DEPARTMENT OF THE AIR FORCE
AIR INTELLIGENCE AGENCY

U.S. AIR FORCE
1947 - 1997

14 MAR 1998

NAIC/CC
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 dated 1 Dec 97, our case number NAIC-98-033.

After reviewing the document you requested, it was determined that it is releasable.

Your request was processed in the "all other" category. The document we are providing contains 13 pages. All fees have been waived.

Sincerely

Richard G. Annas

RICHARD G. ANNAS, Colonel, USAF
Commander

Attachment
FASTC-ID(RS)T-0679-92

FASTC-ID(RS)T-0679-92

FOREIGN AEROSPACE SCIENCE AND TECHNOLOGY CENTER

THE ENGINE FOR THE FASTEST AIRCRAFT IN THE WORLD IS RUSSIAN

by

Jean-Rene Germain

THE ENGINE FOR THE FASTEST AIRCRAFT IN THE WORLD IS RUSSIAN

By Jean-Rene Germain

Whereas NASA fights against depression, and Europeans make conferences, the Russians, themselves, in spite of the economic collapse of their country, have made fly the engine which will be used for the aerospace planes of the third millennium. Intended originally for a Soviet missile, it is proposed for sale for international civilian purposes. Its creators detail for us the history, the problems and the current goals.

For uninitiated persons, the news is amazing: in a few days, Mr. Donat A. Ogorodnikov, current director of TsIAM (Russian acronym of the Central Institute of research on Aircraft Engines) and his assistant, Mr. Vlatcheslav A. Vinogradov, person in charge of the section of gas dynamics of aerospace engines, will go to the United States to present to NASA a "staggering" realization: a hypersonic "super ramjet engine". A Similar engine is likely to propel a space plane beyond Mach 6, i.e. at six times the speed of the sound [1]. A super-Concorde to some extent, which would put Tokyo at three hours from New York (instead of eighteen hours with the current airliners)! Tests have already taken place, and the machine actually flew at this speed.

For the Americans, the surprise is more than intense: The United States, still the most advanced of developed countries in this field, did not plan to put to test such an engine before three or four years, in spite of the colossal sums invested in their project of aerospace plane: a budget of 260 million dollars for only the year 1993. As for Europeans ....

In the formidable confusion which preceded and followed the fall of what former president Reagan called the "evil empire", the Soviet engineers "ha worked effectively, if not calmly. It is easily understood that The US Air Force and the European Company of Propulsion (SEP) sent to Ts'AM requests for information.

