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The second stage would be powered by liquid hydrogen and liquid oxygen. Seven SSME-type engines are envisaged, giving a total thrust of nearly 1,490 tonnes. This stage would take the payload to a 500km-high circular orbit. Recovery would be initiated by the. stage's two manoeuvr-ing engines, and the craft would be protected during re-entry by ablative insulation. A special feature of the stage is a protruding aft skirt panel capable of providing some directional aerodynamic control. A braking para-chute would be deployed during the descent, later followed by three large canopies. The stage would come down on land, and three of the craft's engines would be fired to soften the impact.
The payload shroud attached to the second stage could be tailored to payloads ranging in density from 20 to 100kg/m3

. The denser the payload the better, since a small
shroud means less weight. Another advantage of dense payloads is that the shroud, which is not recovered, is cheaper if it is smaller. The launch mass of the two-stage Class 4 launcher would be nearly 6,500 tonnes.
A Boeing study of launch rates possible with this type of cargo ship suggests 750 flights per year, almost unbelievable by today's standards. With this rate and dense payloads, the estimated cost per launch is $9 million or just over $30/kg. A rate of only 20 flights per

The combination below left is a Space Shuttle derivative designed to
carry 90 tonnes of cargo into low Earth orbit. The two conventional
Solid Rocket Boosters have been replaced by liquid-propellant versions.
The cylindrical cargo container and engine pod have taken the place
of the Orbiter. The arrangement below right (not to the same scale) depicts a two-stage reusable launcher designed to orbit 230-270 tonnes. The protruding aft skirt of the second stage aids directional control. Different lengths of shroud would be used to cope with variations in payload density

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year would probably result in a launch cost of $45/kg, which is still extremely attractive. The annual payload target of 125,000 tonnes would be possible with the Class 4 launcher provided that high load factors and launch rates were achieved.
The development cost of such a system is not as high as one would imagine. Some 750 flights a year over 15 years would cost a total of about $11,000 million in development and production, less than twice the cost of the present Space Shuttle.
Perhaps the most exotic of the heavy-lift launcher proposals is the single-stage-to-orbit vehicle. Almost all rockets to date have had more than one stage, since efficiency increases with the number of stages until the extra weight and complexity impose a limit. The single-stage-to-orbit launcher succeeds by brute force, trading performance for simplicity and reusability. One study proposes a craft capable of orbiting 230 tonnes. The development costs of the single-stage launcher are likely to be high, and the large annual totals of flights needed to make this idea economically attractive are unlikely to arise this century.
The Class 5 (300-450 tonnes payload) launcher has not been studied in any great detail. This level of performance is unlikely to be needed for years to come, and current interest is concentrated on the Shuttle derivatives.

Although the Shuttle has still to make its first flight, currently set for late this year or early 1980, the USAF has already expressed a need for increased payload. The required improvement is not large and can probably be achieved by modifying the SRBs and raising SSME chamber pressure. But once the Shuttle is operational, it will only be a matter of time before more payload capacity is required. Derivatives, particularly a conventional Shuttle with liquid-propellant boosters, are attractive because they do not require vast sums of money to develop. Q

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20 kg/m3
PAYLOAD
SHROUD

100 kg/m3
PAYLOAD
SHROUD

STAGE 2

STAGE 1

100 200 ft