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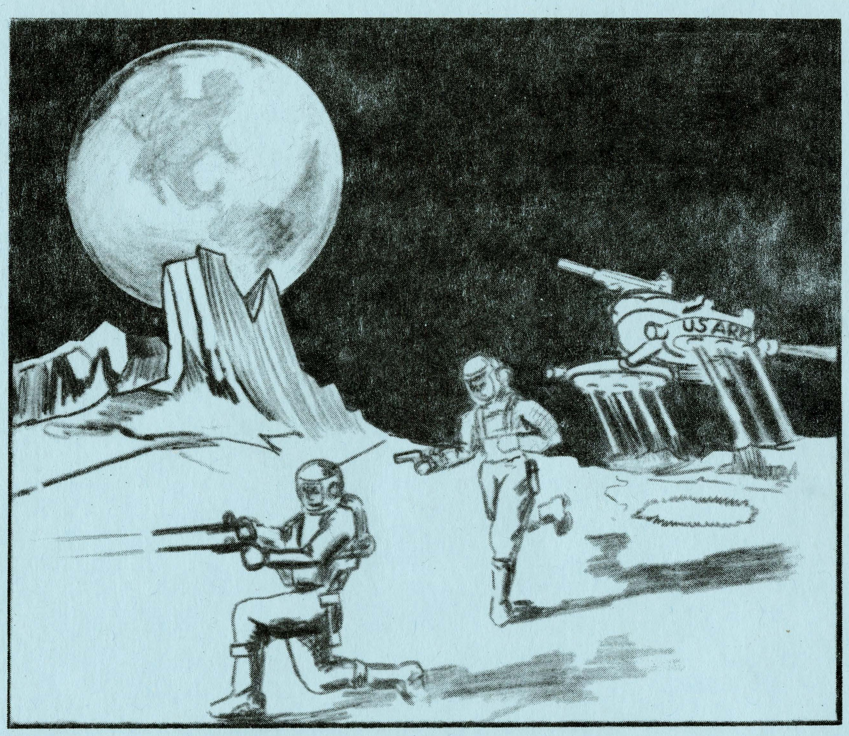

"THE MEANDERINGS OF A WEAPON ORIENTED MIND WHEN APPLIED IN A VACUUM SUCH AS ON THE MOON" (U)

JUNE 1965

CLASSIFIED BY USA Weapons Command
SUBJECT TO GENERAL DECLASSIFICATION
SCHEDULE OF EXECUTIVE ORDER 11652
AUTOMATICALLY DOWNGRADED AT TWO YEAR
INTERVALS DECLASSIFIED ON DEC. 31 1971.

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"THE MEANDERINGS OF A WEAPON ORIENTED MIND WHEN APPLIED IN A VACUUM SUCH AS ON THE MOON"(U)

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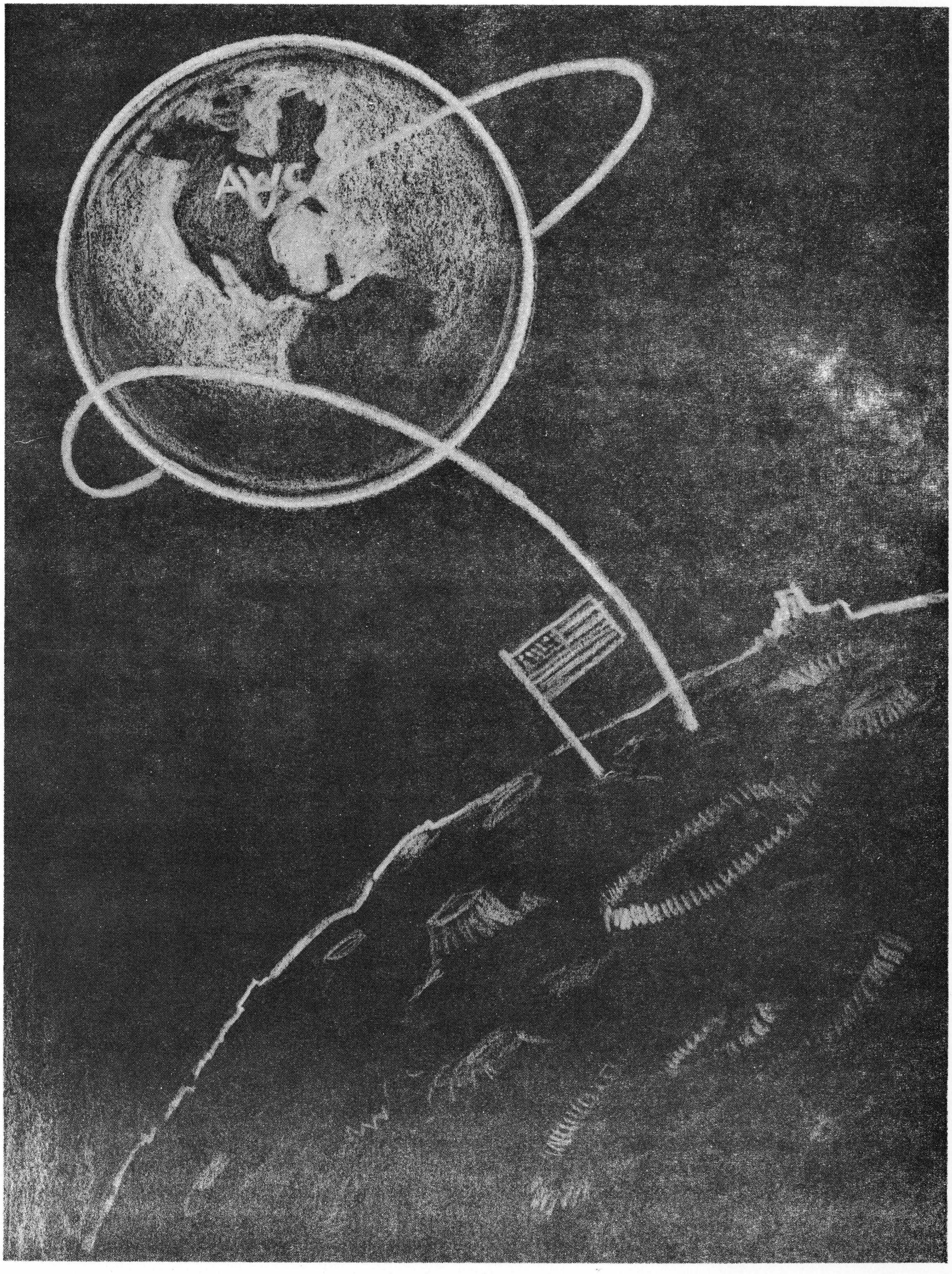
TABLE OF CONTENTS



