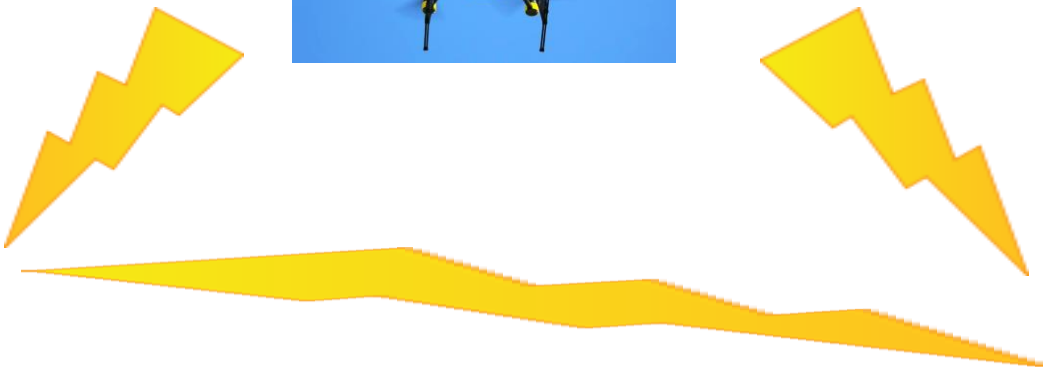

Industry Network Technology Council (INTC) webinar 2020 APR 02

Small UAS ("Drones"): Some Network Related Standards Work in Progress

earlier version presented to IETF 107 Drone Remote Identification Protocol (DRIP) WG

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Primary focus: identify & track [cooperative] [dangerous] [mobile] physical objects

Some acronyms (sorry, mostly use case related)

- UA: Unmanned Aircraft (“drone”)
- GCS: Ground Control Station (pilot uses to operate UA)
- UAS: Unmanned Aircraft System (UA + GCS)

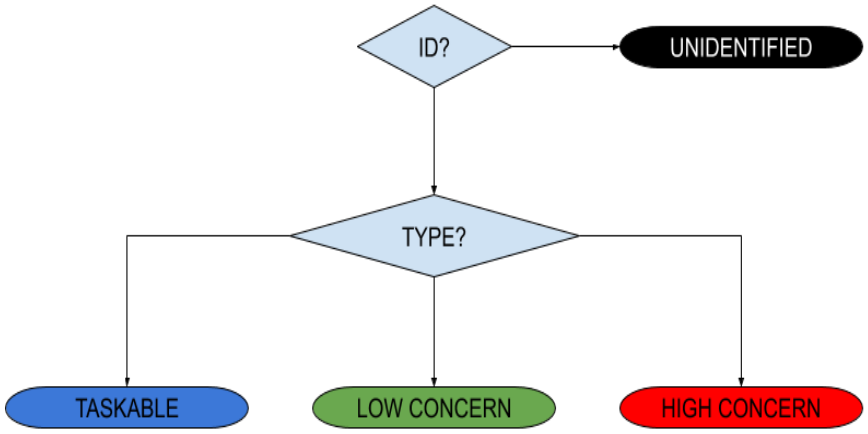
- **USS:** UAS Service Supplier
- SDSP: Supplemental Data Service Provider
- **UTM:** UAS Traffic Management (distributed system inc. many USS, SDSP, etc., hoped to scale better than humans using voice comms for Air Traffic Control [ATC])
- UVR: UAS Volume Reservation (temporary no-fly zone for most operators)
- **UAS RID:** UAS Remote Identification [&Tracking]

- SDO: Standards Development Organization
- ASTM: ASTM International, formerly American Society for Testing and Materials (SDO)
- CTA: Consumer Technology Association (SDO)
- CAA: Civil Aviation Authority (regulator)
- EASA: European Union Aviation Safety Agency (CAA)
- FAA: United States Federal Aviation Administration (CAA)
- NPRM: Notice of Proposed Rule Making

- PII: Personally Identifiable Information (more generally, information to be kept private)
- AAA: Attestation, Authentication, Authorization, Access Control, Accounting, Attribution, Audit

UAS Remote ID is Critical for UTM

- Observing UA at a particular location, need to learn **who** (ID)
  - Using that ID, observer can look up **what, why, "friendly",** etc.
  - FAA has declared that in the US, there will be no operations over people until UAS RID is deployed
- Relevant for many entities for various reasons
  - Air Traffic Control (ATC), Public Safety Officials, Homeland Security, General Public, Private Security Personnel, Drone Operators...
  - Vehicle to Infrastructure (V2I) + Vehicle to Vehicle (V2V) = V2X
  - Command & Control (C2) of UA
  - coordinated separation / collision avoidance / Detect And Avoid (DAA)
  - payload mission…
- Trust begins with identity
  - So identity needs to be trustworthy!



Complex, rapidly evolving environment…

- Constituent systems/technologies in loosely coupled development – RID, DAA, V2X, Comm Protocols/Radios/Spectrum…
- Until UTM w/multiple interoperating USS is deployed, we have a partial solution:

  the Low Altitude Authorization & Notification Capability (LAANC)
- UTM is a moving target… but we still need to hit it…
  - 2 architectures still being debated – federated *vs* global
  - **InterUSS Discovery & Synch. Service** – most USS prototypes don't yet fully interoperate
  - SDSPs – no standardized interface
  - Flight Priority/Deconfliction – not well defined
  - Government / Public Safety Access & Priority – required, but unspecified
  - Operator & UAS registries/databases – unaddressed
  - Information Sharing – InterUSS protocol defined, but who can share what with whom…
- Cybersecurity, Access Control & Trust Frameworks – still being defined
  - International Civil Aviation Organization (ICAO) Aviation Trust Framework (**IATF**) / Global Resilient Aviation Interoperable Network (GRAIN)
- Urban/Advanced Air Mobility (UAM/AAM, think robotic air taxi) & EU U-Space (UTM/ATM) requirements – just beginning to be considered…

FAA UTM Pilot Project 2 (UPP2) Architecture

(DRIP must fit here as well as in EU equivalent)

