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MINUTES OF AN INFORMAL MEETING ON NUCLEAR ROCKETS

Report written by:

Frederic de Hoffmann

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MINUTES OF AN INFORMAL MEETING ON NUCLEAR ROCKETS

Attendance:

The meeting was held at Los Alamos on January 17, 1949. Those in attendance were: Dr. G. Gamow, Chairman; Drs. D. Hall, J. Hall, T. Hill, F. de Hoffmann, F. Mc Lure, N. Metropolis, E. Plesset, F. Reines, B. Sage, E. Teller, L.T.E. Thompson and S. Ulam.

The group took as its premise that an effective method for the delivery of nuclear bombs had to be available. There are essentially four methods available for this purpose indicated by the following diagram:

TABLE I

CHEMICAL PLANE	NUCLEAR PLANE	
CHEMICAL ROCKET	NUCLEAR ROCKET a. Nuclear motor becomes bomb on landing.	b. Nuclear motor with extra bomb carried along.

The present discussion concerns itself essentially with the discussion of the bottom two squares, and their respective advantages and disadvantages.

The group first considered the possible development problem in chemical rockets which could carry an atomic war-head. For the sake of comparison, the assumption was made that a laboratory of the Inyokern type involving a community of about 8,000 people would devote full time to the development. In this case the following table might apply:

TABLE II

Range of Rocket = 5,000 miles

Bomb weight	10,000 lbs	5,000 lbs	2,000 lbs	1,000 lbs
Bomb diameter	60 in.	45 in.	30 in.	$\leqslant$ 30 in.
Rocket weight	140,000 lbs*	70,000 lbs#	40,000 lbs#	25,000 lbs##
Likely dollar cost	5.10^8	2.10^8	1.10^8	$\leqslant 10^8$
Likely years for development (not production)	5 - 10	4 - 8	4 - 6	4 - 5

* 3 Stage rocket # 2 Stage rocket ## 1 Stage rocket

Table II assumes that the difficulty in chemical rockets is definitely increased by going from single stage to multi-stage rockets, but that the minimum time would be required to lick basic problems. It appears that if one limits oneself to a one stage rocket the weight of the atomic war-head including the guidance system may not exceed 1500 lbs. and 30 inches in diameter. Of these 1500 lbs. one may have to count about 500 lbs. for the guidance system. Thus for the sake of a single stage rocket, it seems that the atomic war-head must probably be about 1,000 lbs., but that there is no significant gain in going below that figure since the guidance system itself is liable to be fairly weighty.

In comparing the two bottom squares of Table I, the group drew up Table III. (Details of Table III are explained below, unless self-explanatory.)

CD2 - The larger size has two disadvantages:

(a) The rocket is physically difficult to build.

TABLE III

CHEMICAL ROCKET		NUCLEAR ROCKET	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
CA1 - Ejects burned gas. CA2 - Some experience available. CA3 - Fuel available.	CD1 - Carries less war head or must be multi-stage. CD2 - Size larger.* CD3 - Gliding type.*	NA1 - Large range. NA2 - Smaller size.# NA3 - Fast target approach.#	ND1 - Expensive fuel. ND2 - High temperature problems. ND3 - No experience available. ND4 - Personnel required of highly competitive type.

* More Vulnerable

\# Less Vulnerable

(b) The rocket is more vulnerable to any interception. With the very large size of chemical rockets it may be possible to intercept them even if they travel at a high speed.

CD3 - A chemical rocket would have to be of a very high multi-stage type to escape the earth's atmosphere and have the rocket follow a celestial trajectory. More likely, therefore, a chemical rocket would remain within the earth's atmosphere and thus have a gliding trajectory. In consequence, a rather accurate guidance system would have to be devised for a chemical rocket. It is unlikely that this guidance problem could easily be solved by guidance from the origin; more likely it would have to rely on an idea such as beacons in enemy territory.

NA1 - Obviously a nuclear rocket might, as far as the earth's surface is concerned, have essentially unlimited range. It would also be feasible to shoot at the moon and thus obtain interesting physics data.

NA4 - The guidance problem could in essence be solved as follows: The rocket is fired; the nuclear motor stops working after a few minutes and the rocket is now outside the atmosphere. It is still over friendly territory and its trajectory is observed. The rocket carries a small explosive device, designed to alter its trajectory due to the ejection of a small amount of mass side ways. At a signal from the ground this device will be triggered so that it fires at a time shortly preceding impact, thus causing its trajectory to hit the target. It was pointed out that thought would

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have to be given to danger from radiation to the "trajectory adjusting" equipment due to the nuclear motor.

NA5 - The development of the nuclear rocket is liable to yield other nuclear information of considerable interest. An example of such incidental benefit is the Dragon program discussed below.

