PRICING POLICIES FOR THE SPACE SHUTTLE

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I. INTRODUCTION*

In the early 1980s, the National Aeronautics and Space Agency's present non-recoverable launch vehicle program will largely be replaced by the recoverable space shuttle. The shuttle will carry a wide range of cargoes--weather and reconnaissance satellites, synchronous orbit boosters, space laboratories, space telescopes, perhaps small manufacturing plants--of varying sizes and weights up to a maximum of 32-1/2 tons, for a variety of users--other U.S. government agencies, private domestic businesses, foreign businesses, and foreign governments. How should prices be set for this range of uses and users?

Our aim in this paper is to consider the economic principles germane to the formulation and evaluation of alternative pricing policies for the space shuttle. Toward this end, we formulate several alternative policy options, and compare their advantages and disadvantages. We try to provide a decisionmaker's guide to the economic theory needed for analyzing and comparing alternative pricing policies, and thereby to suggest a way of thinking about pricing policy issues facing the space shuttle.** Economics has important and useful principles relevant to this matter. However, in this, as in many policy domains, economic considerations do *not* lead to an unequivocal conclusion, invariant with respect to non-economic aspects of the matter.

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*A preliminary and abbreviated version of this paper was presented at the International Astronautical Federation's XII Congress in Anaheim, California, October 15, 1976.

**The authors' principal contact with the space shuttle program occurred in connection with an earlier study we did for NASA, dealing with pricing and recoupment policies for commercially-useful technology resulting from NASA programs. (*Pricing and Recoupment Policies for Commercially-Useful Technology Resulting from NASA Programs*, C. Wolf, Jr., W. R. Harris, R. E. Klitgaard, J. R. Nelson, and J. P. Stein, R-1671-NASA, January 1975. See also R. E. Klitgaard, *The Pricing of Spinoffs from Space*, The Rand Corporation, P-5606, February 1976.) In that study we considered the pricing policy options for NASA's launch vehicle program, and acquired some familiarity with the space shuttle program as it stood at that time. In the following observations, we will be drawing on this earlier study.

II. COMPLEXITY OF THE PROBLEM

The complexity of the choice among alternative policies for pricing goods and services produced from government programs is suggested by: (a) the confusing formulation of the original User Charges Statute of 1951;* and (b) the conflicting implications of the conventional wisdom and common-sense clichés that surround the matter.

The User Charges Statute declared that whenever a federal agency confers a benefit on, or performs a service for, an identifiable person or group, the provision of such service or the conferring of such benefit shall be "self-sustaining to the full extent possible." The head of each federal agency was authorized to prescribe *fair* and *equitable* fees, charges or prices, taking into consideration: (1) the direct and indirect cost to the government; (2) the value to the recipients; (3) the public policy or interest served; and (4) any other "pertinent facts." Amounts collected were to be paid to the Treasury as miscellaneous receipts.**

One does not have to think very hard about these four considerations to realize they can lead in different and conflicting directions. For example, cost to the government may be low while value to the recipient is high; the public interest (e.g., in advancing new technology, or conferring benefits on particular foreign countries), may be substantial or nil or even negative, respectively. In an analytic sense, the result is a policy maze rather than a policy direction, and this even without going into the question of "other pertinent facts!"

When one turns to conventional wisdom and common-sense clichés, the picture is equally confusing. On the one hand there is the view that "he who benefits should pay." Yet government agencies in general, and NASA

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*See 31 USC 483a or 5 USC 140.

**Although NASA is not, strictly speaking, legally bound by the User Charges Statute by virtue of its own independent enabling legislation, the statute still exerts an indirect effect. NASA's general pricing policies, and the pricing of space shuttle services in particular, depend on policy decisions by the federal government, and these in turn are influenced by the background and precedents of the 1951 statute.

in particular, are urged "to promote technological progress," which might conflict with making beneficiaries pay. Policymakers are also admonished "to cover your costs," to try "to make money" and to be more "businesslike," to "be fair to taxpayers and reduce the tax burden," and to make foreign users "pay their fair share."

In order to clarify this confusing background, it is worthwhile to distinguish between two sets of criteria for evaluating alternative pricing policies: those relating to *efficiency*, and those relating to *distribution* or equity.

Efficiency criteria evaluate alternatives from the standpoint of their contribution to resource productivity and to the national product. In general, for resources to be allocated and utilized efficiently, the price of a good or service must equal the cost of providing the *last* or "marginal" unit of that good or service. If, for example, price exceeds marginal cost, the national product will, in general, be raised by increasing utilization and output of the service or good, while if price is less than marginal cost, the national product will generally be raised by decreased utilization and output, and a transfer of the saved resources to other uses.

