View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Institute of Transport Research:Publications

UAV World, 6th International Conference, 2012

An UAS Demonstration BLOS Mission Selection Framework

Frank Morlang
Institute of Flight Guidance
German Aerospace Center, Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
Braunschweig, Germany

***Abstract*—The framework for the selection of Unmanned Aircraft System (UAS) demonstration Beyond-Line-of-Sight (BLOS) mission candidates bases on a ranking system, where rankings according to different selection aspects are summarized to a final ranking where the selected candidate is derived from. The calculations for the different rankings as well as for the deduction of the final ranking incorporate a set of importance scores and weight factors, whose extents and balancing will be explained and substantiated.**

Keywords-UAS; BLOS; Framework

I. Introduction

The framework's main indicators are addressed by the identified Air4All challenges [1]. The consideration focus exemplarily aims at Step 2 of the Air4All roadmap due to the fact that this level is associated with a current/near future demonstration potential of the time span 2010/2011. Additional indicators highlight the core area of BLOS aspects whereas Air Traffic Control (ATC) interface requirements are covered by infrastructure and radio bandwidth need considerations. Satellite Communications (SatCom) related aspects are analyzed by an own ranking, taking into account satellite capabilities as well as the associated Unmanned Aerial Vehicle (UAV) equipage relevance.

Each mission candidate ranking is calculated by the following formula:

$$\text{Score}_{\text{mission candidate}} = \sum_{n} (1/\text{rank}_n) * \text{weight}_{\text{mission candidate}} \quad (1)$$

In (1) a higher score means a better selection ranking. The mission candidate specific weight factor takes into account that there must be a choice possibility for mission candidates addressing the same quantity n and sort of issues, where the candidate ranking score would be the same without any weight factors.

II. MISSION CANDIDATES

The different mission candidates are shown in TABLE I. , representing three different sea missions (no. 1, 2 and 4) and two different land missions (no. 3 and 5), which were given by a project's pre-evaluation phase.

TABLE I. NAME AND NUMBER OF THE MISSION CANDIDATES

Mission Candidate	No.
Maritime surveillance and coastguard (Atlantic Region)	1
Maritime surveillance and coastguard with sector hand-over (Atlantic Region)	2
Fire-fighting (Mediterranean Island)	3
Maritime surveillance in the South Mediterranean	4
Security Monitoring of Hazardous Materials (HazMat) transportation by train	5

III. AIR4ALL CHALLENGES

The AIR4ALL challenges of the Step 2 consideration focus and the associated ranking of importance are shown in TABLE II. . The different ranks of importance in Table 2 arise from the facts that:

- Secure and sustainable communication for UAV controlling is essential (= rank 1)
- Collision avoidance is fundamental for operations under Visual Flight Rules (VFR) in non-segregated airspaces (= rank 2)
- ATC interfacing is essential for integration into non-segregated airspace (= rank 3)

Ranks 4 to 8 are ordered with respect to their safety relevance. The specific weight factors for five different mission candidates in TABLE III. reflect the traffic density as well as weather condition relations. There were big differences in the regional/local traffic densities and average weather/wind conditions of the different mission candidates. A higher traffic density and more challenging weather conditions were associated with a better mission suitability for challenges demonstration purposes.

TABLE II. RANKING OF IMPORTANCE OF THE AIR4ALL CHALLENGES

No.	AIR4ALL challenges	Rank of importance
1	Collision avoidance	2
2	Secure and sustainable communication for C2	1
3	Radio bandwidth allocation	4
4	ATC interface	3
5	Dependable emergency recovery	5
6	Health monitoring/Fault detection	6
7	Weather detection/protection	7
8	Operator interface	8

TABLE III. MISSION CANDIDATE SPECIFIC WEIGHT FACTOR MATRIX OF THE AIR4ALL CHALLENGES

	AIR4ALL challenges no.							
Mission Candidate no.	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***
1	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
2	0.7	0.7	0.7	0.7	0.7	0.7	1.0	0.7
3	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.6
4	0.8	0.8	0.8	0.8	0.8	0.8	0.6	0.8
5	1.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0