FRONTISPIECE

PREFACE

(U) The purpose of this brochure is to stimulate the thinking of weapon people all the way from those who are responsible for the establishment of requirements, through those who are responsible for funding, to the weapon designer himself.

(C) Although the primary purpose of man in space (on the moon or other planets) will not be to fight, he requires the capability to defend himself if necessary. There may be other countries desirous of preventing U.S. access to the moon and other planets. If space is truly for peace, we must be strong there just as we are on earth.

(C) Because of the entirely new and different environment and conditions facing man in space, we cannot wait until the eleventh hour to "crash" a weapon program through with any hope of success, for we may even now be standing on the edge of the battleground of Armageddon. To quote our President before he ascended to the Presidency, "Space is infinite. Man's knowledge of space is finite. The sum of our understanding is not yet sufficient for us to comprehend how vast the dimensions of our ignorance."

EARLY THOUGHTS

(C) When first applying ground-bound weapon thinking to a lunar atmosphere, one is liable to contemplate the worst that can happen. For instance:

1. The temperature extremes of from -250° F. to +250° F. would be impossible to meet with current propellants. Muzzle velocity variations may be as high as 25 - 50%.

2. The high vacuum environment will cause metals to weld together.

3. Lubricants will evaporate, leaving mechanisms unlubricated.

4. The low gravity of the moon means any weapon system devised will have to be recoilless.

5. Materials will have a marked reduction in physical properties due to the high vacuum and extreme temperatures.

6. A directed energy weapon, such as a laser, may be the answer.

CORRECTED THINKING

(C) Discussions with personnel of the U.S. Air Force Materials Laboratory, the U.S. Air Force Avionics Laboratory, the U.S. Army Materiel Command, and the Extraterrestrial Research Agency of the Office of the Chief of Engineers, expelled some of the above as "old wives' tales." For example:

1. Although the widely advertised temperatures of from -250° F. to +250° F. are actualities on the moon, they are

the approximate extremes reached on the surface at midday and midnight. (Days and nights are two weeks long.) The surface of the moon is a poor conductor of heat, consequently a little shade during the day and earth light during the night, plus a reversible white and black umbrella may be sufficient to keep the temperature in the vicinity of the space suit within limits of from $-65°$ F. to $+125$ to $+160°$ F. Assuming a direct proportion to the reflecting area, earth light on the moon will be sixteen times greater than moonlight on the earth.

2. Although it is reported that a high vacuum (and low temperature) causes the fusion of two similar metals, it should not be overlooked that to accomplish it requires that these parts be clean, free from oxidization, etc. Even with a clean surface, there are coatings available that can considerably reduce or eliminate this effect. Therefore, this phenomena is not considered to be a serious problem. The coefficient of friction increases from two to six times or more in such an atmosphere and must, therefore, be considered, but these effects are not insurmountable.

3. Lubricants do indeed evaporate in a vacuum, but it has been observed that there are bearings (for example) which have been lubricated on earth that function very well for long periods of time in space without additional lubrication. This leads scientists to the postulation that perhaps an item carries its own atmosphere with it through space or that the atmosphere next to a space vehicle is different from that at some discrete distance. An attempt to measure

this was at one time planned for the Manned Orbiting Lab. program, but was eliminated due to its cost and the work being done on earth. In general, however, for application to the lubrication problems of space mechanisms, the following conclusions regarding the affect of surface films and their removal in vacuum are considered significant by the authors of the "Space Materials Handbook".

a. Where metal parts operate in contact with one another, tenacious surface films that are not stripped off in vacuum, and that offer some lubrication for the moving parts to which they are applied, should be used.

b. Running metals in direct contact with one another should be avoided, particularly if the contacting metals are mutually soluble in one another.

c. Where possible, materials that come in contact with each other should be dissimilar, e.g., a metal surface with a plastic or a ceramic surface.

These conclusions can often be applied without much difficulty.

4. Materials do have a change in physical properties at high vacuum and at the lunar temperature extremes, but these changes can generally be predicted and the effects eliminated by proper design, material selection, and the consideration of using the item only once. The effect of a vacuum on metals is not necessarily deleterious. In fact, on the basis of available data derived from laboratory tests, unless the test specimen is altered in composition

or structure by diffusion inward of the gaseous environment, or outward of hydrogen or other volatile constituents, it will be stronger in vacuum than in gas. However, except for fatigue life, no large strengthening effect of vacuum on mechanical properties of metals has been reported. This phenomena can aid the designer in keeping the weapon weight at a minimum. Due to the high cost of transporting one pound of material from the earth to the moon, the ultimate weight of an item is a significant factor in estimating its ultimate cost.

5. Although the moon does have a low gravitational effect (1/6th that of the earth, or 5.37 ft/sec^2) the weapon system used does not need to be recoilless. It should, however, have no more than 1/6th the tolerable recoil momentum acceptable on earth.

