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Exceptional optical phenomena observed during the operation of Russian launchers

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ABSTRACT

Experimental: data on the extraordinary optical phenomena observed in our country and abroad during selected rocket launches are discussed. A particular interpretation of these data on the basis of common methodological and theoretical positions is presented.

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1. Introduction

Large-scale dynamic optical phenomena associated with the operation of rocket engines in the upper atmosphere under favorable illumination and weather conditions can be observed over a very large area. At the phenomenon localization height of about 150 km, such phenomena can be observed at a distance of up to 1000 km and an elevation angle of more than 10 degrees. Taking into account the singularity of the phenomenon, the absence of sound and “space miracle” expectations in the form of a “real UFO”, it is not surprising that some of these events have received excessive attention [1]. Below are examples of these events.

This article represents an attempt to explain the optical phenomena of this type from the point of view of common methodological and theoretical positions.

2. Qualitative description of the optical phenomena recorded during rocket launches

The most colorful and large-scale phenomena emerging during rocket launches can be observed in the upper atmosphere at altitudes of more than 100 km. These effects are associated with the scattering of solar light by the dispersed particles of gas-dust clouds generated by the rocket engine exhaust. No natural analogies of these phenomena are known because at these altitudes, there are no aerosols of natural origin in the atmosphere. As the atmospheric density at heights more than 100 km is very low, expanding combustion products (CPs) of rocket fuel form clouds of different, often quite regular, geometric shapes, with dimensions of tens and even hundreds of kilometers.

The brightness of gas-dust clouds of CPs can exceed the brightness of all known natural phenomena in the upper atmosphere [2,3] due to the great mass of the scattering substance. For example, the concentration of ice crystals in noctilucent clouds at a height of 75–90 km is approximately one particle in 1 cm^3. As the characteristic size of the ice crystals is 0.1–1 μm, the mass of ice contained in a volume of 1 km^3 is approximately 1 kg. In addition, the rate of injection of the CP products by the engines of the second or subsequent rocket stages is greater than 100 kg/s.

The intensity of radiation scattered by the ensemble of particles in the Rayleigh approximation (particle size much smaller than the wavelength of the incident radiation) is proportional to the sixth power of their characteristic size [4]. It is obvious, therefore, that the larger the “grinding” of the substance is, the higher the

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intensity of scattered radiation is.

Modeling of such phenomena implies a solution of two independent problems: the formation of dispersed particles in the exhaust stream of the rocket engines and the expansion dynamics of the CP gas-dust clouds.

The CPs of solid fuels always contain dispersed particles (soot, Al, and Al_2O_3). During operation of liquid fuel rocket engines, dispersed particles can be formed only as a result of water vapor and carbon dioxide condensation in the rocket plume as result of the sharp temperature drop in the CP with increasing distance from the nozzle [5].

The phenomena accompanying rocket launches of both liquid and solid propellant engines are very similar. However, there is a certain type of phenomenon unique to the launches of solid propellant missiles [6].

The forms of gas-dust clouds of solid fuel CPs depend on the rocket height and the engine operation mode, as well as on the methods of engine thrust cut-off [7]. A solid fuel engine shutdown is achieved by means of a sharp decrease in the pressure within the combustion chamber. If this process is performed by opening the side flaps and the rocket rotates around the longitudinal axis, then the dust trail will take the form of a spiral. Upon release of pressure through the front valve, the observer can see two torches suddenly emerging in front of the rocket and behind it. In the mode of reverse thrust, the luminous cloud can adopt many different forms, depending on the method of this operating mode implementation. Note that during engine activation and cutoff, large dispersed particles, which produce intense light dispersion, are released into the environment due to incomplete fuel combustion.

Separation of the rocket steps by means of squibs is accompanied by the formation of an approximately spherical cosmosol (from words “cosmos” (space) and “aerosol”) cloud, which may take the form of a “bagel”. At altitudes of $\leq 50–60$ km, lighting effects can be observed during the combustion of the separated rocket fragments in the atmosphere.

One more class of effects associated with the interaction of rocket fuel CPs with air components should be noted. Depending on the height, these effects can be observed for a long time and at large distances from the rocket trajectory [8–10]. Such optical phenomena, as a rule, are difficult to differentiate from natural glow, as the effects of CP impacts manifest themselves mainly in the weakening or strengthening of the well-known issues. The appearance of new emission lines either is unlikely or their intensity is sufficiently small.