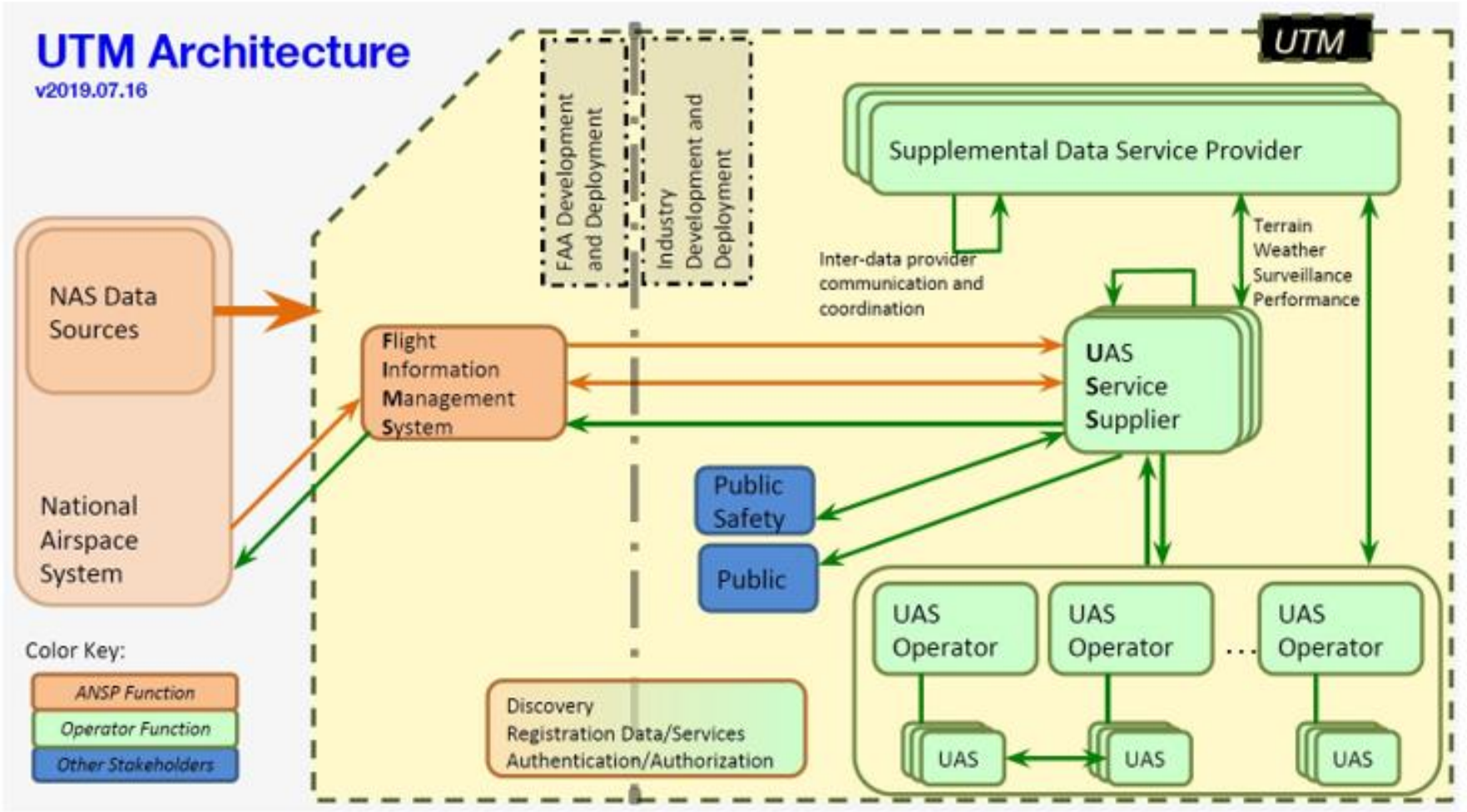


Figure 4-1: Notional Architecture

some but not all of the arrows have interface standards, especially **InterUSS**

ASTM F3411-19 Standard Specification for Remote ID and Tracking (1st version from F38.02 WK65041)

- Focused on message formatting & performance in Remote ID
- Broadcast RID
  - Direct from UA to observer device (data link, not network)
  - Bluetooth 4/5 & Wi-Fi w/Neighbor Awareness Networking (NAN)
    - "selected for compatibility with commonly carried hand-held devices"
    - BT4 Advertisement beacon payload limit of 25 bytes (24 usable)
  - Broadcast always while in flight
- Network RID
  - Typically GCS -> cellular LTE -> Internet -> NETSP
  - Net-RID Service Provider (NETSP)
    - UTM USS to which the UAS is subscribed
    - Receives, stores & answers NETDP queries re: UAS ID, location, etc.
  - Net-RID Display Provider (NETDP)
    - Aggregates info from multi NETSP
    - Provides picture of airspace volume in response to client queries
    - May or may not itself be a USS
  - Only NETSP<->NETDP is fully specified, uses JSON / RestAPI
- Security methods punted to implementors, only framing specified

