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Monthly Progress Report, September 1959

FUNDAMENTAL ASPECTS OF SPACE WEAPONRY

Prepared for
PICATINNY ARSENAL
Feltman Research and Engineering Laboratories

Contract No. DA-04-495-501-ORD-1777

new

EOS Report 380-MFL-1 ✓

9 October 1959

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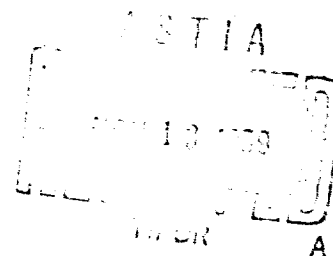
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F. S. Manov
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SPACE WEAPONS SYSTEM DIVISION



ELECTRO-OPTICAL SYSTEMS, INC. - PASADENA, CALIFORNIA

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I SUMMARY OF WORK ACCOMPLISHED PREVIOUS TO CURRENT REPORT PERIOD

No work was done officially as of the start of this reporting period; the contract became effective on 2 September 1959.

A good deal of work was done unofficially. Members of the technical staff of Electro-Optical Systems, Inc. met with representatives of Picatinny Arsenal and others over a period of several months preceding the signing of the contract. In these meetings the problem was formulated, the scope of work determined, and the end objectives of the work established; in addition, the total problem was divided among the several participating companies and Picatinny Arsenal Laboratories. Some preliminary analyses of kill mechanisms were undertaken at EOS. Work began officially at EOS immediately upon the signing of the contract as a major full-scale effort with highest priority. The considerable progress and the results obtained to date are reported in the sections that follow.

**II SUMMARY OF WORK ACCOMPLISHED DURING THE CURRENT REPORTING PERIOD
(September 1959)**

1. FORMULATION OF PROBLEM

Working with representatives of Picatinny Arsenal and others on September 22 and 23, and again on September 30, the EOS staff was able to define the immediate tasks for EOS. For a Phase I accelerated effort activities are centered on a preliminary study of certain selected kill mechanisms. A date of 15 January 1960 has been set for a report of these studies to ARPA by Picatinny Arsenal. A "minimum list" of ten classes of kill mechanisms was assigned to EOS as its major responsibility. Additionally assigned work included determination of space target characteristics, delivery system characteristics, and weaponization feasibility. Electro-Optical Systems, Inc. is the only team group which will consider the

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decoy problem; this to be done on a second priority basis. Electro-Optical Systems, Inc. is also strongly urged to consider any other kill mechanisms it may have in mind. The assignments are not intended to restrict creative thinking on the part of anyone; assignments are made to each team group to avoid excessive duplication and to insure that all classes of kill mechanisms known at this time are studied by at least one agency. A complete list of the work assignments for EOS is presented in Apdx. A.

2. LITERATURE SEARCH

In order to avoid unnecessary duplication of work, and to see if some of the gaps in knowledge could be filled from the work of others, a literature search was conducted. About 30 reports were reviewed and pertinent information used in our work. The literature search is continuing and a bibliography will appear in the final report.

3. TARGET CHARACTERISTICS

Some idea of target characteristics was necessary to orient the detailed studies. An open literature search was made to establish probable characteristics of Soviet satellite targets. This information was combined with classified data available. Five classes of satellites have been partially described: scientific types such as Sputniks and Explorers, communication satellites, reconnaissance satellites, manned satellites, and atomically armed strategic bombardment satellites. ✓

For our preliminary analyses, we have assumed the target to be a spherical satellite, five feet in diameter, with an aluminum or magnesium skin 0.01 inches thick. It turns out that these are the only assumptions needed for the preliminary evaluation of the kill mechanism we have studied so far. (Solar furnace, corrosive chemicals, pellets, poisoned fragments, ion beams) Detailed information on target characteristics we have compiled will be discussed in the final report. ✓

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4. **KILL CRITERIA**

In addition to the target characteristics we found it essential to define kill criteria. It was necessary to describe what one wants to do to a satellite, and what constitutes a satisfactory "kill." This is a complicated problem, depending largely upon the military objective desired and the political acceptance of the action taken to achieve it; kill criteria run from complete vaporization of the target to "frustration" type kills such as making optical windows opaque. The overall weight and size of the kill generator is (usually) critically dependent on the criteria selected as the desired objective. In general, the vaporization of a satellite requires the depositing of very large amounts of energy in a short time. Frustration, such as spraying optical systems with paint might be relatively easy, but may present difficult post attack assessment problems. Kill criteria are discussed and ranked in a short paper that will be incorporated in the final report.

