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NASA TECHNICAL MEMORANDUM

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SPACE SHUTTLE SOLID ROCKET BOOSTER RECOVERY SUBSYSTEM

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TECHNICAL MEMORANDUM

SPACE SHUTTLE SOLID ROCKET BOOSTER RECOVERY SUBSYSTEM

INTRODUCTION

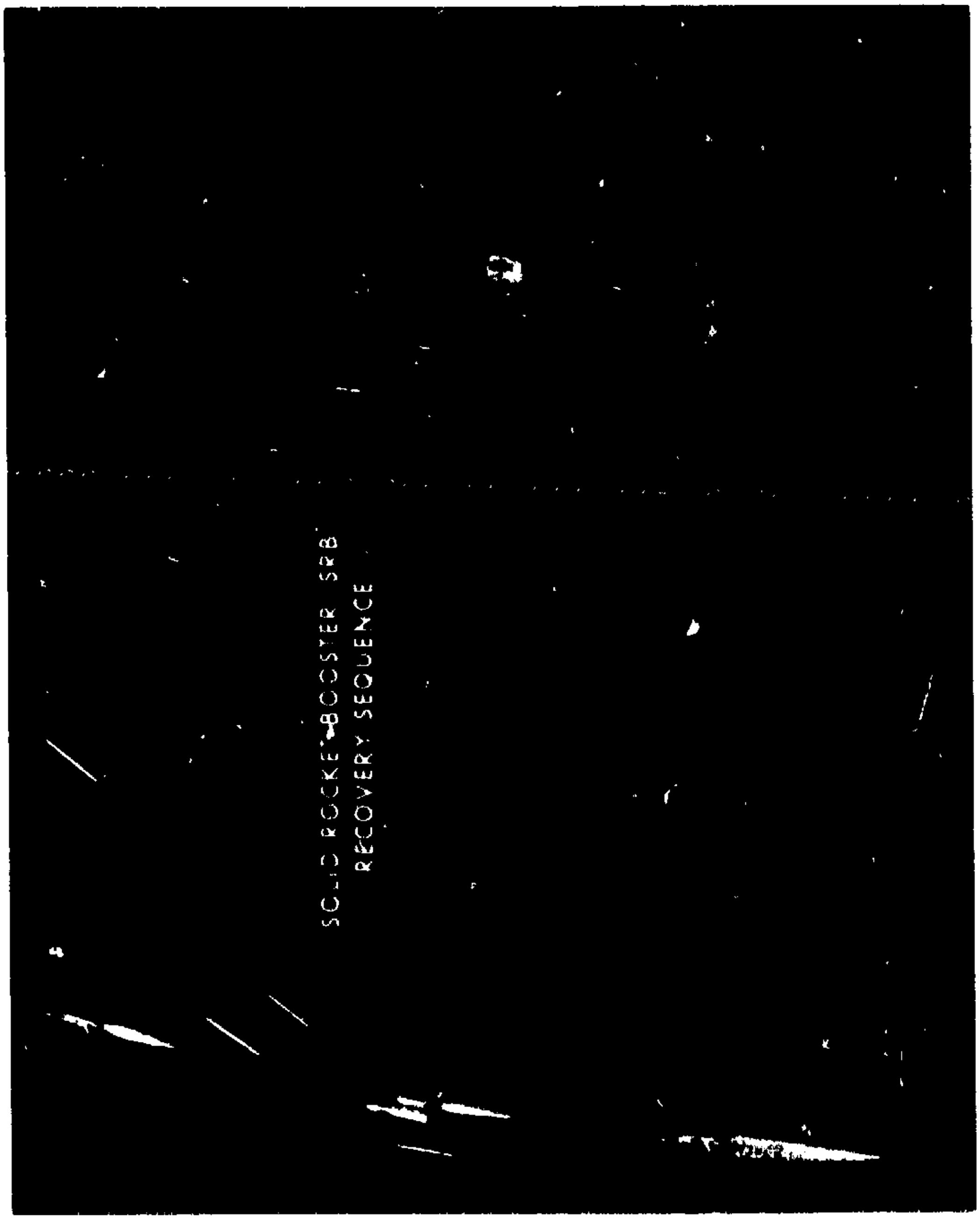
The Space Shuttle Transportation system is composed of three main elements: the orbiter; an external tank (ET), which contains propellant used by the orbiter's main engines; and two Solid Rocket Boosters (SRB's). The orbiter and the SRB's are reuseable, while the ET is discarded on each flight.

