# Disaster Response Search and Identification Attritable Air Vehicle (Dr. SAAV)

AIAA Aircraft Design Technical Committee, POC: Gregory L. Roth, Gregory.Roth@us.af.mil

## Background

With the changing climate, hurricanes, typhoons, and cyclones are expected to increase in their intensity and ferocity, even if they do not increase in their frequency [1]. Some studies even suggest their frequency will also increase [2]. These weather phenomena cause great damage and appear to be spreading across more of the globe over time [1]. In addition to habitat and building structural damage, ships at sea are also at risk of capsizing or otherwise experiencing shipwreck states. Earthquakes, too, cause great damage, and even though there is no long term evidence of greater earthquake frequency [3, 4], global population growth leads to more and more people being affected by earthquakes than ever before. Finally, tornadoes and waterspouts cause great structural damage even if the impact is only within a relatively concentrated area.

Collectively, these natural disasters affect millions of people per year globally. First responders' initial effort is to locate people that need their help. Hours and minutes saved in search operations often lead to lives saved. An air vehicle capable of searching a large ground (or sea) surface area quickly and identifying victims in need of help could save lives and help target where limited rescue resources should be applied. Whether affected by violent weather, unexpected flooding, or even individuals that have lost their way in the wilderness, expeditious search and contact with these people can have great impact.

The purpose of the current effort is to design an air vehicle (or collection of vehicles) to find and identify victims in need of first responder help, potentially within a sea of other debris in less than ideal flight conditions. Initial entry into service (EIS) is expected to be 2028. Once victims are identified, the objective transitions to delivering life-saving drinking water and a communication radio to connect victims with those that can help. Each of the KPP (Key Performance Parameter) thresholds listed below are required to be accomplished by the resultant air vehicle in a primary search and identification mission (not subsets of the KPPs in multiple, separate missions). A second mission that maximizes loiter (allowing range to shrink to 0 nm) is also of interest. Finally, a third mission that demonstrates maximum range with no loiter is also desired.

## References

[1] https://www.c2es.org/content/hurricanes-and-climate-change/
[2] https://www.washingtonpost.com/weather/2021/12/02/atlantic-hurricanes-increasing-frequency-climate/
[3] https://www.usgs.gov/faqs/why-are-we-having-so-many-earthquakes-has-naturally-occurring-earthquake-activity-been
[4] http://www.earthquakes.bgs.ac.uk/news/EQ_increase.html

## Primary Mission

- Search a large area and ID people needing help after a natural disaster (hurricane, shipwreck, tornado, earthquake, building collapse, etc.)
- Drop/deliver communication radio and drinking water to disaster victims (30 min radio operation provides contact with rescuers, assume victims are in groups of a maximum of two individuals each)

## Desirements

- Long ferry range to allow light logistics for deployment anywhere in the world within hours
- Ability to operate in rough weather (may need to begin search before weather has returned to normal, consider e.g. downdrafts, rain, dust)
- Small overall size to facilitate logistics and possible air launch from larger rescue vehicles (potential Air National Guard assets)
- Minimal operational logistics (e.g., attritable, no depot/heavy maintenance operations, minimal turn-around time/requirements)

- Simple design minimizing protuberances and control effectors that could be damaged or be caught/tangled in brush or affected by excessive dirt/debris
- Novel methods to reduce acquisition costs/enhance performance (i.e., flow control, topology optimization, additive manufacturing, etc.)
- Beneficial trade-off of cost vs attritability as loss of some vehicles is expected due to the potentially harsh operating environment

