PRESENTATION TO NASA HEADQUARTERS
LANDING AND IMPACT SYSTEMS

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INTRODUCTION

Manned spacecraft with a blunt, lifting body configuration, such as the Mercury, Gemini, and Apollo spacecraft, require an auxiliary landing system for successful completion of the mission and safe return of the crew. Landing systems with widely varied performance characteristics are presently available or in various stages of development. The primary consideration in selection of a landing system for a particular space vehicle and mission is crew safety, or system reliability. Beyond reliability, the mission terminal flight plan will dictate the required landing system performance. For example, if the normal mission terminates with impact in water or an unprepared land surface, a near vertical terminal descent is preferable. Landing on a prepared land surface, on the other hand, leads itself to an aircraft type flared landing. A degree of gliding or range control then becomes necessary to insure landing on a prepared surface. (This does not necessarily mean that even with range capability the best method of landing is horizontally). The impact shock attenuation requirements are likewise predicated on the type landing system selected. Basically impact systems can be broken down into two required types; one for high vertical rate of descent with wind drift considerations, the other for lower vertical rate of descent with a horizontal velocity. Basic considerations such as weight, volume, deployment, stability, control, redundancy, and/or emergency escape, and complexity must also be evaluated in selecting a landing system for a particular vehicle.

APOLLO

1. The Apollo is one of the two Manned Spacecraft Center spacecraft presently under development. The Apollo landing system requirements are generally as follows:

a. A high degree of reliability, and a system that can be used under all flight conditions for earth landing requirements. This includes normal reentry, maximum dynamic pressure escape, and pad abort.

b. Stabilizes the Command Module during post-entry descent and reduces the vertical landing velocity to 30'/sec at 5000' altitude. Horizontal drift due to wind not to exceed 30 knots.

c. Reduces impact accelerations such that neither the Command Module structure or flotation is impared. Further attenuations to be by crew seat shock attenuation devices.

d. System to be compatible with the use of a moderate L/D terminal landing system such as a Parawing (this requirement was later deleted date May 18, 1962).

2. The system selection by MSC to most nearly fit the established requirements is as follows:

a. Descent System

(1) System selection criteria

The advantages and disadvantages for the selection of a cluster of three parachutes are shown in slide 1. The advantages of a parachute cluster are as follows: it is within the state-of-the-art, provides excellent pendulum stability, provides a high degree of reliability, very low weight and volume, is an easy way of obtaining redundancy, and it is a passive system. The only major disadvantages of a cluster is that it is nonmaneuverable. For Apollo, the use of a single parachute would have required that it have a diameter of approximately 127'. Present state-of-the-art in parachutes have determined test parachutes of this size are difficult to fabricate. Large parachutes also present a packing and installation problem. To provide redundancy, this would have also resulted in a heavier landing system and requiring more volume than the selected cluster arrangement.

(2) Deployment sequence

Slides 2 and 3 depict the deployment sequence for the Apollo earth landing system. The sequence of events are the aft section of the Command Module is jettisoned, a 13' diameter drogue chute is mortar deployed, the drogue chute is jettisoned at a predetermined altitude and the three main parachutes are deployed by mortar deploying pilot parachutes. The pilot parachutes then in turn pull the extraction chutes which deploy the main parachutes. The main parachutes are reefed for a period of six seconds prior to full inflation.

(3) Test program

The Apollo earth landing system will be tested at El Centro, California. The test will be conducted utilizing a B-66, C-130 and C-133A aircraft. The B-66 aircraft will be utilized in testing the drogue parachutes. The C-130 and 133A will be utilized in testing the single main parachute and the complete earth landing system. The present status of the Apollo test program is that 3 tests have been conducted on a single 88' diameter parachute to establish optimum parachute reefing parameters. It is anticipated that approximately 70 tests will be required for the development and qualification of the earth landing system. The parachute system flight envelope is probably best described at this point.