3. Launch of rocket booster “Vostok” september 20, 1977

Early in the morning of September 20, 1977, in the vast North-Western region of the former USSR territory and in the adjacent areas of Finland, an amazing optical phenomenon was observed that caused confusion among a huge number of eyewitnesses.

“Sotsialisticheckaya Industria” (“Socialist Industry”) Soviet newspaper on September 23, 1977, provided the following description of this effect in the news story “An unknown phenomenon”.

“Residents of Petrozavodsk have witnessed an unusual natural phenomenon. On September 20, about four o'clock in the morning, a huge star suddenly flashed in the dark sky throwing shafts of light to the earth. This “star” slowly moved towards Petrozavodsk and overhung the city as a giant “jellyfish”, showering the city with myriads of subtle light beams giving the impression of pouring rain.

After a while, the glow ceased. The “jellyfish” turned into a bright semicircle and resumed its movement in the direction of Lake Onega, the horizon of which was covered with grey clouds. According to the witnesses, the phenomenon lasted 10–12 min”.

Various hypotheses about the observed effects were suggested, ranging from chemiluminescence as a result of “a stratospheric ozone breakthrough into the upper troposphere” [11] to the specific shape of the gas electric discharge.

The opinion that more than 30 objects of observation (but not a single one) were recorded in this region also became widespread, probably in accordance with the number of places from which reports were received.

To a large degree, all of these hypotheses were based on eyewitnesses' subjective estimations, particularly that the observed effects were localized in a relatively lower atmosphere. Because a large number of observers were Petrozavodsk residents and, in accordance with their description, the phenomenon was observed directly above the city, this effect was named “Petrozavodsk phenomenon”. Passionate interest regarding this phenomenon became one of the reasons for the organization of the “physical nature of the anomalous aerospace phenomena” studies in the former Soviet Union [12].

However, the objective data concerning the localization of this phenomenon have been collected and analyzed. Relying on the data reported by observers of the Petrozavodsk phenomenon, A. Mezentsev (Petrozavodsk State University) performed triangulation calculations to estimate the azimuth and elevation angle of the active phase of the phenomenon for Petrozavodsk and other locations separated from Petrozavodsk by many hundreds of kilometers. All of these data indicated that the altitude of the phenomenon amounted to $\sim$200 km over Archangelsk.

The nature of this phenomenon is not trivial; rather, it is quite understandable and explicable.

TASS (Telegraph Agency of the Soviet Union, main USSR news agency) reported the following: “On September 20, 1977, at 04.03 a.m., a regular satellite “Kosmos-955” was launched in the USSR. The satellite was put into orbit with the following parameters: initial period of treatment of 97.5 min; maximum distance from the Earth's surface 664 km; minimum distance from the Earth's surface 631 km; orbital inclination of 81.2°”. Such orbital inclination suggests that the course of the satellite launch was directed to the North from Plesetsk and passed over Archangelsk (note that the first who linked the observed phenomenon with the satellite “Kosmos 955” launch was an American researcher named D. Oberg). Fig. 1 shows a diagram illustrating the respective positions

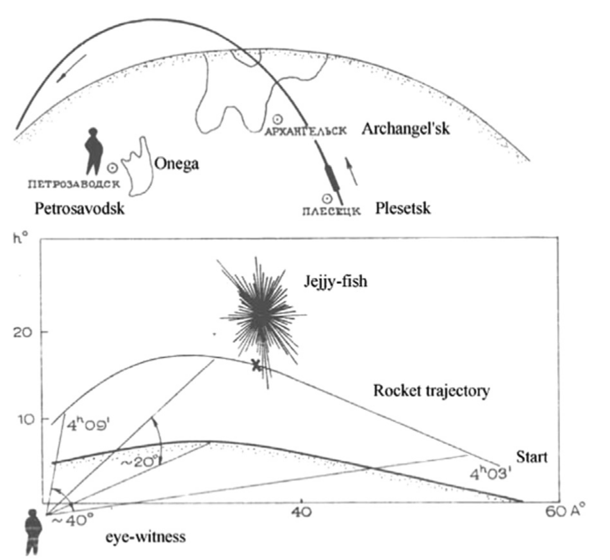

Fig. 1. Diagram of the respective positions of Petrozavodsk observers and the “Kosmos-955” flight path.

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