5. **SOLAR FURNACE AS A KILL MECHANISM**

Our preliminary analysis shows that a solar furnace located on the ground would be at least 300 miles from the target; it would have to be very large, perhaps some five to ten miles in diameter. Further, it would not work during local cloud cover. For these reasons, a satellite-borne solar furnace as a kill mechanism was investigated. Preliminary calculations show that an idealized parabolic collector 18 feet in diameter placed at a distance of 500 feet from the target and held there continuously would raise the temperature of a satellite to no more than 500°C. This is insufficient to vaporize it, although it would likely kill a man inside. It would degrade the performance of photo-cells, suncells, transistors and some forms of electronic equipment. It would melt solder. It may not cause permanent damage; the components may recover if the heat beam is removed. Such a temperature rise might also upset the satellite's heat balance scheme. Geometrical requirements may impose very severe operational restrictions on the scheme.

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6. CORROSIVE AGENTS

Very little is known about corrosive processes in a space environment. Some unique problems are those arising from the very rapid evaporation rate of corrosive liquids in the near perfect vacuum which exists in outer space. Similarly, gases tend to expand very rapidly. Many corrosive actions also depend on water vapor or oxygen; supplying these in a space environment may be difficult. The rather low temperature of the satellite material is an additional problem; the rate and extent to which chemical reactions occur are highly temperature dependent.

In a systematic approach to the problem, we have started by studying the effectiveness of chemical elements against a target. We have initially assumed the target to be a 5-foot diameter aluminum satellite having a skin thickness of .01 inches and having a temperature of -25°C to 75°C . It is interesting to note that all of the Soviet satellites, on which data is available from open sources, indicate that an aluminum alloy is used for the skin.

Each of the elements in the periodic table was examined. Most of them were ruled out as possible corrosive agents either because they are inert to aluminum or because they will not work within the temperature range assumed. (A preliminary study indicates that liquid bromine may be of interest. Similarly, fluorine may be important and will be studied further.) A simple experiment was performed using bromine against aluminum. (Pressure of 1 atmosphere, temperature 20°C) After a delay of about 1 minute, a vigorous reaction took place. A similar experiment is planned in a vacuum. A mathematical model was established to estimate the kill probability as a function of the diameter of the corrosive gas cloud, delivery accuracy and the total weight of corrosive agent required in the cloud. The results are plotted in the form of curves which are generally useful for estimating the kill probability of kill mechanisms of this kind.

Numerical calculations were made to determine the total mass of a bromine cloud which would achieve a kill probability of 0.9 against the target for an assumed delivery accuracy of 500 feet. The calculations

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show that approximately 2×10^5 pounds of fluorine would be required to etch away all of the .01-inch aluminum skin. If the payload were limited to 200 pounds, the kill probability would be of the order of 0.13. These calculations represent the minimum weight required. As an educated guess, the weight of a jelly which might be required to confine the fluorine for the time needed for effective action might be something like 40 times the weight of the gas. This leads to some very large preliminary estimates of the total weight required by a corrosive kill mechanism ; probably 8×10^6 pounds. [Based on this analysis, this kind of corrosive action does not appear attractive. The next cut at this study will consider making optical windows (solar cell filters, camera lenses) opaque. The weights required are expected to be much lower. ✓

7. POISONED FRAGMENTS

The basic idea in the use of a "poisoned fragment" is to place an agent on the fragment which will cause a metallurgical or chemical change in the material it strikes and hopefully lead to failure of the structure. (Radioactive fragments will be considered later.)

