Analysis, synthesis and modelling of air individual smart rescue system

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Abstract. The morphological approach is a successful analytical tool for development schematic, conceptual and preliminary design of new engineering systems in Aerospace. This investigation used a morphological approach to engineering solutions development as well as to tools for creating promising individual smart rescue system on conceptual design stage. The problem was solved in two stages. At a higher level of the hierarchy, the principle of action in morphological box was chosen. In the second phase, specific engineering solutions were explored. Analysis of engineering systems, solutions and solving technique and systems and their potential opportunities with technique provide correct guidelines to supply the reasonable decisions. Flight simulations, depending on different initial conditions, were performed using the LANE program.

1. Introduction
The problem of rescuing people when they fall from a height (rescue from buildings in fires, when helicopters and planes crash, when landing as an alternative to a spare parachute) is very relevant nowadays. To date, no effective engineering systems (ES) have been developed to provide independent evacuation from buildings in case of emergency. Car ladders widely used nowadays have lifting heights from 17 to 60 m, which allows evacuation from 14- and 17-storey buildings. Meanwhile, there are more than 7300 skyscrapers over 100 m high, and another 2500 are under construction, 17 of them exceed 100 floors (and 18 are under construction). The highest of these buildings - Burj Khalifa complex in Dubai - has 828 m and 163 floors.

2. State of the art
The existing methods, as well as the devices implementing these methods, for independent evacuation of people from buildings, or for their rescue by fire and rescue services can be divided into the following types [1]:

- portable stairs,
- jumping rescue devices,
- aerodynamic means,
- rope release devices,
- sleeve rescue devices,
- means of evacuation on vertical rails,
evacuation device "Disposable elevator".

The category of aerodynamic rescue means was chosen for analysis and synthesis, as only in this category it is possible to create universal rescue devices serving both for application in arai situations on flying apparatuses, and for rescue of people in fires from high-rise buildings.

The most often encountered devices in the form of parachutes, so was created a specialized parachute "SOS Parachute", pre-targeted for evacuation from high-rise buildings. The main parachute is opened by means of a small additional parachute and is intended for evacuation from buildings, the height of cm 50 m and provides reduction of a person with a speed of 5.5 m/s [1]. The main problems in the use of such means: the practical inapplicability of unprepared persons and the difficulty of landing in the city.

There is a well-known rescue device, which is an aerodynamic inflatable system [2]. This device (system "Rescuer" or "Volan") weighs 30 kg and consists of an inflatable brake device and a cylinder with compressed air (figure 1). In the inflatable state braking device has the form of a bagel, the middle of which is tightened with a mesh, and in the center of an inflatable platform placed the saving object. In case of emergency, a person should put it on his back. Then closes the lock located on his chest. Then person sit on the window sill with his back to the street, and pull the handle, which is located in the area of the chest. When the handle is pulled, the automatic lawn filling system is activated. As a result, the device becomes conical and rigid, like a huge badminton flounce, inside of which, in its lower part, lying on a special trap and protected from all sides, and there is a person to be rescued. Since the aerodynamic drag coefficient of such different shaped bodies (parachute - dome up, "Volan" - dome down) differs by more than 30%, the inflatable braking device has even larger transverse dimensions than the parachute. In addition, a parachutist at a typical landing speed of 4-6 m/s must land on two bent legs, otherwise he gets injured. When descending on "Volan" at the same speed a person lands with his back [1].

![Figure 1. Device for emergency descent of a man from a high-altitude object [1,2].](image)

Figure 2. The variants of device for emergency descent of a person from a high-altitude object (patents drawing) [3,4].

In the future, this direction has been developed in a number of ES and patents [5]. Space Rescue Systems Ltd. has created the Rescue Pneumatic Transformable Autonomous Satchel (figure 3). At a weight of 25 kg ES provides a descent to the ground of a person weighing 45-120 kg from a height of 5-1000 m during a time of 30-150 s. The device is ready to use in 45-60 s and is decreased a speed until 5-7 m/s.
Figure 3. The landing configuration of Rescue Pneumatic Transformable Autonomous Satchel [5].

It is also known a personal aircraft - a jetpack, worn on the back, allowing a person to rise into the air through a reactive thrust (figure 4) [6]. The thrust is created by the engine being thrown vertically down the jet. The aircraft is equipped with a rocket engine, movable mounted on a ball hinge at the top of the corset. The rocket engine itself consists of a gas generator and two rigidly connected pipes, which end with jet nozzles with guided tips.

Figure 4. The jetpack (patent drawing) [6].

