Payload Piggybacking Aboard Shuttle Solid Rocket Booster

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I. Introduction

RECENTLY, a concept known as the Shuttle Solid Rocket Booster-Piggyback Research Platform (SRB-PREP) has been analyzed. Becaused the SRB forward skirt compartment is largely an existing volume (with existing access) and the SRB-to-Orbiter payload exchange ratio[1] exceeds 11:1, it is possible to lift substantial scientific and engineering research payloads to high altitudes inside the Shuttle's large twin solid rockets. Two such Shuttle Solid Rocket Boosters are launched as a matter of course with each Shuttle mission. As depicted in Table 1, the SRB Piggyback Research Platform can offer a platform for research into variety of pure and applied scientific fields, such as atmospheric physics, ionospheric studies, cosmic ray science, and space instrument development. Additionally, by making routine research activities a part of many Shuttle launches, PREP will increase the efficiency of use of the space transportation system (STS).

The purpose of this report is to demonstrate the primary economic and performance attributes of the SRB-Piggyback Research Platform. SRB-PREP is compared to conventional sounding rockets in order to demonstrate its quantitative advantages and disadvantages with respect to these vehicles, in terms of flight performance, reliability, and repeatability. Other technical aspects of the PREP concept will also be addressed. Finally, the economic impacts of PREP on the STS are examined. In this regard, it is noted that no formal PREP cost or feasibility studies have yet been made by NASA.

II. Concept Definition

As depicted in Fig. 1, the SRB-PREP concept consists of a payload autonomous support system (PASS) mounted in the SRB forward skirt compartment. This existing available volume, which measures approximately 11 ft in height and 11 ft in diameter and is now used to structurally transfer launch loads, provides a space for SRB development flight instrumentation and assists in postlanding buoyancy maintenance. PREP payloads will have to adhere to the same access door clearance and flight safety requirements imposed on development flight instrumentation.

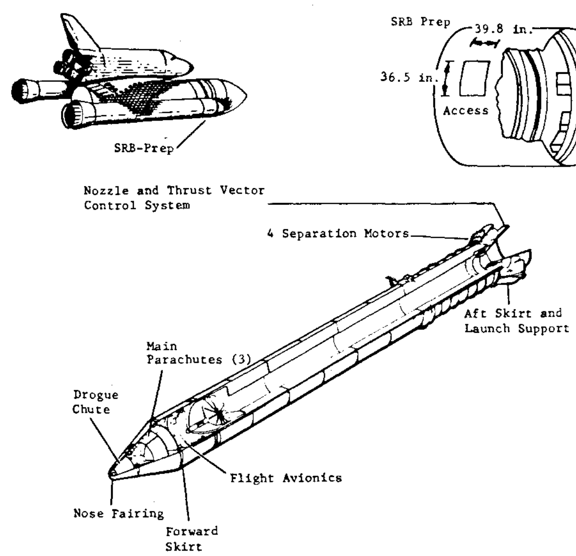
Configuration studies have demonstrated that SRB-PREP could most easily be integrated into the Shuttle solid rocket boosters if it supplies its own data-handling, power, and timing services. In this way, the PASS plus PREP experiment payload could avoid electrical and RF interfaces to the SRB, and require only structural mounting bracketry, hardpoints, and perhaps a high quality broad-bandpass quartz window for experiment viewing. A configuration such as this permits PREP payloads to be carried on those STS flights which retain excess payload-to-orbit margin, without introducing substantial scar-weight onto those flights which cannot accommodate piggyback payloads. Requirements studies indicate that two LR-40AH batteries, a Z80 microprocessor with internal clock, and a MARS 1400 airborne data recorder would provide sufficient performance and redundancy to support a variety of research programs. All of these components are space-flight qualified.

Consider now the technical capabilities of the SRB-PREP system. Table 2 provides a comparison of the flight environment and performance characteristics of PREP against two widely used sounding rockets: the Nike-Black Brandt and Taurus-Orion. Compared to these vehicles, SRB-PREP can be seen to exhibit a considerably more benign acceleration environment, higher anticipated launch rates, higher demonstrated reliability, and a four-times-lower launch cost per payload-pound.[3] Additionally, PREP's payload lifting performance is several times greater (particularly when recalling that the sounding rocket payload weights include allowance for recovery, telemetry, and attitude control systems). Similarly, PREP's available volumetric envelope is at least 35 times greater and much less constrained in terms of maximum allowable payload diameter. One concludes from these data that the SRB-PREP system could provide to payloads superior lift weight and volume performance capabilities than typical sounding rockets.

