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# A REVIEW OF LAUNCH VEHICLE RECOVERY STUDIES

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# SUMMARY

As a part of a NASA-wide review of past and current work in the field of payload and launch vehicle recovery, this paper presents a summary of launch vehicle recovery studies conducted under sponsorship of the MSFC Future Projects Office. Previous study programs are reviewed, a current assessment of mission prospects and vehicle concepts is presented, and current MSFC studies in this area are outlined. Areas are suggested in which research and experimental work can hlep establish a foundation for future vehicle developments.

# A REVIEW OF LAUNCH VEHICLE RECOVERY STUDIES

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## INTRODUCTION

With our greatly expanded space program objectives, space launch vehicles will soon become a major new form of transportation. Launch vehicles to date, patterned after their ballistic missile predecessors, are characterized by "one-shot" operation in which the vehicles of highly refined design are discarded after a flight operating lifetime of only a few minutes. Recovery of expensive flight equipment, and the strong need for first hand flight test information, have prompted work for some time toward launch vehicle recovery; however, the difficulty of the task in some cases, but more often the over-riding priority of primary program objectives, have resulted in little concrete progress to date.

Interest and work toward booster recovery at MSFC date back to REDSTONE and JUPITER projects (as part of the Army Ballistic Missile Agency) in 1958/1959. Considerable work has continued since that time, as described in the MSFC papers given at this meeting. The three preceding papers have reviewed individual Marshall projects relating to launch vehicle recovery. This paper will present a summary of past and current MSFC work in this area, including a number of system studies, conducted under direction of the MSFC Future Projects Office. This material will be presented in the following arrangement:

(1) Summary of previous launch vehicle studies, and recovery methods considered.

# Summary

## POTENTIAL BENEFITS of RECOVERY

- POST FLIGHT EXAMINATIONS
- RE-USE OF FLIGHT-PROVEN HARDWARE
- COST REDUCTION
- AVOID EXPENDED BOOSTER FALL-OUT
- ABORT CAPABILITY

(2) A brief discussion of recovery implications, and comparisons of recovery methods.

(3) A current assessment of mission prospects and vehicle concepts.

(4) An outline of current reusable vehicle studies at MSFC, and suggestions for complementary research and experimental work.

## POTENTIAL BENEFITS OF RECOVERY

It might be helpful to begin with a review of the potential benefits of launch vehicle recovery, some of which are listed in table 1. Most booster recovery studies have been begun with the incentive of reducing costs. As these studies progressed, however, there has been an increasing recognition that the operational benefits of vehicle reuse will likely be more important than costs, particularily for the high traffic rate transportation of passengers and cargo between earth and orbit.

The reuse of vehicles which have operated successfully on previous flights is believed to be of advantage, compared to the use of completely new equipment on each flight. Post-flight examinations of actual flight hardware should allow quicker diagnosis and correction of early design deficiencies than with limited telemetry data, and a faster growth to design maturity in the development phase. Growth to higher reliability levels can also be expected through repeated flight checkouts and design refinements.

The extent of range safety problems will depend on actual launch rates encountered, and upon future desires or necessity to relax restrictions in launch site location and launch azimuth. In any of these circumstances, the problem of expended booster fallout will be alleviated

## PREVIOUS RECOVERY STUDIES

| | |
|---|---|
| • REDSTONE/JUPITER | 1958/59 |
| • SATURN S-I PARACHUTE & PARAGLIDER | 1959/60 |
| • ECONOMICAL BOOST SYSTEM STUDIES | 1959 |
| • RECOVERABLE BOOSTER STUDIES (AIR FORCE) | 1959/60 |
| • 2-3 MILLION LB. THRUST BOOSTER STUDIES | 1960/61 |

## RECOVERY METHODS CONSIDERED

- DECELERATION

| DRAG | LIFTING |
|---|---|
| BALLISTIC BODY | FIXED WINGS |
| DRAG BRAKES | FLEXIBLE WINGS |
| PARACHUTE | ROTARY WINGS |
| BALLOON | |

- MANUEVER & LANDING

| VERTICAL DESCENT | HORIZONTAL LANDING |
|---|---|
| BALLOON FLOATATION | FIXED WINGS |
| RETRO-ROCKETS | FLEXIBLE WINGS |
| TURBO-JETS | |
| ROTARY WINGS | |

by their recovery.