At liftoff, the two SRB motors and the orbiter's main engines fire simultaneously, to produce sufficient thrust to escape the Earth's gravitational pull. At approximately 150,000 ft, the two SRB's, their fuel expended, are ejected. Later in the launch sequence, the empty ET is also ejected. These two events allow the orbiter's main engines to push the orbiter into Earth orbit and accomplish its intended mission.

This report deals specifically with the recovery subsystem on the SRB's. The final SRB recovery sequence is shown in Figure 1.

TRADE STUDIES

Because the SRB structural design was to be complete before the Recovery Subsystem contract was let, numerous detailed trade studies were required to properly define the required structural interfaces and to arrive at the most economical and reliable final design for the SRB recovery subsystem. These trade studies were conducted in the 1973-1979 time period. Some of their results were the final determination of the SRB terminal velocity, the required number and size of main parachutes, the required size of the drogue parachute, the parachute reefing stages, the structure interface definition, deployment sequence, and the recovery subsystem weight. Two important results of these early trade studies were as follows: (1) It is economically advantageous to retrieve and refurbish the parachutes and the frustum structure since the SRB retrieval vessels will be in the vicinity during SRB retrieval operations; and (2) three main parachutes, one drogue parachute and one pilot parachute were determined to be the design that would give the greatest flexibility to changing requirements and, at the same time, minimize complexity, thereby lowering costs and increasing reliability.


SOLID ROCKET BOOSTER SRB
RECOVERY SEQUENCE

DESCRIPTION OF SYSTEM

The SRB Recovery System provides for the safe return of the spent SRB to Earth by decelerating the falling SRB case to an acceptable water impact velocity (85-90 fps). The floating SRB case can then be towed back to shore and refurbished for subsequent reuse.

The SRB Recovery System uses a two-stage baroswitch that is armed on ascent after the SRB's have separated from the orbiter/ET. This baroswitch fires the nose cap thrusters at 15,000 ft. The ejected nose cap deploys the 11.5-ft pilot parachute, which in turn deploys the 54-ft drogue parachute. The drogue parachute orients the SRB to a "tail first" attitude to enable the deployment of the three main 115 ft parachutes to take place. The three main parachutes slow the falling SRB to a terminal velocity of 85-90 ft per second.

The second stage of the baroswitch closes at 6500 ft and fires the linear shaped charge that severs the 146-in. diameter frustum from the SRB. The drogue parachute pulls the frustum away from the SRB, and this same action extracts the three main parachutes from the frustum and enables them to inflate to their first reefed stage. Both the drogue parachute and the three main parachutes disreef twice (drag area increases) to reach their final diameter. All parachutes are 20 degree conical ribbon construction.

The main parachutes are released from the SRB at water impact by the pyrotechnic firing of six separation nuts. This separation action deploys a 50-ft tow pendant which the retrieval vessel uses to tow the SRB case to shore.

The frustum has flotation that is sufficient to support its weight in water, as well as that of the drogue parachute. In addition, the frustum has a flashing light and a radio beacon to aid in its location and retrieval. The separated main parachutes have flotation bags attached to their canopies and sonar pingers are attached to the risers to assist in their location and retrieval.

RECOVERY SYSTEM PHYSICAL ARRANGEMENT

The Solid Rocket Booster Recovery System is located in the forward end of the SRB. The majority of the components are located in the nose cone (consists of nose cap and frustum) as shown in Figure 2. The main parachute separation nuts and the tow pendant are located on the forward ring of the forward skirt as shown by Figure 3.

