"HENRI COANDA"
AIR FORCE ACADEMY
ROMANIA

"GENERAL M.R. STEFANIK"
ARMED FORCES ACADEMY
SLOVAK REPUBLIC

INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER
AFASES 2015
Brasov, 28-30 May 2015

ANALYSIS OF THE LIGHT OFF-ROAD VEHICLE ENDOWMENT POSSIBILITIES IN ORDER TO USE IT FOR AIR FORCE MISSIONS

Cornel Aramă *, Mariana Sava, Lavinia Cucu

* Faculty of Aeronautics Management, "Henri Coandă" Air Force Academy Brasov, Romania

Abstract: *The possibility to use a fast, maneuverable and high passing capacity mobile platform, characterized by a large modularity, in order to be endowed with different special equipments has been analyzed by several researchers, who have focused their studies on the performances of each model.*
The following paper presents a study on two possibilities of endowing a light off-road articulated prototype vehicle, DAC 2.65 FAEG, in order to fulfill some specific missions for Air Force: an UAV mobile cell for forward reconnaissance missions and a combat mobile cell against low altitude targets.
In order to establish the best solution to endow this suggested mobile platform, the researchers are going to use the advanced multi-criteria analysis method. The final result will be interesting due to the fact that the suggested vehicle prototype has a high modularity towards being endowed with different special equipments.

Keywords: *mobile platform, unmanned air vehicle (UAV), combat mobile cell, advanced multi-criteria analysis*

1. INTRODUCTION

The global current security situation is an environment which is characterized by asymmetric conflicts where one of the engaged parties has been specializing in classic or urban guerrilla war and the military-developed countries have been improving their antiterrorist fighting continuously.

This is the reason why the weapons industry is focusing more and more on the combat mobile cells production which has to display a more increased viability in antiterrorist or guerrilla fights. From our point of view a combat/fighting mobile cell, seen as an acting system, must comprise the following main parts (Figure 1.1):

- the terrestrial subsystem consisting of crew, intelligent equipment (gadgets such as: computer, sensors, communication and reception data gadgets etc.), maintenance equipment, military assets and the mobile platform;
- the air subsystem consisting of UAV, the intelligent equipment for acquisition, communication and control data, and possibly, depending on the constructive variant, special equipment for self-destruction;
- the interface between air and terrestrial subsystems.

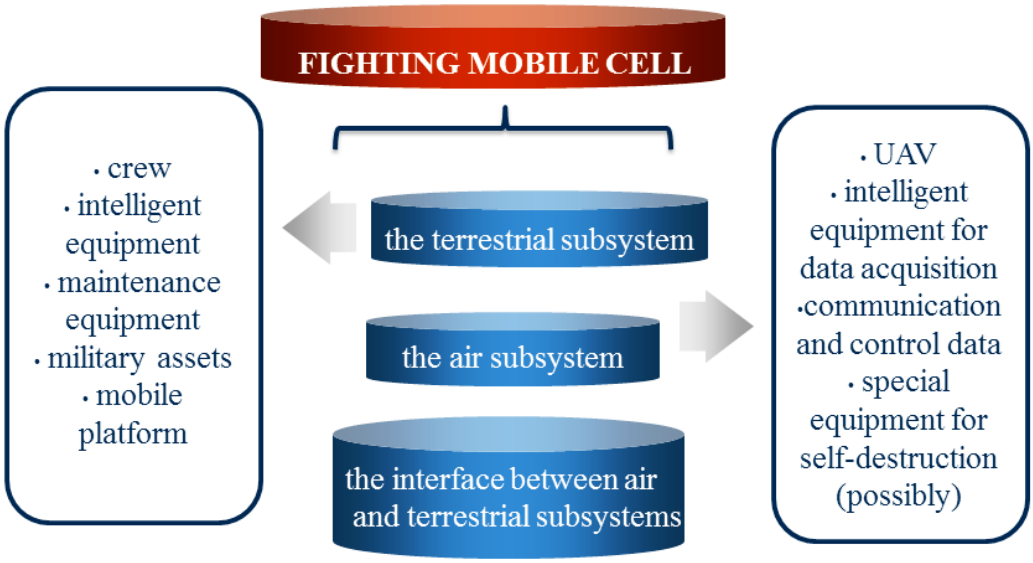

Fig. 1.1 The general structure of a combat/fighting mobile cell

Due to the possibility of working directly on the prototype vehicle, this paper presents a study on two possibilities of endowing a light off-road articulated prototype vehicle, DAC 2.65 FAEG, in order to fulfil some specific missions for Air Force: an UAV Forward Reconnaissance Mobile Cell - FRMC (Figure 1.2) and a Combat Mobile Cell Against Low Altitude Targets - CMCALAT (Figure 1.3).