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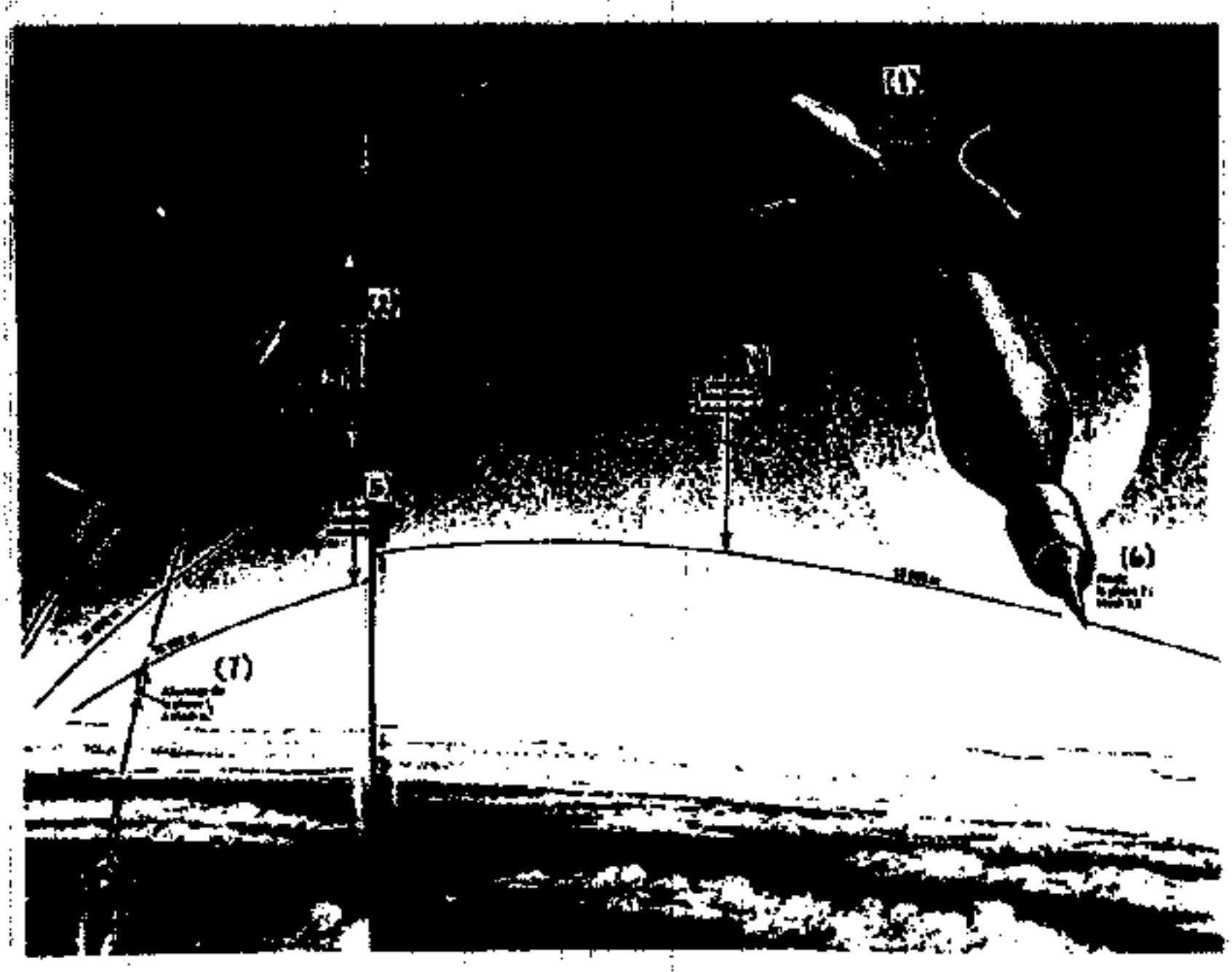
1. One calls Mach number the ratio between the speed of the plane (or of the missile or the flow of a fluid) and the speed of sound (341 m at sea level). Mach 1 = 1227.6 km/h. Mach 6 = 7365.6 km/h.



THE SUPER RAMJET ENGINE HAS FLOWN AT MACH 6

Launched from the cosmodrome of Baikonour by a ground-to-air missile, the ramjet reached Mach 6 during some one hundred thirty seconds flight at a distance of 100 km. During this flight, it was fired twice thanks to a pre programmed order.

Phase 1. The super ramjet engine was fired at 18 km of altitude, when the rocket reached Mach 3.5. It functioned twenty seconds, bringing speed to Mach 6 and the machine to 25 km of altitude. During the five last seconds of this phase, combustion functioned in a supersonic mode.

Phase 2. A new firing of the engine took place at 23 km of altitude, whereas the rocket, after having reached a maximum altitude of 35 km started its descent. Its speed was then Mach 4.5. Length of operation: ten

seconds. This phase was used to check the systems design of firing. At the end of this phase, the rocket was at 18 km of altitude, at a speed of Mach 3.5.

Key: (1). Firing of phase 2 at Mach 4.5. (2). 5 seconds of subsonic combustion. (3). End of phase 1: Mach 6. (4). 15 seconds of subsonic combustion. (5). 15 seconds of subsonic combustion. (6). End of phase 2: Mach 3.5. (7). Firing of phase 1 at Mach 3.5.

The stakes are sizeable. The hypersonic ramjet was supposed to be the answer, somewhat varied, from the American shepherdess to the European shepherd that had manufactured Concorde. It was also, for the large airframe manufacturers, "the" plan for the future: in time, it was supposed to be able to provide for the replacement of the Boeing 747 and similar craft, whose design goes back about thirty years. Whence the need for studying a new generation of planes for the next decades. In particular for intercontinental connections. The boxes of the principal manufacturers have contained for several years various projects - in the state of simple ideas, for the moment - planes at very high speed (Mach 6 and beyond), which will be either stratospheric apparatuses, flying in the high layers of the atmosphere, or recoverable orbital launchers [2]. However, the engine most indicated for this new type of vehicle, is precisely the "super ramjet engine" ("Scramjet" in American) - the exact one that the Russians tested.