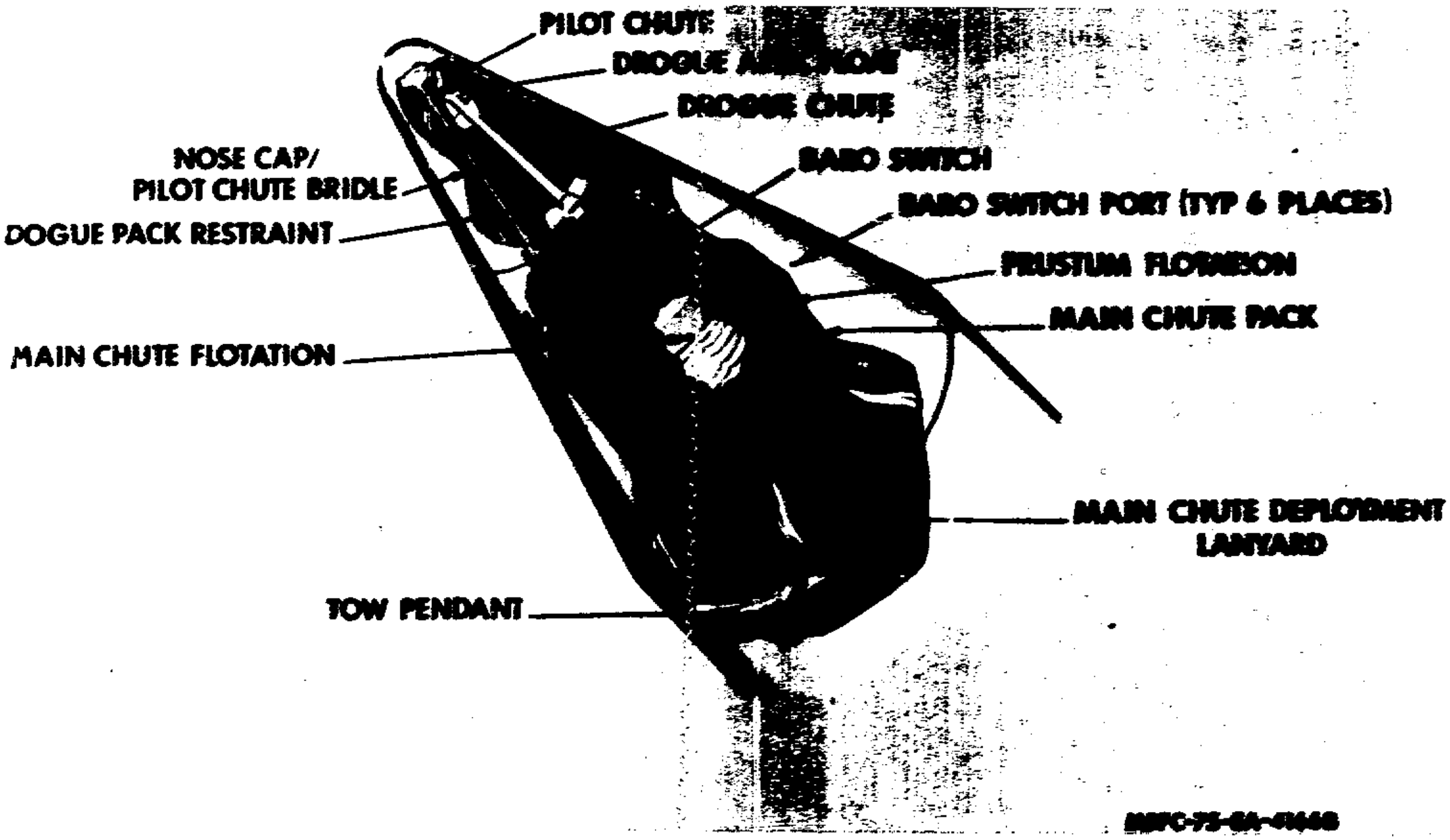


Figure 2. SRB Recovery System.

