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JPL Requirements for Spacecraft Landing and Recovery

Research and Technology
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A. Introduction

The Jet Propulsion Laboratory is engaged in the design, manufacture, and operation of instrumented Spacecraft for NASA's Lunar and Planetary programs. In this capacity, the Laboratory has current interest in the landing and recovery field in two areas: 1) the return of small probes from the lunarsurface and, 2) the entry of instrumented probes into planetary atmospheres and operations using these probes near and on the planet surfaces.

At the present time there are no active projects for lunar return packages; however, some study work has been completed. It is clear that the search aspects of the problem are the only ones unique to the lunar return mission; the return guidance will require a search area of about 1000 x 2000 km, and the size of the capsule will preclude any but the most rudimentary on-board equipment.

The planetary program requires flights to Mars and Venus at each opportunity. The planning calls for entry attempts to be made as soon as adequate payload is available, and it is now believed that this will occur during the 1965-66 period.

The recovery and landing aspects of the designs are of utmost important, and are being considered in the studies. It is our opinion that the Laboratory will do very little in the in-house development of these systems, but will depend heavily on the other NASA centers and industry.

The following is a brief set of notes outlining the problem as we see it. The first section describes mission criteria, the second restraints, and the third lists major areas where R and D effort needs to be applied to obtain the best chances of success.

iii) If possible obtain data on planetary parameters - rotational rate, pole inclination, surface magnetic field, etc.

iv) Make near-planet particle and field measurement.

b) Mars

i) Do biology experiments on the surface.
ii) Investigate the atmosphere.
iii) Investigate physical surface properties. This might include local mapping, surface constituents seismology, etc.
iv) Near planet particles and fields.

C. Planetary Mission Restraints.

Many restraints can be written down for spacecraft design, but the ones listed here are prime for the planetary missions and must be carefully considered, both technically and economically.

1) Environment - In addition to the space environment considered for earth satellites, the change in heliocentric radius during a mission adds considerable complication to all systems. Also, the planetary environments contain many extremes and the models are based on a very small amount of information. The result is that the design problems are unique and difficult.

2) Infrequent Opportunities - 19 months for Venus, 25 months for Mars.

3) Dual Planet Capability - The general requirement for maintaining as much standardization in subsystems as possible is recognized as being most important. It is expected that the entry capsules will differ more than the spacecraft, but the Spacecraft-Capsule interfaces will certainly be as uniform as possible.

4) Reliability - The important items are:

a) Long lifetime - Mission durations of 120 days for Venus and 230 days for Mars are typical values. Subsystems which must work at the planets must also be "storable" in space for this period of time. Simplicity, redundancy, margins of safety, etc., must be carefully integrated into the effort.
b) The systems developed must be as "testable" as possible both in a development and qualification sense.

5) Sterilization - This will be a hard requirement for both planets, with most emphasis on Mars. Current JPL specs. call for heat sterilization (type approval) consisting

f three cycles, each 36 hours at 145°C. It is required hat this procedure be applied to the completely assembled ntry [illegible] ptions require a comprehensive demon- ration of [illegible] ient capability.

D. **R & D Requirements**

In considering po[illegible]ole designs to meet the above requirements, certain areas for R and D effort have become apparent. Those pertinent to recovery and landing are listed.

1. Retardation systems for Planets.

   a) Maximum [illegible] ment Mach Numbers for retardation systems need to be increased to the highest possible value. This appears to be especially critical in the Mars situation because of the large scale height and low atmospheric density.

   b) Materials for high temperature operations (Venus, [illegible] sterilization compatibility need development. [illegible] vacuum storage must also be understood.

   c) The entry environment imposes a high "g" [illegible] tradeoffs on the retardation system design [illegible] this needs study. Typical values [illegible] and 500 g for Venus.

   d) The general scaling of retardation system [illegible] and Venus conditions needs considerable thought. [illegible] instance, some simple scaling [illegible] Mars parachute to carry a given mass [illegible] speed might be about twice the diameter and [illegible] weight of the earth equivalent. It is [illegible] a careful [illegible] of parachute [illegible] than testing under simulated planet[illegible] [illegible] gravity [illegible] together [illegible] adeq[illegible] quire careful thought and ingenuity.

Deployment Control Development.

a) Systems to [illegible] deployment [illegible] planet e[illegible] [illegible] or [illegible] measure[illegible] [illegible] from [illegible] this [illegible] ssib[illegible] [illegible] measuremen[illegible] [illegible] deployment maximum speed consistent with known (tested) decel... strength, stability, and heat resistance.

c) The above functions will certainly introduce compl... not suffered by the present simpler sensors such as acceleration and pressure sensors, but such complex... will undoubtedly be worth the performance gains. At Mars, for instance, altitude gain may be a factor of 2 over that realized by the simpler system's attempting provide safe deployment conditions over a wide spread in possible atmosphere properties.

3) Development of Balloon Systems. There are two major reasons for considering balloon systems.

a) To allow extended observation time under some specific set of conditions (constant altitude, for example).

b) To provide time for an Earth controlled landing site selector maneuver. The reaction time for the simplest form of Earth based selection is probably of the order of one hour.

Balloon schemes are most certainly considerations fo[illegible] (not Mariner), but in our opinion require extensive [illegible] ment. They appear to be heavy, fairly complex, an[illegible] the benefit of much real experience in terms of [illegible] control flight deployment, vacuum storage, etc.