Graph No. 1 gives the drogue parachute design envelope and is self explanatory. Normal drogue parachute deployment is initiated at 25,000 feet. At a dynamic pressure of 140 psf, the Command Module is stabilized with the drogue chute descending to an altitude of 15,000 feet, where the main chute's deployment sequence is initiated at a dynamic pressure of 64 psf. The drogue parachute has been designed to be capable of deployment at a q of 210 psf and at any altitude from 3500 ft to 25,000 ft. In the case of "pad abort", the drogue chute can also be deployed through this same altitude range at a minimum dynamic pressure of 10 psf. Graph No. 2 shows the design envelope of the main parachutes. The main parachutes have been designed to be capable of being deployed at a maximum dynamic pressure of 96 psf at any altitude from 3500 to 15,000 ft and likewise, they are capable of being deployed at a minimum dynamic pressure of 10 psf. This low dynamic pressure could be encountered in the case of a "pad abort". There are some problem areas with this earth landing system which are anticipated although are not considered to be major obstacles to overcome. These problem areas are (1) the mortar deploying of all three main parachutes and (2) the effects of a malfunction of a single parachute on the other two parachutes.

b. Impact System

(1) System description

Slide 3 depicts the capsule impact attenuation system. This consists of 6 air oil struts for vertical attenuation and 8 aluminum honeycomb double acting struts for horizontal attenuation. The oil used in the air oil strut is Oranite 8515. The total stroke of the air oil strut is approximately 12". The aluminum honeycomb strut has a stroke of approximately 4".

Slide 4 shows the attenuation system used for the individual crew seats. This consists of 4 honeycomb shock struts for vertical loads, two honeycomb struts for horizontal loads and two honeycomb struts across the chest. The aluminum honeycomb struts are designed to control the "g" buildup.

(2) Design consideration

The known safe human tolerances are shown on graph no. 3. This impact attenuation system is designed for the following nominal conditions which are within the safe zone.

3 chutes out - vertical rate of descent 23 fps
horizontal rate of drift 30 fps
Max slope of 5° at impact
Allows 20 g's vertically; 10 g's horizontally at 250 g's/second.

Design emergency conditions:

2 chutes vertical rate of descent 30 fps
horizontal rate of drift 50 fps
Max slope of 15° at impact
Allows 40 g's vertically; 10 g's horizontally

(3) Test program

Present plans call for impact tests utilizing a full scale boilerplate Command Module. These tests will be conducted at NAA on a test rig presently under construction. This rig will not be available until probably January 1, 1963.

To reduce the number of boilerplate impact tests, a 1/4 elastically scaled model program will soon start at LRC. This model has a scale strength heat shield and strut attenuation system. This model will be tested on sand, hard surface, and water to determine the dynamics and acceleration loads.

The difficulty with an active system is the somewhat lower reliability because of the operation of additional mechanisms which have to be employed in releasing the heat shield.

Another problem would be the necessity to choose between having a deployed or nondeployed impact system when landing in water. For instance, with the proposed Apollo system, there is a great possibility that the heat shield, if deployed, may dig into the water causing severe capsule motions.

CURRENT ADVANCED LANDING SYSTEMS STUDIES

1. At this point some of the programs which are presently being conducted by Manned Spacecraft Center in support of both future spacecraft and Apollo should be described.

2. The first program is the development of a parachute known as the Glide-sail. This program is being accomplished by Northrop Ventura and has as a primary objective, the development of a gliding parachute having an L/D of approximately 0.7 to 1 and which can also be controlled directionally.

3. It is realized that the performance goals for a parachute of this nature would not provide a range capability but would allow avoidance of local obstacles and partially alleviate the impact attenuation problem by being able to overcome wind drift. The present status of this program is as follows: A wind tunnel test program has been completed by Ames Research Center using 18' diameter parachutes in the 40' x 80' wind tunnel; the results of the wind tunnel program have been verified by drop tests of both 63' diameter single and 3 chute

[illegible] El Centro, California; preliminary drop test data have verified the wind tunnel results which indicated a maximum L/D of approximately .5 to .7. This program is scheduled for completion in early October.

4. The second program consists of an in-house development of a similar glidesail parachute for descent and incorporating a landing rocket for attenuation. Air drop tests of the parachute, without the landing rocket, and static firings of the rocket motor have been completed. The results of these tests have shown the feasibility of a controllable parachute retro rocket earth landing system; therefore, air drop tests of the complete system utilizing a C-119 airplane will be conducted at Houston in the near future.

5. A third program is the development of a deployment technique for the Paraglider. A review of all the work being accomplished on Paragliders, indicated paraglider deployment was one of the major problems to be solved before it could be used as an earth landing system. A joint program with LRC has been initiated to investigate parawing deployment. Langley will conduct the tests using the 19' transonic tunnel utilizing elastically and dynamicscale models. It is believed this program can contribute significantly to developing a satisfactory means of paraglider deployment.