UPP2 Use Case 4

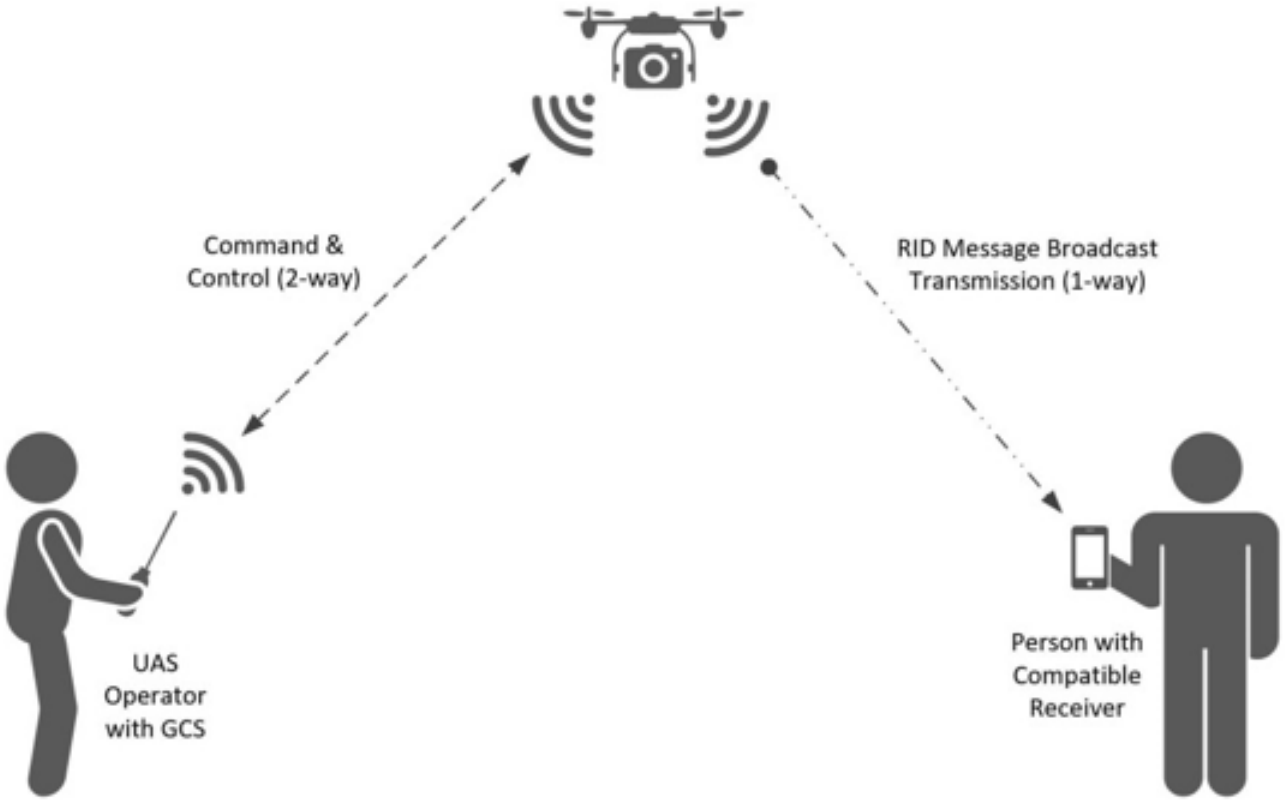


Figure 9-2: Remote ID Message Transmission via Broadcast

UPP2 Use Case 4

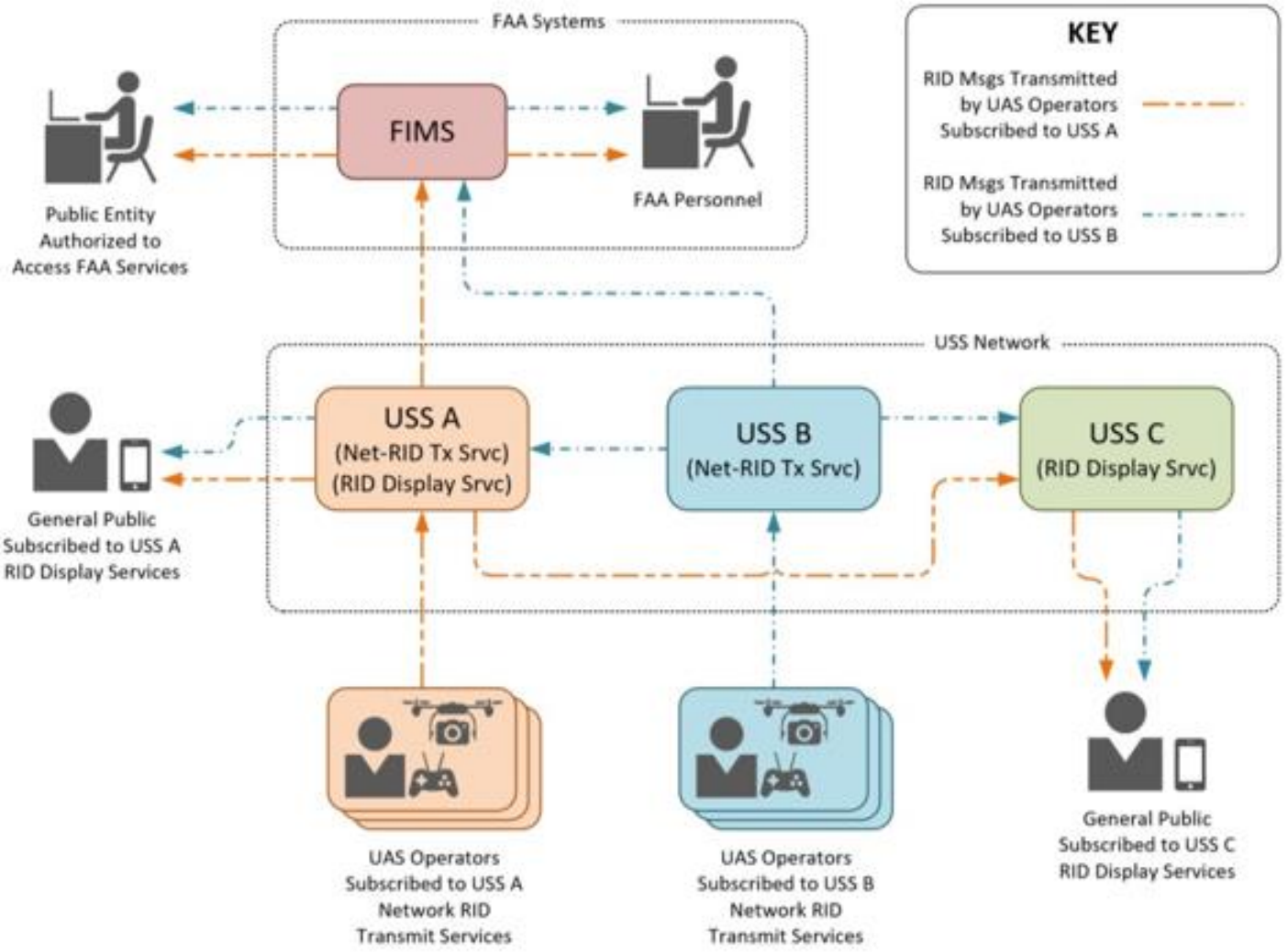


Figure 9-1: Remote ID Message Transmission via Network Publication Flow

Regulations *vs* Industry Consensus Standards

- Overall they are intended to complement each other
  - EASA, FAA, *et al* rules mandate what must be done & performance requirements
  - ASTM *et al* technical specifications detail one or more means that might be used
  - Regulators may designate industry standards as “accepted means of compliance”, relieving operators who buy gear whose manufacturers assert they follow such standards from each having to prove their own compliance
- Slightly different terminology, e.g.
  - FAA NPRM “Remote ID USS” == ASTM “Net-RID Service Provider”
  - FAA NPRM “Session ID” which could be an ASTM “UTM Assigned ID” == UUIDv4
- Acceptability of tech spec options vary per regulators, e.g. ASTM F3411-19 UAS ID Types
  - Type 1: Manufacturer assigned Hardware Serial # per **ANSI/CTA-1063-A**: required by EASA; allowed by FAA
  - Type 2: CAA assigned ID (e.g. aircraft registration number): not allowed by either
  - Type 3: not allowed by EASA; “randomly-generated alphanumeric code that is used only for one flight”) Session ID encouraged by FAA (p. 21, NPRM)
- The sole fully ASTM F3411-19 specified Network RID interface is NETSP<->NETDP but FAA NPRM does not recognize the NETDP as a distinct entity
- Stakeholder needs recognized by regulators will influence standards that manufacturers will follow in producing aircraft & ground systems that will remain in use for many years

Regulations & Means of Compliance: Industry "Consensus" Standards

	ASTM Broadcast RID Bluetooth/WiFi direct from UA	ASTM Network RID Internet from UAS (UA or GCS)
EASA Europe likely to influence rest of world outside N. America	**Pilot/GCS & UA locations** **UA serial # (manufacturer assigned)**	**N/A**
FAA NPRM Limited RID Small UA, Visual Line of Sight (V-LOS) within 400' of pilot	**prohibited**	**Pilot/GCS location only** **UA serial # or 1-time session ID**
FAA NPRM Standard RID	**Pilot/GCS & UA locations** **UA serial # or 1-time session ID**	**Pilot/GCS & UA locations** **UA serial # or 1-time session ID**

- NPRM says RID is an enabler of DAA, V2X, etc.;
  but ASTM F38.02 says RID is just RID.
- NPRM calls for error correction;
  but ASTM F3411-19 does not specify any.
- NPRM calls for cybersecurity to protect integrity & authenticity;
  but ASTM F3411-19 specifies only the framing of authentication data.
- Everyone says protect operator privacy;
  but pilot/GCS location is broadcast in the clear &
  no one specifies how to protect PII in registries…