6. The laser, for practical application as a weapon, is 20 years away.

DISCUSSION

(C) Now that some of the first worries have been dispelled, one should approach the problem of space weaponry with a clear unbiased mind. One should recognize the differences in conditions, but not be discouraged by extremes. Instead, a positive approach based on unrestricted thinking utilizing the experience gained in the space program to date is the primary asset required in formulating the weapon and vehicle requirements and concepts for use in an extra-terrestrial environment.

(U) If we apply this type of thinking to some basic calculations to obtain a feel for the lunar conditions and their effects we find that due solely to the curvature of the moon (mean radius 1080 miles) the 5 to 95 percentile man has an unrestricted maximum line of sight of from 1.4 to 1.6 miles.

(C) Any projected object is subjected to a downward pull due to the gravitational force of the moon at an acceleration of 5.37 ft/sec^2. An object (projectile, rocket, rock, sphere, flechette, etc.) propelled horizontally from the shoulder of a man six feet tall (shoulder approximately 5 feet above the surface) would impact the surface after an uninterrupted flight of 2.73 times its velocity. For a velocity of 3000 ft/sec the impact point would be 8190 feet or about 2500 meters. It is of more than casual interest to note that due to the lack of atmosphere on the moon, the initial velocity which is imparted to an object is retained throughout its flight. The only force acting upon it is the gravitational attraction of the moon itself. Therefore, the maximum range of a projected object at a velocity of 3000 ft/sec is about 320 miles when propelled at an angle of 45 degrees with the lunar surface. Its maximum ordinate is approximately 80 miles above the surface.

(U) After the initial shock of these figures wears off, we find that a quick check with a good reference discloses that the escape velocity on the moon is 2.4 kilometers per sec, which converts to 7900 feet per second, or about 5400 miles per hour. The orbital velocity at or near the lunar surface can then be calculated as $7900/\sqrt{2} = 5600$ feet per sec. These velocities are both attainable within the present state-of-the-art. It follows, then, that to keep from filling the space around the moon with flying objects (space debris) the velocity of any object projected thereon should be kept below 5500 ft/sec, and possibly initially much below this in order to keep the maximum range under control.

(U) To get an idea of sighting requirements, it is easily calculated that an object projected horizontally at 3000 ft/sec from five feet above the lunar surface will experience a drop of only 2.4 inches in 100 meters. A complex set of sights does not therefore appear to be required.

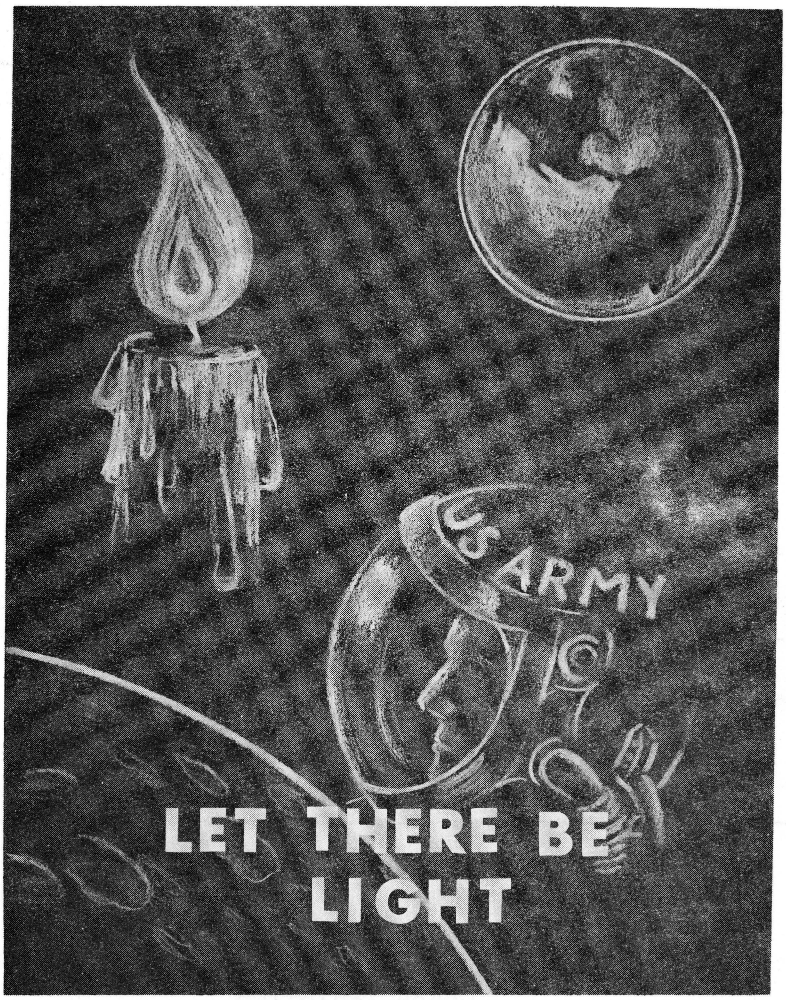
(C) Although the shape of an object theoretically does not affect its range or velocity on the moon, the shape does have its affect on penetration. A high sectional density may be desirable for maximum penetration. Initially, it might be sufficient to penetrate a space suit since the suit would then suddenly decompress. However, a low level penetrator can be easily defeated, and vehicles of some form will probably soon appear after the first landings (example: NASA's Lunar Roving Vehicle). It seems only logical then that the first defensive personnel weapon carried to the moon should have a capability of penetrating (at the minimum) thin skinned vehicles. Following along this thought path further, it seems only logical and economical that the first weapon on the moon have the highest penetrating capability that the state-of-the-art can provide within weight and design limitations. It should be kept in mind here that penetration and lethality on the moon are almost synonymous since penetration of a pressurized vessel on the moon may be tantamount to defeating it.

(C) It would seem desirable, if not required, that the weapon also have a capability in an environment such as the earth's or that which will be found in a space station or inside a lunar base. In Appendix I are some ideas whose feasibilities have not been determined and are presented here solely to stimulate thinking.