**Key Performance Parameters**

| KPP # | KPP Title | Threshold[a] | Objective[b] |
|---|---|---|---|
| KPP.01 | Maximum Vehicle Weight (lbs) for Potential Air Launch | 4,800 | 3,000 |
| KPP.02 | Minimum Cruise Ingress Range (nm) at 30,000 ft[c] | 650 | 850 |
| KPP.03 | Minimum Cruise Ingress Speed (Mach) at 30,000 ft[c] | 0.7 | 0.86 |
| KPP.04 | Minimum Loiter Time (hrs) at 30,000 ft[c] & Mach 0.7 | 3.5 | 5 |
| KPP.05 | Minimum Cruise Egress Range (nm) at 30,000 ft[c] | 1,650 | 2,000 |
| KPP.06 | Minimum Cruise Egress Speed (Mach) at 30,000 ft[c] | 0.5 | 0.86 |
| KPP.07 | Maximum Landing Concrete Runway Length (ft) | 4,000 | 1,500 |
| KPP.08 | Minimum Dash Speed (Mach) capability at 30,000 ft[c] | 0.8 | 0.9 |
| KPP.09 | Minimum Available Cruise Electrical Power (KW) | 12 | 24 |
| KPP.10 | Minimum Loiter Time (min) at Recovery/Landing Site | 30 | 45 |
| KPP.11 | Minimum Mission Payload Weight[d] (lbs) | 200 | 300 |
| KPP.12 | Minimum Free Flight Loads (g's) | 4.5 | 6 |
| KPP.13 | Maximum Mission Payload Swap Time (min) | 10 | 5 |
| KPP.14 | Maximum Time to Replenish Operating Fluids (Fuel, Oil…) (min) | 10 | 5 |
| KPP.15 | Maximum Time to Replenish Engine Start Consumables (min) | 10 | 5 |
| KPP.16 | Minimum Number of Sorties Life with only Search and ID Ops | 25 | 50 |
| KPP.17 | Maximum Take-Off Concrete Runway Length[e] (ft) (Launch trade) | 4,000 | 1,500 |
| KPP.18 | Upward Flight Limit Loads (g's) | 2.5 | 3 |
| KPP.19 | Downward Flight Limit Loads (g's) | -1 | -1.5 |
| KPP.20 | Landing Maximum Vertical Descent at Max. Landing Weight (fps) | 10 | 15 |
| KPP.21 | Landing Maximum Vertical Descent at Max. Take-Off Weight (fps) | 6 | 10 |
| KPP.22 | Factor of Safety (structural) | 1.3 | 1.5 |

[a] Thresholds are typically considered mandatory requirements and should all be satisfied by your proposed design (see note regarding designs that do not close based on your modeling capabilities)

[b] Objectives state values and conditions that provide additional value to the customer (tradable "requirements"), but exceeding these objective values/conditions provides no additional value to the customer

[c] operational altitudes should result from pertinent trade studies with minimum achievable performance as specified in the Key Performance Parameters table

[d] see Initial Estimated Sensor Payload Table

[e] Take-Off Length maximum threshold assumed to be ground roll, but preference for 30 ft obstacle clearance (may assume sea level standard conditions, ISA atmospheric model, and dry pavement conditions, but state wet pavement performance as well)

**Initial Estimated Subsystems Payload**

| Item | Weight (lbs) |
|---|---|
| Flight Control Unit (FCU) | 20 |
| System Control Unit (SCU) | 18 |
| Flight Transduces | 3 |
| Power & Engine Control Unit | 7 |
| Power Converter Assembly | 4 |
| GPS Receiver (Anti-Jam) | 25 |
| GPS Antenna | 6 |
| Battery (Non-Propulsion) | 13 |
| Cooling and Pressurization | 5 |
| Air Data Probe | 1 |
| Anti-Ice | 2 |
| Thermal Management | 23 |
| Misc. Electrical Wiring | 5 |
| Basic Satellite Radio | 34 |
| Data Handling and Linking | 24 |
| Flight Termination System | 10 |
| Navigation Fusion Processor | 9 |
| Transponders | 15 |
| **Total** | **222** |

**Initial Estimated Sensor Payload**

| Item | Weight (lbs) |
|---|---|
| Radar | 63 |
| Nose EO/IR/LIDAR | 100 |
| Aft EO/IR/LIDAR | 50 |
| Sensor Growth | 15 |
| **Total** | **228** |

**Navigation Note**

GPS use has been assumed in the Initial Estimated Subsystems Payload that relies on access and communication with external resources (i.e., satellites). You may also wish to consider other, self-contained navigation aids, such as inertial navigation systems (INS) for added overall system value and operational capability.