Abort capability will be important to launch vehicle life as well as range safety. In fact, some data from aircraft experience indicate that abort capability, perhaps more than reductions in malfunction rates, is the key to extended vehicle life.

## PREVIOUS RECOVERY STUDIES

The possibility for recovery of REDSTONE and JUPITER missiles prompted conceptual studies of recovery methods in 1958/1959, leading to design and fabrication of parachute recovery systems as described in the preceding papers. Other studies have followed, as indicated in table 2. The first two of these involved the addition of recovery systems to vehicles of existing design, whereas the latter three investigated vehicles of new design, incorporating a veriety of recovery concepts. The latter study produced comparative designs of recoverable and expendable vehicles in the SATURN C-3 class, concentrating on fixed wing or paraglider recovery of one or both stages.

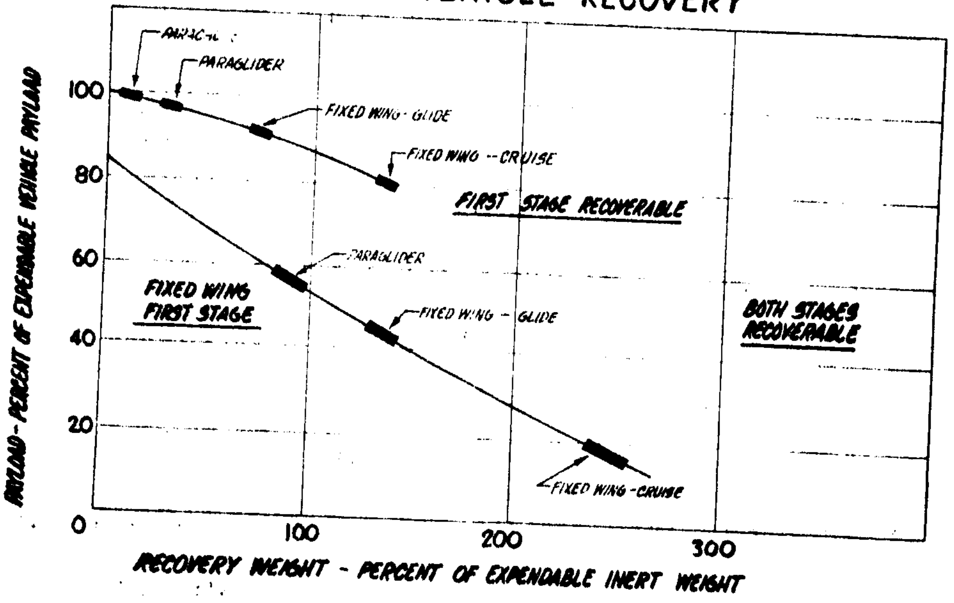
The various recovery methods considered during these studies are tabulated in table 3. In all cases, aerodynamic drag and/or lift is the means for primary deceleration for the expended stage. A number of methods have been suggested for the maneuver to a selected landing site, cancellation of residual velocity, and for final touch-down. The simpler methods allow little or no deviation from the ballistic impact point for the expended stage. The glide capability inherent in fixed or flexible wings allows greater freedom in this respect; however, studies have shown

# RECOVERY OPERATIONS CONSIDERATIONS

- *WATER IMPACT*
  - *DEPLOYMENT OF RECOVERY FORCE*
  - *RETRIEVAL*
  - *TRANSPORT TO LAUNCH SITE*
  - *POSSIBLE IMPACT & WATER DAMAGE*
- *FIXED DOWN-RANGE LANDING SITES*
  - *LIMITS FLIGHT PATH SELECTION*
  - *TRANSPORT TO LAUNCH SITE*
- *RENDEZVOUS FOR RETURN*
  - *DEPLOYMENT OF SHIPS OR TOW AIRCRAFTS*
  - *RENDEZVOUS AND TIMING*
  - *TRANSPORT TO LAUNCH SITE*
- *POWERED CRUISE RETURN*
  - *MINIMUM RANGE EQUIPMENT AND OPERATIONS*

## *Weight and Performance Penalties*

### LAUNCH VEHICLE RECOVERY



that favorably staged vehicles will require auxiliary propulsion (such as air-breathing engines) to allow the desired return of expended booster stages to the launch site.