CONCLUSION

(C) If the moon and other planets are explored and possibly colonized, the world could eventually see a second evolution of weaponry and protection therefrom. Visualize starting with a weapon capable of penetrating thin skinned vehicles. The vehicles then get thicker skin. The weapons then attain a greater penetrating capability. The vehicles get even thicker skinned until the weight and cost thereof becomes insurmountable. The weapons attain longer ranges, etc., etc., etc. This proceeds through the mortar, howitzer, gun and tank stages until eventually you have missiles, antimissiles and nuclear weapons much as the earth had prior to World War III.

APPENDIX I



POSSIBLE WEAPON CONCEPTS
WHOSE FEASIBILITIES HAVE NOT BEEN DETERMINED
BUT ARE PRESENTED AS IDEAS TO STIMULATE THINKING

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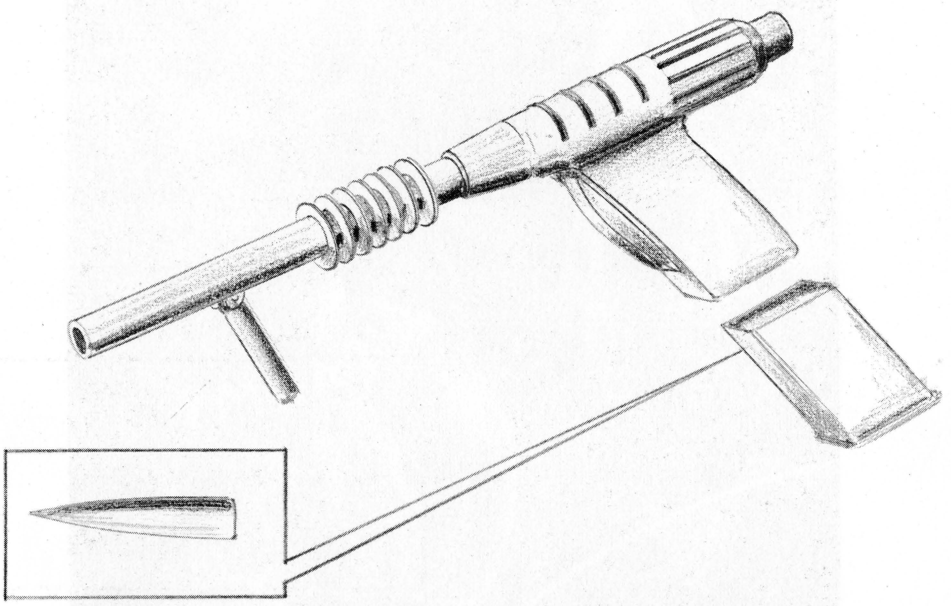
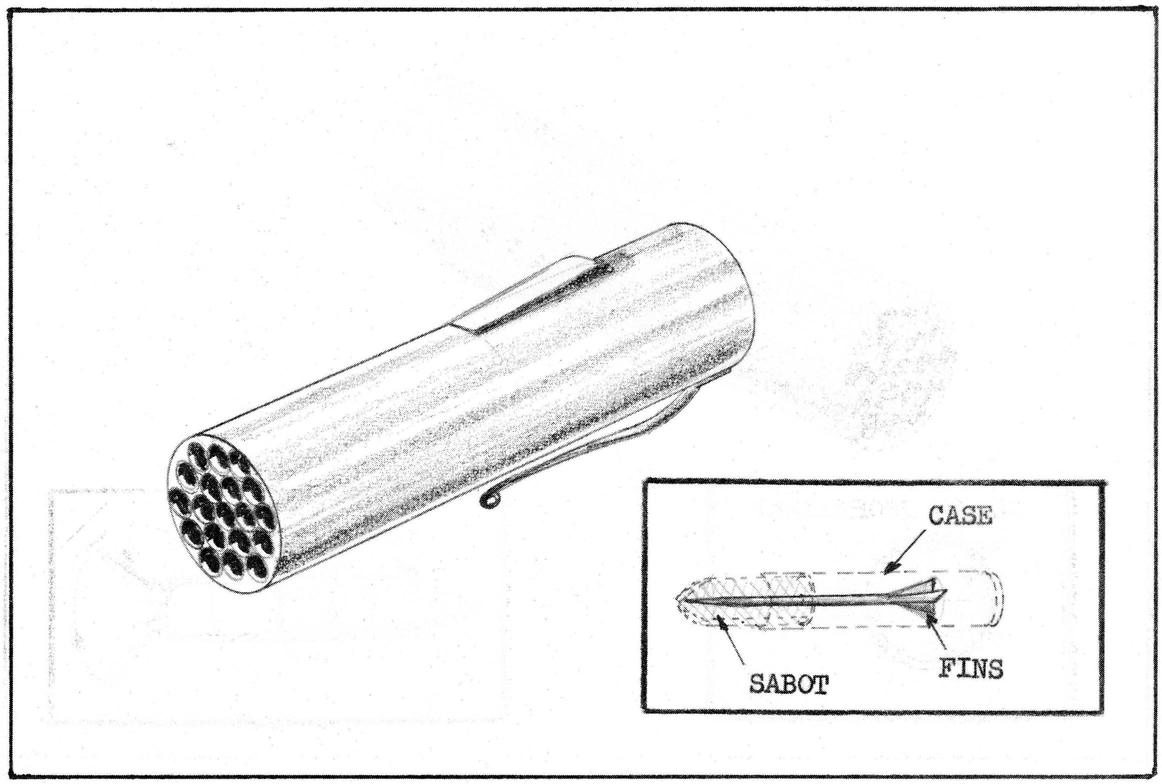
SPIN STABILIZED MICRO GUN



CHARACTERISTICS

Method of Propulsion	Propellant
Projectile Weight	.0027 lb.
Projectile Length	.78 in.
Projectile Diameter	.14 in.
Muzzle Velocity	3000-4000 fps
Weapon Weight	2-4 lbs.
Rate of fire	Semiautomatic
Nr. of Rounds	30-50
Weapon Length	18-24 in.
Weapon Width	1.5 in.
Weapon Height	4-6 in.

