensor, etc.)

3.1 Point Out

A point out will be a report of a vehicle sighting that might be useful to other operations in the area. It is not required to submit such a UREP for every sighting of every other aircraft. Typically, the goal should be to provide information to the UTM System that it might not have available through means other than a first-hand account (for example, an unplanned balloon flight or hang gliders in an unexpected area). The point out will include the type of vehicle observed, position of the observed vehicle, and some information about that vehicle's state. Details are provided in the YAML Ain't Markup Language (YAML) description below.

3.2 Weather Phenomena

In general, the reporting of weather phenomena matches the way in which PIREPs report weather phenomena. This allows for easy translation, if required, to traditional PIREPs as well as compatibility with other weather products. The types of reportable weather includes (in no particular order):

1. Visibility
2. Flight weather
3. Turbulence
4. Icing
5. Temperature
6. Wind

4 UREP Formatting

This section is provided as an initial reference. For the most up-to-date schema information, automated documentation will be available from the FIMS.

The following YAML provides a human-readable version of the proposed schema.


```yaml
Urep:
  type: object
  required:
    - altitude
    - source
    - submit_time
    - time_measured
    - user_id
  properties:
    air_temperature:
      type: number
      format: double
      description: Air temperature in degrees Celsius.
    aircraft_sighting:
      type: array
      description: An aircraft is in the vicinity of the report.
      items:
        $ref: '#/definitions/PointOut'
    altitude:
      type: number
      format: double
      description: >-
        The altitude as measured via a GPS device on the aircraft. Units
        in international feet using the WGS84 reference system.
    gufi:
      type: string
      description: The UUID of the reporting operation, if appropriate.
    icing_intensity:
      type: string
      description: >-
        A qualitative measure of icing intensity. Use 'NEG' when icing was
        expected, but not encountered.
      enum:
        - TRACE
        - TRACE_LGT
        - LGT
        - LGT_MOD
        - MOD
        - MOD_SEV
        - SEV
```

```yaml
    - NEG
icing_type:
  type: string
  description: >-
    The type of icing encountered. Can only be submitted with
    icing_intensity.
  enum:
    - RIME
    - CLR
    - MX
location:
  description: 'The location of the observed activity. '
  $ref: '#/definitions/Point'
proximity:
  type: string
  description: >-
    Qualifier for any weather value provided. Use this field if the
    observed phenomenon is not at the provided location, but is nearby.
    Must be equal to VC.
  enum:
    - VC
remarks:
  type: string
  description: >-
    Any free text that cannot be captured using the standard fields.
    General use not advised.
source:
  type: string
  description: >-
    How the measured/observed activity was measured/observed. In the case
    of OTHER comments should be supplied in the remarks field.
  enum:
    - VEHICLE
    - OBSERVER
    - GROUND_SENSOR
    - AIRBORNE_SENSOR
    - OTHER
submit_time:
  type: string
  format: date-time
  description: UAS Operator-assigned time for when the UREP was sent to the FIMS.
time_measured:
  type: string
  format: date-time
  description: UAS Operator-assigned time for when the data were initially measure
time_received:
```

```
  type: string
  format: date-time
  description: >-
    FIMS-assigned time for when the UREP was received at the FIMS for
    processing.
turbulence_intensity:
  type: string
  description: >-
    A qualitative measure of turbulence intensity. Use 'NEG' when
    turbulence was expected, but not encountered.
  enum:
    - LGT
    - LGT_MOD
    - MOD
    - MOD_SEV
    - SEV
    - SEV_EXTRM
    - EXTRM
    - NEG
urep_id:
  type: string
  description: FIMS-assigned identifier for a UREP.
user_id:
  type: string
  description: Id of the user submitting the UREP, populated by FIMS.
visibility:
  type: number
  format: double
  description: >-
    Visibility in statute miles, rounded down if necessary. Maximum value
    99 indicates unrestricted visibility. Only use partial SM less than 1
    SM (0.5 SM, but not 20.5 SM).
weather:
  type: string
  description: Flight visibility and flight weather, follows PIREP/METAR coding.
  enum:
    - DRSN
    - BLSN
    - DRDU
    - DRSA
    - DZ
    - FZDZ
    - DU
    - BLDU
    - DS
    - FG
```

```
    - FZFG
    - FZRA
    - FC
    - GR
    - SHGR
    - HZ
    - IC
    - PL
    - SHPL
    - BR
    - BCFG
    - PRFG
    - RA
    - SHRA
    - SA
    - BLSA
    - SS
    - MIFG
    - SHGS
    - GS
    - FU
    - SG
    - SN
    - SHSN
    - PY
    - SQ
    - TS
    - UP
    - VA
    - PO
weather_intensity:
  type: string
  description: >-
    Qualifier for any weather value provided.  Without a weather_intensity
    value, MODERATE is assumed.
  enum:
    - HEAVY
    - MODERATE
    - LIGHT
wind_direction:
  type: number
  format: double
  minimum: 0
  maximum: 359
  description: >-
    Magnetic wind direction, 0 to 359 degrees. Must be submitted when
```

```
        wind_speed is provided in the UREP. Double is accepted, but will
        be rounded to int upon storage.
    wind_speed:
      type: integer
      format: int32
      minimum: 0
      description: >-
        Wind speed in knots. Must be submitted when wind_direction is provided
        in the UREP.

PointOut:
  type: object
  required:
    - altitude
    - bearing
    - distance
    - north_ref
    - point
    - state
    - track
    - vehicle_type
  properties:
    altitude:
      type: number
      format: double
      description: >-
        The altitude of the target. Units in feet using the WGS84 reference
        system. May be estimated.
    bearing:
      type: integer
      format: int32
      description: >-
        Degrees from north (as defined by north_ref) from reporter's position
        to target.
    distance:
      type: number
      format: double
      description: Horizontal distance in Nautical miles from reporter's position to t
    north_ref:
      type: string
      description: The reference for 'north' in reporting values
      enum:
        - TRUE
        - MAGNETIC
    point:
      description: The longitude and latitude of the reporter's position.
```

```
      $ref: '#/definitions/Point'
    remark:
      type: string
      description: Any free text that cannot be captured using the standard fields.
    state:
      type: string
      description: The current state of the target.
      enum:
        - CRUISE
        - DESCENT
        - CLIMB
        - HOVER
        - LOITER
        - UNKNOWN
    track:
      type: number
      format: double
      description: The track in decimal degrees relative to Double north_ref.
    vehicle_type:
      type: string
      description: The type of vehicle being pointed out.
      enum:
        - SMALL_UAS
        - LARGE_UAS
        - HELICOPTER
        - SMALL_MANNED_FIXED_WING
        - HANG_GLIDER
        - BALLOON
        - LARGE_MANNED_FIXED_WING
        - OTHER

Point:
  type: object
  required:
    - coordinates
  properties:
    coordinates:
      type: array
      description: >-
        Pairs of longitude-latitude values. If a third element is provided for
        altitude, it is silently ignored.
      items:
        type: number
        format: double
    type:
      type: string
```