Equity or distributional criteria evaluate alternatives from the standpoint of which particular individuals, groups, or sectors would benefit and which would pay. Distributional considerations are also reflected in the specific objectives of individual NASA programs and projects such as the space shuttle, as well as in the objectives of NASA as an agency, or of the Executive Branch or the Legislative Branch of the government. For example, NASA's objectives may include (a) furthering technological collaboration with foreign countries, (b) demonstrating to Congress the validity of agency claims that technological spinoffs from NASA programs are highly valued by the private sector, or (c) a desire to maintain employment levels at the agency's facilities. Each of these examples reflects concern for the benefits received by, or the costs imposed on, a particular group or sector. It is also worth noting that among the distributional considerations, the goals of primary concern to NASA may or may not be the same as the primary goals of other parts of the government.

It is important to distinguish between efficiency and distributional considerations because each pricing policy may entail different tradeoffs between them. A policy that contributes most to the efficient use of resources may not be the policy whose distributional consequences are preferred, and vice versa.

III. ALTERNATIVE PRICING POLICIES

Policies for pricing commercially-useful systems resulting from government programs consist of four principal options:

1. Marginal cost pricing, in which price is set equal to the cost of providing an extra unit of the specified good or service. (The distinction between marginal cost and what NASA, in pricing launch-vehicle services, has called "identifiable additional cost" will be discussed later.)
2. Average cost pricing, in which price is set equal to the total cost of producing the specified product or service divided by the number of units produced. (The distinction between average cost pricing and what is commonly referred to by NASA as "full cost" pricing will be discussed later.)
3. Profit-maximum (or "monopoly") pricing, in which price is set so as to maximize the difference between total receipts and total costs;* and
4. Multipart pricing, in which more than one price is charged for different units of the specified good or service, or to different users.

Marginal and average costs depend on the time horizon used for analysis and the unit of sale. These issues will be discussed more fully in Section IV. Briefly, marginal cost in the short run (defined as the shortest time period over which budget allocations are generally made, say, one year), is the cost of adding an extra shuttle flight to the year's schedule. Short-run marginal cost (SRMC) might include fuel and labor costs and added depreciation on equipment and facilities. Marginal cost includes no fixed cost and only that part of variable costs related to producing the extra unit.

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*Monopoly pricing maximizes profits given the constraint that only one price can be charged to all buyers. See below, p. 9ff, for a discussion of profit maximizing through multipart pricing.

As the time period is lengthened, some fixed items become variable, and marginal cost is larger. Over a long enough time period it may be possible to expand the capacity of the entire shuttle program so as to be able to launch one more launch per year than was previously possible. Long-run marginal cost (LRMC) would then include a portion of the added facilities and expenditures associated with the expanded capacity, and any associated R&D, in addition to fuel, labor and depreciation costs. So marginal cost is generally larger the longer is the planning horizon.

Similarly, average cost is larger the longer is the planning horizon. Average cost includes fixed and variable costs averaged over a specified time period. In the short run, annually fixed costs include administrative and overhead costs at shuttle ground support facilities. In the long run other fixed costs might be incurred (R&D and capacity expansion) and these would make long-run average cost (LRAC) greater than short-run average cost (SRAC). Also, marginal and average costs look to the future, so prior or "sunk" costs are not included. However, marginal and average costs do include future maintenance and replacement costs of previously purchased fixed items, to the extent these are increased by a marginal or average launch. Since prices must be set *ex ante*, marginal cost pricing can only strive to predict this component of marginal cost.

The marginal cost of an extra kilogram attached to an already scheduled launch with unutilized capacity will generally be much smaller than the per kilogram marginal cost of an entire launch, or series of launches. Ideally the smallest possible unit is appropriate if marginal cost pricing is to allocate resources efficiently. Otherwise, some launches would go with unutilized capacity while users were willing to pay the marginal cost for that capacity. In practice, the marginal cost of adding an extra kilogram to an already scheduled launch may be negligible, leading to an unacceptable pricing policy. The ideal and the practical may be balanced by making the sales unit depend on the production decision under consideration. Generally, this decision concerns the launching of a marginal flight, in which case the shuttle flight is the appropriate unit, as will be assumed in this paper.