Circumstances have not allowed investigation of all concepts in equal depth. Choices for particular applications have resulted in greatest depth of MSFC study in parachute systems, paraglider, and fixed wing vehicles.

## SOME IMPLICATIONS OF RECOVERY

In studies investigating reusable vs expendable mode of operation and the relative merit of the different recovery concepts, many considerations of course come into play. Comparisons on the basis of three significant considerations are summarized in tables 4 and 5 and figures 1 and 2.

Table 4 compares recovery operations required for the simpler forms of recovery, involving down-range water landings, with the more extensive forms of recovery, which allow glide or cruise to a prepared landing site. Although probably acceptable for low launch rates, sea recovery operations (similar to Project Mercury experience) would become unwieldy for higher launch rates. Immediate return of boosters into the refurbish and check-out cycle at the launch site - avoiding water impact, down-range recovery operations, and transport back to the launch site - is considered an important factor in selection of recovery methods.

All known forms of recovery increase vehicle inert weight through addition of equipment and/or increased structural strength, resulting in payload penalty of some degree. Figure 1 shows penalties typical of various booster recovery methods; second stage recovery penalties, as discussed in the preceding paper, are shown for reference. In comparative

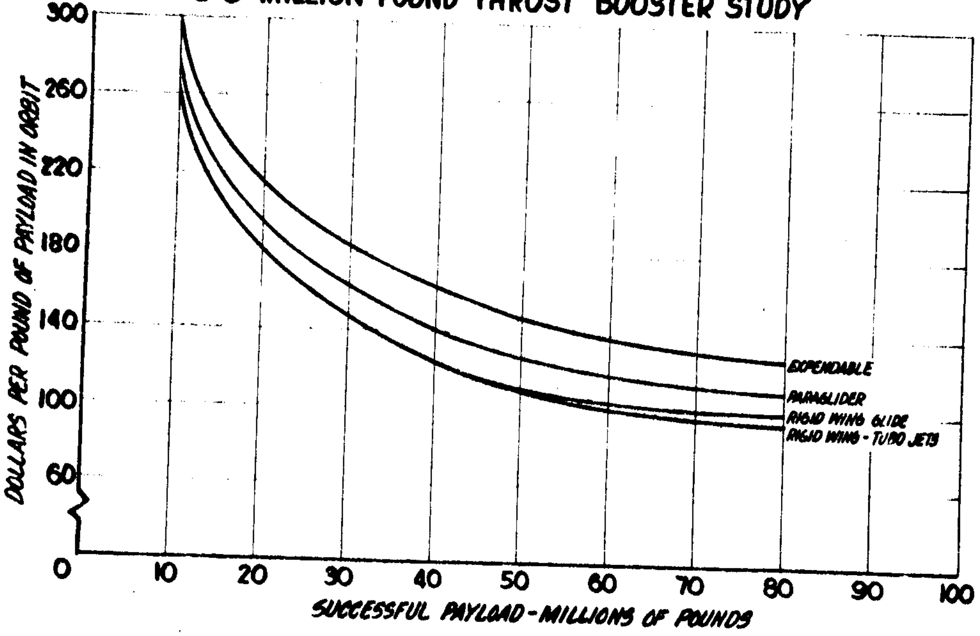
# COST CONSIDERATIONS

- *DIRECT OPERATING COSTS*
  - *BOOSTER PURCHASE PRICE*
  - *NO. OF USES PER BOOSTER*
  - *RECOVERY/RE-FURBISHMENT*

- *AMORTIZED COSTS*
  - *DEVELOPMENT*
  - *FACILITIES*

## COMPARATIVE COST ESTIMATES

2-3 MILLION POUND THRUST BOOSTER STUDY



analyses, this performance decrement is reflected in costs through additional launches required to deliver equal (cumulative) pa loads, or increased booster size to provide performance equal to that of an expendable stage.

Primary factors determining the degree of cost benefit from booster reuse are shown in table 5. For the simpler recovery methods, booster reuse rate vs recovery/refurbish costs dominate, whereas increased booster purchase price and development costs become more prominent for reusable vehicles of advanced designs.