UPP2 Use Case 5

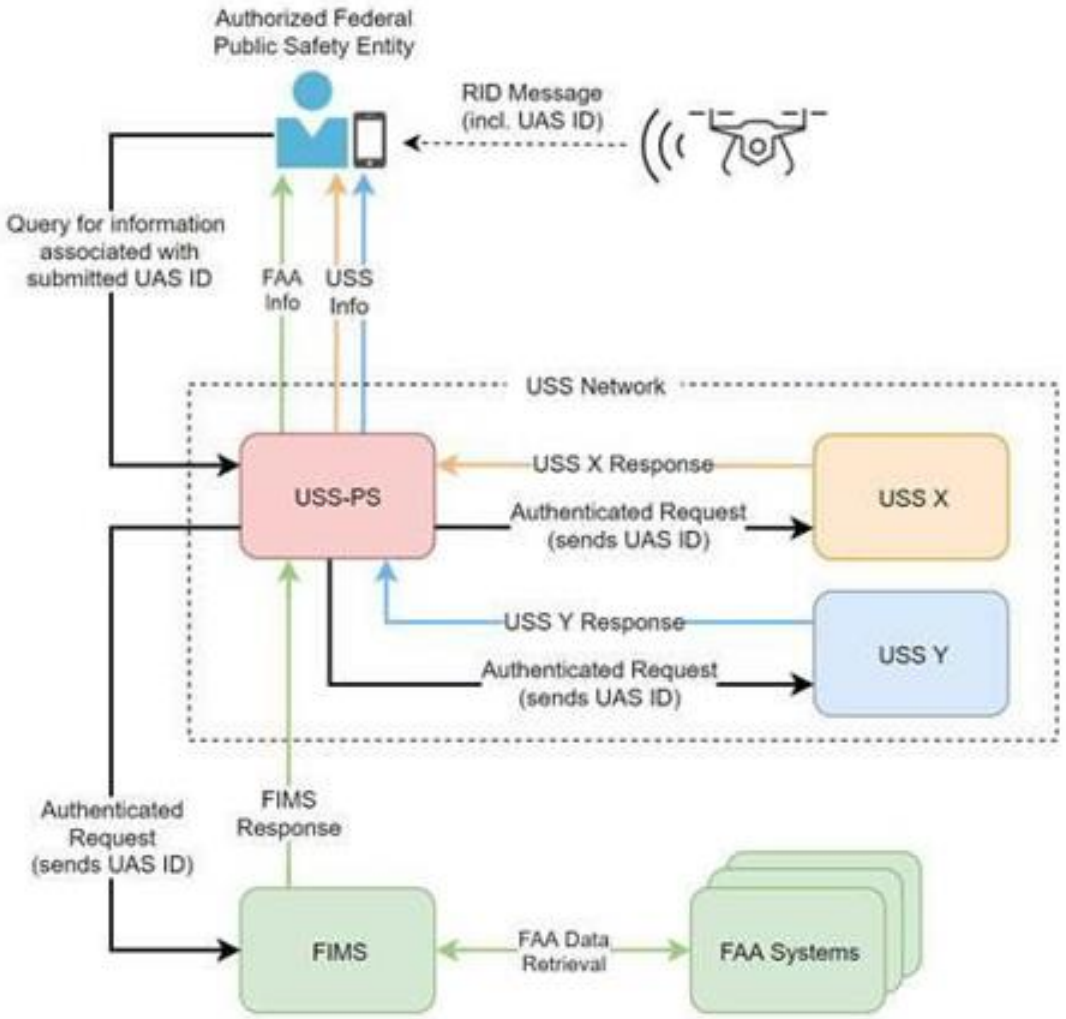


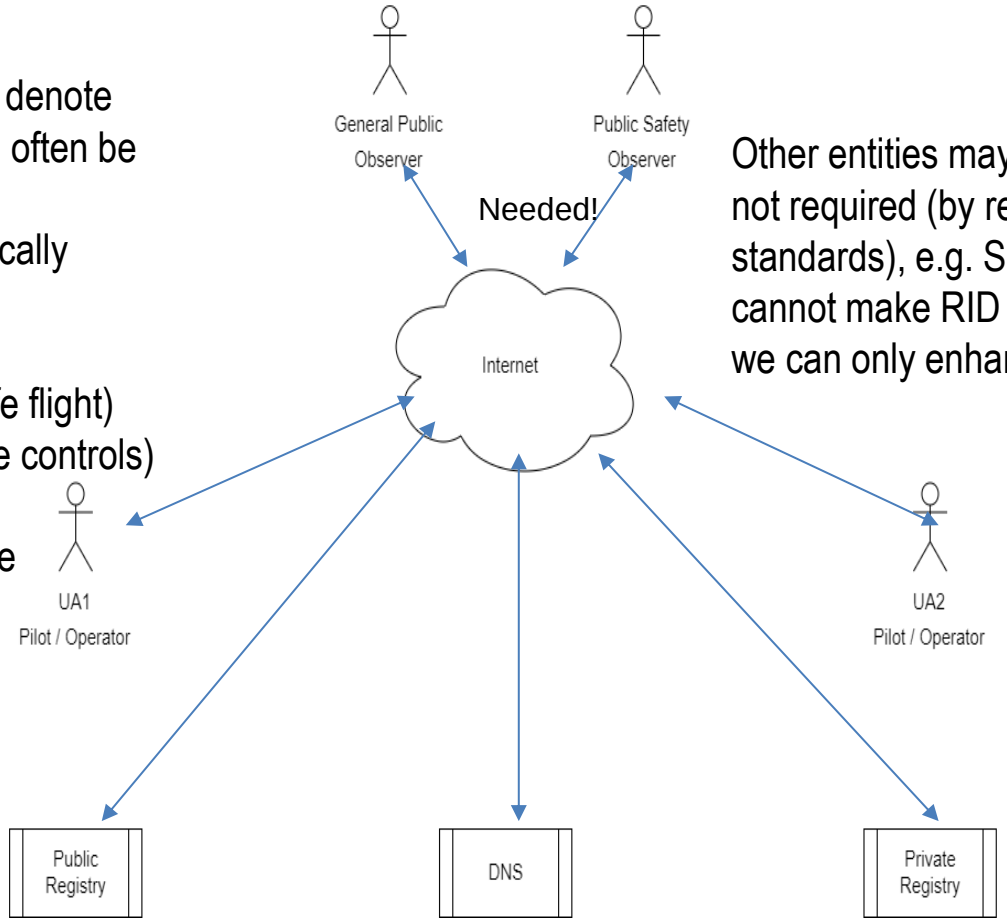
Figure 10-1: Direct Query to FAA and USS Network

“Reference Architecture”:
really just the cast of characters

UA is Broadcast RID source

By “Pilot/Operator”, we denote several entities that will often be identical or colocated:

- UAS Operator (typically owner or lessee)
- Pilot In Command (responsible for safe flight)
- Remote Pilot (at the controls)
- GCS (the controls)
- Network RID source



Other entities may be in play but are not required (by regulations or external standards), e.g. SDSPs, but we cannot make RID depend on SDSPs, we can only enhance it w/such

By “registry”, we denote several functions that will almost certainly be offered by the same service bureaus:

- UAS Operator registry
- UA registry
- UTM USS
- Net-RID Service Provider
- Net-RID Display Provider

ASTM Broadcast RID w/o DRIP enhancements:

Unverifiable weakly correlated assertions of identity, position, velocity…

UA broadcasts Basic ID etc.

Observers:

- attempt to correlate Basic ID w/other (esp. track) data
- look up operator info in TBD registries via TBD query/response protocols protected by TBD access control mechanisms over the Internet.

Our Proposed DRIP Approach

- UAS RID should be **immediately actionable**:
  - Trustworthy *information*
  - Show whether *operator* is trusted, even w/o observer Internet connectivity
  - Enable instant Observer to Pilot & M2M secure comms, when IP connectivity is available between endpoints

  Privacy must be maintained if not forfeited by the UAS operator through clueless, careless or criminal actions

- Complement existing external standards
  - ASTM, CTA, International Civil Aviation Organization (ICAO), CAAs…
  - FAA cites ASTM F3411-19 as potential means of compliance… but security & threat model not addressed!
- Leverage existing Internet business models, services, infrastructure, protocols & IETF expertise
  - Complement ASTM F3411-19 to mitigate its shortfalls
  - Support a variety of applications related to UAS RID (e.g. C2, DAA, V2X)
- Stretch goal: integrate sources of track information other than operator direct self-reports
  - Gateway Broadcast RID to Network RID
  - Enable multilateration of relayed reports

Some network issues compounded by aero comms, constraining solutions

- Today's Internet has significant weaknesses in
  - Mobility, Multicast, Multihoming
  - Management, QoS, Security
- Aero wireless networking compounds these
  - Each non-trivial aircraft has multiple radios of different types
  - Many types of radios hand off between base stations frequently
  - Most open standard protocols are challenged by
    - Low data rates, High error (or loss) rates, Long latencies
    - Link asymmetry, Rapid wide variation in channel characteristics
- ASTM F3411-19, per regulator guidance to support current smartphones as observer devices, imposes further constraints
  - One-way Bluetooth 4 advertisement (beacon) broadcast frames carry at most 24 bytes of payload
  - Paged multi-frame messages carry at most 224 bytes (minus any error control) to hold a signed message or certificate
- Security protocols requiring cryptographic processing are further challenged by
  - Limited on-board processing power
  - Brief contact time w/fast moving platforms
- Yet enormous safety implications (e.g. drone crashes into people or critical infrastructure) of insecure or unreliable protocols
- Aggregation of enough publicly broadcast RID transmissions enables inference of sensitive information about the physical world (e.g. air operations routes & schedules)

Updated ASTM F3411 + Updated Selected IETF Standards = DRIP

- Mapping an observed UA's **physical location -> UAS ID** similarity to the inverse problem of mapping an Internet **host ID -> logical location** (IP address) inspired leveraging Host Identity Protocol (HIP), bringing other benefits.
- We propose 2 minor tweaks to the ASTM F3411-19 UAS RID application standard.
  - Define a UAS ID Type (presumably 4) as a Hierarchical Host Identity Tag (HHIT)
  - Allow full 10 BT 4.x pages of Authentication Message to contain authentication data

  We participated in ASTM F38.02 UAS RID standard ratification because FAA needed to cite something now. ASTM F38.02 leadership agrees revision is needed & likes our ideas but will wait for FAA NPRM feedback.
- We propose several updates/enhancements to the IETF HIP standards.
  - New crypto must be integrated to fit signatures & certificates in the very small Bluetooth packets.
  - Host Identity Tags (HITs) must be extended to allow for a registry hierarchy (HHITs).
- We have both integrated baseline ASTM F3411-19 (OpenDroneID) & prototyped some of our extensions.
  - We have flown successfully test flown this at the NY UAS Test Site.
  - We have updated our prototypes to authenticate UAS RID claims & will soon fly again.