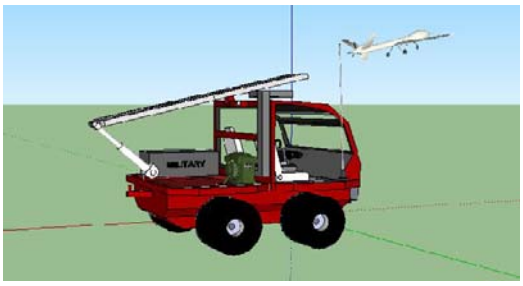

Fig. 1.2 An UAV Forward Reconnaissance Mobile Cell (concept)

Fig. 1.3 A Combat Mobile Cell Against Low Altitude Targets (concept)

2. A SHORT PRESENTATION OF THE MOBILE PLATFORM

A light off-road articulated vehicle is a vehicle with a maximum weight of less than three tones and consisting of two equal vats connected to each other through a central pivoting bearing which allows moving both parts around the vehicle longitudinal central axis (Figure 2.1). [1]

Fig. 2.1 The light off-road articulated vehicle DAC 2.65 FAEG

The main technical characteristics of the light off-road articulated vehicle DAC 2.65 FAEG are [1]:

- 4 Wheel Drive off-road utility vehicle consisting of two vats connected with a "Center Rotational Articulation"; the first vat has the power unit (the most part) and the driving control point and the second vat is empty and it could be used for special equipment; remarkable crossing capacity due to 4x4 system and to the central pivoting

bearing which allow the vehicle to follow the ground conformation permanently by keeping all the wheels in contact with land; moreover, the vehicle has enormous approach and rear overhang angles which allow it to attack very high obstacles;
- no suspension but center articulation - 45 degrees of travel;
- it could be equipped as an amphibious vehicle (optional) because it is calculated to move on the water by using the wheels alone or combined with a propeller or a system of propellers which are trained by a power take-off from the rear axle differential;
- 4 Wheel Power Steering; very good maneuverability (swiveling radius less 10 m) due to the possibility of steering by using all the wheels;
- very good stability due to very low center of gravity;
- simple and robust construction;
- the theoretical impossibility to be stuck in mud due to very wide wheels which determine a very high upward force, the wheels which are operated directly from a covered body and due to the simple conformation of the "belly" of the vehicles which allow it to crawl without any problems on the muddy ground.

This type of vehicle is very rare. Generally, it has stayed at a prototype stage. Unfortunately, this was the main reason why, while being exploited, some technical problems which must be solved were identified:
- little ground clearance which could create problems when the obstacles are attacked between the front wheels; the obstacles have to be attacked only by one wheel at a time;
- finding an engine capable to move the vehicle because this one must have a small volume, high power and it has to be easily maintained at the nominal temperature; it is working into a tough, not ventilated environment (into the first vat);
- the necessity of an automatic transmission which is going to work into a tough, not ventilated environment as well;
- the lack of suspension which could create comfort difficulties for the occupants of the vehicles;
- the lack of a covered body (because of the necessity to decrease the total weight) which can cause discomfort to the passengers.

3. THE OPERATIONAL MILITARY REQUIREMENTS FOR SUGGESTED ENDOWMENTS VARIANTS

This kind of vehicle has large possibilities to be endowed in order to fulfil a lot of missions from the civilian and military fields. This is due to the fact that the rear vat is almost empty and it can be endowed in different structures without difficulties. The low center of gravity offers the possibility to attach vertical equipment without affecting too much its stability.