FUTURE PROGRAMS

6. The Landing and Impact Systems Section have a number of future programs planned which cover various areas that are not presently being investigated. These programs are:

a. The development of a chute with an L/D greater than one.

b. The development of a landing rocket for attenuation of Apollo size spacecraft.

c. The development of large single parachutes capable of recovering spacecraft weighing 30,000 pounds.

d. Development of drogue parachutes in sizes approximately 14 to 16' in diameter which can be deployed at Mach numbers up to 2 at an altitude of 80,000 feet.

e. Investigate the feasibility of ejection seats for spacecraft.

f. The development of an altitude sensor to be used in conjunction with the landing rocket.

g. The study of soils as they apply to impact attenuation and its effect on the dynamics of the spacecraft.

h. The development of a rotor landing system.

4. The programs are readily understood, however, a few comments are pertinent relative to the last program pertaining to rotors.

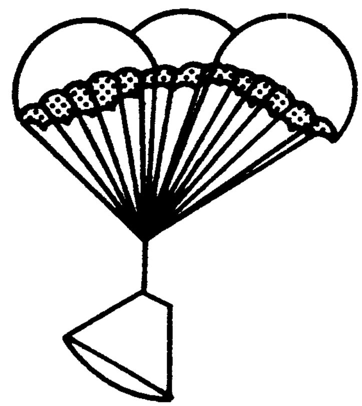
5. LRC as well as the other NASA centers have programs investigating every facet of the parawing and the parachute. Little or nothing has been accomplished on rotors, however, theoretically, from a performance standpoint, the rotor system can provide a touchdown capability of near 0 vertical and horizontal velocity. It is intended that this program be accomplished as a joint effort with the Ames Research Center.

RECOMMENDATIONS

1. It is interesting to note the number of NASA centers which are represented and the general interest which is now being shown in landing systems. The problem of developing any earth landing system is a mammoth one and requires the complete cooperation of all the NASA organizations. It appears that a landing system committee should be established with a possible member from each center and headed by a representative from NASA Headquarters. In this manner, duplication of effort could be avoided. This, in turn, would reduce new landing system development time and cost.

2. I do not know what is the best landing system. It is certain that parachutes for the time being are the most reliable and probably the best known. There is considerable effort being expended in the development of the parawing, however, NASA needs to look toward the future and develop some other system that would overcome the deficiencies of the parawing and the parachute. The selection of such a system probably could best be accomplished by this proposed committee.

PARACHUTE SYSTEM



CLUSTER

PRO

STATE OF THE ART
PENDULUM STABILITY
RELIABILITY
LOW WEIGHT & VOLUMN
REDUNDANT
PASSIVE

CON

NON-MANEUVERABLE

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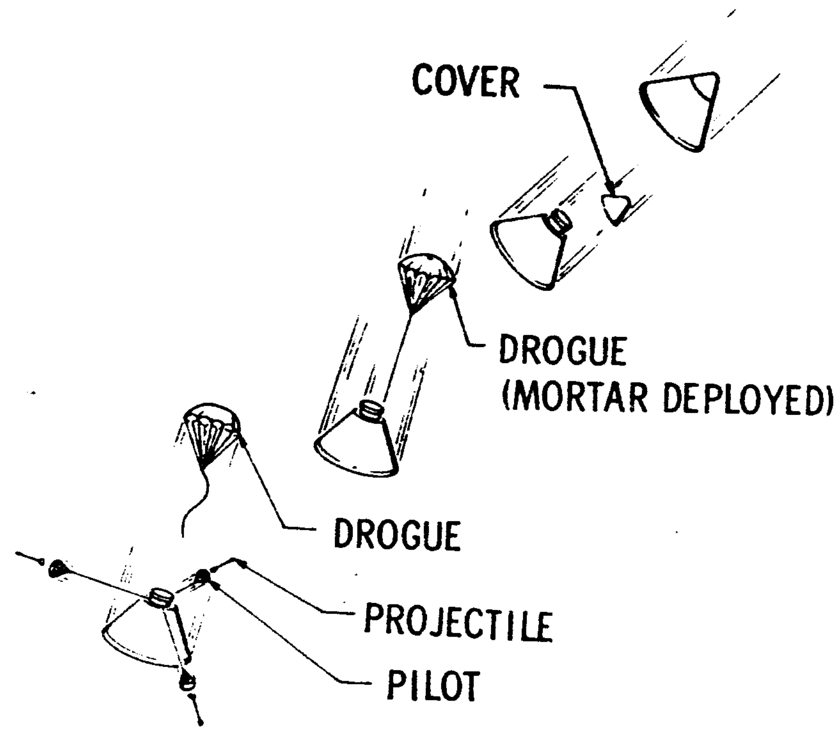
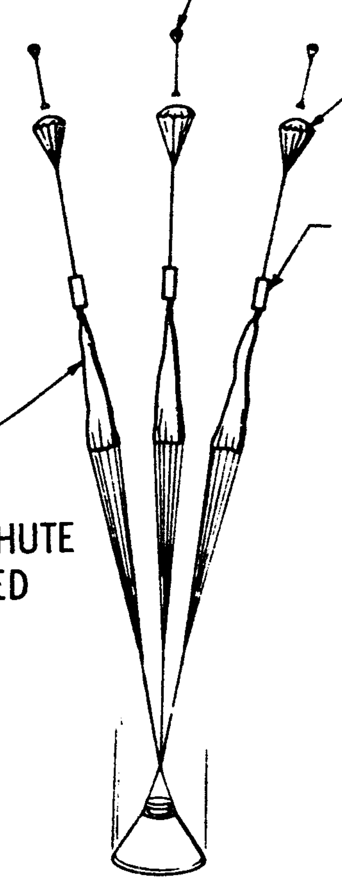
APOLLO LANDING SYSTEM