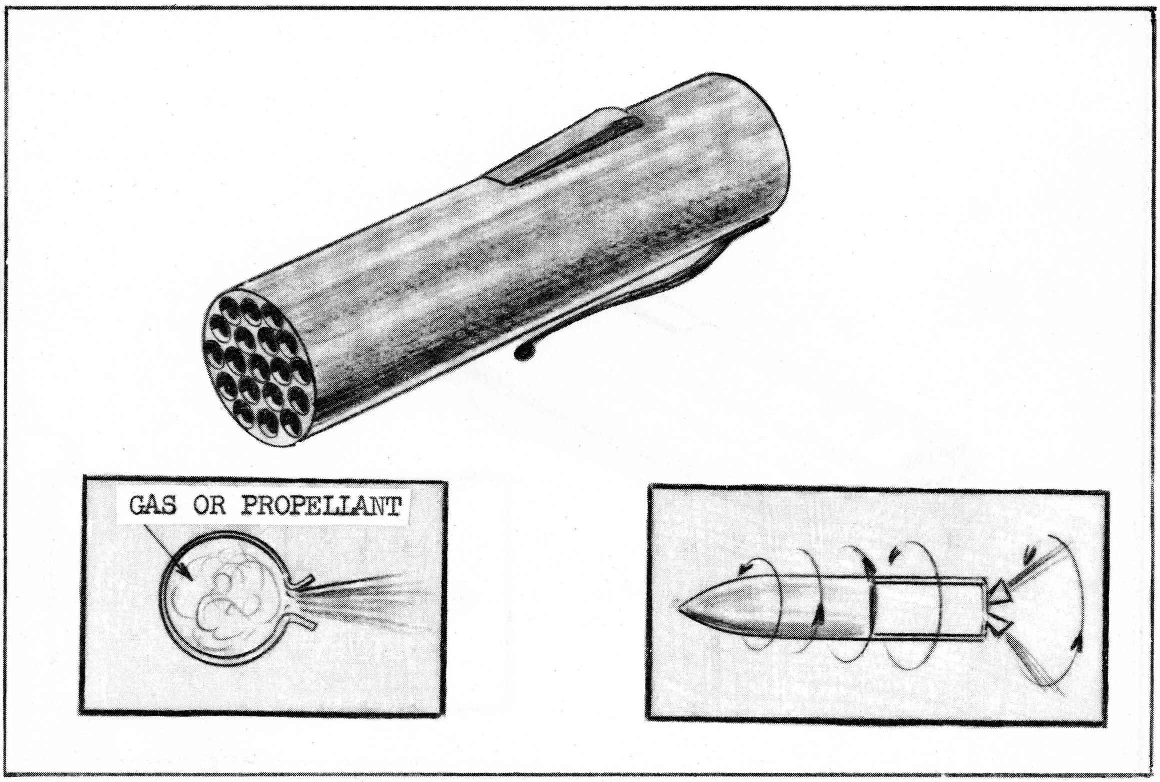
SPIN/FIN STABILIZED SAUSAGE GUN



CHARACTERISTICS

Method of Propulsion.	Propellant
Projectile Weight	1-2 Grains
Muzzle Velocity	3000-4000 fps
Weapon Weight	1 lb or less
Method of Ignition.	Electrical
Rate of Fire.	Semiautomatic
Nr. of Rounds	19 to 37
Length.	6-8 in.
Diameter.	1-1.5 in.
Stabilization	(Spin in Vacuum (Fin in an Atmosphere

