the launch facilities, and logistics and support required to place payloads in orbit. It should also include estimates of the demand expected for such a booster, as future demand would have a marked effect on program life cycle costs. Such a study might also include consideration of recovery and reuse. For example, the Naval Research Laboratory is now exploring a reusable sea-launched booster that would use a pressurized liquid propellant. A Big Dumb Booster concept study might cost between $5 and $10 million, depending on its scope.

ALTERNATIVE APPROACHES

If Congress decides that the Big Dumb Booster requires more focused evaluation, it could task NASA or the Air Force to carry out such studies. For example, the joint Air Force/NASA Advanced Launch System (ALS) study and NASA's Liquid Rocket Booster (LRB) study are already examining issues and technology closely related to the Big Dumb Booster Concept.

Congress could:

1) Task NASA to investigate the Big Dumb Booster concept as an extension of its Liquid Rocket Booster (LRB) Study. NASA's Marshall Space Flight Center is studying the use of liquid fuel boosters to replace the solid rocket boosters on the Shuttle, and is investigating pressure-fed engines. Although the NASA studies show that pump-fed boosters are the clear choice for the Shuttle LRBs, they do not rule out using pressure-fed propulsion systems as the the basis for a new, low-cost expendable "Big Dumb" booster. Adding such tasks to the LRB studies, to which NASA has already committed about $14 million, would require some redirection of the program and additional funding of $2 to $5 million for a detailed concept study, based on the Shuttle LRB. Validating some of the hardware necessary for a launch vehicle, based on a criterion of minimum-cost, could cost much more.

2) Task the Air Force and NASA to investigate the Big Dumb Booster concept as part of the Advanced Launch System (ALS) program. This program is studying systems that contain features of Big Dumb Booster design, such as reduced complexity and design for minimum cost. ALS program managers are examining the entire launch system in order

to achieve cost reductions of a factor of ten in recurring launch costs. If this goal remains the priority, ALS would be the first U.S. launch vehicle designed for minimum cost.[12] Although it is not specifically investigating such concepts as Pressure-fed boosters, the ALS program does provide the systems approach that would be needed to carry out an adequate Big Dumb Booster study. In fact, some ALS contractors' proposals contain features of earlier Big Dumb Booster designs.[13] However, as noted for the previous option, such a course of action would require additional funding for the ALS program.

(3) Fund the Air Force and NASA to investigate technologies related to the Big Dumb Booster concept in other programs. For example, the NASA Civil Space Technology Initiative Booster Technology program is investigating combustion issues related to performance, stability, heat transfer, cooling, and combustor fabrication techniques. This program hopes to resolve some of the problems related to low pressure combustion in very large combustors, as well as tank pressurization concepts for minimizing weight.[14] It might not prove cost-effective for boosters designed to carry large cargos, but might be appropriate for smaller boosters. Various programs within the Air Force and NASA are investigating technologies related to Big Dumb Booster.

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12 One reviewer noted that the Congressional restriction requiring the ALS program to pursue a cost goal of $300 per pound in *recurring costs*, may unnecessarily limit the ALS program. Designing for minimum *life cycle cost could* lead to a less costly launch system.

13 For example, as part of the Phase I ALS studies, McDonnell Douglas investigated a modern version of a Big Dumb Booster, in which the boosters strapped on to the core stage used a pressure-fed engine and liquid hydrogen/liquid oxygen as fuel. The design used low-pressure ratio boost pumps to offset the high pressures normally associated with pressure-fed designs, which also reduced the weight penalty incurred with pressurized tanks.

14 Program managers hope to assemble a pressure-fed liquid booster test bed that would integrate the combustor and gas generator hardware from the technology program with oxidizer and fuel tankage and feed systems, in order to assess and model feed system and combustion system dynamic interactions. This technology base would be applicable to Big Dumb Booster applications, as well as Shuttle LRBs. NASA OAST Program Office, November 1987.

(4) Conduct an independent competition between proponents of the Big Dumb Booster and proponents of alternative launch system designs. The Government could fund two contractors, one a proponent of the Big Dumb Booster, the other a proponent of a more traditional approach, to design an optimized launch system according to the same mission rules (i.e., payload capability, flight rate, and destination). An independent organization, such as the National Academy of Engineering could serve as a study monitor. Although this approach does not guarantee resolution of the debate, it would give proponents of the Big Dumb Booster concept an opportunity to be judged on an equal footing with the traditional design approach.

(5) Remove barriers to adoption of low-cost launch strategies by commercial launch firms. The development of reduced-cost commercially-developed launch systems incorporating elements of the Big Dumb Booster strategy could be achieved by adopting purchase criteria based entirely on performance, i.e., delivery of a specified payload to a specified orbit. Using this strategy would encourage the private sector to arrive at competitive designs and prices to meet government performance specifications. The Reagan Administration Space Policy of February 1988 moved a step in this direction by mandating purchase of launch services for civilian payloads and encouraging such purchases for national security payloads.[15]

Several entrepreneurial launch vehicle firms[16] are developing new launch systems for small or medium-size payloads. These projects present opportunities to incorporate low-cost approaches at little cost to the Government. However, launch firms still complain that the cost of continued excessive government oversight unnecessarily raises the costs of launch services. They argue that government oversight far exceeds the actual risk of a failed mission. The government role, vital during the development and demonstration phases of a new, high technology, becomes counterproductive when the basic technology

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15 The White House, Office of the Press Secretary, "The President's Space Policy and Commercial Space Initiative to Begin the Next Century," *Fact Sheet,* Feb. 11, 1988, p. 3.

16 For example, American Rocket Company, Orbital Sciences Corporation, and Space Services, Inc.

has been successfully acquired, and is needed for ongoing operations. Then, matters of cost and reliability become paramount. However, Government users may fear that boosters not built to government specifications might be too unreliable. Dozens of successful launches would be required to prove high reliability with high statistical confidence. For example, if launch vehicle reliability were actually 95 percent, about 60 launch attempts would be needed to provide 90 percent statistical confidence in a vehicle reliability of at least 90 percent.

(6) Provide no extra funding to investigate Big Dumb Booster. Congress could simply trust that those in charge of making the technical decisions within the Air Force and NASA are carrying out their analytical duties adequately. Proponents of such an option point out that both Air Force and NASA already face extremely strong pressures to reduce launch costs, and argue that directing these organizations to focus specific attention on the Big Dumb Booster would be wasteful micromanagement. The Big Dumb Booster is only one of several means to achieve low-cost access to space. Emphasizing this approach at the expense of others might waste valuable resources.