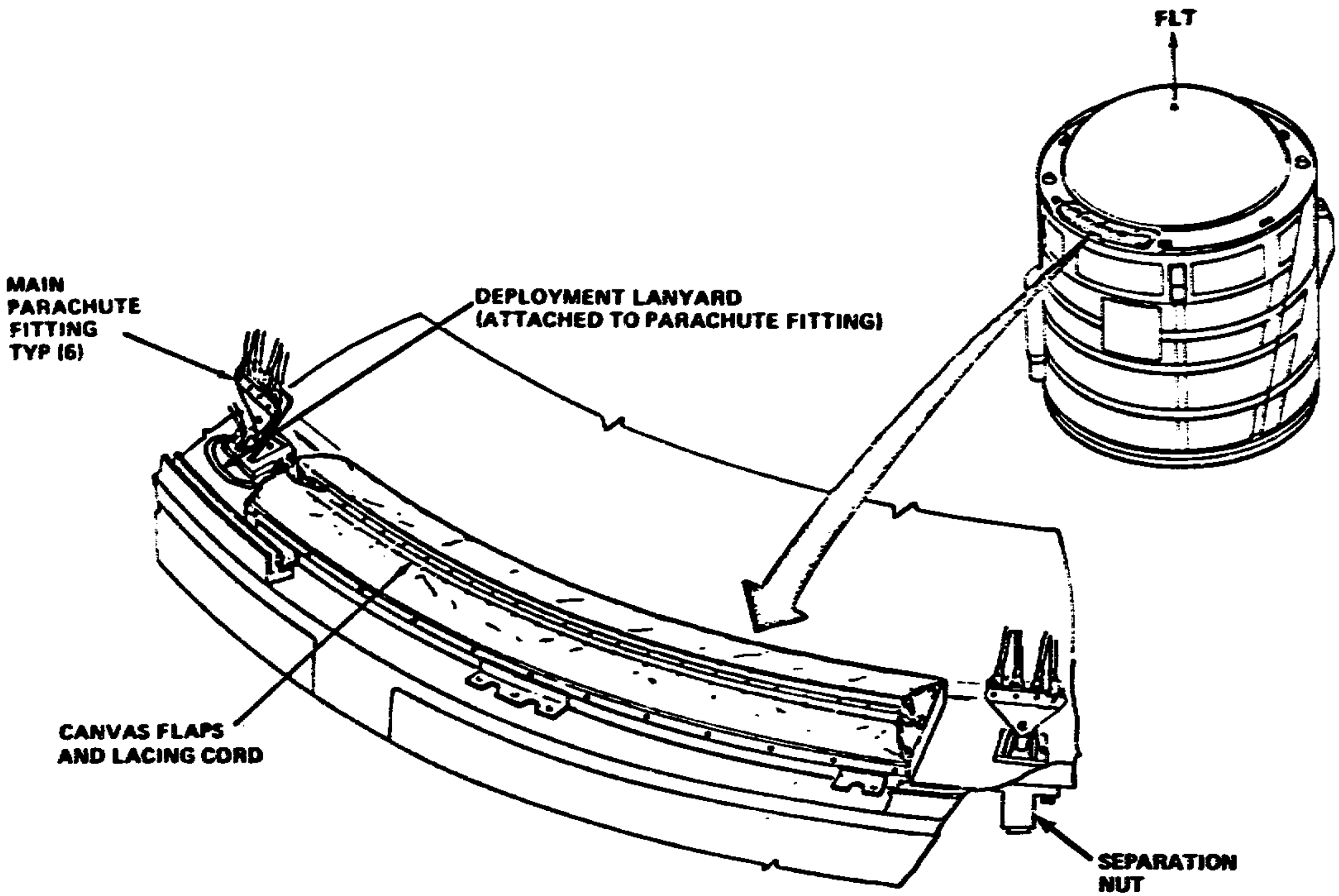


Figure 3. Main parachute separation nuts and tow pendant.

The pilot parachute pack is hand-tacked to the top of the drogue bag. These tacks break when the ejected nose cap pulls the pilot pack off the drogue bag. The drogue pack is held to the top of the frustum by six restraining straps. These six straps terminate into a common loop on the top of the drogue pack. This loop is severed by a reefing cutter approximately 0.5 sec after deployment of the pilot parachute. This cutting releases the drogue pack and enables the pilot parachute to deploy the drogue parachute. The main cluster (the three main parachutes) is contained in the frustum. A metallic isogrid assembly partitions off the three parachutes into separate compartments. The isogrid assembly provides the structural interface between the parachute packs and the frustum structure. It also provides support for the altitude switch assembly. The isogrid assembly is restrained at the top by 12 frustum attach fittings. The three isogrid divider panels are each restrained at the bottom by two monoball struts. The two riser assemblies extending from the bottom of each of the three main packs terminate at two of six attach fittings on the forward skirt. One riser assembly fitting for each parachute has a sonar beacon attached (for ocean retrieval), and one parachute riser assembly on each SRB is attached to the tow pendant deployment lanyard. When the mains are separated at SRB water impact, the stored energy in the riser/parachute system deploys the two pendant.

