Conclusions

Calculated weights for the systems studied show an inert weight advantage of approximately 80% in favor of a jet-pump system. Translated into benefits applicable to a particular missile and orbit, the total savings would increase the payload of a two-solid-engine Titan III type missile system by approximately 300 lb at a 100-naut-mile orbit. Although the jet-pump principle is applicable to solid boosters or sustainers of virtually any size, it is likely that, below some particular size, the weight savings that accrue from low pressure would be nullified by minimum gage effects.

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Deployment of Parawings for Use as Recovery Systems

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RECENTLY the NASA Langley Research Center has conducted a series of investigations to study some of the problems of deploying parawings for the recovery of boosters and nonlifting spacecraft. These investigations were conducted by means of radio-controlled drop tests of free-flying dynamic models. All of the deployment tests were conducted at low subsonic speeds. The prime considerations of the investigations were the mechanics and sequencing of events for deployment and the dynamic stability and control characteristics of the configurations during the deployment.

Models

Four different configurations were investigated and are presented in Figs. 1–4. The models were not exact scale reproductions of any particular vehicle-parawing combinations. The first one (Fig. 1) consisted of a model of a rocket booster with a foldable rigid parawing. Its structural members (the leading edges, the keel, and the spreader bars) were fabricated from aluminum-alloy tubing and were so constructed that the leading edges could be retracted until they were parallel to the keel, and then the leading edges and the keel could be folded back on themselves to make the over-all packaged length approximately one-half of the keel length. The second (Fig. 2) comprised a blunted-cone, nonlifting spacecraft with a telescoping rigid parawing. Again, the structural members were made from aluminum-alloy tubing. After the leading edges were retracted against the keel, they could be telescoped three times, so that the over-all packaged length was approximately one-third of the keel length. The third configuration (Fig. 3) was similar to the second, except that the structural members of the parawing were inflatable fabric tubes. The fourth (Fig. 4) was a Gemini-type spacecraft with an inflatable parawing; its deployment sequence and the suspension line geometry were similar to that proposed for the Gemini vehicle.

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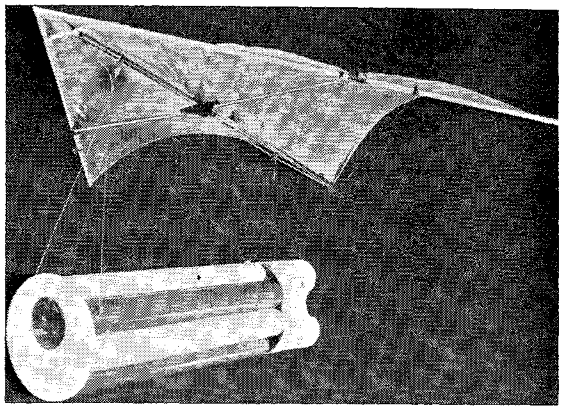

Fig. 1 Model booster and foldable parawing.

Results and Discussion

A separate investigation was conducted with each of the four parawing-vehicle combinations; detailed results of two of them are given in Refs. 1 and 2. These investigations were conducted somewhat in the manner of development projects, that is, they were intended to devise a successful method of deployment for each particular case, rather than to provide an exhaustive study of all possible deployment processes. Successful methods for deploying the parawings were developed in each case, but the development process involved trying a number of deployment steps, or features, that were not always successful. From these successes and failures, some general understanding of the problems and the importance of various features of the deployment process has been obtained. All of the deployment systems developed followed

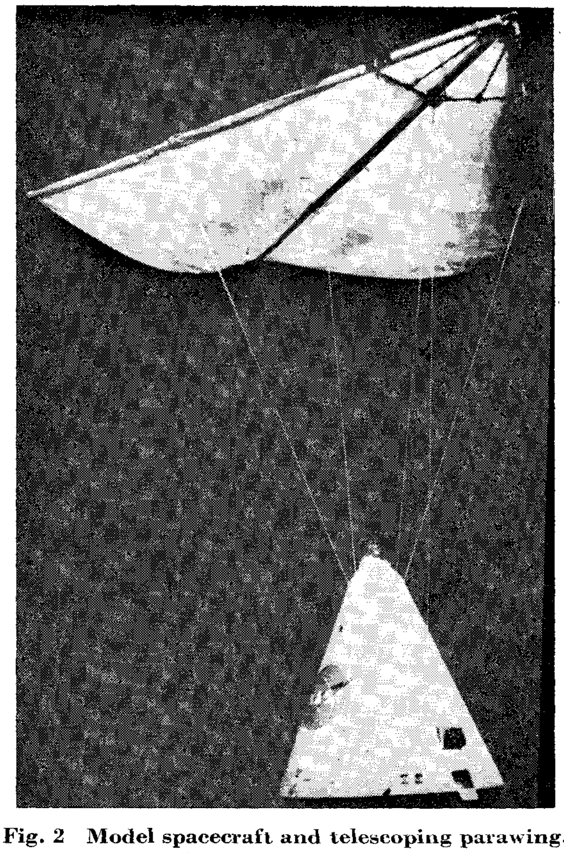

Fig. 2 Model spacecraft and telescoping parawing.

the same general program. The wing was deployed in the zero-lift condition with the apex attached to the spacecraft, or booster; then the transition was made to a lifting condition and gliding flight. Many aspects of the deployment process were found to be common to the four configurations tested and will probably constitute valuable guidance in the development of deployment techniques for future cases. These common aspects are discussed in the following sections in terms of the various phases of the deployment.

