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Preliminary Safety Assessment

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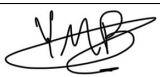
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Glossary

ARP4761A

Aerospace Recommended Practice (ARP) providing guidelines for conducting the safety assessment process on civil aircraft systems and equipment, covering techniques such as FHA, FMEA, and FTA to support system safety analysis throughout the development lifecycle. 3

CoFFE

Combined Functional Failure Effects. 18

FHA

Functional Hazard Assessment. 2, 5

FMEA

Failure Modes and Effects Analysis. 2

FTA

Fault Tree Analysis. 2

1 Introduction

This document compiles the results of the fault hazard analysis and the preliminary drone swarm safety analysis described in ARP4761A [1]. Its purpose is to identify hazards, assess their effects, and define the corresponding high-level safety goals.

1.1 Purpose

The document will be used to create safety goals and as evidence for identified risks.

1.2 Related Documents

Document ID	Document Title
SM-01	Safety Management Plan [2]
ARP4761A	AEROSPACE RECOMMENDED PRACTICE: revision A [1]

Table 1: Related documents

2 Fault Hazard Analysis

2.1 Base Function table

ID	Function
1	Flight
2	Correct communication
3	Search for Subject
4	Task distribution

Table 2: Base functions of the system.

2.2 Extended Function

ID	Function
1	Flight
1.1	Flight controls
2	Correct communication
2.1	Communicate correct health status
2.2	Communicate correct position
2.3	Communicate correctly with agents in area
2.4	Communicate correct search status
2.5	Communicate correct energy status
3	Search for Subject
3.1	Search using RGB camera
3.2	Search using Infrared
3.3	Search using Ultra sound
3.4	Search using LiDAR
4	Task distribution
4.1	Search area distribution
4.2	Task allocation

Table 3: Main functions and sub functions of the system.

2.3 Function Loss

ID	Function	Total Loss	Partial Loss	Malfunction
1	Flight			
1.1	Flight controls	Loss of control	Unstable flight	HW related
2	Correct communication			
2.1	Communicate correct healthstatus	Unknown health status	Health status delayed	HW related
2.2	Communicate correct position	Unknown position	Position accuracy degraded	HW related
2.3	Communicate correctly with agents in area	Unknown retasking information	Retasking information delayed	HW related
2.4	Communicate correct search status	Mission completion rate degraded	Mission completion rate delayed	HW related
2.5	Communicate correct energy status	Mission delay	Mission delay	HW related
3	Search for Subject			
3.1	Search using RGB camera	Degraded search capacity	Degraded search capacity	HW related
3.2	Search using Infrared	Degraded search capacity	Degraded search capacity	HW related
3.3	Search using Ultra sound	Degraded search capacity	Degraded search capacity	HW related
3.4	Search using LiDAR	Degraded search capacity	Degraded search capacity	HW related
4	Task distribution			
4.1	Search area distribution	Task reallocation	Mission delay	HW related
4.2	Task allocation	Mission failure	Mission delay	HW related

Table 4: Function loss table describes what happens when a function is either lost or partially lost.

2.4 Fault Hazard Analysis

Function ID	Function	Loss Phase	Operational Phase	Malfunction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
1	Flight								
1.1	Flight controls	Total Loss	Start	HW related	Degraded search capacity	Delayed rescue	Minor	Catastrophic	Comment: Can lead to death if it is cold in the search area
1.1	Flight controls	Partial Loss	Start	HW related	Degraded search capacity	Delayed rescue	Minor	Catastrophic	Comment: Search Manager in fatal zone
1.1	Flight controls	Total Loss	Search	HW related	Degraded search capacity	Delayed rescue	Catastrophic	Catastrophic	Comment: Agent could be above person(s), can lead to death if it is cold in the search area
1.1	Flight controls	Partial Loss	Search	HW related	Degraded search capacity	Delayed rescue	Minor	Major	Comment: The agents are spread out over a large area which lowers the risk of collision
1.1	Flight controls	Total Loss	Subject Found	HW related	One agent lost	No effect, unless subject underneath	Catastrophic	Catastrophic	Comment: Drones that have found the subject might cause fatal injury if they fall on top of subject
1.1	Flight controls	Partial Loss	Subject Found	HW related	Agent buffer zone increased	No effect	Major	Catastrophic	Comment: Unstable drones have a higher risk of crashing and causing fatal injury in subject proximity
1.1	Flight controls	Total Loss	Return	HW related	One agent lost	No effect	Catastrophic	Catastrophic	Comment: The drones may cause dangerous situations if they crash close to starting point
1.1	Flight controls	Partial Loss	Return	HW related	Agent buffer zone increased	No effect	Minor	Catastrophic	

Table 5: FHA table, 1/12.