SUBSYSTEM TESTING

Testing the SRB Recovery system posed some unique problems. The 80-plus ton weight of the SRB is the largest weight ever recovered by parachute. Because this weight exceeds the load-carrying capability of all drop aircraft, it was decided to build an air drop test vehicle which would approximate one-third the weight of the SRB. This meant that the recovery system would be "Flight Certified" by a development test program and Qualified by the first six DDT&E flights of the Space Shuttle. A rather austeri budget limited the number of air drop tests to six. This meant that multiple objectives would have to be accomplished on each air drop. In addition, two rocket sled tests were conducted with the nose-cap/drogue-pilot section of the nose cone. These two sled tests were used to verify the nose cap deployment concept under the two extreme SRB reentry attitudes.

Figure 4 shows the planned test objectives for each testing phase. Figure 5 reflects the final test objectives and how they were accomplished. The final test objectives vary slightly from the original objectives. This was a result of a dramatic drogue failure on air drop No. 3. One of the two available air drop test vehicles that were used on this test was destroyed; therefore, it was necessary to "work around" the other test vehicle to insure that those tests posing the greatest risk be conducted last. This scheduling offered the best insurance that the remaining test vehicle would enable the Recovery System parachutes to be flight certified on schedule.

	Deployment Process		SRB Design Loads		Parachute Structure				Performance	
	BROADSIDE	SYSTEM FUNCTIONAL	DROGUE	MAIN	DROGUE VENT	DROGUE SKIRT	MAIN VENT	MAIN SKIRT	DROGUE DRAG	MAIN DRAG
DROP TEST 1		○	○						○	
2				○						○
3					○					
4							○			
5						○		○		
6			○							
SLED TEST 1	80°									
2	140°									

Figure 4. Planned test objectives matrix.

