White Paper: Toward a Cooperative NAS

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This white paper is my take away from the just concluded workshop on Sense and Avoid for small Unmanned Aircraft Systens (SAA for sUAS) hosted by NASA Ames Research Center Apr 14-15, 2015. Some themes that keep running through my mind include:

- RaNae Contarino of R^3 sense of urgency in setting our objective on a **cooperative airspace**
- the difficulties of sensing and avoiding non-cooperative objects
- the exclusion of sUAS on sUAS encounters by the sUAS Well Clear and Encounter models breakout group
- the near-term inability to define requirements
- the lack of sUAS encounter data and modeling
- a side discussion where Paul Campbell from the FAA remarked that by focusing on the 100% solution the FAA doesn't always do a very good job of looking at the 90% solution.
- The S.W.S.W.S.W.N. principle

This made me realize that we need a definition for cooperative. For the purpose of this white paper I am defining *cooperative UAS*, *cooperative manned aircraft* and *other cooperative object* as follows:

Cooperative UAS is defined as any UAS of any size that has ADS-B "in", ADS-B "out" and the means to maintain or increase separation from any cooperative object.

Cooperative Manned Aircraft is defined as an ADS-B category set A aircraft or rotorcraft with a pilot in command (PIC), ADS-B "in", ADS-B "out", a means for ADS-B to alert the pilot to loss of separation and the means for ADS-B to invoke an avoidance maneuver either through the PIC or via flight control automation when separation minimums are breached.

Other Cooperative Object is any other ADS-B category set B or category set C emitter having ADS-B "in" and ADS-B "out" capability regardless of its ability to maneuver (e.g. ground based point, line or cluster object; tethered balloon, free-flight balloon, glider, etc.).

Within the UAS category there need to be at least three sub categories:

Line of Sight (LoS): UAS is within line of sight of and controlled by an operator in command via a continuous data link.

Semi-Autonomous Beyond Visual Line of Sight (SA-BVLoS): UAS is out of view but requires access to a data link for remote guidance.

Fully Autonomous Beyond Visual Line of Sight (FA-BVLoS): UAS can execute its mission from takeoff to landing without remote guidance from a data link.

S.W.S.W.S.W.N Principle

Asserts that some will (S.W.) have ADS-B; some won't (S.W.) have ADS-B; so what (S.W.); next! (N). This principle teaches us that we can't expect all actors to be cooperative. What we can do is let them shoulder the consequences of being uncooperative (e.g. risk, liability, higher insurance premiums). For example, if a pilot has no means of situation discovery (e.g. ADS-B "in", UAT, ATC, NOTAM, etc.), then the primary burden for separation should be placed on the pilot's ability to see and avoid. This becomes clear when you divide the encounter problem space using the categories defined above. For brevity the encounter model grid shown below combines some categories that could otherwise be broken out.

Cooperative Manned **Cooperative uBVLOS / uLOS** • uBVLOS automation has primary responsibility for maintaining separation • uLOS operator has primary responsibility for maintaining separation • warning system alerts manned pilot of uBVLOS/uLOS presence and recommends avoidance maneuver • manned pilot in command has fail-safe responsibility for maintaining separation • UTM should alert ATC to possible loss of separation.	**Cooperative Manned** **Uncooperative uLOS** • Regulations should be designed to minimize this type of encounter (e.g. have altitude and range restrictions enforced by UAS automation systems) • uLOS operator has primary responsibility for seeing and avoiding manned aircraft • UTM should alert manned aircraft to presence of UAS activity	**Cooperative Manned** **Uncooperative uBVLOS** • Regulations should prohibit uncooperative uBVLOS
Uncooperative Manned **Cooperative uBVLOS / uLOS** • uBVLOS requires secondary surveillance equipage (electro-optic, acoustic, synthetic vision, …) • uLOS operator has primary responsibility for maintaining separation • Manned aircraft pilot accepts risk of being uncooperative; has primary responsibility for separation from uBVLOS • uBVLOS automation has fail-safe responsibility for maintaining separation	**Uncooperative Manned** **Uncooperative uLOS** • Regulations should have altitude and range restrictions enforced by UAS automation systems • uLOS operator has primary responsibility for seeing and avoiding manned aircraft • Manned pilot has fail-safe responsibility for see and avoid.	**Uncooperative Manned** **Uncooperative uBVLOS** • Regulations should prohibit uncooperative uBVLOS

Two new terms were introduced in the encounter grid.

Primary Responsibility: the actor primarily responsible for maintaining separation.

Fail-Safe Responsibility: the actor responsible for maintaining separation in the event the primary responsibility actor fails.

By separating the problem space in this manner, the following requirements emerge.

R1. All uBVLOS systems must be cooperative and have a secondary surveillance method to handle non-cooperative encounters (e.g. electro-optical, acoustic, radar, lidar, synthetic vision etc.).

R2. uLOS ADS-B and secondary surveillance equipage is up to operator discretion.

R3. uBVLOS systems have primary responsibility for maintaining separation from cooperative objects.

R4. uLOS systems must have automation systems that enforce mandated range and altitude restrictions.

R5. The uLOS operator has primary responsibility for maintaining data link integrity and separation from all other aircraft.

R6. The pilot of a cooperative manned aircraft has fail-safe responsibility for sensing and avoiding all unmanned aircraft.

R7. The pilot of an uncooperative manned aircraft accepts the risk and liability of an encounter with a cooperative uBVLOS system and therefore assumes primary responsibility. uBVLOS secondary surveillance and automation has fail-safe responsibility.

R8. When there is an encounter and actor responsibilities are unequal, the actor with primary responsibility shoulders all of the risk and the liability.

R9. When both systems have primary responsibility for maintaining separation (e.g. uBVLOS on uBVLOS) risk and liability are shared equally. Maneuvers should be coordinated (e.g. procedurally or electronically) and be designed to maximize separation.

In writing this white paper my objective was to create a framework for simplifying requirements analysis relating to encounter models where participants could raise objections and arguments in favor of or against alternative proposals. However, going forward, it is of paramount importance that we not lose sight of the ultimate objective, a **cooperative airspace**.

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