Function ID	Function	Loss Phase	Operational Phase	Malfunction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
2	Correct communication								
2.1	Communicate correct healthstatus	Total Loss	Start	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: The drones will not be able to help in the search and will be reassigned to non critical tasks.
2.1	Communicate correct healthstatus	Partial Loss	Start	HW related	Delayed task distribution	Delayed rescue	Minor	Minor	Comment: The communication will still happen but delay
2.1	Communicate correct healthstatus	Total Loss	Search	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Causes a lot of agents to be put in secondary tasks
2.1	Communicate correct healthstatus	Partial Loss	Search	HW related	Delayed task distribution	Delayed rescue	Minor	Minor	Comment: The agents will be delayed in starting tasks but not by a lot
2.1	Communicate correct healthstatus	Total Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: The agents no longer need to search so broadcasting health status is unnecessary
2.1	Communicate correct healthstatus	Partial Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: The agents no longer need to search so broadcasting health status is unnecessary
2.1	Communicate correct healthstatus	Total Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: The agents no longer need to search so broadcasting health status is unnecessary
2.1	Communicate correct healthstatus	Partial Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: The agents no longer need to search so broadcasting health status is unnecessary

Table 6: FHA table, 2/12.

Function ID	Function	Loss Phase	Operational Phase	Malfunction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
2.2	Communicate correct position	Total Loss	Start	HW related	Degraded search capacity, one agent lost	Delayed rescue	Minor	Hazardous	Comment: This will put the drones in a inoperable state, the drone swarm loses a lot of agents that will not take off
2.2	Communicate correct position	Partial Loss	Start	HW related	Agent buffer zone increased	Delayed rescue	Catastrophic	Catastrophic	Comment: Could cause a crash if wrong position is used in close quarters
2.2	Communicate correct position	Total Loss	Search	HW related	Degraded search capacity, one agent lost	Delayed rescue	Minor	Hazardous	Comment: The loss of agents will slow down the search significantly
2.2	Communicate correct position	Partial Loss	Search	HW related	Agent buffer zone increased	Delayed rescue	Minor	Minor	Comment: Causes the agents position to update slower, since they are far apart collision is not a worry
2.2	Communicate correct position	Total Loss	Subject found	HW related	Decreased search area	Delayed rescue	Major	Major	Comment: The agents will have to re-search the area to find the subject and the faulty drone
2.2	Communicate correct position	Partial Loss	Subject found	HW related	Delayed subject position	Delayed rescue	Minor	Minor	Comment: The rescue will be delayed until a correct position message is sent
2.2	Communicate correct position	Total Loss	Return	HW related	One agent lost	No effect	Catastrophic	Catastrophic	Comment: The drones might crash while gathering on the way back
2.2	Communicate correct position	Partial Loss	Return	HW related	Agent buffer zone increased	No effect	Catastrophic	Catastrophic	Comment: The drones might crash while gathering on the way back

Table 7: FHA table, 3/12.