The Wall Of Heat. The great difficulty that this type of engine poses comes from the fact that combustion is carried out in a supersonic, even hypersonic flow. Indeed, the external air, even if it is somewhat slowed down at the air intake level, remains largely supersonic when crossing the combustion chamber (Mach 4). The theoretical and experimental studies carried out on the ground, Mr. Ogorodnikov told us, already mentioned, show that when one approaches hypersonic speeds (around Mach 6), performances of an ordinary ramjet (in which combustion is carried out with a subsonic flow) degrade quickly. The appearance of shock waves between the air intake and the combustion chamber raises the temperature and the pressure at levels too high for the mechanical resistance of the combustion chamber, which prevents the engine from providing effective thrust.

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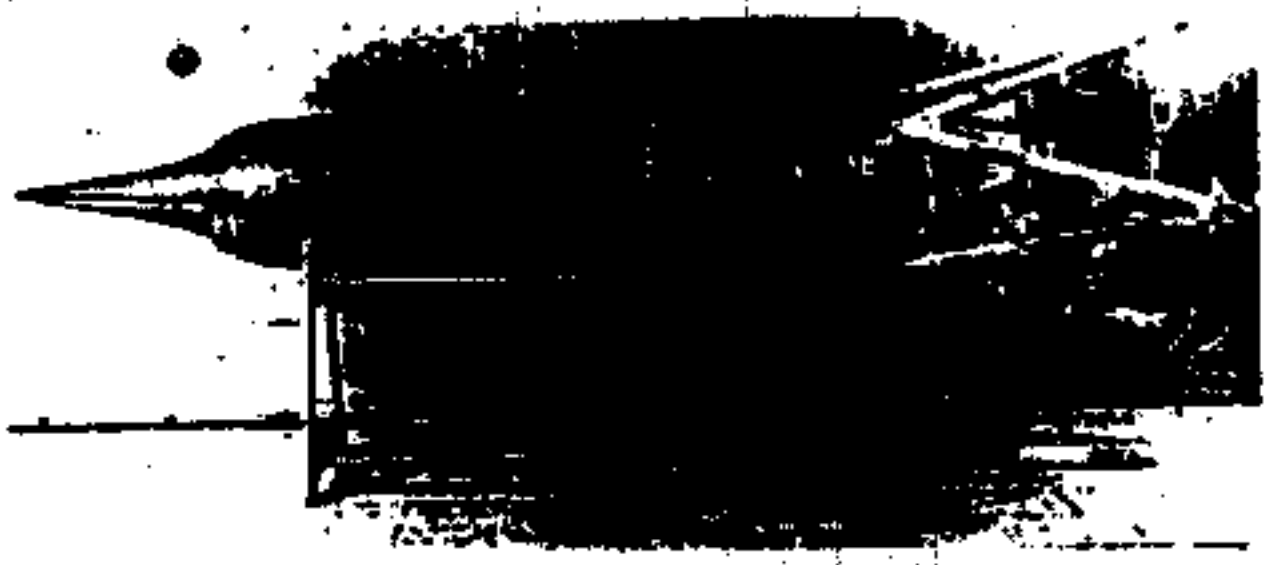
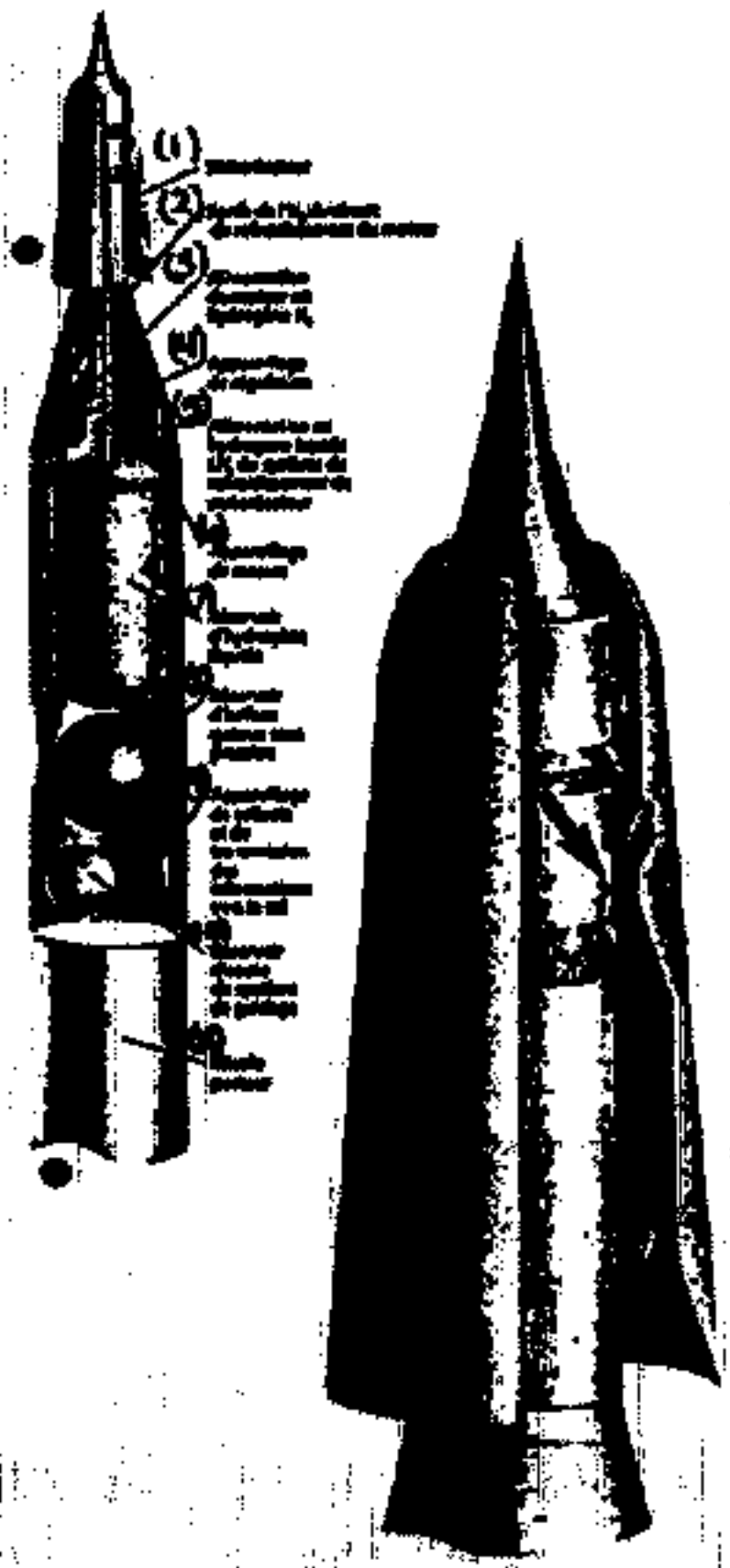
[2] On the stratospheric project of planes see Science and Life No. 820, July 1984.