DRIP: message authentication w/o Internet

UA Broadcasts ID certificate & other messages (e.g. position + velocity) *signed.*

General Public Observer

Public Safety Observer

Not Needed!

Observers verify signatures, ensuring received data (e.g. position track) all really came from UA w/claimed ID.

Internet

UA1
Pilot / Operator

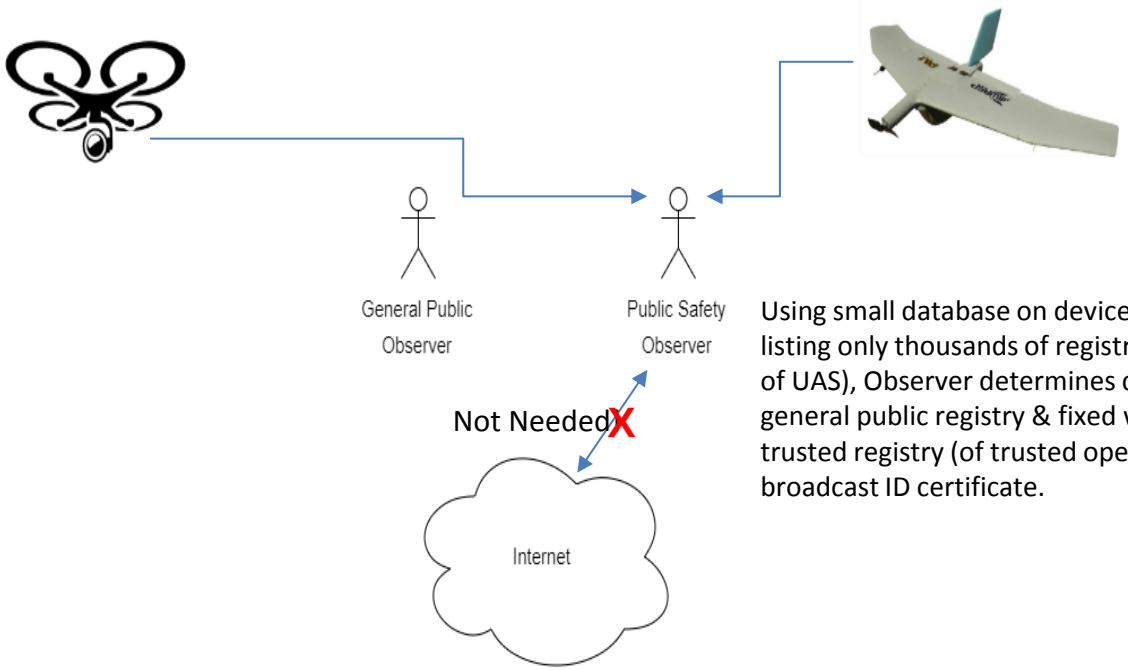
UA2
Pilot / Operator

Public Registry

DNS

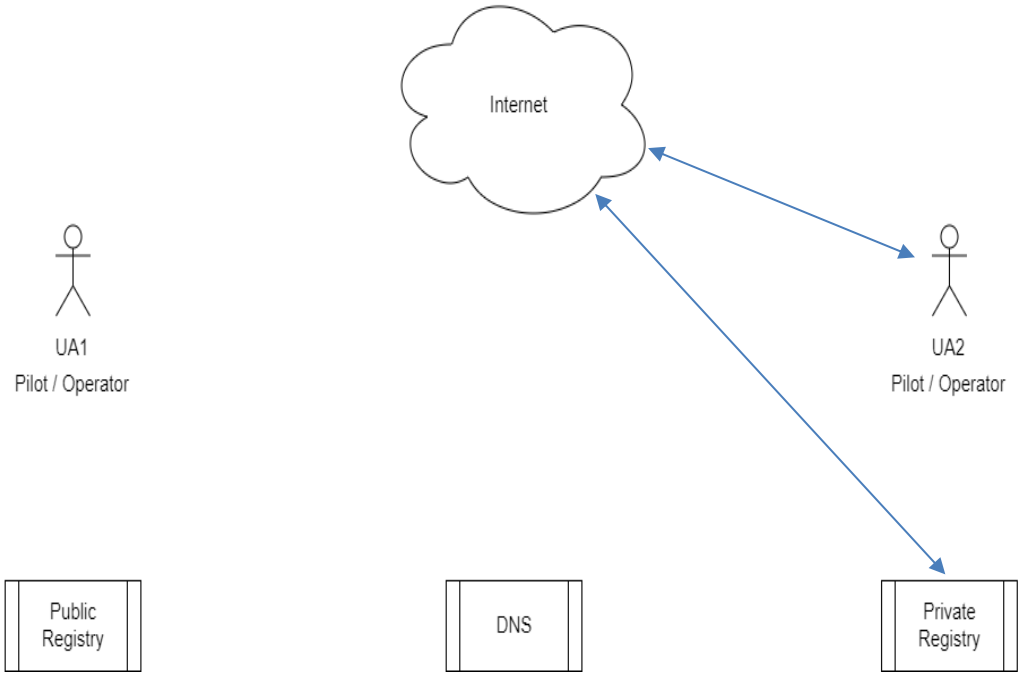
Private Registry

DRIP: Operator trust classification w/o Internet



Using small database on device (e.g., phone) listing only thousands of registries (not millions of UAS), Observer determines quadcopter is in general public registry & fixed wing in Observer trusted registry (of trusted operators) using UA broadcast ID certificate.

DRIP: Operator registration



(1) Operator generates HI keypair (**HIo / HIo(priv)**), from them certificate **Coo**, sends **Coo** to Registry.

(2) Registry validates **Coo**, decides to add Operator to Registry. Registry (using its HI keypair) creates **Cro** & securely sends it back to Operator for confirmation.

DRIP: UA registration

General Public Observer

Public Safety Observer

(6) Operator securely embeds UA keypair & **Cra** into UA

Internet

(2) Operator sends **Caa** & **Coa** to Registry

UA1
Pilot / Operator

UA2
Pilot / Operator

(1) Operator creates HI keypair for UA (**HIa** / **HIa(priv)**), using them generates cert **Caa**. Operator using *his keypair* creates **Coa.**

(4) Registry adds HHIT etc. to DNS

(5) Croa & **Cra** are transmitted securely back to Operator/UA

(3) Registry validates **Caa** & **Coa**, decides to add UA to Registry. Registry (using its HI keypair) creates **Croa** as proof of registration of UA to Operator. Registry also creates **Cra** to be used in DRIP Authentication Message.