Function ID	Function	Loss Phase	Operational Phase	Malfunction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
2.3	Communicate correctly with agents in area	Total Loss	Start	HW related	Degraded search capacity, one agent lost	Delayed rescue	Catastrophic	Catastrophic	Comment: Correct communication is important in close quarter flying
2.3	Communicate correctly with agents in area	Partial Loss	Start	HW related	Delayed task distribution	Delayed rescue	Catastrophic	Catastrophic	Comment: Correct communication is important in close quarter flying
2.3	Communicate correctly with agents in area	Total Loss	Search	HW related	Degraded search capacity, one agent lost	Delayed rescue	Minor	Catastrophic	Comment: losing drones will slow down the rescue
2.3	Communicate correctly with agents in area	Partial Loss	Search	HW related	Delayed task distribution	Delayed rescue	Minor	Minor	Comment: This will slow down communication
2.3	Communicate correctly with agents in area	Total Loss	Subject Found	HW related	Degraded search capacity, one agent lost	Delayed rescue	Major	Major	Comment: The agents will have to re-search the area to find the subject and the faulty drone
2.3	Communicate correctly with agents in area	Partial Loss	Subject Found	HW related	Delayed subject position	Delayed rescue	Minor	Minor	Comment: The rescue will be delayed until a correct position message is sent
2.3	Communicate correctly with agents in area	Total Loss	Return	HW related	One agent lost	No effect	Catastrophic	Catastrophic	Comment: The drones might crash while gathering on the way back
2.3	Communicate correctly with agents in area	Partial Loss	Return	HW related	Agent buffer zone increased	No effect	Catastrophic	Catastrophic	Comment: The drones might crash while gathering on the way back

Table 8: FHA table, 4/12.

Function ID	Function	Loss Phase	Operational Phase	Malfunction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
2.4	Communicate correct search status	Total Loss	Start	HW related	No effect	No effect	No effect	No effect	Comment: No information to transmit
2.4	Communicate correct search status	Partial Loss	Start	HW related	No effect	No effect	No effect	No effect	Comment: No information to transmit
2.4	Communicate correct search status	Total Loss	Search	HW related	Degraded search capacity	Delayed rescue	No effect	Minor	Comment: Delay in retasking, no effect if only 1 agent is delayed, more delay fore each agent delayed
2.4	Communicate correct search status	Partial Loss	Search	HW related	No effect	No effect	No effect	No effect	Comment: It is not a time sensitive mater
2.4	Communicate correct search status	Total Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: The information is no longer relavent
2.4	Communicate correct search status	Partial Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: The information is no longer relevant
2.4	Communicate correct search status	Total Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: The information is no longer relevant
2.4	Communicate correct search status	Partial Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: The information is no longer relevant

Table 9: FHA table, 5/12.

Function ID	Function	Loss Phase	Operational Phase	Malfunction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
2.5	Communicate correct energy status	Total Loss	Start	HW related	One agent lost	Delayed rescue	Minor	Hazardous	Comment: Will lose agents, causes delay in search
2.5	Communicate correct energy status	Partial Loss	Start	HW related	No effect	No effect	Minor	Hazardous	Comment: Slower update about agents moving to refuel
2.5	Communicate correct energy status	Total Loss	Search	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Will lose agents, causes delay in search
2.5	Communicate correct energy status	Partial Loss	Search	HW related	No effect	No effect	Minor	Minor	Comment: Slight delay in replanning
2.5	Communicate correct energy status	Total Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant for the swarm
2.5	Communicate correct energy status	Partial Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant for the swarm
2.5	Communicate correct energy status	Total Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant for the swarm
2.5	Communicate correct energy status	Partial Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant for the swarm

Table 10: FHA table, 6/12.

Function ID	Function	Loss Phase	Operational Phase	Malfunction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
3	Search for Subject								
3.1	Search using RGB camera	Total Loss	Start	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Agents relocate to secondary tasks, slower search
3.1	Search using RGB camera	Partial Loss	Start	HW related	-	-			
3.1	Search using RGB camera	Total Loss	Search	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Agents relocate to secondary tasks, slower search
3.1	Search using RGB camera	Partial Loss	Search	HW related	-	-			
3.1	Search using RGB camera	Total Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant
3.1	Search using RGB camera	Partial Loss	Subject Found	HW related	-	-			
3.1	Search using RGB camera	Total Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant
3.1	Search using RGB camera	Partial Loss	Return	HW related	-	-			

Table 11: FHA table, 7/12.