Stabilization of vehicle before deployment

One feature that seems to be absolutely necessary is that the vehicle from which the parawing is to be deployed must be at some predictable attitude when the deployment is initiated as well as during the deployment itself. If the booster or spacecraft alone is unstable, it will be impossible to predict what the attitude might be at any particular instant during a free fall, and therefore equally impossible to devise a deployment technique that would be successful at all times. Since the boosters and spacecraft tested were not dynamically stable, some auxiliary device had to be employed to make them stable. In each case, a drogue parachute was the smallest, lightest, and most reliable system that would stabilize the vehicle and consequently predetermine its attitude along the flight path, so that the deployment could be started from a known and consistent set of conditions.

Spreading the wing

It was found to be very desirable to spread the leading edges of the wing to the desired flight sweep angle before the wing starts to develop lift. The reason for this is simply that it requires less work to spread the leading edges while the wing is in a zero lift condition.

Separation of wing from vehicle

For each deployment technique, it was found to be essential to provide some positive means for separating the parawing from the vehicle, getting it into a lifting attitude, and holding it in the desired position relative to the vehicle until any oscillations set up by the deployment have damped out. In all of the investigations, a drogue parachute attached to the apex of the wing was used to accomplish these functions.

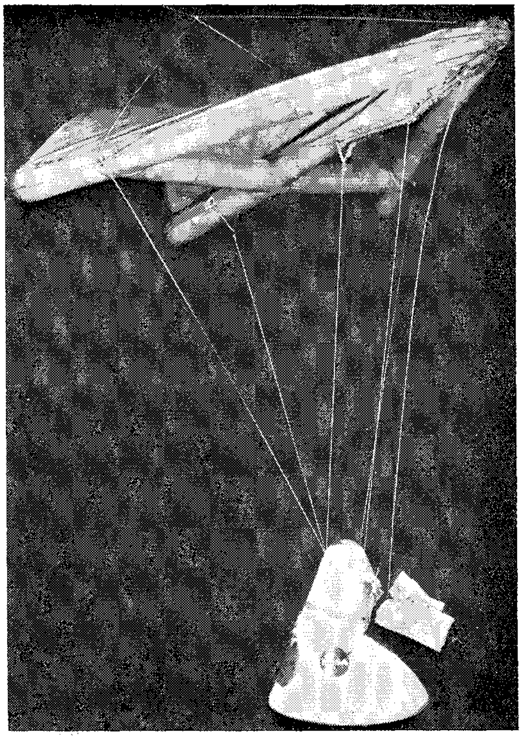

Fig. 3 Model spacecraft and inflatable parawing.

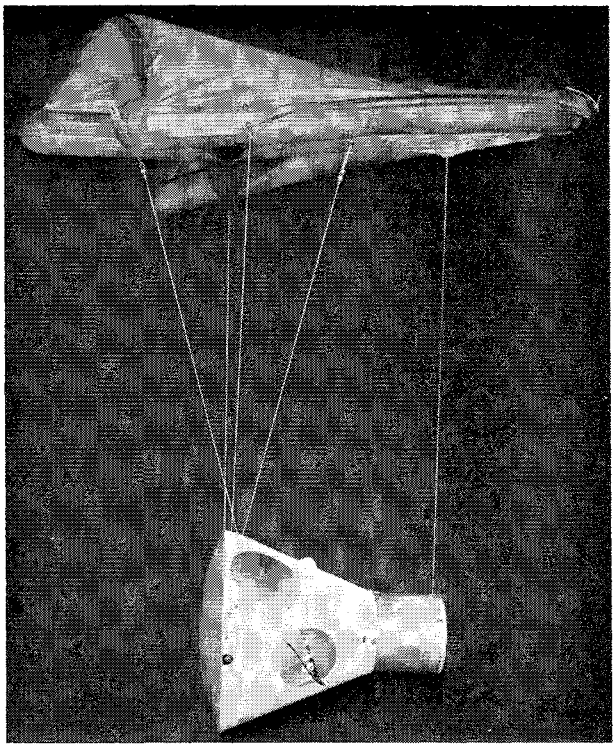

Fig. 4 Model of Gemini spacecraft and inflatable parawing.

Transition to gliding flight

The next important factor common to each deployment technique was that the parawing must not be allowed to make a transition from zero lift to its trimmed gliding condition too rapidly. Not only does this impose excessive loads on the structure, but it may also cause the vehicle to become violently unstable and begin an end-over-end tumbling motion and be completely out of control.

Jettisoning the drogue

The timing of the jettisoning of the drogue parachutes was found to be very important. The drogues should not be jettisoned before the oscillations, resulting from the wing deployment, have damped out for two reasons: first, because the drogue provides a powerful damping of the pitching oscillation, and second, because of the possibility of jettisoning the drogue during a phase of the oscillation when the abrupt change in pitching moment would reinforce the oscillation and cause the model to tumble. Another important aspect of jettisoning the drogue parachutes is to jettison them in the proper sequence when more than one drogue is used.

Load considerations

From the one spacecraft that was instrumented, it was found that the deployment loads may be many times greater than the steady-state flight loads. Therefore, the problem of deployment loads should be studied further with a view toward optimizing the deployment techniques, thereby reducing the structural requirements of the parawing, which in turn will keep the weight and volume of the system at a minimum.

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