The generally operational military requirements which influence the two types of mission which could be conducted by the endowed variants from this study are (the ones which are not relevant to the study have been removed because they are identical for both missions):
- constructive simplicity;
- high reliability;
- compactness;
- tactical-operational mobility – marching;
- low overall dimensions;
- low weight;
- easy exploitation to fulfil the missions;
- high maintainability;
- high ergonomics for the crew;
- protection of transported materials;

- crew protection;
- transportability;
- efficiency of combat actions – the results that can be obtained;
- profitability – the fast and restoration costs of fighting capacity.

In order to fulfil an advanced multi-criteria analysis method the researchers will select from this list the most important military operational requirements. The aim of the study is to establish the most viable structure for this kind of vehicle in order to use it in the military field.

4. ESTABLISHING THE BEST STRUCTURE FOR THE SUGGESTED VEHICLE BY USING THE ADVANCED MULTI-CRITERIA METHOD

The advanced multi-criteria analysis method is a general method of comparing some item categories. This method is going to be used in order to obtain some useful conclusions for the endowment of the mobile platform which has been suggested to be part of the mobile combat cell which is going to be used in air force missions.

It is known that it is better to combine the multi-criteria analysis method with the "brainstorming" method especially when launching new items on the market. The steps of the creative process which are developed into this method are the market necessities study, the identification of the project theme, the launching of different new variants for the implementation of the project and the evaluation of the solutions suggested by the multi-criteria analysis method.

In this situation, the market necessities involve the endowing of the mobile platform (the light articulated off-road vehicle DAC 2.65 FAEG) with a most viable structure in order to fulfil air force missions. Thus, the project theme and the new endowment variants for the project have been identified. The suggested variants are:

- UAV Forward Reconnaissance Mobile Cell and
- Combat Mobile Cell against Low Altitude Targets.

4.1 The Criteria Establishment. The chosen criteria necessary in order to achieve this analysis require a precise definition because they have to allow the limiting of some characteristics that are imposed as an analyzing object in order to result in a characterization without any ambiguities [5]. In this research seven operational requirements were selected as criteria for the advanced multi-criteria analyzing method. Thus, the selected criteria are:

- constructive simplicity;
- compactness;
- easy exploitation to fulfil the missions;
- high maintainability;
- high ergonomics for the crew;
- efficiency of combat actions;
- profitability.

4.2 Determining the weight of each criterion. The weight factors need to be calculated in order to determine the weight of each criterion. The criteria taken into consideration are written down into a table both on the rows and columns using the following abbreviation:

- constructive simplicity – CS;
- compactness – CO;
- easy exploitation to fulfil the missions – EE;
- high maintainability – HM;
- high ergonomics for the crew – HE;
- efficiency of combat actions – EC;
- profitability – PR.

Within this table, the criteria are compared to one another by using the notations: value 1 when the row criterion is more important than column criterion, value 0,5 when both of them are equally important and value 0 when the column criterion is more important than the row criterion.

The classification of the criteria is made by the amount of the row points for each criterion. If two or more criteria have the same number of points, the position into the classification will be the value of their semi-sum (in case there are more criteria, the arithmetic average). The criterion with the most number of points will be on the first place, and the criterion with the least number of points will occupy the last place.

Table 4.1

Criteria	CS	CO	EE	HM	HE	EC	PR	Points of the criterion	Level (classification)	Weight factor [γ_i]
CS	0,5	1	0	0	0	0	0	**1,5**	**6**	**0,47**
CO	0	0,5	0	0	0	0	0	**0,5**	**7**	**0,10**
EE	1	1	0,5	0,5	1	0	0,5	**4,5**	**3**	**2,36**
HM	1	1	0	0,5	0	0	0	**2,5**	**5**	**0,93**
HE	1	1	0	1	0,5	0	0	**3,5**	**4**	**1,53**
EC	1	1	1	1	1	0,5	1	**6,5**	**1**	**5,42**
PR	1	1	1	1	1	0	0,5	**5,5**	**2**	**3,55**

The weight factors can be calculated by using different formulas. The FRISCO formula was used in order to find out the coefficients because it is globally recognized as the most performant and it is very practical.

$$\gamma_i = \frac{p + m + \Delta p + 0,5}{-\Delta p' + \frac{N_{crt}}{2}}$$

where:

p – the amount of the row points for the element taken into account;

m – the number of the criteria which were surpassed by the criteria taken into account;

Δp – the difference between the score of the item taken into account and the score of the item from the last level; if the item taken into account is placed on the last place, Δp will have the value 0;

Δp' – the difference between the score of the item taken into account and the score of the item from the first level; if the item taken into account is on the first place, Δp' will have the value 0; N_{crt} – the number of the criteria taken into account. Thus, the result is the table 4.1.