Now consider flight time and altitude performance comparisons between PREP and sounding rockets. Although sounding rockets often reach much higher altitudes (and therefore exhibit correspondingly longer flight durations than PREP), PREP apogees will in fact occur above over 99.99% of the atmospheric mass. If SRB outgassing after burnout is not too severe, both ultraviolet (UV) and Infrared sensors will be able to operate free of the atmospheric absorption ex-

Table 1 Sample SRB-PREP research potential

Meteorology/aeronomy	Plasma physics
Ozone chemistry	Chemical release
Stratospheric dynamics	Active pumping
Mesospheric sample return	Ionospheric studies
Other areas	
Cosmic ray/meteoric dust collection	
Astronomical studies	
Satellite overflight calibration	
Sensor development/qualification	



Dimensions, Weights Approximate	
Length	45.46 m (149.16 ft)
Diameter	3.70 m (12.16 ft)
Gross Weight	586,506 kg (1,293,004 lb)
Inert Weight	82,879 kg (182,714 lb)
Propellant Weight	503,627 kg (1,110,190 lb)
Thrust (Sea Level)	(2,900,000 lb)

Fig. 1 Space Shuttle SRB-PREP configuration.

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Table 2 Comparison of SRB-PREP to other high altitude platforms

Attribute	SRB-PREP	Nike-Black Brandt	Taurus-Orion
Research altitudes, km	50-80	100-350	70-250
Maximum payload weight[a]	3200 lb/SRB	970 lb	550 lb
Maximum payload volume	>1000 ft/SRB	27 ft	18 ft
Cost/payload, lb	\$110[b]	\$475	\$455
Usable flight time, s	150	440	480
Pointing capability	none	P/L provided	P/L provided
Maximum launch acceleration, *g*	2.5	19	25
Reliability (FY 82,83)[c]	1.00	0.94	0.93
Launch rate (FY 86)	30	8	10
Launch sites (FY 86)	2	4	4

[a]SRB-PREP payload weight limited here by 1% penalty on Orbiter design payload-to-orbit capability. [b]This is a pessimistic cost/lb assessment assuming Orbiter payload is displaced for PREP payload. As shown in the text, SRB launch is effectively zero if Shuttle payload capacity is volume limited. [c]Reliability data excludes developmental flights.

perienced by ground-based observatories and aircraft-based platforms.

It is important to note (see Fig. 2) that SRB's reach their maximum altitudes directly in the important Ozone layer—a height at which rockets spend little time as they continue upward. Because balloons and aircraft also cannot reach this altitude, little in-situ research has been performed in the Ozone layer. For this reason atmospheric researchers have recently characterized this region as the 'ignorosphere'.

The recognized advantages which sounding rockets enjoy over PREP are their accurate pointing capability and their variety of launch sites. Lack of postseparation pointing is perhaps the largest obstacle in the way of SRB-PREP meeting the requirements of many researchers. It is also worth noting that sounding rocket acoustics/vibration loads are somewhat lower than SRB loads.

Returning to Tables 1 and 2, we conclude that SRB-PREP offers a variety of research applications which are enhanced by the great payload weight and volume carrying capacity of the SRB and are fundamentally limited only by the unpointed nature of the rockets.

Turning now to ongoing engineering analysis issues, several areas of technical concern are discussed. First among these are the twin problems of SRB inflight stability and postflight floatability. Both of these are influenced by the incremental mass and center of gravity shift which would be incurred on SRB's equipped with PREP payloads and support structures. Preliminary analysis has shown that PREP payload weights of less than a ton (per SRB) will not significantly affect either current Shuttle-SRB stability or SRB floatability performance. This can be most easily understood in light of the fact that all STS solid rocket boosters now in use employ ballast in their forward skirts to maintain adequate flight stability. An equal exchange of forward skirts ballasts for useful payload would not change SRB dynamic stability or floatation characteristics.

Other difficulties which the SRB design forces on PREP design are at times the severe loads experienced on water impact as well as the possibility that salt water may be introduced into the forward skirt after landing. These problems should not be of great concern, however, because development flight instrumentation (i.e., sensors and avionics) has been successfully flown in the forward skirt on many SRB flights. Complications could also result from STS requirements to man-rate PREP experiments so that they could ride aboard the Shuttle system. Although it is worth noting here that the Get-Away-Special program has adequately addressed this problem for a wide variety of both simple and relatively complex Orbiter-based experiments over the past three years, care will have to be taken in this area if SRB-PREP comes to fruition.