TABLE IV. MISSION CANDIDATE RANKING DERIVED FROM DEMONSTRATED AIR4ALL CHALLENGES

Mission Candidate	**Demonstrated AIR4ALL challenge(s)**	**Score (according to (1) and TABLE III.)**	**Derived Ranking**
1	1,2,3,4,5,6,7,8	1/2 * 0.9 + 1 * 0.9 + 1/4 * 0.9 + 1/3 * 0.9 + 1/5 * 0.9 + 1/6 * 0.9 + 1/7 * 0.9 + 1/8 * 0.9 = 2.45	2
2	1,2,3,4,5,6,7,8	1/2 * 0.7 + 1 * 0.7 + 1/4 * 0.7 + 1/3 * 0.7 + 1/5 * 0.7 + 1/6 * 0.7 + 1/7 * 1.0 + 1/8 * 0.7 = 1.90	4
3	1,2,3,4,5,6,7,8	1/2 * 0.6 + 1 * 0.6 + 1/4 * 0.6 + 1/3 * 0.6 + 1/5 * 0.6 + 1/6 * 0.6 + 1/7 * 0.8 + 1/8 * 0.6 = 1.66	5
4	1,2,3,4,5,6,7,8	1/2 * 0.8 + 1* 0.8 + 1/4 * 0.8 + 1/3 * 0.8 + 1/5 * 0.8 + 1/6 * 0.8 + 1/7 * 0.6 + 1/8 * 0.8 = 2.14	3
5	1,2,3,4,5,6,7,8	1/2 * 1.0 + 1 * 1.0 + 1/4 * 1.0 + 1/3 * 1.0 + 1/5 * 1.0 + 1/6 * 1.0 + 1/7 * 0.7 + 1/8 * 1.0 = 2.68	1

IV. ADDITIONAL TECHNICAL CRITERIA

The additional technical criteria and their ranking of importance are shown in TABLE V. . This order arises from the facts that:

- Demonstrating the safety and security of the BLOS data link represents the fundamental prerequisite (= rank 1)
- Specific latency constraints for ATC, Command and Control (C2) and Sense and Avoid (S&A) relay are directly associated with the use of BLOS data link operations (= rank 2)
- Air4All brought forward aspects are an essential project request (= rank 3)

Ranks 4 to 7 are ordered with respect to the following considerations:

- Ground Control Station (GCS) handover aspects, especially referring to LOS/BLOS switching, are important for safe operations (= rank 4)

- Payload specific aspects play a role of medium importance (= rank 5)
- Suitability for the use of multiple operational analysis centers is a more "nice to have" aspect (= rank 6)
- Suitability for the being scaled towards multiple UAS, possibly supported by one GCS has a "follow on" character in comparison to the essential aspects to be covered (= rank 7)

The different mission candidate specific weight factors in TABLE VI. reflect the following considerations:

- Criteria 1, 5 and 6:
    - The different mission candidate specific weight factors reflect the suitability due to already existing UAV/UAS experience in the relevant area.
- Criteria 2, 3, 4 and 7:
    - These specific weight factors reflect the different traffic densities of the mission candidates.

TABLE V. RANKING OF IMPORTANCE OF THE ADDITIONAL TECHNICAL CRITERIA

No.	Criteria	Rank of importance
1	Suitability for the use of multiple GCS and the associated requirements to handover communications between LOS, BLOS of various GCS	4
2	Suitability for the use of multiple operational analysis centres which receive the mission data	6
3	Specific latency constraints for ATC, C2 and S&A relay	2
4	Need for demonstrating the safety and security of the BLOS data link	1
5	Suitability for the being scaled towards multiple UAS, possibly supported by one GCS	7
6	Air4All brought forward aspects	3
7	Payload mission based on the interest of related communities	5

TABLE VI. MISSION CANDIDATE SPECIFIC WEIGHT FACTOR MATRIX OF THE ADDITIONAL TECHNICAL CRITERIA

	Criteria no.						
Mission Candidate no.	***1***	***2***	***3***	***4***	***5***	***6***	***7***
1	1.0	0.9	0.9	0.9	1.0	1.0	0.9
2	0.9	0.7	0.7	0.7	0.9	0.9	0.7
3	0.8	0.6	0.6	0.6	0.8	0.8	0.6
4	0.7	0.8	0.8	0.8	0.7	0.7	0.8
5	0.6	1.0	1.0	1.0	0.6	0.6	1.0