This crippling fall of the output has two origins: the irreversible degradation of the mechanical energy through the shock waves, and a reduction in the heat balance of combustion. Moreover, at the high temperatures reached occur endothermic reactions which dissociate the reagents of the fuel. To avoid or attenuate these problems, one must maintain gas flows in the ramjets at subsonic speeds, a difficulty which increases with the speed of the plane equipped with such engines. Today, the Russians seem to have well controlled supersonic flows.

THE HYPERSONIC FLYING LABORATORY



Thus the specialists in Russian TsIAM call the experimental device of flight tests of the hypersonic ramjet, made up of the engine itself (1) and higher stage (2) of a ground-to-air missile with liquid propulsion aided on takeoff by 4 blocks of powder. The unit is 4.3 m long for a maximum diameter of 0.70 m, and weighs 1360 pounds (including 37.4 of hydrogen).

In the channel where flows the air inside the ramjet (1 - arrow) are located various injectors of hydrogen. This latter, stored in liquid form in a cryogenic tank placed in the final stage of the missile, is injected in gas form after being heated by a passage around the nozzle. The theoretical bases of combustion at hypersonic speeds were patented in 1956 by Pr. E. S. Chichetnikov, collaborator of Serguei Pavlovitch Korolev (photo), the celebrated manufacturer of the spaceships of the former USSR.

Key: (1). Ramjet. (2). Exit of the H_2 from the coolant circuit of the engine. (3). Engine supply of hydrogen H_2. (4). Equipment of regulation. (5). Liquid hydrogen supply LH_2 of the system of cooling of the ramjet. (6). Measuring equipment. (7). Liquid hydrogen tank. (8). Gas helium tank under pressure. (9). Equipment of collection and transmission of information to the ground. (10). Nitrogen reserve of the system of guidance. (11). Carrying missile.