4) Landing Guidance and Control.

The landing problems are not unique to the planetary missions, but the stakes may be higher than for an inst[illegible] ented probe in the earth's atmosphere. Problems inclu[illegible]

a) [illegible] site selection - This means detection of [illegible] [illegible] th surface properties as opposed to [illegible] which would certainly depend on [illegible] [illegible] orbital control. There are o[illegible] [illegible] lunar problem. The main [illegible] [illegible] communication times. [illegible] [illegible] es and the desire to land [illegible] success of biology exper[illegible]

[illegible] a parachute type [illegible] ent velocity [illegible]

[illegible]

and [illegible]

of a planet has many inherent problems. It is fortunate that in this process one can probably draw on the experience gained from the lunar programs. Techniques investigated for lunar missions include rocket landings (Surveyor) and crushable structures (Ranger). The vehicle should be designed on the basis of no site selection since a partial failure of site selection guidance should not cause mission failure. Other problems to be investigated include release of the retardation system after impact, accounting for both axial and transverse approach velocities, and the effects of any landing mechanisms on the entire system and its operation (i.e., communications, science).

6) Post Landing Orientation and Survival

a) Reorientation methods will be largely dependent on degree of landing guidance accuracy, i.e., minimization of drift and impact velocities.

i) For the case where these velocities are appreciable, the vehicle should be designed to tumble passively with minimum absorption of lateral momentum. When motion has ceased, orientation may be achieved a) wholely within the envelope of the vehicle, say by gravity or optics, in which case minimum expended energy and all orienting mechanisms are protected from the environment (heat, blowing sand, wind), or b) by actively altering the surface of the vehicle to produce torques tending to right the vehicle; however, these devices (legs, spring, draglines) have been exposed to impact injury and continue to be subject to environmental influence. Energy expended is greater since entire system may be lifted.

ii) For the case where precise landing control is available, orientation devices may be deployed before impact (legs, grapnels, attitude feelers, etc.) with lesser chance of damage.

b) Survival will require, in any case:

i) Thermal protection from solar or surface and atmospheric heating (cooling)
ii) Mechanical protection against winds, dirt, (humidity), attitude control with respect to local surface.
iii) Location of Earth Direction (communication to Earth) (omni-directional communication to an orbiter)
iv) Location of landing site on planet (astronomical observations). If an orbiter is available it may geographically locate the lander's radio signal.

In addition, it would be most helpful if efficient schemes for extracting electrical energy from the planetary environment could be devised. Possible sources might be flight kinetic energy, surface winds, diurnal temperature cycles. Any useful developments in this area will probably have to await results from initial entry capsules.

7) Testing Techniques

One of the most significant tests which can be performed on planetary entry vehicles is a simulated entry on Earth of a complete system under controlled conditions. The objectives of such tests are to observe the operations of the system throughout the conditions of peak heating and loads, retardation, landing, etc., and to do this early enough before the flight to permit the addition of any reliability measures. Flight tests of this type involve a great deal of effort and dollars. It is therefore proposed that the following be studied:

a) How would tests of this type be performed? Can all factors be investigated in one flight or must they be broken down and performed on several flights.

b) How many flight tests per mission function and/or per mission would be necessary.

c) In performing such tests, how much of the actual flight mission is compromised by:

   i) Splitting up the test in functions.

   ii) Fitting the entry vehicle to a different booster.

   iii) Instrumentation.

   iv) Is the knowledge gained from the tests worth the cost and effort of performing them?

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JPL ACTIVITY IN RECOVERY FIELD

Part of the Mariner mission consists of the entry capsule, split off a flyby spacecraft, into a planetary atmosphere. This atmosphere-measuring probe was the first recovery problem faced by JPL. (Lunar landing by retro rocket has previously been studied here for Ranger.) Early work on recovery has been in the following categories:

1. Re-entry to Impact Trajectory Studies - Parametric study, assuming ballistic entry, translational motion only, and drag a function of Mach number. Parameters varied are:
    a. Entry conditions (path angle and velocity)
    b. Atmosphere density profile (since there is considerable tolerance in existing knowledge)
    c. Capsule ballistic coefficient
    d. Parachute deceleration with varying sequences opening at various flight conditions.

    It has been found that all the above effects influence the usefulness of a recovery system in meeting mission objectives, such as descent time and atmosphere depth to be sampled during this time.

2. Optimum Design of Parachute System for Planetary Missions - In order to determine a) the effects of (1) the general design and fabrication of parachute systems for the planets and b) the extent to which current parachute capabilities permit maximum utilization of available variations in entry parameters for

entrancing mission performance, a study contract has been let to a firm specializing in recovery technology.

3. Landing Impact and Reorientation Studies -

   a. Experimental and theoretical investigations into the properties of crushable materials for impact energy absorption.

   b. Preliminary studies on weight efficiencies of some orienting devices.

4. Recovery Study Based on Specific Hardware -

   As a part of a JPL-funded study to establish the overall suitability of the Discoverer vehicle for Mars atmospheric entry, General Electric MSVD made recommendations of a parachute system and deployment method.

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5. Evaluation of Certain Crushable Materials, Technical Report 32-120, Jet Propulsion Laboratory, Pasadena, Calif., January 13, 1961.

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