Public Registry

DNS

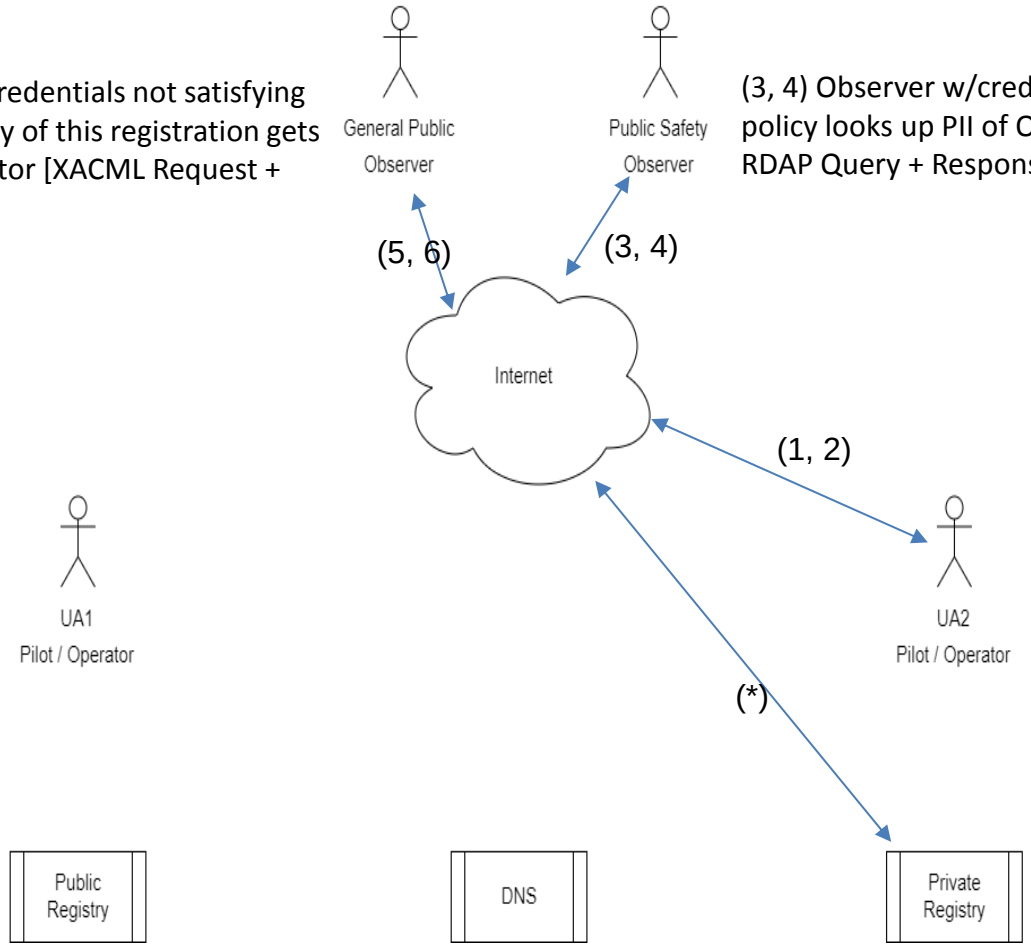
Private Registry

RDAP, EPP, XACML: access controlled registry lookup (we could use your help here!)

(5, 6) Observer w/credentials not satisfying access control policy of this registration gets denied PII of Operator [XACML Request + Denial].

(3, 4) Observer w/credentials satisfying access control policy looks up PII of Operator [XACML Authorized RDAP Query + Response].

Leverage scalable protocols, infrastructure & business models of Internet domain name registration.



(1, 2) Operator privately registers HHIT based domain name.

DRIP UAS Identifier Requirements satisfied by a HHIT w/proposed new crypto in DNS & Whois (w/RDAP, EPP & XACML) used for only 1 UAS flight

1. 20 bytes or smaller
2. sufficient to identify a registry in which the UAS is listed
3. sufficient to enable lookup of other data in that registry
4. unique within a to-be-defined scope
5. non-spoofable within the context of Remote ID broadcast messages (some collection of messages provides proof of UA ownership of ID)

- A DRIP UAS ID MUST NOT facilitate adversarial correlation of UAS operational patterns; this may be accomplished e.g. by limiting each identifier to a single use, but if so, the UAS ID MUST support defined scalable timely registration methods.

- Mechanisms standardized in DRIP MUST be capable of proving ownership of a claimed UAS ID, and SHOULD be capable of doing so immediately on an observer device lacking Internet connectivity at the time of observation.

- Mechanisms standardized in DRIP MUST be capable of verifying that messages claiming to have been sent from a UAS with a given UAS ID indeed came from the claimed sender.

DRIP General Requirements easily satisfied if UAS ID is a HHIT w/proposed new crypto in DNS & Whois, plus HIP is deployed on participating UTM nodes

1. verify that messages originated from the claimed sender
2. verify that the UAS ID is in a registry & identify which one
3. lookup, from the UAS ID, public information
4. lookup, w/AAA, per policy, private information
5. structure information for both human and machine readability
6. provision registries with
    1. static information on the UAS & its Operator / Pilot In Command / Remote Pilot
    2. dynamic information on its current operation within the UTM
    3. Internet direct contact information for services related to the foregoing
7. close the AAA-policy registry loop by
    1. governing AAA per registered policies
    2. administering policies only via AAA
8. dynamically establish, w/AAA, per policy, E2E strongly encrypted communications w/the UAS RID sender & entities looked up from the UAS ID, inc. the GCS & USS

It is highly desirable that Broadcast RID receivers also be able to stamp messages with accurate date/time received and receiver location, then relay them to a network service (e.g. distributed ledger), *inter alia* for correlation to assess sender & receiver veracity.

DRIP: Observer to Pilot (O2P) comms

(1)

General Public Observer

Public Safety Observer

Observer w/credentials satisfying access control policy instantly establishes mutually authenticated, strongly encrypted comms w/pilot (e.g. to command exit from emergency UVR).

Steps:
(1) RID Bluetooth Broadcast
(2) DNS Query
(3) HIP Resource Record
(4) XACML Authorized RDAP Query
(5) Operator Personally Identifiable Information (PII)
(6,7) HIP sets up IPsec ESP Bound End-to-End Tunnel (BEET)

Internet

(7)

(6)

UA1
Pilot / Operator

UA2
Pilot / Operator

(5)

(2) (3)

(4)

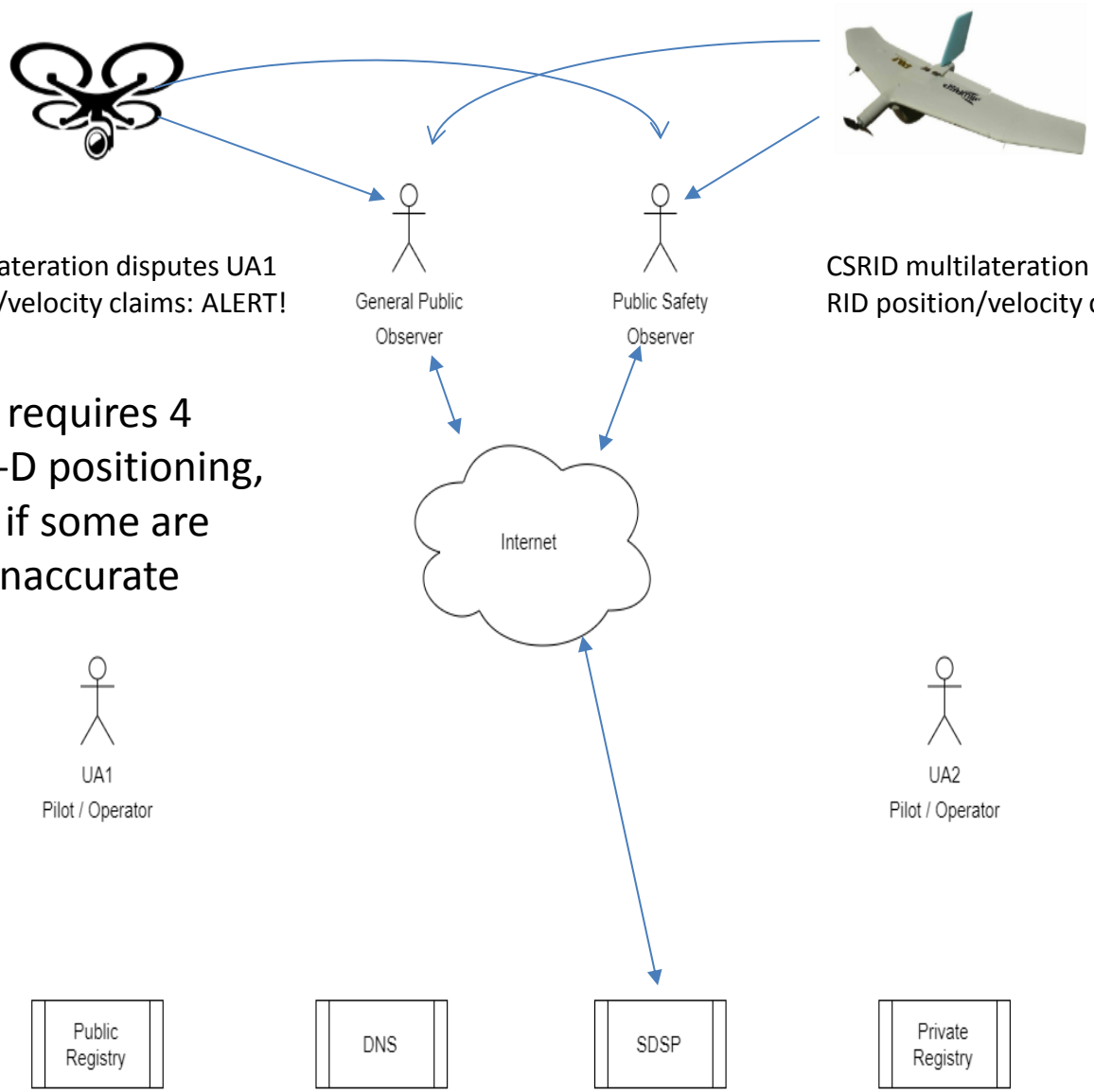
Pilot/Operator gets alert in web browser, accepts SIP VoIP call from Observer.