But they have not started from nothing. The Soviets had indeed solid experience in this field: in the decades 1920 and 1930, they had carried out tests on rockets and planes, that were based on studies of F. A. Tsander, B. S. Stechkine and V. I. Dudakov. They thus experimented with in 1939, the ramjet of military engineers Yu. Pobedonostsev and I. A. Merkulov, mounted on a Polikarpov I-152 plane. World first: January 24, 1940, the pilot P. Ye. Logenov made several fly-overs of the central airport Frunze, in Moscow, with an I-152 equipped with a ramjet DM-2. In total more than 140 flights were realized thereafter with DM-2 and DM-4. But the Second World War stopped research. The Stalinist repression which followed devastated the ranks of the researchers, and work entered a long hibernation.

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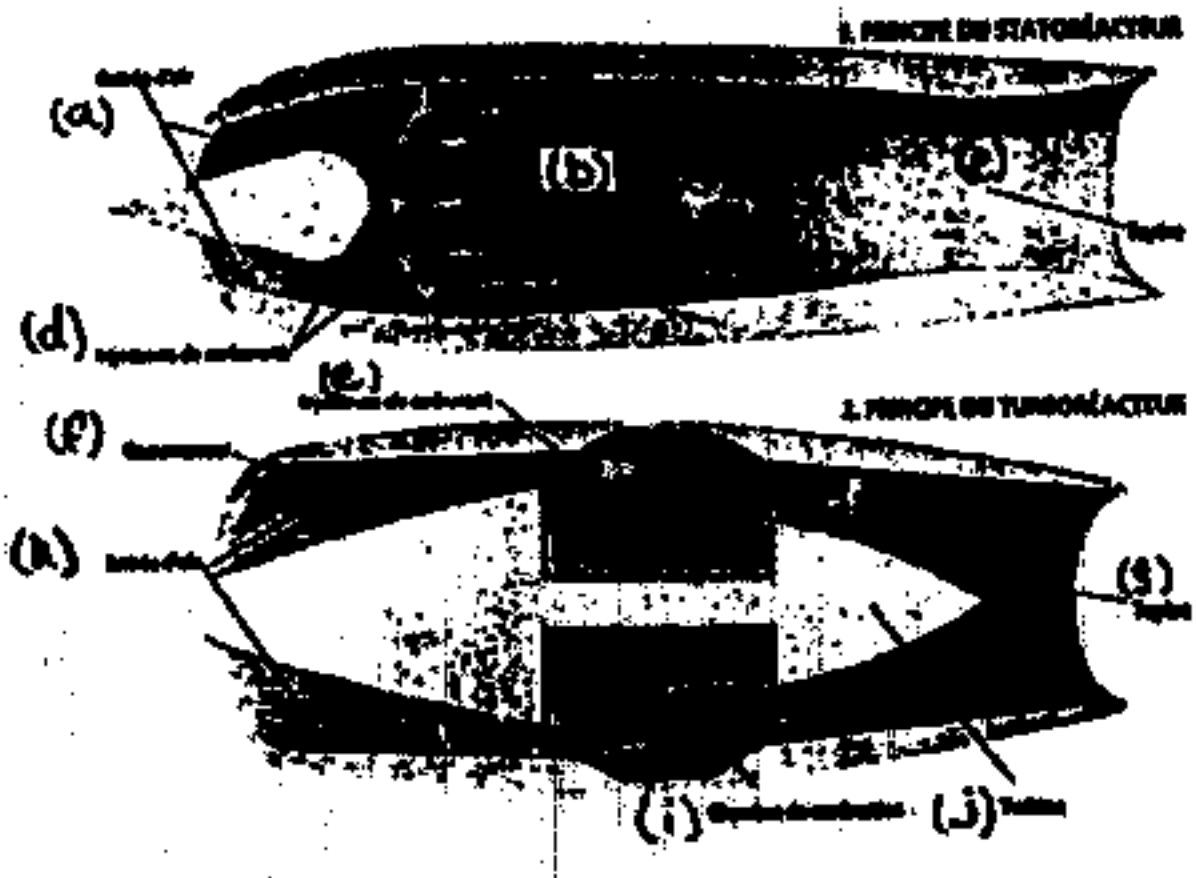
Incidentally, let us wipe away a tear: the ramjet is, in origin, a French invention. It is Rene Lorin who invented, in 1913, the simplest reaction engine which was: an open tube at its two ends. Once this tube reached its initial speed thanks to an external engine (a plane-carrier, for example) the external air rushes in at a certain speed. The geometry of the air intake compresses it and heats it, the fuel (kerosene, liquid hydrogen or something else) is injected by jets laid out inside the tube, and the mixture is fired. The gases burned and strongly expanded resulting from combustion are channeled toward the back of the tube, thus providing the thrust (see drawings above and p. 91).