III. Economic Feasibility

It is important to examine the relative costs of launching a pound of PREP payload onto a suborbital trajectory to the

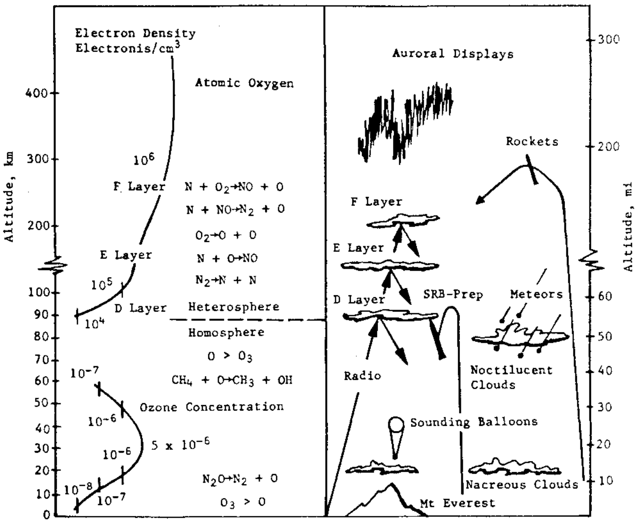

Fig. 2 The upper atmosphere displays many complex processes, some of which can only be assessed in-situ by SRB-PREP.

costs of launching a pound of payload onto a similar trajectory by sounding rockets. For this purpose, the Black-Brandt and Taurus-Orion are use for comparison. It is also important to assess the economic impact on the STS which results from exchanging STS orbital payloads for SRB-PREP suborbital payloads.

Consider first the cost to launch each pound of sounding rocket payload against the per-pound cost of launching a Shuttle-PREP payload. Taking the Black Brandt as a paradigm, the \$400,000 mission expense to launch a (heavy) 950-lb scientific payload results in a launch cost figure-of-merit near \$475/lb; similarly, the smaller Taurus-Orion vehicle results in a launch cost figure-of-merit near \$455/lb. Now consider the economics of PREP. By 1986, the cost to launch a pound of Shuttle payload into orbit will exceed \$1200/lb[4]; it must be remembered, however, that 11 lb of SRB-PREP payload can be substituted in exchange for each lb of Orbiter payload. Therefore, every 11 lb of PREP payload which displace a lb of revenue-producing STS payload should cost the STS about \$1200 of lost revenue. Taking the 11:1 exchange ratio into account, it can be seen that PREP payload launch costs should be in the neighborhood of \$110/lb, if revenue producing payloads must be sacrificed. Although we will demonstrate below that revenue producing payloads need not be sacrificed in exchange for PREP payloads, it can be seen that even under this pessimistic assumption, PREP is a far less expensive transportation system than the either Black Brandt or Taurus-Orion.

The impact on Shuttle launch performance and revenue structure resulting from the subsitution of PREP payloads for

Orbiter payload are now examined. Taking the FY85-FY86 timeframe as a representative sample of the Shuttle manifest,[5] we find that only 30% of the scheduled NASA STS flights are currently weight constrained and unable to carry additional payload into orbit. The other 70% are either volume constrained or exhibit weight-carrying capacity margins ranging from 1200 to 9600 lb. Because the Shuttle only suffers a 1-lb payload-to-orbit penalty for each 11 lb of additional SRB weight, it can be seen that substantial PREP payloads could be boosted without sacrificing required lift capability.

The 55% of the FY85-FY86 Shuttle flights which are volume constrained cannot, by definition, garner additional revenue from satellites or equipment placed in the Orbiter's payload bay since there is no place to put them. Therefore any excess weight carrying capacity on such flights is not available for sale as a revenue-producing commodity for orbital transportation. SRB-PREP missions could be conducted on such flights without reducing Orbiter payload weight to orbit (since excess lift capability is present). On this basis, we conclude that the majority of the FY85-FY86 Shuttle flights (those which are volume limited/weight capable) could lift PREP payloads without sacrificing revenue producing Orbiter payloads. The net effect of this important result is that launch costs associated with such PREP flights should be largely limited to the cost of integration the PREP payload into its SRB,[6] and that the STS system could be operated at higher performance efficiency without need of revenue loss if PREP payloads were carried.

IV. Summary

SRB-PREP, though not without drawbacks, is technically attractive. Chief among its deficiencies is a lack of stabilized pointing. Among PREP's greatest assets are its capability to lift large volume, heavy-weight payloads above the obscuring lower atmosphere (and directly into the important ozone layer), where they have access to a high-vacuum environment. PREP can lift several times the payload weight and many times the payload volume of sounding rockets. Further, PREP offers the capability of sustaining higher and higher flight rates as a direct by-product of its intimate association with the Space Shuttle. As demonstrated in this Note, the excess boost capability which most Shuttle flights exhibit (due to full payload bay volume utilization), indicates that SRB-PREP payloads could be launched at zero cost/lb revenue loss to the Space Transportation System.

References

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