Function ID	Function	Loss Phase	Operational Phase	Malfunction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
3.2	Search using Infrared	Total Loss	Start	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Agents relocate to secondary tasks. slower search
3.2	Search using Infrared	Partial Loss	Start	HW related	-	-			
3.2	Search using Infrared	Total Loss	Search	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Agents relocate to secondary tasks. slower search
3.2	Search using Infrared	Partial Loss	Search	HW related	-	-			
3.2	Search using Infrared	Total Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant
3.2	Search using Infrared	Partial Loss	Subject Found	HW related	-	-			
3.2	Search using Infrared	Total Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant
3.2	Search using Infrared	Partial Loss	Return	HW related	-	-			

Table 12: FHA table, 8/12.

Function ID	Function	Loss Phase	Operational Phase	Malfuction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
3.3	Search using Ultrasound	Total Loss	Start	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Agents relocate to secondary tasks. slower search
3.3	Search using Ultrasound	Partial Loss	Start	HW related	-	-			
3.3	Search using Ultrasound	Total Loss	Search	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Agents relocate to secondary tasks. slower search
3.3	Search using Ultrasound	Partial Loss	Search	HW related	-	-			
3.3	Search using Ultrasound	Total Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant
3.3	Search using Ultrasound	Partial Loss	Subject Found	HW related	-	-			
3.3	Search using Ultrasound	Total Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant
3.3	Search using Ultrasound	Partial Loss	Return	HW related	-	-			

Table 13: FHA table, 9/12.

Function ID	Function	Loss Phase	Operational Phase	Malfuction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
3.4	Search using LiDAR	Total Loss	Start	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Agents relocate to secondary tasks. slower search
3.4	Search using LiDAR	Partial Loss	Start	HW related	-	-			
3.4	Search using LiDAR	Total Loss	Search	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Agents relocate to secondary tasks. slower search
3.4	Search using LiDAR	Partial Loss	Search	HW related	-	-			
3.4	Search using LiDAR	Total Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant
3.4	Search using LiDAR	Partial Loss	Subject Found	HW related	-	-			
3.4	Search using LiDAR	Total Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: Information no longer relevant
3.4	Search using LiDAR	Partial Loss	Return	HW related	-	-			

Table 14: FHA table, 10/12.

Function ID	Function	Loss Phase	Operational Phase	Malfunction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
4	Task distribution								
4.1	Search area distribution	Total Loss	Start	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Agents will not be able to participate in the search and will be used for secondary roles
4.1	Search area distribution	Partial Loss	Start	HW related	Delayed task distribution	Delayed rescue	No effect	Minor	Comment: Slight time delay in planing and replanning
4.1	Search area distribution	Total Loss	Search	HW related	Degraded search capacity	Delayed rescue	Minor	Hazardous	Comment: Agents will not be able to participate in the search and will be used for secondary roles
4.1	Search area distribution	Partial Loss	Search	HW related	Delayed task distribution	Delayed rescue	Minor	Major	Comment: Slight time delay in planing and replanning
4.1	Search area distribution	Total Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: Search area distribution no longer necessary
4.1	Search area distribution	Partial Loss	Subject Found	HW related	No effect	No effect	No effect	No effect	Comment: Search area distribution no longer necessary
4.1	Search area distribution	Total Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: Search area distribution no longer necessary
4.1	Search area distribution	Partial Loss	Return	HW related	No effect	No effect	No effect	No effect	Comment: Search area distribution no longer necessary

Table 15: FHA table, 11/12.

Function ID	Function	Loss Phase	Operational Phase	Malfuction	Effect on Swarm	Effect on Subject	Severity of one (1) Agent failure	Severity of 50% of Agents in Swarm failing	Assumptions, Comments, Rationale
4.2	Task allocation	Total Loss	Start	HW related	Degraded search capacity, one agent lost	Delayed rescue	Minor	Catastrophic	Comment: Agents will be unable to participate in mission
4.2	Task allocation	Partial Loss	Start	HW related	Delayed task distribution	Delayed rescue	Minor	Major	Comment: Time delay in task relocation
4.2	Task allocation	Total Loss	Search	HW related	Degraded search capacity, one agent lost	Delayed rescue	Minor	Catastrophic	Comment: Agents will be unable to participate in mission
4.2	Task allocation	Partial Loss	Search	HW related	Delayed task distribution	Delayed rescue	Minor	Major	Comment: Time delay in task relocation
4.2	Task allocation	Total Loss	Subject Found	HW related	One agent lost	No effect	No effect	No effect	Comment: Agents will have trouble returning
4.2	Task allocation	Partial Loss	Subject Found	HW related	Delayed task distribution	No effect	No effect	No effect	Comment: Agents will have trouble returning
4.2	Task allocation	Total Loss	Return	HW related	One agent lost, agent buffer zone increased	No effect	Catastrophic	Catastrophic	Comment: Agents can not receive avoiding tasks, can cause air collision
4.2	Task allocation	Partial Loss	Return	HW related	Delayed task distribution	No effect	Minor	Minor	Comment: Agents will be slow to receive avoiding tasks, can cause air collision