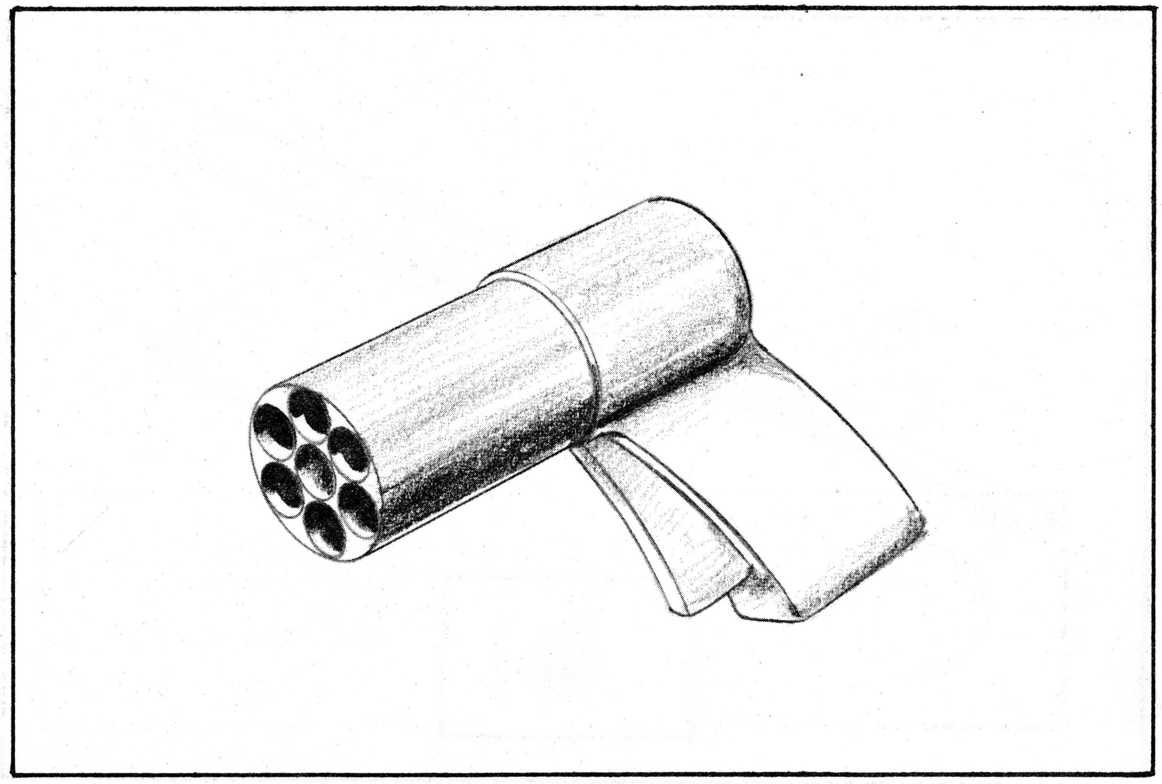
SAUSAGE GUN #2



CHARACTERISTICS

Method of Propulsion.	Gas or Propellant
Projectile Weight	.005 lb.
Projectile Diameter	0.25 in.
Muzzle Velocity	3000 fps
Weapon Weight	1 lb. or less
Nr. of Rounds	19 to 37
Length.	6-8 in.
Diameter.	1-1.5 in.
Method of Firing.	(Puncturing of Seal or (Ignition of Propellant

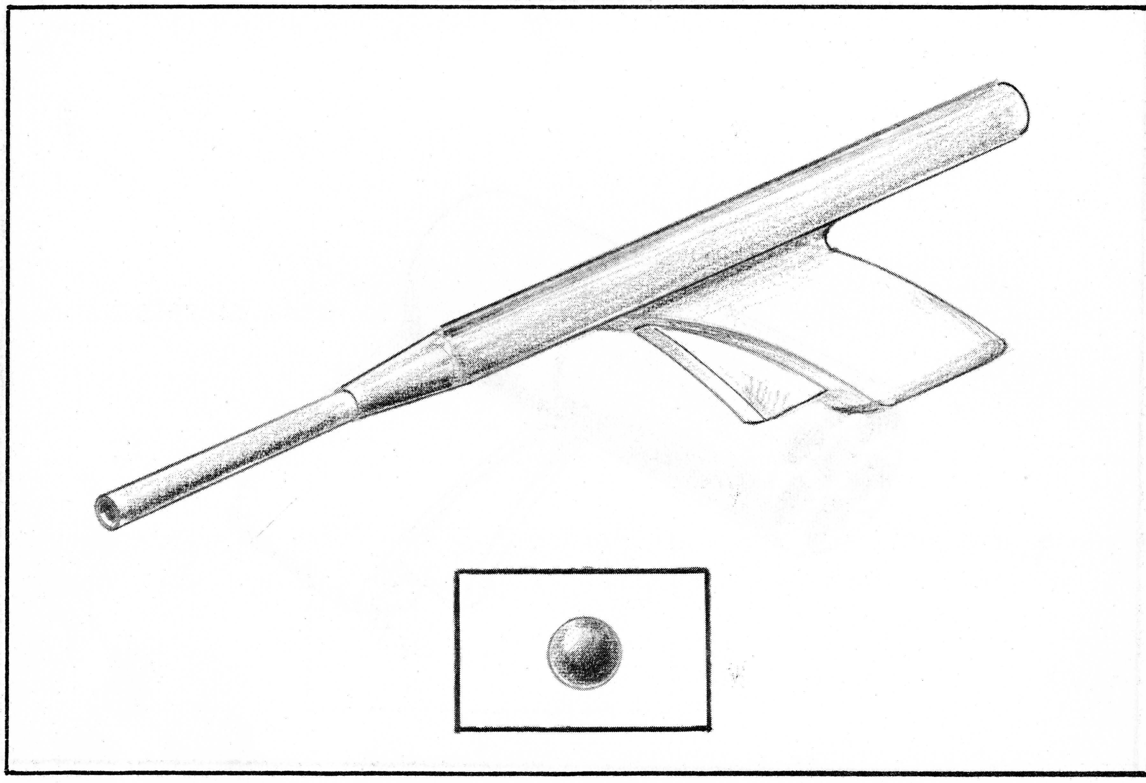
DIRECTED GAS WEAPON FOR CLOSE IN FIGHTING



CHARACTERISTICS

Range	3-6 ft.
Lethal Agent	Directed Gases from High Explosive Detonation
Rate of Fire.	Single Shot or Semiautomatic
Nr. of Shots.	1 to 7
Weapon Weight	1 to 2 lbs.
Weapon Length	4 to 5 in.
Weapon Diameter	1.5 in.