**Notes and Assumptions**

- Overall objective is to provide best value to customer based on systems, operational, and lifecycle costs; air vehicle performance for all missions; life-cycle logistics footprint; and ease of operation, including required training of operators and maintainers
- Anticipated un-crewed air vehicle solution, but other options are possible if shown to have an advantage
- Provide details of your proposed operation (remotely piloted, autonomous, etc.) and why this is the best value to the customer
- Your proposed solution can be a single air vehicle design that will be used for all mission capabilities, or a collection of air vehicles that may be composed of different air vehicles to operate as a unit – either case must be justified for cost and value to the customer as well as suitability to accomplish required missions
- Must meet applicable Federal Aviation Administration certification rules to allow operation over continental United States
- Flying qualities for crewed system not required (unless your proposal is for a crewed system), but justification for controllability in adverse weather conditions required – may be satisfied by providing maximum crosswind take-off and landing performance, maximum climb performance as a function of altitude, effects due to rain of various intensities, capabilities in icing conditions, and qualitative justification of adverse weather performance
- Weight and balance conditions throughout the mission should be tabulated and accounted for to ensure a controllable air vehicle(s) is (are) proposed
- Specify quantity of fresh water delivered to stranded victims and how long this will last them in your concept of operations discussion – if needed, multiple visits to same victims is allowable based on delivery capability of your solution as long as mission impact is considered. Assume stranded victims in immediate need of drinking water and will remain stranded for at least six additional hours until help arrives. May also consider other useful items to deliver to victims (e.g., first aid kit) if this adds value to your proposal.
- You may deliver fresh water and a communication radio with the search air vehicle or communicate with other assets and deliver these items with a different vehicle – if another vehicle is used to deliver these items, provide justifications and basic performance parameters of this vehicle as well. A trade study on "precision" delivery of items could add additional overall value to your solution.

- Should identify all systems functionality and components that are required for the air vehicle(s) to operate in both controlled and uncontrolled airspace
- Specify concept of operations and in-field operations (e.g., time to refuel, time to prepare for next mission, repair-ability, etc.)
- If the Initial Estimated Sensor Payload is not consistent with your air vehicle needs, you are free to propose and justify a different sensor payload, but each of the recommended sensor capabilities must be maintained and performance of substituted components must be specified. Primary mission is to locate stranded victims as quickly as possible to provide communication and help.
- Air vehicle and victim communication requirements based on expectation that all land based communication facilities (antennae, towers, etc.) have been destroyed within 1000 nm of air vehicles. Satellite communication is one solution, but stationing multiple air vehicles to communicate in a "daisy-chain" operation is possible as long as at least 1000 nm communication range is provided.
- Some attrition is expected, so vehicle cost is important and a driving concern – report estimated cost for initial operational capability, for 20$^{th}$ system produced, and expected system cost per air vehicle after 100$^{th}$ system produced
- If your proposed solution does not properly close for all mission KPPs, document trade-offs and decisions made, including all assumptions that drove proposed solution

**Proposal and Design Data Requirements**

The technical proposal shall present the design of this aircraft clearly and concisely; it shall cover all relevant aspects, features, and disciplines. Pertinent analyses and studies supporting design choices shall be documented.

Full descriptions of the air vehicle(s) are expected along with performance capabilities and operational limits. These include, at a minimum:

1) A description of the design missions defined for the proposed concepts for use in calculations of mission performance as per design objectives. This includes the selection of operational cruise altitude(s) and operational cruise speeds supported by pertinent trade analyses and discussion.
2) Air vehicle(s) performance summaries shall be documented and the air vehicle(s) flight envelope(s) shall be shown graphically.
3) Payload range chart(s)
4) A V-n diagram for each air vehicle with identification of necessary air vehicle velocities and design load factors.
5) Materials selection for main structural groups and general structural design, including layout of primary airframe structures as well as the strength capability of the structure and how that compares to what is required at the ultimate load limits of the air vehicle(s). The maximum dive speed of the air vehicle(s) shall be specified.
6) Complete geometric description, including dimensioned drawings, control surfaces sizes & hinge locations, and internal arrangement of the air vehicle(s) illustrating sufficient volume for all necessary components & systems.
    a) Scaled three-views (dimensioned) of each air vehicle proposed and 3-D model imagery of appropriate quality are expected. The three-view must include at least:
        i) Fully dimensioned front, left, and top views
        ii) Location of air vehicle aerodynamic center (from nose)
        iii) Location of average center of gravity, CG, location (relative to nose)
        iv) Tail moment arms and other key features as appropriate
    b) Diagrams and/or estimates showing that internal volume requirements are met, including as a minimum the internal arrangements of the payloads and major internal systems (e.g., avionics, fuel tanks, landing gear, structural components, etc.)
        i) Cross-section showing payload configuration (minimum delivered communication radio and water)
        ii) Layout of payload and size and location of any unique access doors
        iii) Layout of cockpit if crewed system or space for automation needs otherwise
        iv) Fuselage centerline diagram for symmetric designs, sufficient cross section diagrams to understand unsymmetrical designs if proposed
    c) Diagrams showing the location and functions for all air vehicle systems

7) Important aerodynamic characteristics and aerodynamic performance for key mission segments and requirements
8) Air vehicle(s) weight statement(s), air vehicle(s) center-of-gravity envelope(s) reflecting payloads in all possible configurations and fuel weight allocations and positioning. Establish both forward and aft center of gravity (CG) limits for safe flight in the normal categories for each air vehicle proposed. Weight assessment summaries shall be shown at least at the following level of detail:
   a) Propulsion system(s)
   b) Airframe structure (adapted as appropriate)
      i) Wing/lifting surfaces
      ii) Empennage/control surfaces
      iii) Landing gear
      iv) Fuselage/payload carrying components
   c) Control systems and subsystems
   d) Payloads for mission operation and for disaster provision delivery
   e) Systems and Subsystems Payload as specified, including:
      i) Instruments and avionics
      ii) Fuel/oil (propulsion batteries if electric or hybrid)
      iii) Hydraulic/pneumatic/electrical systems (if chosen)
9) Propulsion system description and characterization including performance, dimensions, and weights for each air vehicle. The selection of the propulsion system(s), sizing, and airframe integration must be supported by analysis, trade studies, and discussion.
10) Summary of basic stability and control characteristics for each air vehicle; this should include, but is not limited to, static margin considerations.
11) Summary of cost estimates and a business case analysis. This assessment should identify the cost groups and drivers, assumptions, and design choices aimed at the providing best value to the customer.
   a) Estimate the non-recurring development costs of the air vehicle(s) including engineering, FAA/EASA certification, production tooling, facilities, and labor
   b) Estimate the fly away cost of each air vehicle concept (including how many of each concept is needed for your proposed operational solution)
   c) Estimate direct operating cost per air vehicle flight hour (for each air vehicle concept if multiple concepts proposed to operate together)
12) Estimate lifecycle emissions analysis to include emissions from production (especially hazard materials) and in-service emissions such as greenhouse gases and their impact on the environment

The proposal response shall include trade documentation on the two major aspects of the design development, a) the concept selection trades, and b), the concept development trade studies.

Team is to develop and present the alternative concepts considered leading to the down-select of their preferred concept(s). The methods and rationale used for the down-select shall be presented. At a minimum, a qualitative assessment of strengths and weaknesses of the alternatives shall be given, discussing merits, leading to justification(s) as to why the preferred concept(s) is (are) the best proposal response. Quantitative justification(s) of why the selected proposal is the best at meeting the proposal measures of merit(s) will strengthen the proposal.

In addition, the submittal shall include the major trade studies conducted justifying the optimization, sizing, architectural arrangement, and integration of the specifically selected proposal concept(s). Quantitative data shall be presented showing why their concept(s) 'work(s)' and is (are) the preferred design compromise(s) that best achieve(s) the RFP and provides best value to the customer.

Specific analysis and trade studies of interest sought in proposals include:

- Mission performance and sizing for the definition of a mission profiles
- Overall air vehicle concept(s) selection (airframe and propulsion system) vs. design requirements objectives

All concept(s) and technology assumptions must be reasonable and justified for the stated EIS year.