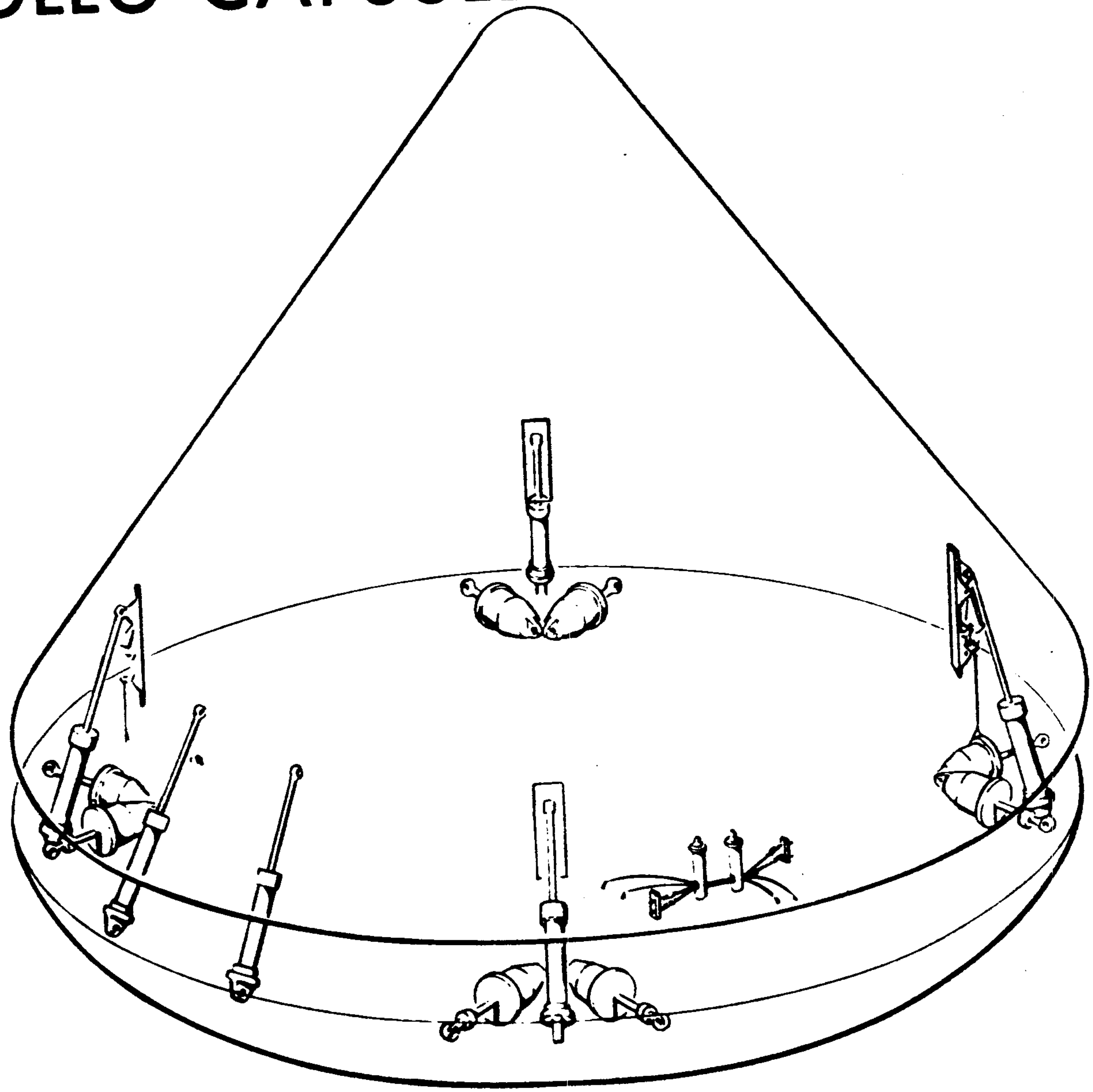
NASA -MSC J. KIKER 6JULY62 S-150-3

APOLLO LANDING SYSTEM