4.3 The identification of the variants, granting the N grade and the establishing of the consequences matrix. This comparative analysis aims at comparing and establishing the best structure of the light off-road articulated prototype vehicle, DAC2.65 FAEG type, in order to be used mainly for the air force mission. The suggested and analyzed solutions are the Forward Reconnaissance Mobile Cell (FRMC) and the Combat Mobile Cell against Low Altitude Targets (CMCALAT).

Table 4.2

Combat variant		FRMC		CMCALAT	
Criterion	**Weight factor** [γ_{ij}]	**Importance grade** [N_i]	$N_i x \gamma_i$	**Importance grade** [N_i]	$N_i x \gamma_i$
EC	5,42	9	48,78	8	43,36
PR	3,55	9	31,95	8	28,4
EE	2,36	8	18,88	10	23,6
HE	1,53	8	12,24	10	15,3
HM	0,93	8	7,44	9	8,37
CS	0,47	7	3,29	8	3,76
CO	0,10	7	0,7	9	0,9
The final classification			**123,28**		**123,69**
The place			**2**		**1**

The grade which was granted to each criterion is a number from 1 to 10. At the same time, it is also called importance grade or contribution to a criterion grade and it granted to each variant based on the technical and tactical characteristics, according to each criterion. The grades N_i which were granted to each variant are shown in table 4.2.

The importance grades are invariably influenced by the weight factors. To this end, the wedge between the importance grades and the weight factors must be calculated for each criterion. The sum of the $N_i \ x \ \gamma_i$ wedges will logically establish the final classification. These calculations are shown into table 4.2, too.

4.4 The results interpretation. As it could be seen in table 4.2, the CMCALAT variant is the best structure for the DAC 2.65 FAEG vehicle according to this analysis. What is interesting is that the difference between the suggested variants is extremely small. This fact can suggest that it is better to redo the calculations and reopen the discussions in order to eliminate as much as possible the subjectivity of the expert appreciations.

For instance, at first glance, one could notice that two criteria which may have major influences on the last decision were omitted: the cost and the easiness of purchasing the special equipment.

As presented in the table 4.1 the criterion efficiency of combat actions – EC resulted as the most important from the weight factors point of view. It is logical. But maybe it is better to make the difference between the missions which can be executed by the FRMC, tactically thinking, combat service missions and the missions which can be executed by the CMCALAT, which are combat missions. If the UAV used by the FRMC is a flying bombe type, the FRMC can fulfil combat missions too.

And this is how this analysis can become more complex and it can be the subject of some next research.

REFERENCES

1. Aramă, Cornel, Aramă A., *"Investigations of the Possibilities to Improve the Dynamic Performances of DAC 2.65 FAEG Light Off-road Articulated Vehicle",* The 15th International Conference of Scientific Papers*"Scientific Research and Education in the Air Force"* AFASES 2013*, "Henri Coandă"* Air Force Academy, Braşov*,* Section: *"Engineering Sciences-Mechanical Engineering Materials and Technology"* May 2013.
2. Aramă, Cornel, Aramă, A., *"A Study Regarding the Analysis of the Fulfillment of the Operational Military Requirements by the Light Off-Road Articulated Vehicle","Review of the Air Force Academy"*, The Scientific Informative Review, No 1(23)/2013, "Henri Coandă" Air Force Academy Printed House, B+, May 2013.
3. Aramă, Cornel, "*Investigation of Possibilities to Improve the Performances of Special Vehicles*", "*Transylvania*" University Braşov, Doctoral Degree thesis, 2006.
4. Bobancu □., *"Creativitate □i inventică",* - course, *"Transylvania"* University of Bra□ov, 2014.
5. Sava, Mariana, "*Analiza viabilității radarelor moderne mobile*", Bachelors Degree thesis, "*Henri Coandă*" Air Force Academy, Braşov, July 2014.