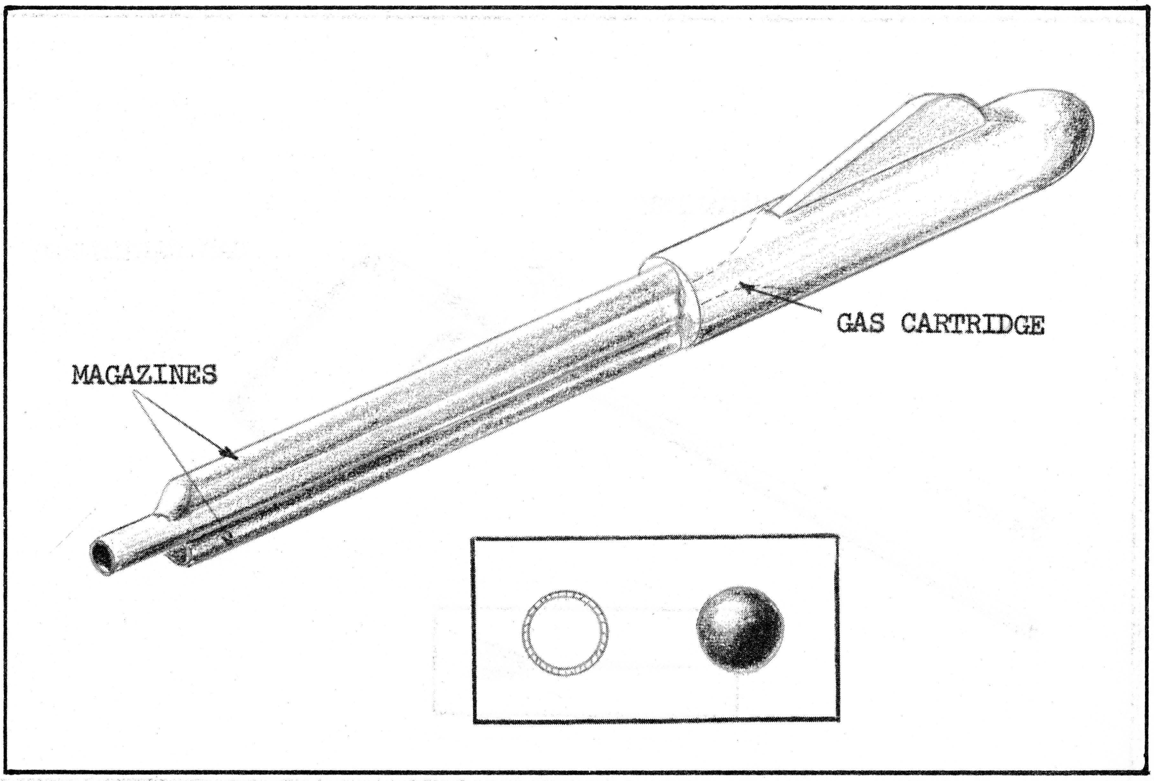
SPRING PROPELLED SPHERICAL PROJECTILE



CHARACTERISTICS

Method of Propulsion	Compressed Spring
Projectile Weight.	0.0012 lb.
Projectile Diameter.	0.20 in.
Muzzle Velocity.	1000-1500 fps
Weapon Weight.	3-6 lbs.
Nr. of Rounds.	20-50 rounds
Length	18-24 in.
Width.	1.5 in.
Height	6 in.

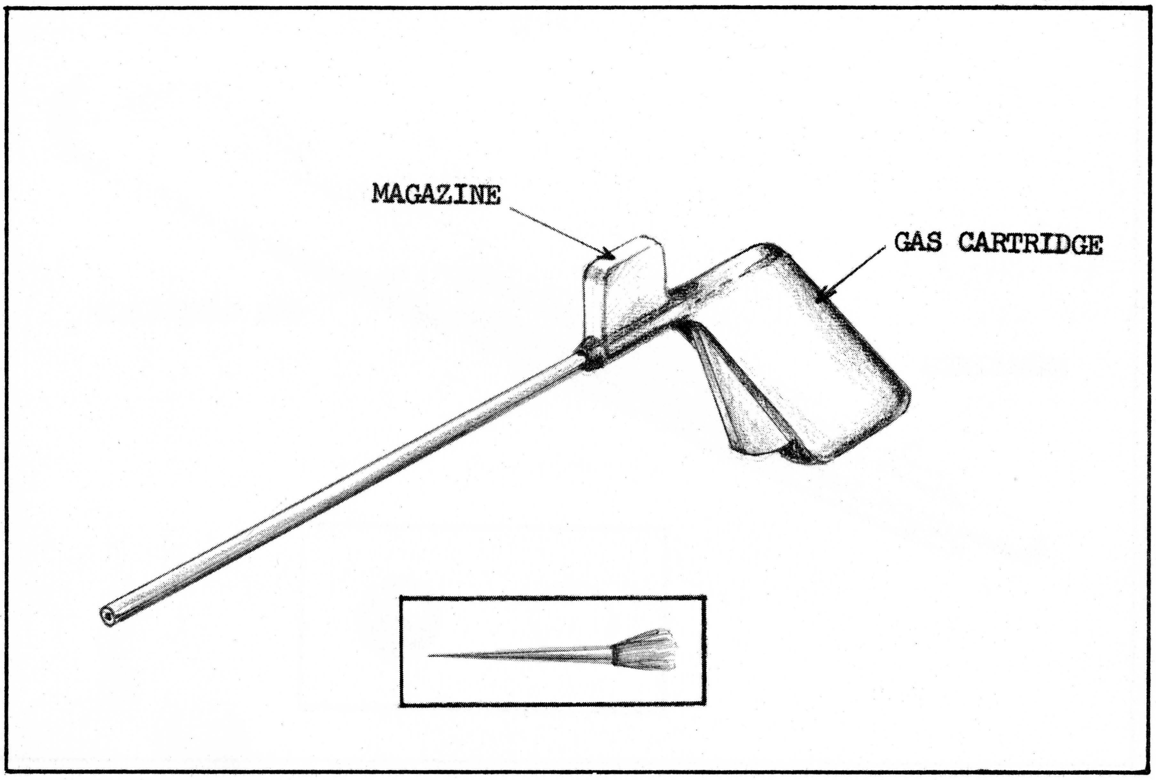
GAS CARTRIDGE GUN



CHARACTERISTICS

Method of Propulsion	Gas
Projectile Weight	0.0012 lb.
Projectile Diameter	0.33 in.
Muzzle Velocity	1000-1500 fps
Weapon Weight	2 lbs.
Nr. of Rounds	25
Length	8 in.
Width	0.5 in.
Height	3.5 in.
Pressure	2000 psi

GAS OPERATED NEEDLE GUN



CHARACTERISTICS

Method of Propulsion	Gas
Projectile Weight	.0012 lb.
Projectile Diameter	.20 in.
Muzzle Velocity	1000-1500 fps
Weapon Weight	2 lbs.
Nr. of Rounds	25
Length	12-16 in.
Width	1.5 - 2.0 in.
Height	6 in.
Pressure	2000 psi

APPENDIX II

CALCULATIONS

RANGE ESTIMATION CALCULATIONS

(U) A missile (projectile, rocket, etc.) is subjected to a force due to the gravitational pull of $\frac{32.2}{6} = 5.37$ ft/sec^2

(C) A missile propelled horizontally from the shoulder of a six foot man (shoulder approximately 5 feet above surface) would then impact the surface (with uninterrupted flight) at a distance determined by

$$d^2 = \frac{8V^2Y}{g}$$

where V = Velocity of missile

Y = Vertical distance (5')

g = Moon's gravitational acceleration

$$d^2 = \frac{(8)(5)}{(5.37)} V^2 = 7.45 V^2$$

$$d = 2.73 V$$

A velocity of 3000 ft/sec is not uncommon or difficult to obtain, therefore

$$d = (2.73)(3000) = 8190 \text{ ft.}$$

This is approximately the same distance the 5-95 percentile man can see.