TABLE VII. MISSION CANDIDATE RANKING DERIVED FROM THE ADDITIONAL TECHNICAL CRITERIA

Mission Candidate	Addressed additional technical criteria	Score	Derived Ranking
1	1,2,3,4,5,6,7	1/4 * 1.0 + 1/6 * 0.9 + 1/2 * 0.9 + 1 * 0.9 + 1/7 * 1.0 + 1/3 * 1.0 + 1/5 * 0.9 = 2.41	1
2	1,2,3,4,5,6,7	1/4 * 0.9 + 1/6 * 0.7 + 1/2 * 0.7 + 1 * 0.7 + 1/7 * 0.9 + 1/3 * 0.9 + 1/5 * 0.7 = 1.96	4
3	1,2,3,4,5,6,7	1/4 * 0.8 + 1/6 * 0.6 + 1/2 * 0.6 + 1 * 0.6 + 1/7 * 0.8 + 1/3 * 0.8 + 1/5 * 0.6 = 1.70	5
4	1,2,3,4,5,6,7	1/4 * 0.7 + 1/6 * 0.8 + 1/2 * 0.8 + 1 * 0.8 + 1/7 * 0.7 + 1/3 * 0.7 + 1/5 * 0.8 = 2.00	3
5	1,2,3,4,5,6,7	1/4 * 0.6 + 1/6 * 1.0 + 1/2 * 1.0 + 1 * 1.0 + 1/7 * 0.6 + 1/3 * 0.6 + 1/5 * 1.0 = 2.30	2

V. ATC INTERFACE REQUIREMENTS

TABLE VIII. RANKING OF IMPORTANCE OF THE ATC INTERFACING REQUIREMENTS

No.	Requirement	Rank of importance
1	Infrastructure and capabilities	1
2	Mission related availability or required radio bandwidth frequency	2

TABLE IX. MISSION CANDIDATE SPECIFIC WEIGHT FACTOR MATRIX OF THE ATC INTERFACING REQUIREMENTS

	Requirement no.	
Mission Candidate no.	***1***	***2***
1	0.9	0.9
2	0.7	0.7
3	0.6	0.6
4	0.8	0.8
5	1.0	1.0

TABLE X. MISSION CANDIDATE RANKING DERIVED FROM THE ATC INTERFACE REQUIREMENTS

Mission Candidate	Addressed ATC interface requirements	Score	Derived Ranking
1	1,2	1 * 0.9 + 1/2 * 0.9 = 1.35	2
2	1,2	1 * 0.7 + 1/2 * 0.7 = 1.05	4
3	1,2	1 * 0.6 + 1/2 * 0.6 = 0.90	5
4	1,2	1 * 0.8 + 1/2 * 0.8 = 1.20	3
5	1,2	1 * 1.0 + 1/2 * 1.0 = 1.50	1

VI. SATCOM RELATED CRITERIA

The different weight factors take into account that there are differences in the regional/local coverage of already existing bandwidth allocations of the mission candidates. A better coverage is associated with a better mission suitability.

TABLE XI. RANKING OF IMPORTANCE OF THE SATCOM RELATED CRITERIA

No.	Criteria	Rank of importance
1	SatCom relevance	1
2	Availability and capability of existing communication satellites	3
3	UAV equipment capable of supporting the SatCom	2

TABLE XII. MISSION CANDIDATE SPECIFIC WEIGHT FACTOR MATRIX OF THE SATCOM RELATED CRITERIA

	Criteria no.		
Mission Candidate no.	***1***	***2***	***3***
1	0.9	0.9	0.9
2	0.7	0.7	0.7
3	0.6	0.6	0.6
4	0.8	0.8	0.8
5	1.0	1.0	1.0

TABLE XIII. MISSION CANDIDATE RANKING DERIVED FROM THE SATCOM CRITERIA

Mission Candidate	Addressed SatCom criteria	Score	Derived Ranking
1	1,2,3	0.9 + 1/3 * 0.9 + 1/2 * 0.9 = 1.65	2
2	1,2,3	0.7 + 1/3 * 0.7 + 1/2 * 0.7 = 1.28	4
3	1,2,3	0.6 + 1/3 * 0.6 + 1/2 * 0.6 = 1.10	5
4	1,2,3	0.8 + 1/3 * 0.8 + 1/2 * 0.8 = 1.46	3
5	1,2,3	1.0 + 1/3 * 1.0 + 1/2 * 1.0 = 1.83	1

VII. ECONOMIC CRITERIA

The mission cost comparison and the derived ranking base on a qualitative estimation of the following types of costs:

- UAV costs
- Ground equipment costs
- Insurance costs
- Costs for transit to and from the mission site
- Satellite communication costs
- Mission planning costs
- Mission conducting costs
- Documentation costs
- Payload costs

- Costs for obtaining regulatory approvals
- Post mission analysis costs

TABLE XIV. QUALITATIVE COST TYPE ESTIMATIONS FOR THE MISSION CANDIDATES

Mission Candidate no.	Cost type					
	UAV costs	*Ground equipment costs*	*Insurance costs*	*Costs for transit to and from the mission site*	*SatCom costs*	*Mission planning costs*
1	+	+	+	+	+	+
2	+	+	+	+	+	+
3	+	+	+	+	+	+
4	+	+	+	+	+	+
5	+	++	++	+	+	++

TABLE XV. QUALITATIVE COST TYPE ESTIMATIONS FOR THE MISSION CANDIDATES

Mission Candidate no.	Cost type				
	Mission conducting costs	*Documentation costs*	*Payload costs*	*Costs for obtaining regulatory approvals*	*Post mission analysis costs*
1	+	+	+	+	+
2	+	+	+	+	+
3	+	+	+	+	+
4	+	+	+	+	+
5	++	++	+	++	+

TABLE XVI. MISSION CANDIDATE RANKING DERIVED FROM THE COSTS FOR THE DEMONSTRATION

Mission Candidate	Costs for the demonstration	Derived Ranking
1	+++++++++++	1
2	+++++++++++	1
3	+++++++++++	1
4	+++++++++++	1
5	+++++++++++++++++	5

VIII. COMMITMENT OF STAKEHOLDERS

TABLE XVII. MISSION CANDIDATE RANKING DERIVED FROM THE STAKEHOLDER COMMITMENT

Mission Candidate	Commitment of the stakeholders	Derived Ranking
1	++	1
2	+	3
3	+	3
4	+	3
5	++	1

IX. FULFILMENT OF STAKEHOLDERS NEEDS

TABLE XVIII. MISSION CANDIDATE RANKING DERIVED FROM THE FULFILMENT OF STAKEHOLDER NEEDS

Mission Candidate	Fulfilment of the stakeholders needs	Derived Ranking
1	++	1
2	+	3
3	+	3
4	+	3
5	++	1

X. TOTAL RANKING

The total ranking is derived from the average of the different sub-rankings (TABLE XIX.). It shows that especially the stakeholder related sub-rankings lift out mission candidate 1 and mission candidate 5 due to the feedback and input from the relevant stakeholders. Because of the fact that it addresses the highest challenges and complexity, resulting in related top sub-rankings, mission candidate 5 is assumed to be associated with the highest costs for the demonstration, resulting in the worst sub-ranking for the cost criteria, leading to an average of 1.7 and a derived total ranking of 2 and not 1 (TABLE XIX.). Mission candidate 1 represents the best balance between demonstrated challenges on the one hand and generated costs on the other hand, making it the selected mission for the demonstration.

TABLE XIX. MISSION CANDIDATE TOTAL RANKING

Mission Candidate	Sub-rankings	Average of the sub-rankings	Total Ranking
1	2,1,2,2,1,1,1	1.4	1
2	4,4,4,4,1,3,3	3.3	4
3	5,5,5,5,1,3,3	3.8	5
4	3,3,3,3,1,3,3	2.7	3
5	1,2,1,1,5,1,1	1.7	2

XI. CONCLUSION

Although the presented BLOS mission selection method must be regarded in a generic manner, thus making it a framework, it takes into account the values and balancing of all relevant aspects for the selection of an UAS challenges demonstration with "paving-the-way" character. Enhancement and adaptation of the framework for future selection processes depend on the granularity of known and/or provided data. Especially cost type aspects can be switched from qualitative estimations to quantitative levels if precise costs are known, can be calculated or can be derived from experiences.

REFERENCES

[1] Final Air4All Report for 'UAV insertion into General Air Traffic (GAT) Follow On Contract', 2009

AUTHOR BIOGRAPHY

Frank Morlang received the Dipl.-Ing. degree in materials science from the Technical University Darmstadt, Darmstadt, Germany, in 1999.

From 1999 to 2001, he was a project engineer at Aerodata company, Braunschweig, Germany. Since October 2001, he is scientist at the Institute of Flight Guidance, German Aerospace Center (DLR), Braunschweig, Germany, in the area of ATM Simulation.