Table 16: FHA table, 12/12.

2.5 Classification Description

Classification	Effect on Swarm	Effect on Subject
Catastrophic	Unable to find Subject; Agent crash causes fatal consequences	Subject exposed to fatal circumstances
Hazardous	Search ability of Swarm greatly limited; Agent crash causes critical consequences	Subject exposed to critical circumstances due to search time increase
Major	Search ability of Swarm limited; Agent crash causes non-fatal consequences	Subject exposed to exacerbated non-fatal circumstances or physical distress due to manageable increase in search time
Minor	Search ability of Swarm slightly limited; Agent crash causes physical discomfort to person(s)	Exacerbated physical discomfort of Subject due to slight increase in search time
No effect	No effect	No effect

Table 17: Classification meanings.

2.6 Flight Phases

Operational Flight Phases:

- Start
- Search
- Subject Found
- Return

3 Preliminary Drone Swarm Safety Assessment

3.1 Interdependence of Functions & Systems

Function	Failure Condition ID	Failure Condition	Communication System	Power System	Sensors System	Flight System	Positioning System
Flight	F-1	Collision with ground		x	x	x	x
Flight	F-2	Collision with other agent(s)	x		x	x	x
Flight	F-3	Collision with other flying object(s)			x	x	
Search for subject	S-1	False negative when subject found	x		x		
Search for subject	S-2	Search capacity lost		x	x		
Correct communication	C-1	Health status incorrect/lost	x	x	x		
Task distribution	T-1	Task does not reach agent	x				
Task distribution	T-2	More than 1 agent on same task	x				
Task distribution	T-3	An agent is assigned a task beyond its qualification	x		x		

Table 18: Interdependence table of functions' relations to systems.

3.2 Combined Functional Failure Effects

This is the result of The fault mode effect analysis. Each table represents one fault mode.

Case	Power System	Sensors System	Flight System	Positioning System	Effect	Does it result in the failure event?
1	Operational	Operational	Operational	Failed	The agent does not know where it is, this causes degraded terrain awareness, can no longer return to base	YES
2	Operational	Operational	Failed	Operational	The agent loses the ability to fly	YES
3	Operational	Failed	Operational	Operational	The agent can no longer recognise the ground, this causes degraded terrain awareness	NO
4	Failed	Operational	Operational	Operational	The agent loses power, can no longer fly	YES
5	Operational	Operational	Operational	Degraded	The agents position is more uncertain, terrain awareness degraded	NO
6	Operational	Operational	Degraded	Operational	The agents ability to fly is degraded, it might become unstable	YES
7	Operational	Degraded	Operational	Operational	The agents ground clearance becomes uncertain, terrain awareness degraded	NO
8	Operational	Failed	Degraded	Operational	The agent becomes unstable and terrain awareness degraded	YES
9	Degraded	Operational	Operational	Operational	The agents power status becomes unstable	NO
10	Degraded	Degraded	Operational	Operational	The agent will have unknown power status and degraded terrain awareness	NO
11	Degraded	Operational	Operational	Degraded	The agent will have unknown power status, position in reference to home is uncertain, leads to failure to return	YES