ND4 - One of the major draw-backs of the nuclear rocket; as realized by the Lexington Project, is that heat resistance studies as well as heat transfer studies in a completely new region would have to be made. The heat transfer problem is clearly different in nuclear rockets than in chemical ones, since in the chemical ones the heat is developed in the material which is burning (therefore indicated as an advantage - CA1).

It was agreed, that while it appeared advantageous at first sight to combine motor and bomb, this might lead to a very inefficient overall use of fissionable materials. This is so, because a bomb assembled out of a nuclear reactor is likely to be exceedingly inefficient. Thus it seems better to go to type B, i.e., nuclear motor which carries along a nuclear bomb. It might be feasible to have the nuclear rocket drop off the nuclear bomb and therefore have the rocket return to its home base.

If the nuclear reactor is separated, it may be of the slow neutron type, thus reducing the amount of fissile material considerably. Thus even if the nuclear motor is expended on impact, the overall efficiency is likely to be greater than that in type A.

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Some remarks concerning other squares of Table I were made:

Nuclear Plane

It was pointed out that the shielding problem was not necessarily as bad as assumed in the Lexington report. For instance, it might be possible to find a heavy isotope having a large inelastic cross section which would slow down neutrons to 50 kv from which point conventional methods could easily stop them without the emission of gamma rays. In this case the aspect of the problem would shift to that of manufacturing such an isotope.

Nuclear Plane vs. Nuclear Rocket.

Note was taken of the fact that a nuclear powered aircraft would, by present estimates, weigh about 70 tons because of shielding. For a subsonic plane this would require a thrust of about 5 tons. However a subsonic plane is hardly likely to meet future battle conditions. A supersonic plane on the other hand would need about 20 tons of thrust. This is an enormous figure compared to that needed for a rocket motor.

It was stated that the nuclear rocket remains in the air for only a few minutes, whereas the nuclear plane would have to remain in the air for a great many hours. Thus the problem of materials under high radiation might be considerably less in the nuclear rocket.

Suggested Immediate Program

The group felt that a one to two year program might be indicated - divided into an experimental phase and a theoretical evaluation. This program should be planned in such a way that the outcome is of considerable value for all phases of the delivery problem and not only for the nuclear reactor one.

In consequence, the following experimental program should be initiated:

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A. <u>Heat Studies</u>

(1) Heat transfer studies from various materials to hydrogen. It is clear that if a nuclear rocket is to be chosen, all its advantages would be practically wiped out if the molecular weight of the gas were higher than hydrogen.

(2) Studies concerning the structural resistance of materials to hydrogen at high temperatures.

The heat studies are essentially a non-nuclear problem, and could be carried out, for instance, by making mock-ups where the heat is supplied by electric heating. The experiments should be set up so as to use liquid hydrogen. A total cost of perhaps $100,000 for the liquid hydrogen is envisaged. This might supply of the order of a cubic meter of liquid hydrogen to experiment with. It is recognized that liquid hydrogen is a dangerous substance. It is hoped that if an early start is made on using liquid hydrogen in the experiments a well trained group of experts will be available by the time full scale operation demands such personnel.

It is believed that program A could be carried out by a laboratory such as Inyokern with the cost amounting to several hundred thousand dollars with an upper limit of one million dollars. It should be noted that program A can be carried out entirely apart from a nuclear laboratory since it does not involve fissionable material and only declassified nuclear data are needed. However, some liason with a nuclear laboratory should be provided so that the proper materials from a nuclear point of view are chosen.

B. <u>Criticality, Studies on Dragon Type Reactors.</u>

Specific studies should be made of Dragons where most neutrons are in the 1,000 to 10,000 electron volt region. Hydrogen could

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be used as part of the moderating material. Expulsion of the hydrogen would be a fast and effective mechanism to shut off the reaction. It is believed that little would be lost from the point of view of physical interest by deciding to build such a Dragon instead of a completely fast neutron Dragon. As a matter of fact, the spectrum available in the moderated Dragon would be more easily separated by time of flight methods. The Dragon itself need not be dangerous if the following precautions are taken:

(1) It is designed so that an explosion would not be of particular danger because of the explosive force proper.

(2) There is no plutonium in the system so that an explosion could not cause plutonium to be dispersed.

(3) It is never run long enough so that significant fission products build up which would cause lethal contamination in case of an accident.

It is recognized that a Dragon and nuclear rocket differ in two critical respects. The Dragon will operate in the region of prompt criticality - in the rocket we want to avoid this condition. The rocket would involve thrust; the Dragon would not measure this. Nevertheless it seems of interest to compromise on the above Dragon in order to accomplish a wider job.

It is recognized that Table III is by no means complete or accurate, and it is recommended that an immediate full study of this type be undertaken. The Rand Corporation was suggested as a possible group which could perform this task. Aid from Los Alamos to guide them in their point of view with respect to nuclear matters was suggested.

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