The idea of Lorin did not remain a dead letter: December 26, 1956, engineer Rene Leduc made fly in Istres a subsonic ramjet plane. This model 0.22 took off even by its own means thanks to a turbojet Atar 101-D3; then, once in flight, the pilot fired the ramjet. Beautiful success, which had one fault however: it was necessary to equip the plane with two different engines. Too complicated! The idea was abandoned. Only a small-size subsonic ramjet, was used thereafter, largely for many cruise missiles (Bomarc, Tatar, etc.).

The Soviets, themselves, took up again research upon coming out from the Stalinist night. "The theoretical bases of combustion at supersonic speeds in an engine, established by Pr. E. S. Chetaeikov, collaborator of Sergueï Pavlovitch Korolev (photo p. 90), the celebrated manufacturer of the spaceships, had been the subject of a patent applied since 1938", specifies Mr. Ogorodnikov. But the Soviets did not think of aviation: like others, they intended the engine for a hypersonic cruise missile. It is such an engine adapted to civil use which has just flown. "The tests took place on November 28, 1991, official date of the first flight of a ramjet with liquid hydrogen", still specifies Mr. Ogorodnikov.

One had thus controlled the problems exposed above (resistance of the combustion chamber, degraded effectiveness of the thrust, dissociation of the reagents of the fuel), and some others moreover. For example, explains our Russian interlocutor, the engine can function only with the flows of air provided with speeds greater than 3500 km/h. Which carries the air admitted at a temperature of 2000°C. Of all the possible fuels, only liquid hydrogen gathers the necessary qualities (the high energy value, for the very least of problems arising with injection and vaporization) to supply such a machine. "It was thus necessary to test the behavior of this fuel under critical thermal conditions, in order to make sure that it burned correctly as well in a subsonic flow as supersonic", continues the future Russian host of American NASA. At this stage, flight tests were essential. Besides, ground tests imitating the conditions of flight would have been "very complicated and very expensive to implement," emphasizes Mr. Ogorodnikov. " Moreover, it is practically impossible to imitate on the ground speeds of Mach 6, which is however that of the cruising speed. Admittedly, one could have made computer simulations, but in the final analysis experimentation in flight was the surest means to check calculations."



FROM MACH 3 TO MACH 10

The insight (1) is the simplest engine there is. The external air rushing in at high speed, is compressed under the effect of the geometry itself of the air intake in a channel before being mixed with fuel. The mixture is ignited in the combustion chamber. The produced gases then expand and are ejected violently by the nozzle at the other end of the channel, thus ejecting the thrust. The great advantage of this

ramjet is that it does not have any moving part. On the other hand, it can function only once animated by a high starting speed, whence the need for launching it thanks to a carrier aircraft or a rocket.

Conversely, a turbojet (2) is able to start from the stop, but it is composed of a great number of moving parts: a compressor with several stages sucks in the external air, compresses it and injects it into the combustion chamber, where it is mixed with the fuel; expansion of gases resulting from this combustion - before leaving by the nozzle and providing the thrust - turn a turbine, it also multistage, whose axis drives the compressor. And so on. Friction due to this large number of parts in rotation limit the turbojets to maximum speeds of Mach 2-3, whereas the ramjets can reach Mach 10 and more.

Key: (1). PRINCIPLE OF THE RAMJET. (A). Air intake. (b). Combustion chamber. (c). Nozzle. (d). Fuel injector. (2). PRINCIPLE OF THE TURBOJET. (a). Fuel injector. (f). Compressor. (g). Nozzle. (h). Air intake. (i). Combustion chamber. (j). Turbine.

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Launched from the cosmodrome of Baikonour by an old ground-to-air missile equipped with 4 solid propellent boosters, the "super ramjet engine" reached Mach 6 during a flight of 130 s at a distance of 180 km (see drawing p. 88). A few tens of seconds to thus crown years of efforts. All was done in TsIAM: design of the "hypersonic flying laboratory" that represented in fact this missile crammed with sensors, that of the engine itself, the study of operation, cooling, etc.