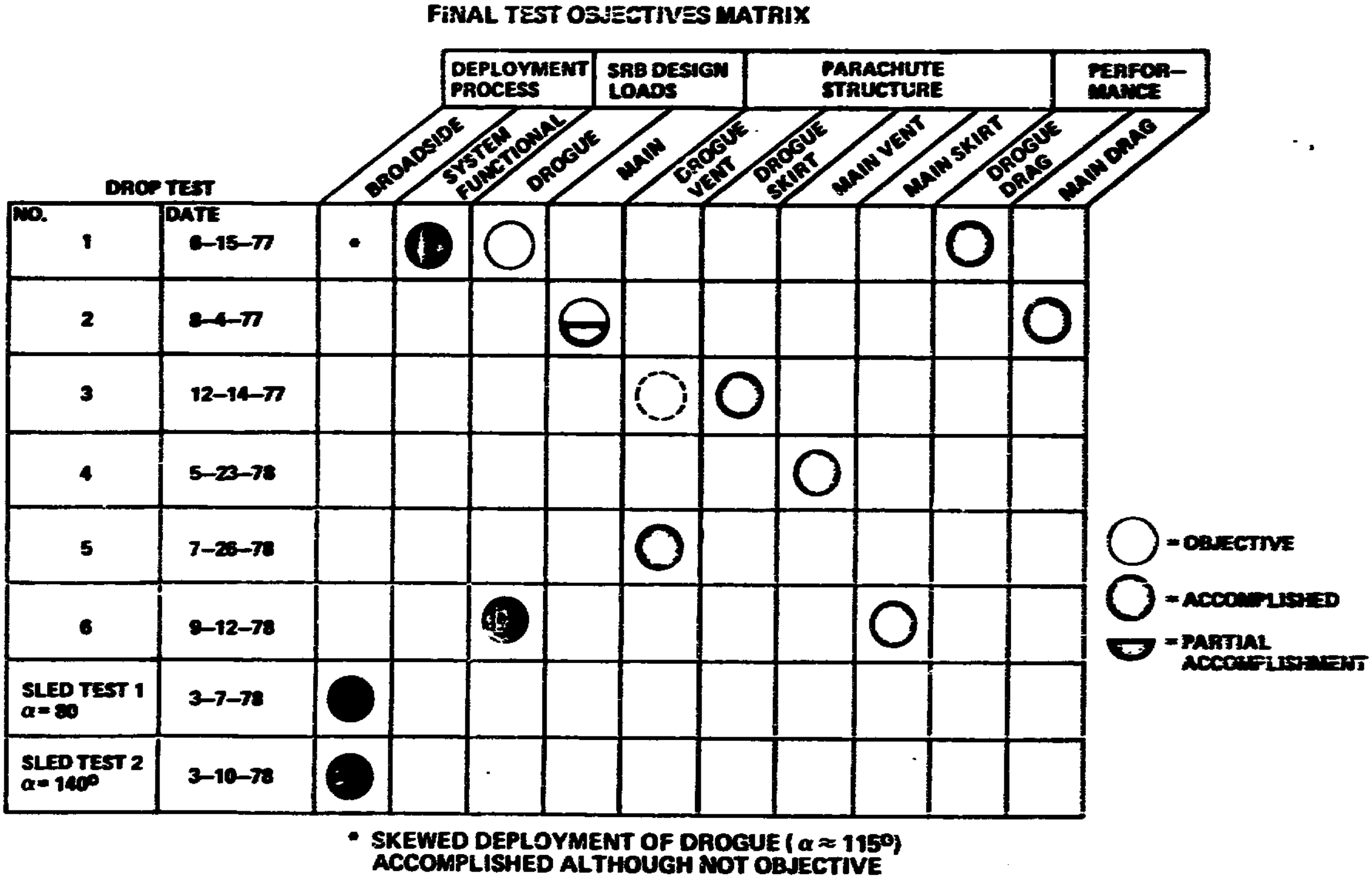


Figure 5. SRB decelerator subsystem major test program.

Because of the limited drop weight, it was impossible to get flight load profiles on the drogue and main parachutes. The air drop test program was a compromise of cost and time considerations. The parachutes were deployed in overtest dynamic air pressure conditions in an attempt to verify structural integrity of discrete areas in the canopy. The skirt area of the drogue parachute was structurally tested by accident on air drop No. 3 when the total canopy was loaded to failure. The main parachute canopy was not subjected to full design loads but was certified flight-worthy by analysis.

A typical air drop scenario was as follows: Pack the parachutes in the drop test vehicle; transport overland, by truck from El Centro, California to Edwards Air Force Base; load the drop test vehicle on the B-52G drop air craft; and perform final checkout tests. The B-52 then flies the drop test vehicle to the National Parachute Test Range at El Centro and drops the drop test vehicle from an altitude of 20,000 ft (Fig. 6). A timer actuated drogue gun fires a slug which deploys a 2-ft vane parachute. Three separation bolts fire, releasing the cover from the 8-ft ribbon extraction parachute. At a predetermined altitude, three separation nuts release the drop test nose cap. The extraction parachute provides the energy to deploy the flight type 11.5 ft ribbon pilot parachute. From this point on, the program is a flight deployment sequence; i.e., pilot deploys drogue, frustum is severed from drop test vehicle and drogue deploys mains, and the mains then lower the drop test vehicle to the ground. Figure 7 shows the RSS parachutes and the drop test vehicle.

The drop test vehicle was made strong enough to be reuseable. This provided a significant cost savings to the recovery system development program.

SUMMARY

The Space Shuttle Solid Rocket Booster Recovery Subsystem definition evolved from very detailed trade studies with firm guidelines regarding simplicity, low cost per flight, reuseability, and high reliability. The development of the recovery subsystem was unique in that the subsystem's impact on the SRB structural design (i.e., loads) had to be determined before any final detailed design or testing of the recovery system. Also, because of NASA budget cut-backs, the actual building and testing of the recovery system were delayed, and the development was compressed since the delivery dates were held the same. In addition, against the advice of all the known parachute "experts," the air drop test program was limited first to 13 air drops and finally cut to six because of budgetary constraints.

In spite of these tight constraints, the program progressed through design, development, fabrication, and delivery of flight hardware with a minimum of problems. This was achieved because of a great deal of personnel attention from a small in-house team and, to no small extent, because of the dedicated efforts of a competent and dedicated contractor.

The Space Shuttle Solid Rocket Booster Recovery Subsystem has completed all required testing and is certified flight worthy for the first shuttle flight. The flight components for STS-1 are now "on board" the first launch vehicle, and all flight hardware for STS-1 through STS-6 has arrived at Kennedy Space Center on or ahead of schedule and await assembly on their respective launch vehicles.