A scheme often quoted is that of using mercury on the fragment. We have briefly examined the chemistry of this. Aluminum would react very violently with the atmospheric oxygen if it were not for the self-protecting coating which forms upon contact with the air. What happens when mercury is placed on aluminum can perhaps be best described in terms of a simple experiment we have performed. A small droplet of mercury was placed upon a 2" x 2" sample of aluminum sheet (Reynolds Wrap about 2 mils thick). A knife blade was plunged through the droplet and the aluminum oxide coating scratched. The mercury was then removed so that the scratch was exposed. An examination showed that the mercury had wet the aluminum and deposited itself in the scratch. In about 5 minutes, whitish crystals looking somewhat like wet sugar had grown out of the scratch to a height of about .2 of an inch. The aluminum structure subjected to such an experiment would be considerably weakened or even caused to fail.

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What appears to happen is that if the protective coating is removed the mercury allows the oxygen in the air to continue to react with the aluminum. The important thing to note is that oxygen is essential to the phenomena and might not be easily supplied in outer space. In any case, the weight of the oxygen required would be comparable to the weight of the aluminum consumed. Based on this preliminary examination, the use of a fragment poisoned with mercury may not be very useful as an anti-satellite measure. ✓

Action of Ga on Al

In a discussion with one of our consultants, Dr. Pol Duwez, it developed that certain unclassified work done as early as 1910 showed that an attack on aluminum by the chemical element gallium has some interesting properties. What happens here can again be best described in terms of a simple experiment which we performed.

A tensile coupon of commercially pure Al was electrolytically polished, so that the grain boundaries could be visually detected by holding the specimen at various angles to the incident light. The grains were quite large, having typical linear dimensions of the order of a centimeter, so that several grain boundaries ran completely across a section of the coupon. A small amount (not weighed, but estimated to be less than 100 milligrams) of Ga was gently rubbed over a portion of the surface with the finger. The Ga promptly melted, since its melting point is about 86°F, which is below normal body temperature. It was observed, both by sight and touch, that the liquid Ga wetted the surface of the Al very efficiently. A very finely divided black substance was generated by the interaction. Several minutes after applying the Ga, it was found that the tensile strength of the coupon had dropped to essentially zero. The individual crystals of Al were very neatly separated, and the freshly separated surfaces exhibited a brilliant luster. ✓

The effect is basically the same as several others which have been commonly observed for many years. For example, alloys completely lose their strength when heated to the solidus temperature, because of the generation at that temperature of a small amount of liquid phase, which then penetrates the grain boundaries of the remaining solid phase.

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As another example, a stressed brass specimen fails rapidly if brought into contact with liquid mercury. The action of Ga on Al is dramatic because (1) it takes place at ordinary temperatures, (2) it requires very little Ga to disintegrate a considerable amount of polycrystalline Al, and (3) it involves the destruction of a material very commonly used in aircraft, missiles and satellites.

It should be emphasized that the effect is strictly one of surface forces (for a general discussion see C.S. Smith, Trans. Amer. Soc. for Metals, 45: 533-575, 1953). In our present case, for example, the effect is not an amalgamation of the Al by the liquid Ga. [What occurs is a rapid penetration of the grain boundaries, made possible by the low angle of contact between the liquid Ga and the surface of an Al crystal, which is also manifested in the ability of Ga to wet Al. Our study of this phenomena is continuing.

8. HIGH-SPEED PARTICLE BOMBARDMENT

The possibility of killing a satellite by means of particle bombardment was examined. The real difficulty in assessing the value of this technique as a kill mechanism arises from lack of believable "knowledge" as to what constitutes a "lethal fragment."

There is a very extensive family of literature on the subject of particle penetration. For our study we have used the penetration theories of Whipple. We have assumed a satellite target, 5 feet in diameter, with an aluminum skin .010 inches thick, and further assumed that one particle through the skin constitutes a kill. The 1 sigma value of the delivery system accuracy was taken to be 100 feet. For a desired kill probability of 0.90, a 400-foot diameter cloud of fragments is required; particle mass need only be one microgram and a total payload of only 7 milligrams is required. On the surface, these results are hardly believable; and yet they are based on information having some substance. This dilemma simply reflects the lack of basic input data needed for such analyses. A second analysis was made assuming the same target characteristics; here, we calculated how large a particle

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might be to achieve a 0.90 kill probability without exceeding 200 pounds as the total weight of fragments. Approximately 7,000 particles are required to achieve at least one hit with a probability of 0.9; each fragment can have a mass equal to 0.465 ounces. With a differential velocity of 20,000 fps, one would expect a fragment of this size to be lethal.