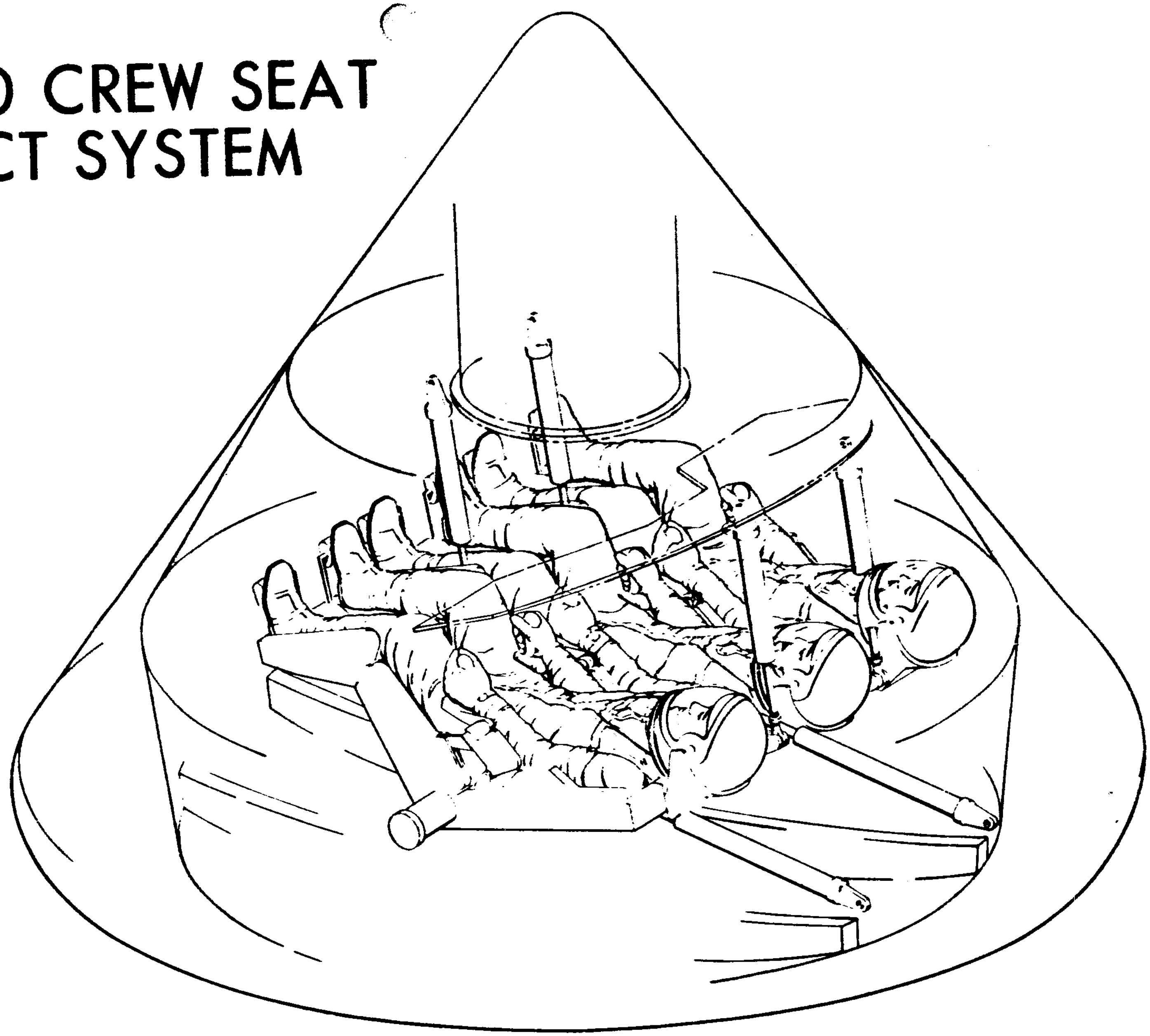
NASA -MSC J. KIKER 6JULY62 S-150-6

APOLLO CAPSULE IMPACT SYSTEM



NASA - MSC J. KIKER 