Table 19: CoFFE table of failure condition F-1

Case	Communication System	Sensors System	Flight System	Positioning System	Effect	Does it result in the failure event?
1		Operational	Operational	Failed	Agent loses ability to broadcast its location, may lead to collision, use sensors to avoid other agent(s)	NO
2	Operational	Operational	Failed	Operational	Agent will fall to the ground, may hit other agent(s)	YES
3	Operational	Failed	Operational	Operational	Agent will not be able to avoid incoming air threats, position broadcast will prevent collisions	NO
4	Failed	Operational	Operational	Operational	Agent will not be able to broadcast position, use sensors to avoid collision	NO
5	Operational	Failed	Operational	Failed	Agent will not be able to broadcast its position or avoid air threats	YES
6	Failed	Failed	Operational	Operational	The agent loses the ability to avoid air threats and to communicate its position	YES
7	Operational	Operational	Operational	Degraded	The agent's position becomes uncertain	NO
8	Operational	Operational	Degraded	Operational	The agent becomes unstable	NO
9	Operational	Degraded	Operational	Operational	The agent's air threat detection becomes degraded	NO
10	Degraded	Operational	Operational	Operational	Communication becomes less effective	NO
11	Operational	Operational	Degraded	Degraded	Unstable flight combined with uncertain position	YES
12	Operational	Degraded	Degraded	Operational	Degraded flight combined with degraded air threat detection	NO
13	Degraded	Operational	Degraded	Operational	Unstable flight combined with uncertain position	YES
14	Degraded	Degraded	Operational	Operational	Uncertain position combined with degraded air threat detection	YES
15	Operational	Degraded	Operational	Degraded	Uncertain position combined with degraded air threat detection	YES

Table 20: CoFFE table of failure condition F-2

Case	Sensors System	Flight System	Effect	Does it result in the failure event?
1	Operational	Failed	Agent falls, might hit other flying object	YES
2	Failed	Operational	Loses ability to detect air threats	YES
3	Operational	Degraded	Unstable and slow response time	YES
4	Degraded	Operational	Slowed response time to air threats	YES

Table 21: CoFFE table of failure condition F-3

Case	Communication System	Sensors System	Effect	Does it result in the failure event?
1	Operational	Failed	Subject can not be found	YES
2	Failed	Operational	Subject found can not be communicated	YES
3	Operational	Degraded	Subject may be missed	YES
4	Degraded	Operational	Communication slower	NO

Table 22: CoFFE table of failure condition S-1

Case	Power System	Sensors System	Effect	Does it result in the failure event?
1	Operational	Failed	Subject can not be found	YES
2	Failed	Operational	Sensors have no power, drone crash	YES
3	Operational	Degraded	Search capacity limited	NO
4	Degraded	Operational	Sensors may be impacted by power problems	YES

Table 23: CoFFE table of failure condition S-2

Case	Communication System	Power System	Sensors System	Effect	Does it result in the failure event?
1	Operational	Operational	Failed	Sensors stop working	NO
2	Operational	Failed	Operational	Power stops working, agent crash	YES
3	Failed	Operational	Operational	Communication lost	YES
4	Operational	Operational	Degraded	Sensors may give false information	YES
5	Operational	Degraded	Operational	Power unstable may affect sensors and communication, may not provide correct power status	YES
6	Degraded	Operational	Operational	Could send out incorrect status	YES

Table 24: CoFFE table of failure condition C-1

Case	Communication System	Effect	Does it result in the failure event?
1	Failed	Communication lost	YES
2	Degraded	May get false information	YES

Table 25: CoFFE table of failure condition T-1

Case	Communication System	Effect	Does it result in the failure event?
1	Failed	Communication lost, no task can be assigned	NO
2	Degraded	May get false information	YES

Table 26: CoFFE table of failure condition T-2

Case	Communication System	Sensors System	Effect	Does it result in the failure event?
1	Operational	Failed	System lost search capability	NO
2	Failed	Operational	Lost communication	NO
3	Operational	Degraded	May get false sensor status	YES
4	Degraded	Operational	May send out sensor status	YES

Table 27: CoFFE table of failure condition T-3

References

- [1] *Guidelines for Conducting the Safety Assessment Process on Civil Aircraft, Systems, and Equipment (ARP4761A)*, SAE International Std. ARP 4761A, Dec. 2023, aerospace Recommended Practice.
- [2] E. Målvist, *Safety Management Plan*, Intelligent Replanning Drone Swarm, Oct. 4 2025, Version 1.0.