There is also a known personal flying machine - a jet backpack, worn on the back, which allows a person to rise into the air by means of jet thrust. The traction is created by the jet jet thrown vertically down by the engine. The back consists of a rigid fiberglass corset, which is attached to the pilot's body by a system of belts. The corset has a tubular metal frame at the back, on which three cylinders are mounted: two with liquid hydrogen peroxide and one with compressed nitrogen. The aircraft is equipped with a rocket engine movably mounted on the ball joint at the top of the corset. The rocket engine itself consists of gas generator and two tubes rigidly connected with it, which end with jet nozzles with controlled tips. The engine is rigidly connected with two levers, which pass under pilot's hands. With these levers the pilot tilts the engine forward or backward, and also to the parties. On the right hand lever there is a rotary traction control handle connected with a cable to the fuel supply valve. On the left lever there is a steering handle, which is connected with the controlled tips of jet nozzles by flexible traction.

The drawbacks of known solutions are:
- inconvenience (low ergonomics),
- weight and size,
- a long time period for start device,
- highly qualified pilots.

3. Analysis, synthesis and problem solving on morphological approach base
Modern morphology approach was developed by astrophysicist Fritz Zwicky [7,8]. He applied morphological analysis to astronomical studies, jet and rocket propulsion and different aspects of space flights. The morphological analysis was designed for multidimensional, multicriterial, non-quantifiable problems by uncertainty conditions [9].

At present, there are many methods to search and synthesize solutions based on the morphological analysis in a variety of physical and engineering areas [9]. The power of the morphological set can reach millions of possible solutions. To reduce the order of dimensions of a morphological array, the advanced morphological approach on the cluster analysis basis of was developed [10-11].

The problem was solved in two stages. At a higher level of the hierarchy, the principle of action was chosen (table 1). In the second phase, specific solutions were explored (table 2). The first morphological matrix shows possible principled ES. The second matrix shows the ES.

| Attributes                      | Option 1         | Option 2         | Option 3         | Option 4         |
|--------------------------------|------------------|------------------|------------------|------------------|
| 1 Braking (system property)    | passive          | active           | hybrid           | -                |
| 2 Formation                    | no               | expandable       | inflatable       | rigid            |
| 3 Adaptivity                   | adaptive system  | adjustable       | no               | -                |
| 4 Control                      | yes              | no               | -                | -                |
| 5 Dependence on the environment| yes              | no               | -                | -                |

| Attributes                      | Option 1         | Option 2         | Option 3         | Option 4         |
|--------------------------------|------------------|------------------|------------------|------------------|
| 1 Propulsion                   | solid-fuel rockets | gas jet engine | air-hydraulic jet engine | liquid-propellant rockets |
| 2 Engine control               | program          | height sensor   | manual           | -                |
| 3 Scheme                       | opening          | inflatable       | rigid            | -                |
| 4 Adaptivity                   | adaptive system  | adjustable       | unmanaged        | -                |
| 5 Control                      | yes              | no               | -                | -                |
| 6 Engine control               | no               | thrust cutoff    | interpreters     | -                |
The essence of the found engineering solution is shown in the figure 5. The main principle is the use of pulsed thrust for braking when approaching the object to the Earth.

Figure 5. The principle of the found engineering solution.

4. The modeling and calculations applying the program LANE
After the morphological stage of structural synthesis and analysis were modeling and calculations applying the program Lane [12]. Program LANE calculates the complete range of performance parameters over a user-specified range of ballistic and aerodynamic variables. Lane provides a powerful framework to support the iterative process of unconventional aircraft conceptual design. Figure 6 shows the flight object trajectory.

Figure 6. Trajectory dependencies for an object weighing 75 kg (LANE screenshot).
5. Conclusion

The problem of rescuing people when they fall from a height (rescue from buildings in fires, when helicopters and planes crash, when landing as an alternative to a spare parachute) is very relevant nowadays. This investigation use a morphological approach to engineering solutions development as well as tools for creating promising individual smart rescue system of on conceptual design stage. The problem was solved in two stages. At a higher level of the hierarchy, the principle of action in morphological box was chosen. In the second phase, specific engineering solutions were explored. Flight simulations, depending on different initial conditions, were performed using the LANE program.

The merits of the engineering solutions:

- compact,
- functionality sustaining a wide range of control modes to ensure safe landings in different weather conditions and at different sites,
- the relative simplicity of the design, which ensures a fairly high reliability of work,
- small mass and dimensions,
- convenience,
- adaptability.

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