[So far, we have considered fragments which actually puncture holes in the satellite.] We have some simple experiments underway involving what is essentially a sandblasting approach to see what kind of particle sizes and numbers would be required to reduce the transmission of optical windows to some low value.

Techniques appear to be within reach for accelerating particles of known size to velocities of interest for this study. (Velocities in a range of 30,000 to 50,000 feet per second.) Our work will include the design of some simple experiments with suggestions on how to carry them out.

9. ION BEAM GENERATOR

[The use of an ion beam was considered to determine its feasibility as a kill mechanism.] Only very preliminary results are presented here. The use of a Von Ardenne ion source such as a 1-ampere proton type with an accelerating voltage of 100,000 volts and 100-kw power capacity would without a doubt melt a hole in the aluminum skin, instantaneously. The ion beam diameter would be a function of such parameters as distance from target, beam divergence, power source, etc. An educated guess is that a 1/4-inch diameter beam may be achieved within a standoff distance of 1 mile. This appears to be feasible, based upon projected developments expected within the next 5 to 10 years. Electrostatic generators of 100-kw size are available today at a cost of 1/2 lb/kw, exclusive of the primary power. Based upon projected developments, one can expect an overall primary power supply to weigh about 10 to 20 lb/kw. Thus the ion beam kill generator looks interesting from power requirements and weight consideration. Our first estimates indicate that a complete kill ✓

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mechanism employing an ion beam might have a kill distance of a mile; ✓
it would weigh less than 1000 lb if it were required to supply the beam
continuously for a year.] This presents some exciting possibilities.
Work is continuing with high priority.

III WORK TO BE ACCOMPLISHED DURING THE NEXT REPORTING PERIOD

During the next period we shall complete preliminary reports on the following kill mechanisms: corrosive chemicals, poisoned fragments, and solar furnaces. These preliminary reports will be in the form of short self sufficient monographs in which we will describe the technique, present the fundamental physics, mathematics, and numerical examples. These will also include analysis of the weaponization problems, and a summary with an assessment of the probable worth of the scheme based on the work done. We shall continue studies on the ion-beam generator and attempt to make a preliminary assessment of the feasibility of the scheme. We shall begin the analysis of particle bombardment on optical systems, and present recommendations on work to be undertaken to estimate what constitutes a lethal fragment. We shall also undertake a study of the decoy problem; while this is a low priority consideration, some preliminary thinking we have done indicates that the identification problem may not be difficult unless the enemy is willing to pay some very severe weight penalties. Work will also be undertaken on all of the other kill mechanisms assigned. We have already given some consideration to focussed atomic warheads; any real hope of coming out with a practical device based on these ideas is not readily apparent; however, the "wild blue" kind of thinking which is probably required to solve the problem is being exercised and will continue.

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APPENDIX A MAJOR KILL MECHANISM STUDIES ASSIGNED TO ELECTRO-OPTICAL SYSTEMS, INC.

1. "Wild Blue" type of thinking to conceive of new kill mechanism.
2. Target Characteristics
3. Delivery Systems
4. Corrosive Chemicals
5. Poisoned Fragments
6. Particle Beams
7. Electromagnetic
8. Electrostatic
9. Electronic Countermeasure
10. Solar Furnace
11. Ion Clouds
12. Effect on Optical Port
13. Ablation
14. Salted Warheads
15. Focused Warheads
16. Weaponization
17. Decoy Problem (2nd priority)

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ELECTRO-OPTICAL SYSTEMS, INC. 170 N. DASH AVENUE, EL PASO, TEXAS 79901

Reference: Contract DA-04-495-501-000-1777

Subject: Labor and Overtime Report for September 1959
380-L-1, Space Weapons

Date: 16 October 1959

Research hours expended on above referenced contract
for September 1959 were 496 regular hours and 0- overtime.

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