Public Registry

DNS

Private Registry

Crowd Sourced RID (CS-RID): Broadcast RID → Network RID Gateway & Multilateration



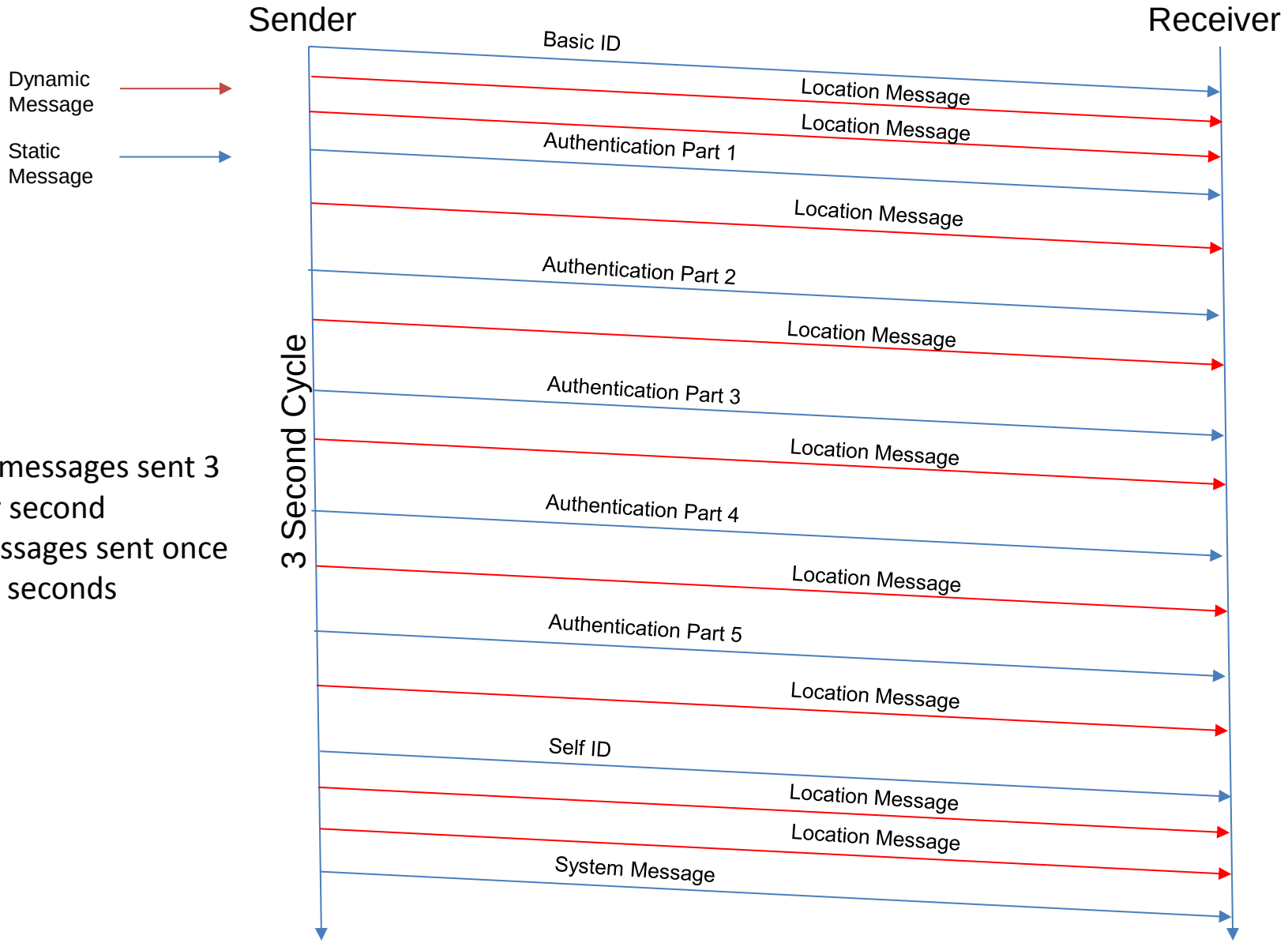
Multilateration requires 4 observers for 3-D positioning, more help esp. if some are [intentionally] inaccurate

Urgent Need

- Stakeholder needs recognized by regulators will influence standards that manufacturers will follow in producing aircraft & ground systems that will remain in use for many years.
- UTM & UAS RID will facilitate airspace useful Situational Awareness *only if* information is **immediately actionable.**
  - Trustworthy
    - Balance privacy of operators with legitimate authorities' Need To Know
    - Robust against cyber attack, poor wireless connectivity & clueless/careless operators
  - Enable observers to instantly determine UAS operator trust class (even w/o Internet)
  - Enable observers to instantly establish secure comms w/operator (w/IP connectivity)
  - Enable observers to confirm claimed position and velocity
- Much can be achieved by adopting/adapting existing Internet standards & infrastructure.
- We have gone a ways down the HIP road but are open to anything meeting the need.
- **We need your help!**

BACKUP SLIDES

UAS RID Authenticated Message Passing (AX prototype)