Unimaginable thing during the time of the USSR, Mr. Ogorodnikov is not miserly with details. "The engine, he told us, has a configuration of axial symmetry (see drawings p. 91). It includes an air intake on several stages of compression, a combustion chamber of variable diameter and a shortened nozzle. The air intake, of a diameter of 0.23 m and a total length of 1.28 m, was calculated so that the engine fires spontaneously beyond Mach 3 and remains then stable during all the operations (...)."

"The geometry of the combustion chamber was conceived so as to take account of the two operations of the ramjet. At supersonic "low speeds" (between Mach 3 and 5), the combustion of hydrogen is carried out there at subsonic speed. But between Mach 6 and Mach 8, the gases of combustion rush into the channel at hypersonic speed. The hydrogen supply is carried out with injectors with multiple slits, which make it possible to maintain operation at various speeds."

"The ramjet was installed on the upper part of a stage of rocket (the old missile mentioned above - see drawing p. 91). In the final stage of the rocket, one installed 250 sensors, measuring instruments, as well as controls of fuel feeding during the flight and the cryogenic tank [3]. One also installed there a system of measurement and the data-processing memories and systems of retransmission of the data to the ground."

"The development was used with experiments of equipment technology and dynamics of the gases, which allowed, inter alia, to establish the parameters of the air intake, of the combustion chamber, the whole of the engine and equipment of control, the regulation of the fuel feed and the cooling of the channel."

"The principal difficulty," continues the Russian engineer, "was to fill and supply this engine with liquid hydrogen at the remarkably low temperature of -253°. For that, we invented a mobile system of filling and a new device for onboard feeding."

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"The thrust developed by the ramjet varied between 200 and 500 kg. The temperature in the combustion chamber ranged between 1500 and 1800°C for a pressure from 1 to 2 atmospheres."

"The results of the experimental flight, under study, show right now that the engine can function with the two flight modes (subsonic and supersonic) and that one can receive information during the passage from one mode to another."

For the Russian engineer, "the super ramjet engine should make it possible to replace the multi-stage rockets, which are usable only one time, by aerospace planes with multiple uses. What we call experimental hypersonic laboratory' must be also used to develop true cosmic vessels, in Russia and abroad".

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The following stage: Mach 10 and beyond. Confident with these successes, the Russians do not intend to stop on such a good path. They hope to test soon a hypersonic ramjet even more

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[3] In a tank making it possible to preserve hydrogen in liquid state to -253°.

powerful: Mach 10 with an altitude of 35 km before the end of this year. Then, they wish to test ramjets of different geometries. They must have for that a rocket more powerful than that of last 28 November; it should not be too difficult to find.

But Russia is not rich, and TsIAM did not receive yet, for the year in progress, a single kopeck. If our two engineers thus go to the United States, it is to find financing for the whole of their program thanks to foreign collaboration, which moreover is not limited to the Americans.

The history of the Russian ramjet shows, certainly, the economic difficulties of the old USSR. But it also shows that intelligence knows neither borders, nor political regimes, and that to some extent (Forgive us the exaggeration of the image), one can arrive at a rather beautiful result with a hammer, sheet metal, wrangling and grey matter.

The "RAMJET", A FRENCH IDEA

It is with the Frenchmen Rene Lorin (1) that the idea of the ramjet in 1913 comes to, and to the Russian pilot P. Ye. Loginov to fly for the first time on January 24, 1940 with a L-152 equipped with a ramjet DM 2 designed by military engineers Ya. Pobedonostev and I. A. Merkulov. It is still to a Frenchman, Rene Leduc (2), that comes the privilege to have carried out the tests of modern planes equipped with ramjets in the 1950's.

Being able to function only after being propelled at a high initial speed, the French prototypes were initially released from Breguet (3), then tested in autonomous flight for the first time at Istres, December 26, 1956. That day, Rene Leduc succeeded in making take off his model 0.22 by his own means with a turbojet Atar 101-D3; once in flight, he fired its ramjet.

A few years later, the Griffon (4), military plane equipped with a mixed turbo ramjet engine was tested, but this solution was quickly given up to the advantage of the turbojets. More practical and equipped with a better maneuverability, the latter spread since, to equip combat aircraft as well as civil planes, the formula of the ramjet was finally abandoned, except for the small-size subsonic ramjets, which were largely used for many cruise missiles (Bomarc, Talos, etc.).

