DEPARTMENT OF THE AIR FORCE
NATIONAL AIR & SPACE INTELLIGENCE CENTER (AF ISR AGENCY)
WRIGHT-PATTERSON AFB OHIO

AUG 25 2009

Colonel Mark E. Hess
Vice Commander
National Air and Space Intelligence Center (NASIC)
4180 Watson Way
Wright-Patterson AFB OH 45433-5648

John Greenewald, Jr.
[redacted]

Dear Mr. Greenewald

This letter is in reference to your Freedom of Information Act (FOIA) request for a copy of the document entitled *The Artificial Clouds in the Earth's Atmosphere*, our case number 2009-02553-AF.

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Sincerely

MARK E. HESS, Colonel, USAF

Attachment
Requested Document

AD-B118 005

FTD-ID(RS)T-1409-87

FOREIGN TECHNOLOGY DIVISION

ARTIFICIAL CLOUDS IN THE EARTH'S ATMOSPHERE

by

L.A. Andreyeva, A.A. Khanan'yan

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By: L.A. Andreyeva, A.A. Khanan'yan

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

ARTIFICIAL CLOUDS IN THE EARTH'S ATMOSPHERE

L. A. Andreyeva, Candidate of Physicomathematical Sciences,
A. A. Khanan'yan, Candidate of Physicomathematical Sciences

In the 1950's, when rocket methods of studying the upper atmosphere were just beginning to be developed, Soviet scientist I. S. Shklovskiy and English scientist D. R. Bates suggested the idea of creating an artificial luminous cloud. They proposed discharging a small quantity of sodium vapor into the atmosphere by rockets, thinking that because of resonant emission, the sodium atoms illuminated by the sun should form a luminous cloud in the atmosphere which would be clearly visible from the Earth.

The initial experiments confirmed the reality of implementing this idea, and they were used to study the elementary processes which cause sodium atoms to glow in the upper atmosphere and to measure the wind velocity at altitudes of 85-110 kilometers.

The idea of creating luminous clouds to study the physicochemical and dynamic processes in the upper atmosphere proved to be so intriguing that it was rapidly developed in many rocket experiments. After sodium, other substances began to be used, such as lithium, potassium, cesium, barium oxide, europium, titanium tetrachloride and trimethyl aluminum, which are capable of creating neutral and even ionized clouds. And soon a new type of artificial cloud appeared - smoke clouds formed at stratospheric and mesospheric altitudes due to the rapid combustion of certain chemically active substances in the atmosphere with the subsequent formation of a cloud of submicron particles which are good reflectors of solar radiation.

The use of various substances capable of actively reflecting or reemitting solar radiation and which also glow as a result of chemical reactions with environmental components made it possible to study the state of different layers of the upper atmosphere at virtually any time of day, when natural cloud cover was not present, of course. One can judge how intensively this method of analyzing the upper atmosphere was developed from the fact that during 1969-1975 alone a total of around 300 rocket experiments involving the formation of artificial clouds with the discharge of various reagents were carried out around the world. Using them, it was possible to get an idea of the nature of the physicochemical and dynamic processes in a wide range of altitudes.

In our country, the artificial luminous and smoke cloud method was used in research conducted by the Institute of Experimental

Meteorology of Goskomgidromet [State Committee on Hydrometeorology]. An extensive program of work on studying the thermohydrodynamic characteristics of the upper atmosphere at polar and middle latitudes using the MR-12 rocket complex was carried out here under the management of Doctor of Physicomathematical Sciences, Professor L. A. Katasev. In the 1970's, this program was supplemented by research on electrical fields from observations of the drift of ionized clouds, as well as investigations of the wind structure and turbulence in the stratosphere and mesosphere using M-100B meteorological rockets. During this period, a large number of studies on large-scale specialized projects such as "Aktivnoye Solntse" [Active Sun], "Spokoynoye Solntse" [Calm Sun], "Solntse -- atmosfera" [Sun--Atmosphere], etc. were carried out which enriched our knowledge of the Earth and near-Earth space. The structure of the polar atmosphere under various geophysical conditions was studied with international cooperation in the complex rocket experiments "Polyarnoye utro" [Polar Morning] (1972, 1974), "Dzhoul'" [Joule] (1976, 1977) and "Energeticheskiy balans" [Energy Balance] (1980).