Analyses continue to show cost benefit for booster reuse, with the degree of benefit dependent upon variable estimates for some of the individual elements in which our experience is limited or lacking. Typical results of comparative costs estimates, based on studies of vehicles in the 2-3 million pound thrust class, are shown in figure 2.

## CURRENT ASSESSMENT - MISSION PROSPECTS/VEHICLE CONCEPTS

Our immediate future space program objectives place primary emphasis on:

(1) Increased launch vehicle performance; i.e., capability to perform missions not previously possible.

(2) The need for this capability as early as possible.

Since recoverability would reduce payload capability and might require additional time for design and development, early introduction of recovery into major vehicle programs is not likely.

As in other technological evolutions, however, establishment of a new

## MISSION PROSPECTS

- FOR IMMEDIATE FUTURE GOALS
  - MAXIMUM PERFORMANCE CAPABILITY
  - EARLIEST POSSIBLE AVAILABILITY
- NEXT PHASE OF SPACE ACTIVITY
  - MORE FREQUENT/ROUTINE TRIPS
  - IMPROVE OPERATIONS AND EFFICIENCY
  - PASSENGER FACTOR DOMINANT IN SOME SIZES

## PRESENT STATUS - VEHICLE CONCEPTS

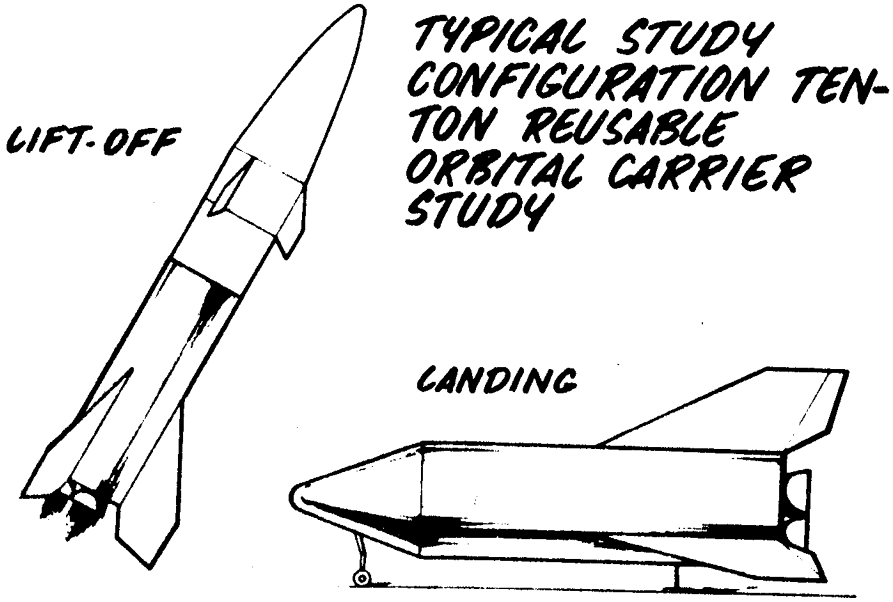
- HIGH TRAFFIC RATE/PASSENGER - CARRYING CLASSES - FIXED WINGS WITH POWERED CRUISE
- LOWER LAUNCH RATE CLASSES - PURSUE WATER IMPACT, PARACHUTE, OTHERS

capability can be followed by concentration on improvement in operations and efficiency. The operating environment for the expected next phase of space activity emphasizes the potential for such improvements through the use of reusable launch vehicles. In contrast with the first phase, frequent and repetitive launchings will be required to support sustained operations in earth orbit and on the moon. Orbital space stations, both manned and unmanned, will require frequent visits for crew rotation, inspection of equipment, maintenance, and repairs. Particularly in some vehicle classes, the passenger-carrying function will place greater emphasis on reliability, safety, and abort capability. In general, this environment suggests a need and an approach similar to that of current air transportation.

At this point, fixed wing boosters seem the most promising choice for high traffic-rate, passenger-carrying classes. Equipped for powered cruise, this concept offers the best probability for recovery and reusability, with a minimum of recovery operations. Also significant with respect to the expected early establishment of orbital space stations, the concept requires only modest advances in technology, allowing timely availability. The simpler forms of recovery are probably more adaptable in the lower launch-rate classes. With no clear cut choice of recovery method apparent at this time, investigation of several methods - including water impact, parachute, and paraglider - should be pursued.

