DAA Use Cases for Auto-Cargo m:N Operations

Use Case 1.

Five UAS (CARGO1, CARGO2, CARGO3, CARGO4, and CARGO5) regularly scheduled, large cargo aircraft are en route and under the authority of a single remote pilot in command (RPIC). Weather conditions at the airport are CAVOK (Clear and visibility OK). The RPIC is responsible for the operations and safety of the aircraft. They are flying through class A airspace at an altitude of 24000 ft (MSL) along the same route. They have filed and are flying IFR flight plans. CARGO1 and CARGO2 are flying in ZZZ sector 1, CARGO3 and CARGO4 in ZZZ sector 4, and CARGO5 in ZZZ sector 7. The aircraft are operating LOS terrestrial C- band datalink with minimal latency. All the aircraft are equipped with a class 2 DAA system which includes a TCAS II system along with a DAA system and on-board non-cooperative sensor (in this case a RADAR).

DAA Event 1.
Multiple corrective alerts.

Three of the aircraft, CARGO2, CARGO3, and CARGO5 sense intruders by ADS-B/In, which are then validated by active surveillance. These intruders will cause a loss of well clear, if no action is taken, representing multiple Corrective Self-Separation Alerts. The RPIC's displays show the corrective alerts and a range of maneuvers that each aircraft can execute to avoid a loss of well clear. The RPIC contacts the appropriate ATC for each aircraft and requests a deviation for traffic specific to each maneuver. The first call (CARGO2) goes to the controller in sector 1, who approves the requested deviation and asks the remote pilot to report when he/she wants to return to the previously assigned clearance. The remote pilot acknowledges the clearance and commands CARGO2 to turn 10 degrees right. The remote pilot then calls the controller in sector 4 and asks for an altitude change for CARGO3 to avoid traffic. The sector 4 controller denies the request, telling the remote pilot that the traffic at 12 o'clock will expedite their descent and be "no factor". The remote pilot then turns their attention to the third corrective alert for CARGO5 and calls sector 7 to request a deviation for traffic. Noting other potential conflicts further ahead, ATC amends the clearance of CARGO5 to begin a turn left of course with new waypoints to rejoin the STAR then as previously cleared. The remote pilot acknowledges the new clearance and uploads the new waypoints to CARGO5. The RPIC coordinates the return to course maneuver for the CARGO2 with ATC, and then executes.

Issues:
- Timeline.
  - Will the RPIC be able to coordinate with (possibly different) ATC and maneuver all the aircraft in time to avoid loss of well clear?
  - Since the remote pilot can only coordinate with one ATC at a time, does possibility of multiple simultaneous RWC alerts mean that the RWC timeline needs to be reexamined? Or, is the likelihood of this "worst case" scenario of 3

simultaneous alerts so small that it doesn't need to impact the requirements and the community is comfortable just handling it in real life, if it ever occurs.

- Pilot workload.
  - Will RPIC workload be too high?
  - Are there additional UA automation requirements that would be needed to enable the remote pilot to turn their attention away from the other 4 UA for so long a period of time?
- Situation Awareness.
  - Will the RPIC's SA be high enough to correctly choose avoidance maneuvers without impacting other aircraft (theirs or other).
  - Will other constraints (e.g. STAR waypoints) make it too difficult for the remote pilot to quickly request a deviation that corresponds to all the other objectives that ATC has, such as traffic flow management?
- Displays/alerts.
  - How do the displays depict the alert status and maneuver options for all the aircraft (and does this scale to 10 or 50)?
  - Does the remote pilot need a pop-up ownship-centric display, or can they handle it all from an airspace-centric display?
- Crew Interaction.
  - If there are more than 1 remote pilots working as a team, does the presence of a RWC or CA alert impact how the crew interacts?
  - Would one crew member focus all their attention to resolving the RWC alert while the other crew member(s) continue to monitor the other N-1 aircraft.