DEPARTMENT OF THE AIR FORCE

88TH AIR BASE WING
WRIGHT PATTERSON AIR FORCE BASE OHIO 45433

U.S. AIR FORCE
1947 - 1997

11 December 1997

88 CG/SCCIADF
Building 16, Area B
2275 D Street, Room 0047
Wright-Patterson AFB OH 45433-7220

John Greenewald, Jr.
[redacted]

Dear Mr. Greenewald

This is in response to your attached 1 December 1997 Freedom of Information Act request for Report No. FASTC-ID(RS)-0679-92.

We are not the release authority for the document you have requested. Your request has been transferred to the address listed below for processing and a direct response to you.

NAIC/SCVMS(FOIA)
4115 Hebble Creek Road, Suite 14
Wright-Patterson AFB OH 45433-5614

Phone (937) 257-6284

Point of contact for this request at 88 CG/SCCIADF is Paul Cassidy at (937) 255-3016, extension 2133 or fax (937) 656-4295.

Sincerely

Carolyn J Landis

CAROLYN J LANDIS
Freedom of Information
Act Manager

Attachments
Your Ltr, 1 Dec 97
88 CG/SCCIADF Ltr, 11 Dec 97

Golden Legacy, Boundless Future...Your Nation's Air Force

[redacted]

DEC 0 1 1997

John Greenewald, Jr.
[redacted]

88CG/SCCIADF
980141PC

Aeronautical Systems Center
88 CG/SCCIADF, Bldg 16
2275 D Street, Room 047
Wright Patterson AFB, OH 45433-7220

Dear Sir,

This is a non-commercial request under the Freedom of Information Act. My category for fee status is academic. I agree to pay up to fifteen dollars for the requested materials.

In a past Freedom of Information Act request to the Defense Technical Information Center, they provided me with an index of documents, and pointed me to your office for this specific document. Thus, under the Freedom of Information Act, 5 U.S.C. § 552, I respectfully request the following document:

AD Number: B168148
Title: The Engine for the Fastest Aircraft in the World is Russian
Report Date: 04 September 1992
Report Number: FASTC-ID(RS)T-0679-92

Thank you for your time, and I look forward to your response.

Sincerely,

John Greenewald, Jr.

Enclosures:
None

[redacted]

DEPARTMENT OF THE AIR FORCE

88TH AIR BASE WING
WRIGHT-PATTERSON AIR FORCE BASE OHIO 45433

U.S. AIR FORCE
1947 - 1997

11 December 1997

MEMORANDUM FOR NAIC/SCVMS(FOIA)

FROM: 88 CG/SCCIADF(FOIA)
Building 16, Area B
2275 D Street, Room 0047
Wright-Patterson AFB OH 45433-7220

SUBJECT: FOIA Request Transfer (John Greenewald)

1. The attached FOIA request is being referred to you for processing and a direct reply to the requester. The requester has been notified of this action.

2. Gary Huelesman accepted this referral on 11 December 1997.

3. Point of contact at 88 CG/SCCIADF is Paul Cassidy at DSN 785-3016, extension 2133 or fax DSN 986-4295.

CAROLYN J LANDIS
Freedom of Information
Act Manager

Attachments:
John Greenewald Ltr, 1 Dec 97
88 CG/SCCIADF(FOIA) Ltr, 11 Dec 97

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DEPARTMENT OF THE AIR FORCE
AIR INTELLIGENCE AGENCY

U.S. AIR FORCE
1947 - 1997

16 Jan 98

NAIC/SCVMS (FOIA)
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 dated 1 Dec 97. We received your request and assigned case number NAIC-98-033 to it. Please reference this case number when inquiring about this request.

Your request will be processed as a category 3 request for fee assessment. This will entitle you to get the first 2 hours of search and the first 100 pages of reproductions free. You will not be required to pay review charges.

A response will be sent to you by 2 Feb 98.

Sincerely

GERY D. HUELSEMAN, TSgt, USAF
Chief, Freedom of Information
Information Management Operations

DEPARTMENT OF THE AIR FORCE
AIR INTELLIGENCE AGENCY

U.S. AIR FORCE
1947 - 1997

NAIC/SCVMS (FOIA)
4180 Watson Way
Wright-Patterson AFB OH 45433-5648

2 Feb 98

John Greenewald, Jr.
[redacted]

Dear Mr. Greenewald

This letter is in reference to your Freedom of Information Act (FOIA) request dated 1 Dec 97, our case number NAIC-98-033. An extension of time is required to search for the records you requested.

Sincerely

GERY D. HUELSEMAN, TSgt, USAF
Chief, Freedom of Information
Information Management Operations