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USV test flight by stratospheric balloon: Preliminary mission analysis

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Abstract

The Unmanned Space Vehicle test flights will use a 7 m 1300 kg aircraft. The first three launches will take place at the Italian Space Agency ASI base in Trapani–Milo, Sicily, through a stratospheric balloon that will drop the aircraft at a predefined height. After free fall acceleration to transonic velocities, the parachute deployment will allow a safe splash down in the central Mediterranean Sea. The goal of this article is to show the preliminary analysis results for the first USV flight.

We carried out a statistical study for the year 2000–2003, evaluating the typical summer and winter launch windows of the Trapani–Milo base.

First, in the center Mediterranean, we define safe recovery areas. They cannot be reached during the balloon ascending phase so, after a sufficiently long floating part able to catch the open sea, the balloon will go down to the release height (24 km). The simulation foresees a 400,000 m^3 balloon and 3 valves for the altitude transfer.

A safe splash down must occur far enough from the nearest coast: the minimum distance is considered around 25 km. The vehicle should be released at a distance, from the nearest coast, greater than this minimum amount plus the USV model maximum horizontal translation, during its own trajectory from balloon separation to splash down. In this way we define safe release areas for some possible translations.

Winter stratospheric winds are less stable. The winter average flight duration is 7 h and it is probably too long for the diurnal recovery requirement and its scheduled procedures.

Comparing past stratospheric balloons flights and trajectories computed using measured meteorological data (analysis), with their predictions made using forecast models and soundings, we obtain the standard deviation of the trajectory forecast uncertainty at the balloon–aircraft separation. Two cases are taken into account: predictions made 24 and 6 h before the launch.

Assuming a Gaussian latitudinal uncertainty distribution for the prediction 6 h before the launch, we are able to identify the forecast trajectories that have a probability greater than 97% to reach the safe release areas.

Simulating the summer windows trajectories for the years from 2000 to 2003 and for the favorable ground wind days, we obtain the number of trajectories with the desired forecast probabilities.

Keywords: Stratospheric balloons; Balloon forecast trajectory; Unmanned Space Vehicle

1. Introduction and scope

The Unmanned Space Vehicle project, conceived for the development of the future generations of spacecraft and new aerospace technologies, it is part of the Italian Aerospace Research Program (PRORA) managed by the Italian Aerospace Research Centre (CIRA). The program foresees, for the first three flight tests, the use of stratospheric balloons to drop the aircraft (7 m aircraft of about 1300 kg) at a required height. Free fall acceleration will push the model to transonic region and, after

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aerodynamic measurements, the parachute will be deployed reducing the velocity before splash down.

The purpose of this document is to show a preliminary mission analysis, in the case of launch performed by using the ASIs facilities in Trapani–Milo. The following sections will be focused on some important aspects of the analysis:

- Main requirements.
- Wind properties.
- Balloon's altitude profile.
- Trajectory's properties and impacts on safety requirements.
- Forecast trajectory uncertainties.
- Release areas and confidence level.
- Statistical results.

2. Main requirements

The following main requirements apply:

• Launch base	Trapani–Milo
• Launch windows	Summer or winter (June–August or December–January)
• Recovery operations	Diurnal
• USV release height	24 km
• Recovery	On sea
• Splash-down distance from costs	No less than 12 Nm

The launch site position does not allow the balloon to reach, during the ascending phase, a safe area having a distance from the coast no less than 12 Nm; the balloon flight must foresee an appropriate floating phase able to catch the release area at open sea.

The launch is assumed to be at 7–8 a.m. local time, due to the ground wind statistical properties of the Trapani–Milo base and the requirement of diurnal recovery.

During summer the stratospheric winds are westward and the splash down will take place out to sea in front of the Algerian coast; in winter the eastward winds impose the balloon to go across the whole Sicily island and the recovery will be managed in the Ionian Sea, between the Italian and Greek coasts. The minimum distances between the launch site and the splash-down area is 70 km for the summer window and about 250 km in winter.

3. Wind properties

The forecast simulation and the reconstruction of the balloon trajectories require the availability of the atmospheric data in the geographical area and at the epoch of interest. The same availabilities are still important to point out the statistical properties of the wind direction and intensity and its impact on the trajectory. The following sources have been used to retrieve the wind data:

- Sounding data, made from the Trapani–Birgi airport and the ASI Trapani–Milo Base.
- Analysis (measured) data from the European Centre for Medium-Range Weather Forecasts.
- Forecast data from ECMWF and MM5 (Fifth-generation Mesoscale Model) models.

Figs. 1 and 2 show the probability distribution of wind directions and speeds for the float altitude (around 10 mb). The winter months have a bigger dispersion. In particular in that period the intensity could be very low, so the balloon will reach the release area few hours before sunset. This advance could be insufficient for the requested diurnal recovery.

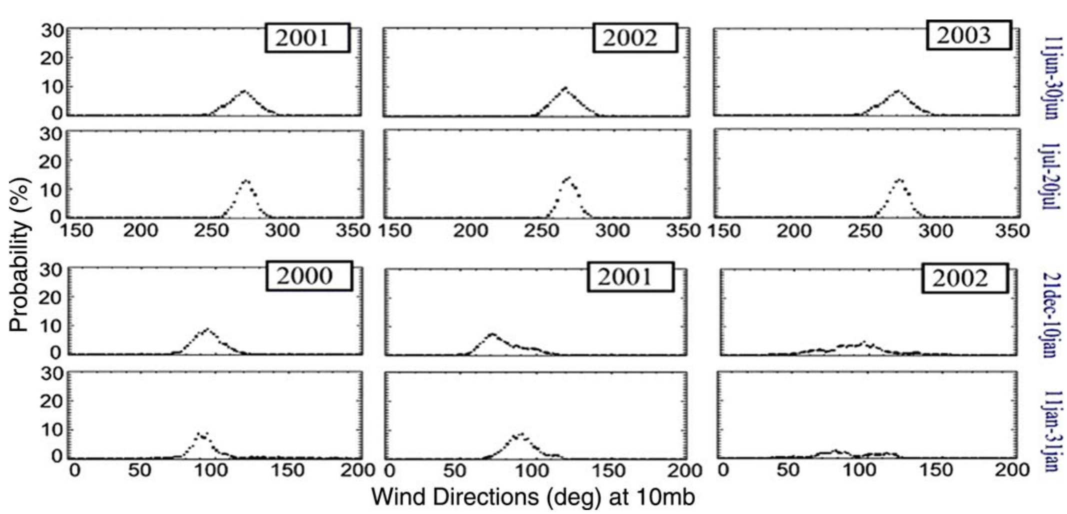

Fig. 1. Stratospheric wind direction: probability distribution for wind directions at floating altitude (10 mb).