6JULY62 S-150-2

APOLLO CREW SEAT IMPACT SYSTEM



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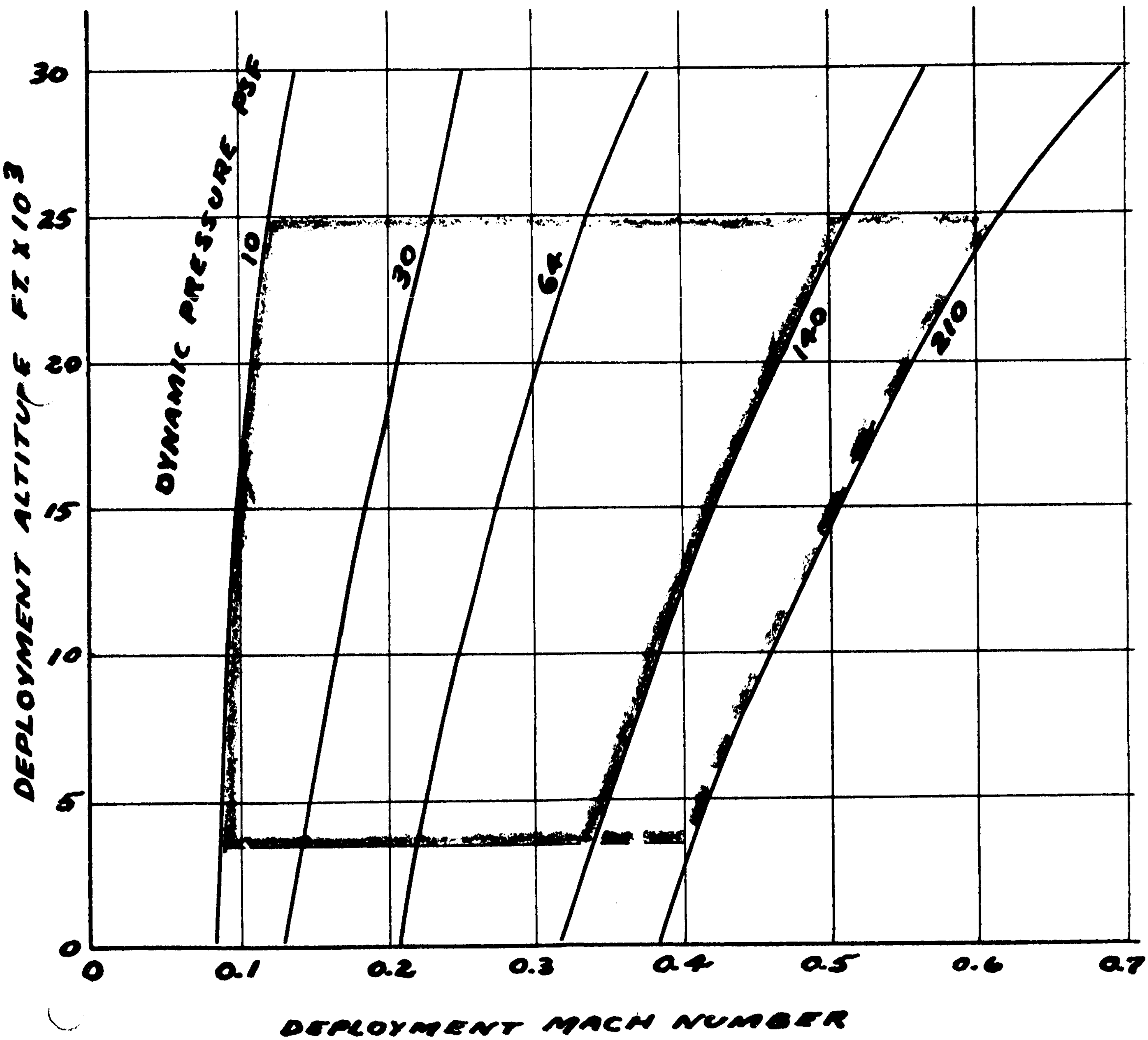
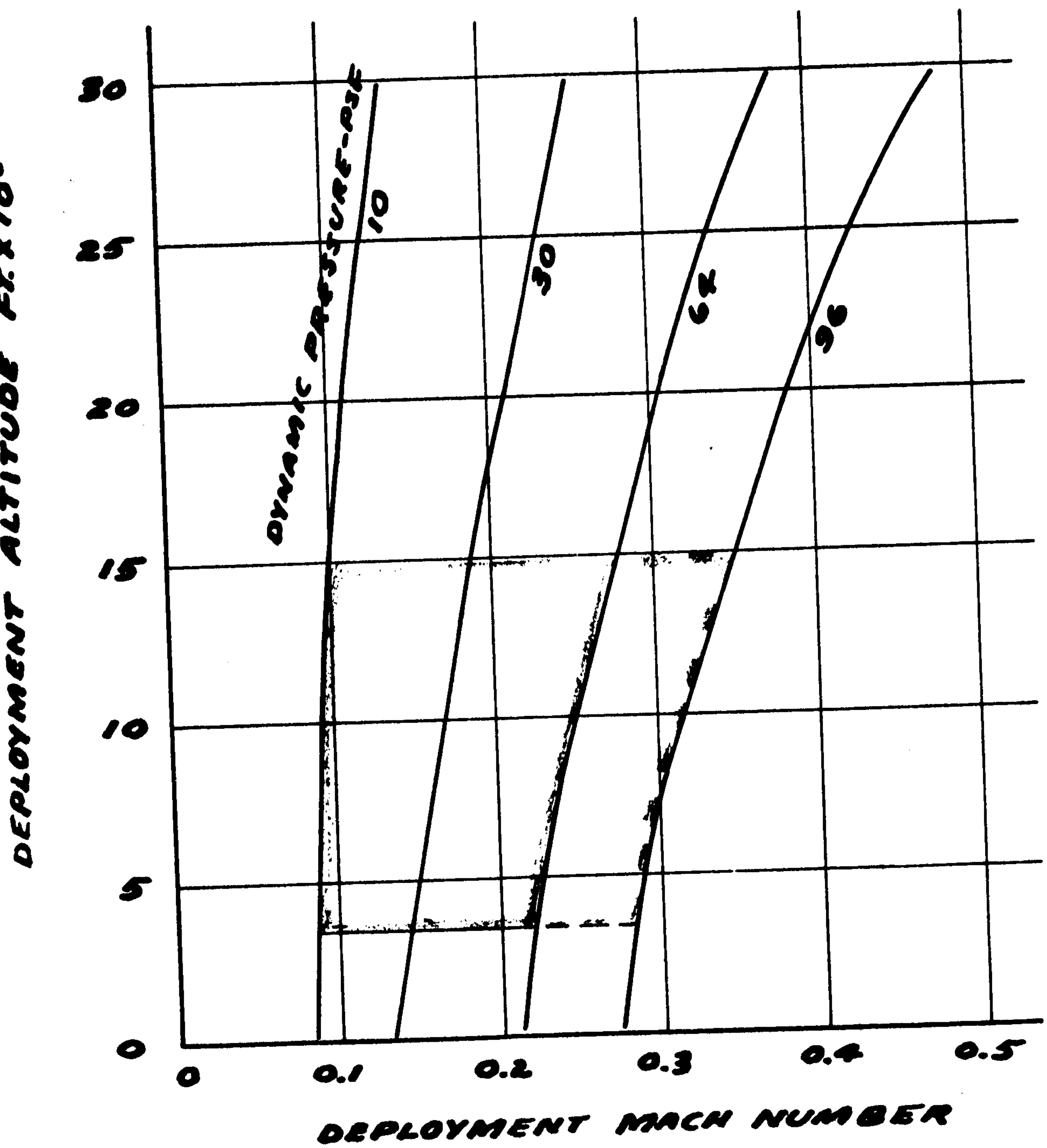
APOLLO DROGUE PARACHUTE DESIGN ENVELOPE