DAA Event 2.
RWC evolves into TCAS RA

Three of the aircraft CARGO2, CARGO3, and CARGO5 sense intruders by ADS-B/In, which are then validated by active surveillance. These intruders will cause a loss of well clear, if no action is taken, representing multiple Corrective Self-Separation Alerts. The RPIC's displays show the corrective level alerts and a range of maneuvers that each aircraft can execute to avoid a loss of well clear. The RPIC contacts the appropriate ATC for each aircraft and requests a deviation for traffic specific to each maneuver. The first call goes to the controller in sector 1, who approves the requested deviation for CARGO2 and asks the remote pilot to report when he/she wants to return to the previously assigned clearance. Before the remote pilot can command the maneuver, a resolution advisory (RA) is issued by the TCAS II system on CARGO5 that the pilot had initially determined to be the lowest priority. The RA includes direct guidance consistent with TCAS II: "*CARGO5: Descend. Descend.*" CARGO5 begins to automatically perform a 1500 fpm descend consistent with TCAS performance assumptions, so the remote pilot calls the ATC in sector 7 to notify them that the aircraft is executing a TCAS RA. The RPIC then turns their attention back to CARGO2 to finish commanding the right turn, which was approved by ATC. While CARGO5 continues to perform the TCAS RA, the remote pilot turns their attention to CARGO3 to request a flight level change from ATC in sector 4. That ATC denies the request, telling the remote pilot that the traffic at 12 o'clock will expedite their descent and be "no factor". The TCAS system onboard CARGO5 issues a "clear of conflict" message. CARGO5 levels out to hold its present altitude and the remote pilot contacts ATC in sector 7 to coordinate the next move. The RPIC coordinates the return to course maneuvers with ATC, and then executes.

Issues:
- o Timeline.
  - o Will the RPIC be able to execute maneuvers for all three aircraft to avoid a loss of separation? Will the RPIC be able to coordinate with ATC in an acceptable time frame?
- o Pilot workload.
  - o Will RPIC workload be too high?
- o Situation Awareness.
  - o Will the RPIC's SA be high enough to correctly execute avoidance maneuvers without impacting other aircraft (their' s or other).
- o Displays/alerts.
  - o How do the displays depict the alert status and maneuver advisory for all the aircraft (and does this scale to 10 or 50)?
  - o Add comment on how an automated maneuver is displayed to the pilot.

DAA Use Case for Auto Cargo m:N Operations
Use Case 3.
Four UAS, CARGO1, CARGO2, CARGO3, and CARGO4, are regularly scheduled, large cargo aircraft are descending to a common destination airport located within Class B airspace. The weather at the airport is CAVOK. All four aircraft are cleared on the STAR and are expecting the

RNAV GPS approach for the active runway. CARGO4 the last aircraft on the STAR has just been transferred to the TRACON.

The aircraft are operating LOS terrestrial C- band datalink with minimal latency. All the aircraft are equipped with a class 2 DAA system which includes a TCAS II system along with a DAA system and on-board non-cooperative sensor (in this case a RADAR).

The aircraft are being flown by a crew of two pilots, Pilot 1 or the RPIC, who is acting as the PF (Pilot Flying) for all four aircraft and Pilot 2, who is acting as the PM (Pilot Monitoring). Both pilots are monitoring the DAA traffic display and Pilot 2 is monitoring the system for DAA alerting and guidance. The RPIC is communicating with ATC. Pilot 2 is monitoring the aircraft systems and performing the pre-landing checklists for each aircraft.

Pilot 2 notices a corrective alert for CARGO1 as ATC clears the aircraft for the RNAV GPS approach and informs the RPIC. The RPIC requests a maneuver away from the traffic from ATC. ATC advises that the aircraft is VFR, has CARGO1 in sight, and will follow the aircraft to the airport. The RPIC acknowledges the information and elects to withdraw his request.

A non-cooperative aircraft causes a corrective alert with CARGO3 as the UA descends though 9000 feet MSL. The corrective alert increases to a warning alert before Pilot 2 can advise a course of action to the RPIC. Pilot 2 informs the RPIC of the warning alert and to immediately turn to the heading recommended by the DAA system. The RPIC turns the aircraft to the heading recommended by the DAA and advises ATC that CARGO3 is responding to a DAA warning alert. ATC acknowledges the transmission, advises that no traffic is displayed, and to advise when ready for further clearance. The RPIC requests a heading for CARGO4 to avoid the area where the traffic was observed, and the controller issues a vector to follow CARGO3. Pilot 2 advises that CARGO3 is clear of traffic and the RPIC requests vectors to the final approach course. ATC assigns a heading to intercept the RNAV GPS approach. The RPIC places the CARGO3 on the assigned heading. ATC issues a vector to CARGO4 that follows CARGO3 to the final approach course.

Issues.
- Timeline.
  - Will added coordination between the RPIC and Pilot 2 reduce the ability of the RPIC to complete the required maneuvers to remain well clear of other aircraft?
  - Can dual roles in the cockpit be divided to allow more efficient performance for all aircraft?

- Pilot workload.
  - How much additional workload is added to accomplish all the tasks required for each aircraft? (checklists, control actions)
  - Do multiple crew members enhance the efficiency of handling multiple aircraft from the GCS?
  - How should the responsibilities of the pilots be distributed among the flight crews?
- Situational Awareness (SA).
  - Does Pilot 2 monitoring provide adequate assistance to the RPIC to maintain adequate SA for each aircraft?
- Displays/alerts.

- What technology may be applied to extend the flight crews capability to handle more than one aircraft?