# PRESENT MSFC STUDY EFFORTS

| Payload Class | Studies |
|---|---|
| ATLAS/TITAN | RS-70 or SST TYPE LAUNCHER |
| SATURN C-1 | REUSABLE 10 TON ORBITAL CARRIER |
| SATURN C3/C-5 | 50-100 TON REUSABLE VEHICLE STUDY |
| C-5/NOVA | POST-NOVA SERIES<br>SEA-LAUNCH & RECOVERY |



TYPICAL STUDY CONFIGURATION TEN-TON REUSABLE ORBITAL CARRIER STUDY

## CURRENT MSFC STUDIES

Based upon this background and conclusions to date, Marshall-sponsored studies as shown in table 8 are now in progress* to help define the next generation launch vehicles.

Paraglider recovery of rocket vehicles in the 5-ton orbital payload class is to be studied, along with possible use of airplane-type boosters, adapted from RS-70 or supersonic transport design for air launching of rocket-powered upper stages.

The 10-Ton Orbital Carrier Study will concentrate on the job of passenger transportation between earth and orbit and, as such, is considered a probable first application for the fixed wing, "rocket airplane" concept. The 50-100 Ton Vehicle Study, on the other hand, is aimed toward a "space truck" cargo carrier concept as a successor to the current SATURN C-5, with a probable primary mission of sustained lunar operations support. The first phase of this study is investigating prospects for conversion of the C-5 into reusable configurations.

There are several study programs now active to determine vehicle configurations for payload capability greater than SATURN C-5; two are listed in which recovery/reuse are being considered. The first of these is conceived as a sea-launched, pressure-fed vehicle which can be recovered by water impact without requiring auxiliary recovery devices. Recovery concepts within the Post-NOVA studies include inflatable drag and flotation devices, integral lifting (glide) capability, etc.

* With exception of the 5-ton payload class study, which is planned as part of FY 63 program.

# RESEARCH AREAS

- STUDY/RESULTS LIMITED BY:
    - PRIOR EXPERIENCE
    - EXPERIMENTATION
- RESEARCH/EXPERIMENTATION NEEDED:
    - RECOVERY METHODS
    - TO ESTABLISH DEGREE OF REUSABILITY
    - DESIGN & FABRICATION FOR REUSABILITY

## RESEARCH & EXPERIMENTAL WORK

As in most advanced concept investigations, past experience in several aspects of vehicle recovery and reuse is very limited or lacking. However, with the date for initiation of second generation launch vehicle developments still a few years away, there is an opportunity to provide a preparatory foundation of research and experimental work in the areas indicated.

### Recovery Methods

With the choice of recovery methods for the different vehicle classes not clearly defined at present, research work for a number of methods should continue. Considerable experience is being gained with parachute and paraglider. Fixed-wing data are being gained from X-15, X-20, and a limited amount of research work now in progress at the Langley Center. Although we have no specific recommendations for research in other methods at this time, studies now in progress may point out additional needs.

### Degree of Reusability

The actual benefit of recovery, examinations, and reuse will remain somewhat intangible until we have gained actual recovery experience. The REDSTONE and SATURN S-I recovery programs would have provided this start had they reached fruition. A program of this nature is needed in the near future, possibly in the form of subscale test vehicles, but preferably through recovery of operational vehicles most closely approaching expected future vehicles.

## Design For Reusability

Although the design of flight vehicles for reusability and long life has a strong background, rocket engines and related systems have been designed almost exclusively for one-time or short-time usage. A project has been proposed by MSFC, as a part of the FY 63 Launch Vehicle Technology Program, to explore the basic question: In what ways should the design and construction of rocket systems differ from present practice when reuse and extended operating life are intended?

With the combined contributions of studies, experimental work, and, hopefully, some operational recovery experience, the following can be accomplished:

(1) Reduce uncertainties in estimates as to recovery and reusability.

(2) Allow selections from alternative designs and procedures.

(3) Equip ourselves for rapid implementation of a reusable vehicle development at the time a decision is made to do so.