Maximum range is $\frac{V^2}{(3)(g)} \sin 2\alpha$

$$R = \frac{9,000,000}{(3)(5.37)} \quad (1)$$

$$R = 558,659 \text{ yds.}$$

$$R = 317.4 \text{ miles}$$

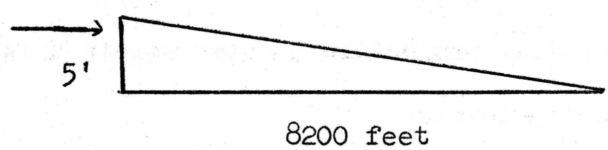
Maximum height is $\frac{V^2}{2g} \sin 2\alpha$

$$h = \frac{(9{,}000{,}000)}{(2)(5.37)} \; (.5) = \frac{4.5 \times 10^6}{10.74}$$

h = 418,994 ft.

h = 79.35 miles

<u>Average drop of a projectile at 3000 fps</u>



$$\text{drop per 100 feet} = \frac{5}{82} = 0.06 \text{ feet} = .72 \text{ inches}$$

drop per 100 meters = (.72)(3.28) = 2.36 inches

<u>Orbiting velocity at surface of moon</u>

Escape velocity of moon = 2,400 meters/sec
= 7,872 ft per sec

$$\text{Orbiting velocity} = \frac{2400}{\sqrt{2}} = \frac{7872}{1.414} \text{ feet/sec}$$

Orbiting velocity = 5567 ft/sec

PENETRATION AND DIAMETER CALCULATION OF A SPHERE

(C) If 3 lb-sec is the impulse that can be acceptable on earth, then it seems reasonable that since the earth's gravity ratio to the moon's is 6 to 1, then the acceptable level of 3/6 or 0.5 lb-sec impulse is the acceptable man can tolerate on the moon.

(C) The diameter of a spherical projectile to stay within this limit is calculated at two velocity levels.

$$\text{Impulse} = F\,t = M\,V$$

$$0.5 = \frac{W}{32.2}\ 3000$$

<u>For V = 3000 fps</u>

$$W = (.5)(32.2)/3000 = .00536 \text{ lbs.}$$

<u>For V = 5000 fps</u>

$$W = (.5)(32.2)/5000 = .00322 \text{ lbs.}$$

$$\text{Vol of sphere} = \frac{4\pi r^3}{3} = \frac{\pi d^3}{6} = .5236d^3$$

density of steel = 0.283 lb/in^3

(Vol)(density) = wt.

<u>For V = 3000 fps</u>

$$(.5236d^3)(.283) = .00536$$

$$d^3 = \frac{.00536}{.14818} = .03617$$

$$d = \underline{.33 \text{ in.}}$$

<u>For V = 5000 fps</u>

$$d^3 = \frac{.00322}{.14818} = .02173$$

$$d = \underline{.279 \text{ in.}}$$

If a more dense material such as tungsten is used (density = .7 or 2.47 times steel) very little reduction in diameter is required.

<u>For V = 3000 fps</u>

$$(.5236d^3)\ (.7) = .00536$$

$$d^3 = \frac{.00536}{.36652} = .01462$$

$$d = .245 \text{ in.}$$

or a reduction of .085 in. diameter or .043 in. radius

The critical velocity for perforating .415 in. of homogeneous steel armor by a 0.4 in. tungsten sphere is 2500 fps at 0° obliquity (wt. = 161.1 grains = .023 lbs),

$$\text{the K.E.} = \tfrac{1}{2} M V^2$$

$$= (\tfrac{1}{2})\ \frac{(.023)}{32.2}\ (2500)^2$$

$$= \frac{.023}{64.4}\ 625 \times 10^4$$

$$= 2232 \text{ ft-lbs.}$$

The K.E. of a .245 in. diameter sphere at 3000 ft/sec

$$\text{K.E.} = \tfrac{1}{2} M V^2$$

$$= \frac{(.00536)}{64.4}\ (3000)^2$$

$$= \frac{.00536}{64.4}\ 9 \times 10^6$$

$$= 749 \text{ ft-lbs.}$$

Penetration is roughly proportional to K.E. Therefore, the .245 tungsten sphere would penetrate

$$(\frac{749}{2232})\ (.415) = .14 \text{ in. of homogeneous armor}$$

PRESSURE REQUIRED FROM COMPRESSED GAS

The acceleration of a projectile over a given distance attaining a specific velocity is given by:

$$a = \frac{6\ V^2}{S}$$

$$a = \frac{6\ (1500)^2}{6} = 2.25 \times 10^6\ \text{ft/sec}^2$$

where velocity = 1500 ft/sec

and projectile travel = 6 inches

The force acting to product this acceleration is given by

$$F = \frac{w\ a}{32.2}$$

Where w = projectile weight = .0012 lbs

$$F = \frac{(.0012)(2.25 \times 106)}{32.2} = 161\ \text{lbs}$$

The average pressure required to generate this force is

$$P = \frac{F}{A} = \frac{161}{(.785)(.33)^2} = 1865\ \text{psi}$$

where A = cross sectional area of projectile

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