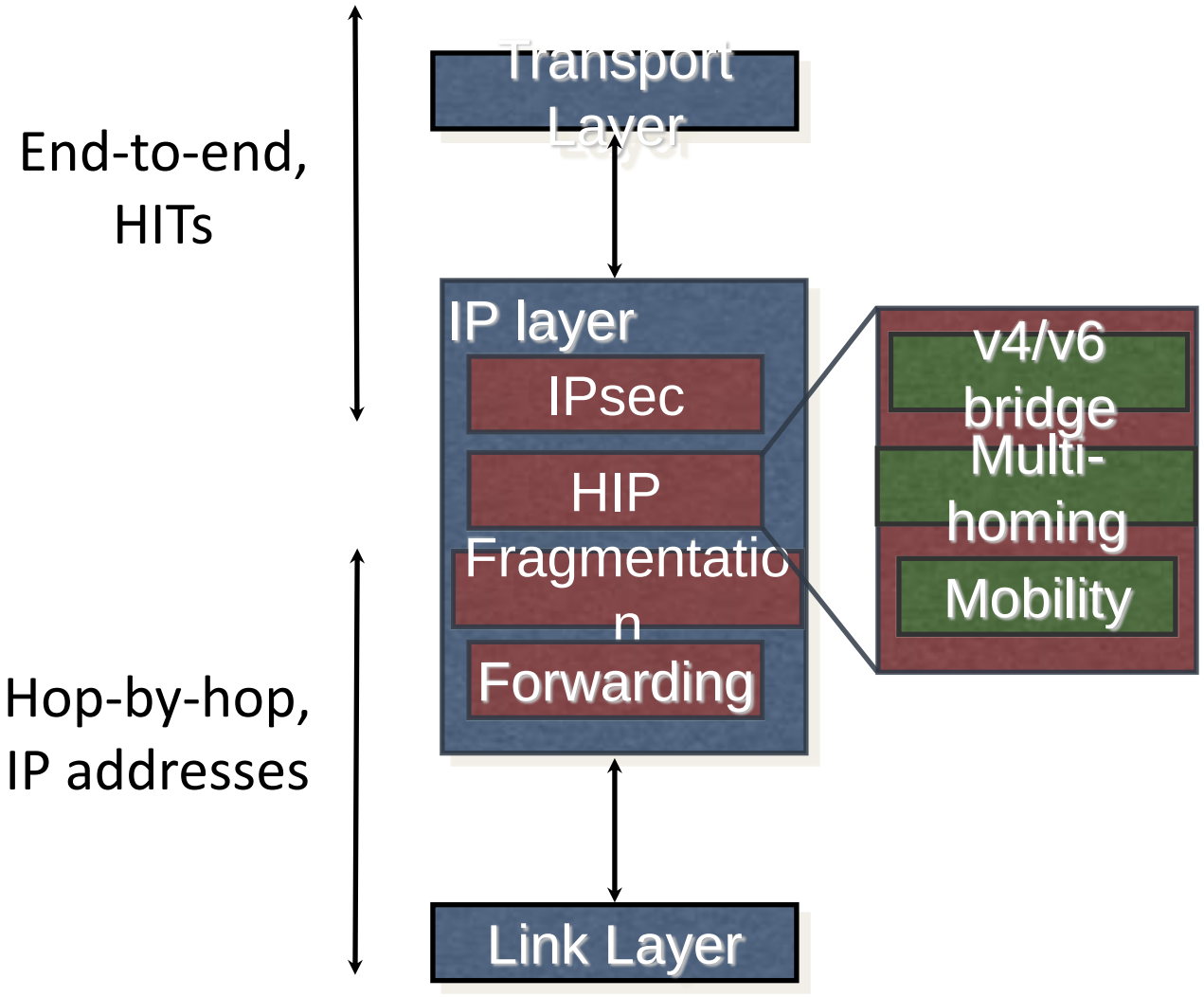
- Dynamic messages sent 3 times per second
- Static Messages sent once per three seconds

HIP Benefits

HIP is standardized in IETF Requests For Comment (RFCs) 4423[bis], 7343 (Overlay Routable Cryptographic Hash Identifier, ORCHID), 7401, 8002 - 8005

- HIP benefits for general network applications
  - Give each device a persistent identifier that remains the same across IP address changes, enabling persistent security associations & TCP connections
  - Give all packets a provenance, as in the "Secure Mobile Architecture" (Boeing, Lockheed-Martin, *et al*) described in, R. Paine's *Beyond HIP: The End to Hacking As We Know It*
  - Auto-configure IPsec VPNs (frustrating to do manually)
- HIP benefits for aero networking applications
  - Associate persistent identifier with aircraft tail #
  - Multihoming for make-before-break smooth handoff
- HIP benefits for the UAS RID application
  - With Internet connectivity (Network RID), also facilitates dynamic establishment of encrypted, mutually authenticated **secure comms** between Observer & UAS Pilot or Proxy (O2P2)
  - With standardized vetting by hierarchical registries, makes UAS ID & any other cryptographically signed claims **trustworthy** even w/o Internet connectivity (Broadcast RID)

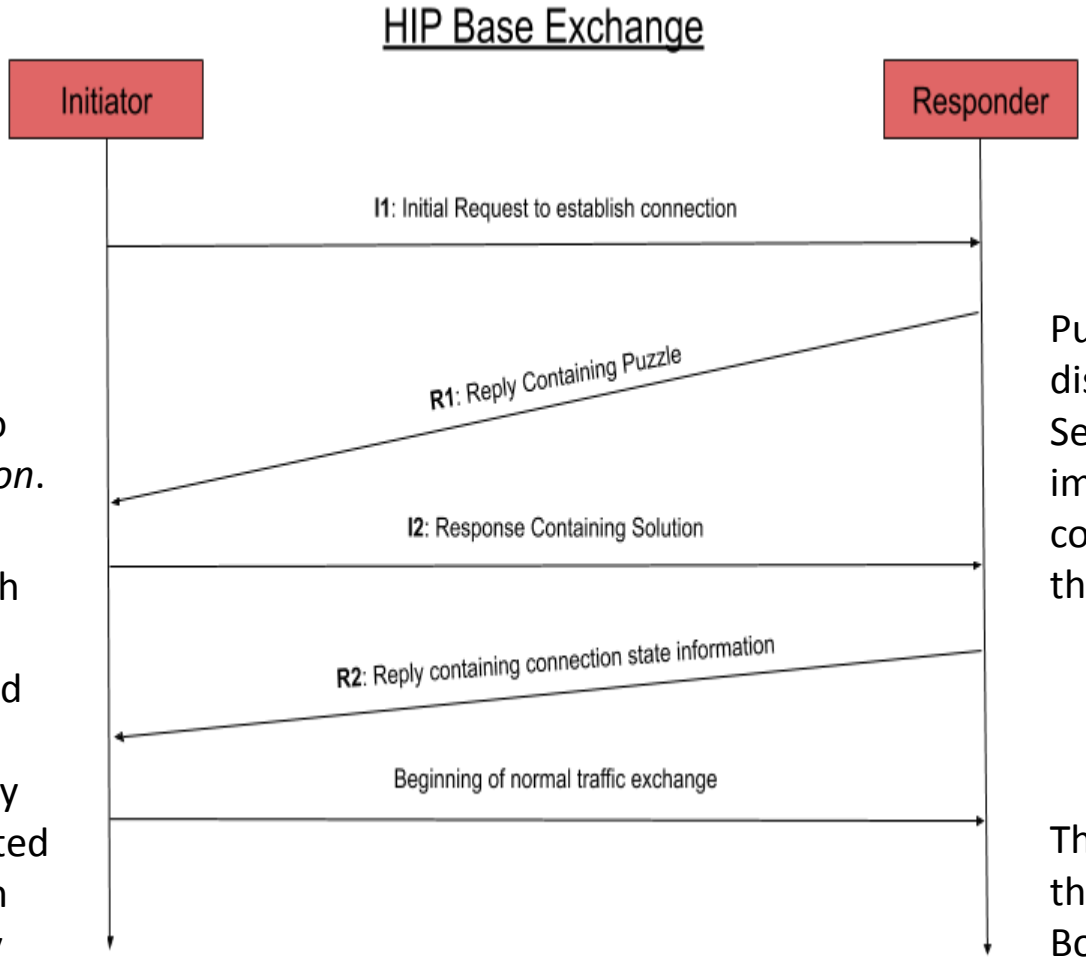
Where HIP Fits in the TCP/IP Stack



How HIP Mutually Authenticates Endpoint Identities

Initiator wants to contact a specific *identity*, has already looked it up in DNS to find its current *location*.

Now identities of both endpoints have been strongly authenticated & an IPsec Encapsulating Security Payload (ESP) encrypted tunnel between them has been dynamically established.



Puzzle defeats distributed Denial of Service attacks by imposing a computational cost on the initiator.

The normal traffic flows through the secure Bound End-to-End Tunnel (BEET).

Encode a HHIT as an ASTM F3411-19 UAS ID Type 1 or Type 3?

- Comply w/ANSI-CTA-2063-A.
- Set length field to 15 encoded as “F”.
- In 15 character serial “number” field, encode:
  - last nibble of IANA HHIT prefix, proposed 0x0 (1 char);
  - HIT Suite / ORCHID Generating Algorithm ID, proposed 0x5 (1 char);
  - 64 bit hash of HI (13 chars, 5 bits each).
- In DNS, map 4 character Manufacturer ID to a HHIT registry (RRA + HDA).
- ➢ Example: MFRX**F27**23456789ABCEFGHJ
- Also map Type 3 (UUIDv4) values to HHITs in DNS?
  - UUIDv6 proposed 2020 MAR 23 in IETF ART meeting looks interesting…

Encode a HHIT as an ASTM UAS ID Type 1 or Type 3?