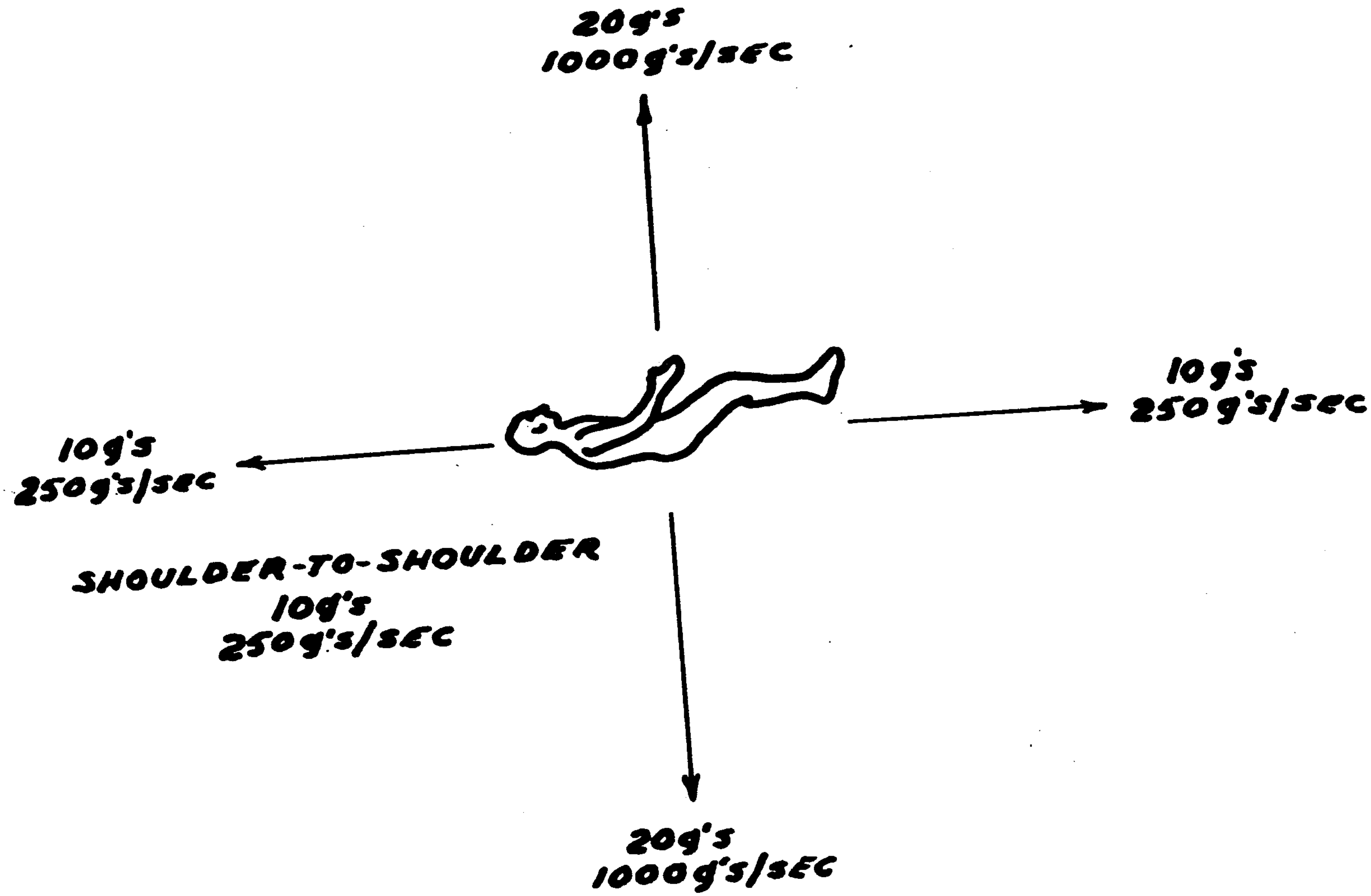
GRAPH #1

APOLLO MAIN LANDING PARACHUTE DESIGN ENVELOPE



GRAPH # 2

KNOWN SAFE HUMAN TOLERANCES



GRAPH #3