With all their apparent simplicity (the cloud was generated, it was photographed, the intensity of illumination in different spectral bands was measured), the joint efforts of a large number of scientists and specialists were required to conduct each of these experiments, both in the stage of preparation and launching the rockets, and later, for processing and analyzing the experimental data obtained. In order to record the clouds, it is necessary to establish ground observation posts outfitted with a set of special photographic and spectral equipment and to provide these posts with the reliable communications system needed to perform synchronous measurements. Because the substances discharged are highly chemically active, a whole series of technical problems must be solved in order to work with them, such as creating special evaporators and devices to successfully discharge the substances into the atmosphere, making it safe to work with them during installation on rocket nose cones, solving the problem of compatibility with other research instruments installed on the rocket, etc.

Special requirements are imposed on the individuals and equipment involved when the experiments are conducted on polar latitudes (e.g., on Ostrov Kheysa in Franz Josef Land, where the northernmost atmospheric rocket sounding station in the world is located). Here each launch requires not only a great deal of work, but sometimes also courage.

As soon as the cloud appeared in the atmosphere, the scientists were rewarded for all their efforts. Literally two-three minutes after the rocket is launched, when the evaporators begin to operate at the required altitude, an astonishing spectacle whose beauty is probably only exceeded by the polar aurora begins to unfold in the sky. A long blue-green wake forms in the atmosphere from the discharge of trimethyl aluminum interspersed with red and orange spheres from the discharges of lithium and sodium, and somewhere on the very top of the wake barium bursts out in a light blue cloud. It is rapidly separated into neutral and ionized parts which go off in different directions. As time passes, this entire rather closely-grouped structure begins to be whimsically transformed by the vertical structure of the wind, molecular and turbulent diffusion. After twenty to thirty minutes, only weak reflections which also soon disappear are left of the bright cloud.

The experiment was completed and the cloud had dispersed, but it was still captured on film and in the memory of the instruments which recorded it. Then the results of the observations are analyzed at the site itself and in laboratories. They are used to reconstruct the details of the pattern of movement of the cloud as a whole and its individual parts through space, which makes it possible to determine the wind velocity and direction in the investigated range of altitudes. The parameters of molecular and turbulent diffusion are estimated from the rate of dispersion of the cloud, and from the emission spectrum - the ambient temperature, etc.

It is logical to raise the question of whether it is practically necessary to conduct experiments with artificial clouds and what parameters and properties should be investigated using them. Such questions always arise when one describes a particular scientific trend or research method. For today any area of research must contribute to the solution of significant scientific, technical and economic problems.

Looking at experiments with artificial clouds from this viewpoint, one must admit that they have already contributed a great deal to understanding the nature of the processes which take place in the upper atmosphere. The first unique data about variations in wind velocity and direction and the density and temperature in the thermosphere were obtained by these experiments; the role of flow movements and internal waves in forming the vertical structure of wind was demonstrated, the most complete information about small-scale turbulence was obtained and the upper limit of its existence in the Earth's atmosphere was established. Studies of the electrical and magnetic fields in the ionosphere and magnetosphere were conducted based on the drift of ionized clouds, and their effect on the neutral component of the atmosphere was estimated.

The investigations carried out showed that the state of the upper atmosphere depends on many geophysical and meteorological factors, and the variations in its parameters are so great and diverse depending on the time of day, latitude, solar and geomagnetic activity, season, etc., that considering its costliness and complexity, it would be impossible to cover this wide diversity by rocket sounding. For this reason, ground and satellite methods of studying the upper atmosphere are being rapidly developed today. These methods can provide continuous monitoring of the state of the atmosphere on a global scale. Further horizons are being discovered for rocket experiments, including for the artificial cloud method, and new research problems are being set up. They include making subsatellite measurements, comparing the measurement and calibration data of the developing ground methods of sounding the upper atmosphere, and verifying the theoretical models being developed. The problem of studying the nature of the propagation of pollutants in the 20-120 kilometer layer as a result of mixing caused by small-scale turbulence is equally important. The solution of these urgent problems will greatly determine t'.e direction of the further development of experiments with artificial luminous and smoke clouds.