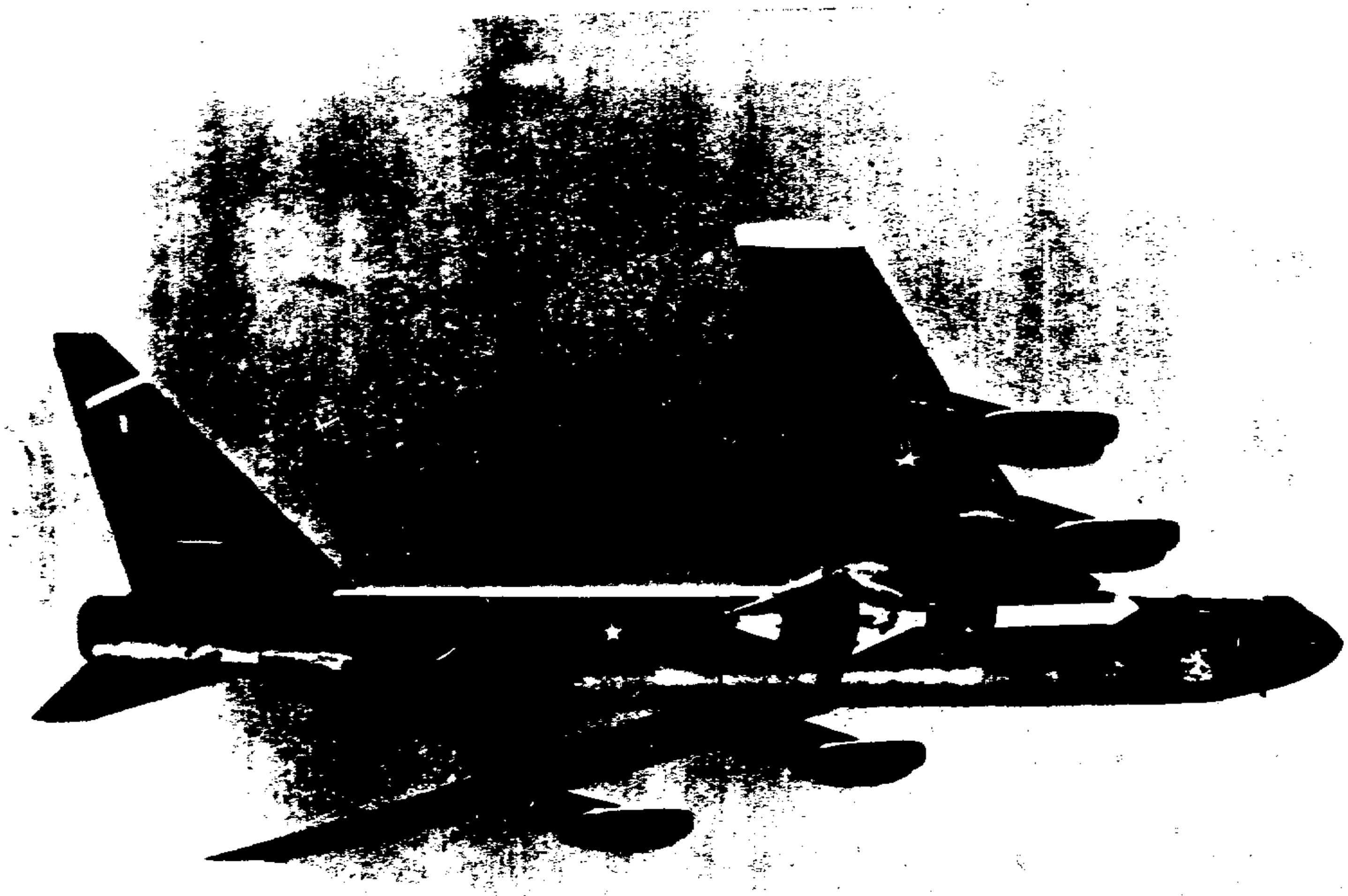


Figure 6. B52 drop aircraft with drop test vehicle.

Figure 7. Development air drop No. 4.

APPROVAL

SPACE SHUTTLE SOLID ROCKET BOOSTER RECOVERY SUBSYSTEM

By Roy E. Runkle

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

A. McCool

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