4.1 Sample UREP as Submitted

The following JSON-formatted code is an example of what might be submitted to the FIMS as a UREP.


```
{
  "submit_time": "2015-10-06T20:45:27Z",
  "time_measured": "2015-10-06T20:39:21Z",
  "gufi": "3cd7d57b-9254-452d-9ce9-e8d657f4cb55",
  "location": "{\"type\": \"Point\",\"coordinates\": [125.222222, 10.111111] }",
  "altitude": "4.5",
  "source": "VEHICLE",
  "visibility": "45.2",
  "weather": "SHGR",
  "air_temperature": "24.5",
  "wind_direction": "340",
  "wind_speed": "4",
  "turbulence_intensity": "LGT",
  "icing_intensity": "TRACE",
  "icing_type": "CLR",
  "aircraft_sighting": [
    {
      "vehicle_type": "HELICOPTER",
      "north_ref": "TRUE",
      "point": "{\"type\": \"Point\",\"coordinates\": [125.111111, 10.222222] }",
      "bearing": "280",
      "distance": "25.4",
      "altitude": "4.5",
      "track": "19.2",
      "state": "HOVER",
      "remark": "TV helicopter."
    }
  ],
  "remarks": "no remarks"
}
```


4.2 Sample UREP as Retrieved

The following JSON-formatted code is how the same UREP from the previous section would look when retrieved from the FIMS.


```
{
  "urep_id": "123ac1fe-1b45-09ae-729c-1b45ed767c22",
  "submit_time": "2015-10-06T20:45:27Z",
```

```
  "time_received": "2015-10-06T20:45:28Z",
  "time_measured": "2015-10-06T20:39:21Z",
  "user_id": "guest",
  "gufi": "3cd7d57b-9254-452d-9ce9-e8d657f4cb55",
  "location": "{\"type\": \"Point\",\"coordinates\": [125.222222, 10.111111] }",
  "altitude": "4.5",
  "source": "VEHICLE",
  "visibility": "45.2",
  "weather": "SHGR",
  "air_temperature": "24.5",
  "wind_direction": "340",
  "wind_speed": "4",
  "turbulence_intensity": "LGT",
  "icing_intensity": "TRACE",
  "icing_type": "CLR",
  "aircraft_sighting": [
    {
      "vehicle_type": "HELICOPTER",
      "north_ref": "TRUE",
      "point": "{\"type\": \"Point\",\"coordinates\": [125.111111, 10.222222] }",
      "bearing": "280",
      "distance": "25.4",
      "altitude": "4.5",
      "track": "19.2",
      "state": "HOVER",
      "remark": "TV helicopter."
    }
  ],
  "remarks": "no remarks"
}
```

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14. ABSTRACT
As the volume of small unmanned aircraft systems (UAS) operations increases, the lack of weather products to support these operations becomes more problematic. One early solution to obtaining more information about weather conditions is to allow operators to share their observations and measurements with other airspace users. This is analogous to reporting systems in traditional aviation wherein pilots (or aircraft) report weather phenomena they have observed or experienced to provide better situational awareness to other pilots. Given the automated nature of the small (under 55 lbs.) UAS platforms and operations, automated reporting of relevant information should also be supported. To promote automated exchange of these data, a well-defined data schema needs to be established along with the mechanisms for sending and retrieving the data. This paper examines this concept and offers an initial definition of the necessary elements to allow for immediate implementation and use.

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