The first three pricing options are illustrated in Fig. 1. They are all "single-part" options in that only one price is charged and all users pay the same price. Assuming the capacity of the shuttle program is not at issue, the appropriate curves for pricing shuttle flights are the short-run marginal and average cost curves, drawn in the figure. The aggregate annual demand curve, AB, shows how many flights all users will buy at different prices, and MR is the marginal or extra revenue resulting from selling additional units. The following discussion assumes that the shuttle program merely supplies shuttle services, but does not represent NASA as a demander of shuttle services. In Fig. 1, SRMC and SRAC describe the supply conditions. The demand schedule facing the shuttle program aggregates NASA's demand for shuttle services with that of other U.S. government agencies, the U.S. private sector, and foreign governmental and non-governmental sectors.

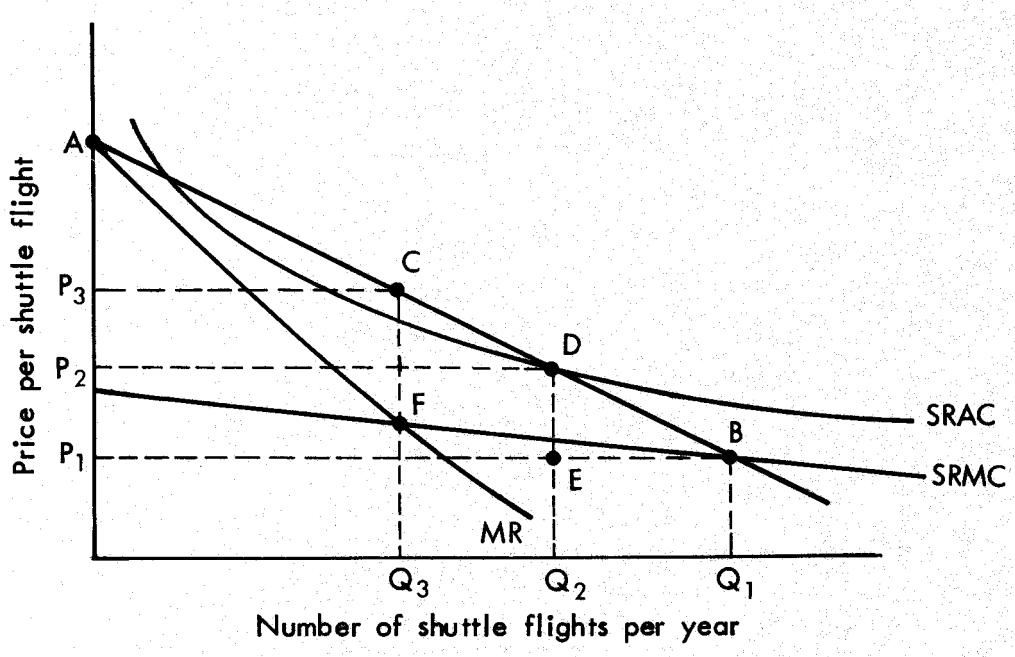

Fig. 1 — Single-part pricing policies: effects on output and costs

SRAC declines with the annual number of shuttle flights since the annual fixed cost of maintaining and administering shuttle support facilities is large relative to the SRMC of a single flight. (LRAC, not shown in the figure, is a larger but also declining function of the number of launches.) SRMC is drawn as fairly constant but slightly decreasing, on the assumption that most short-run variable costs (for fuel and labor) are similar for each flight but that some variable costs (e.g., the purchase of non-recoverable take-off boosters) decrease with scale. (LRMC is also probably a declining function of the annual number of flights since the designed capacity of the entire shuttle program could probably be expanded at a declining cost per unit of additional capacity. Similarly, the shuttle program is an expansion upon the non-recoverable launch vehicle program, and is reducing marginal launch cost.)

As illustrated in Fig. 1, marginal cost pricing leads to price P_1 and output Q_1, while average cost pricing leads to price P_2 and output Q_2, and profit-maximum pricing (equating marginal cost with marginal revenue) leads to price P_3 and output Q_3. Under the supply and demand conditions reflected in Fig. 1, average cost pricing and profit-maximum pricing result in output levels that are less than optimal (that is, inefficient), in the sense that additional units of output would add more to total national product than they would cost to produce.*

In an enterprise characterized by declining average costs, such as the space shuttle, marginal cost is below average cost at all reasonable levels of output. In this case, marginal cost pricing does not cover total costs, and there is a deficit. In Fig. 1, this deficit is equal to the difference between average and marginal cost times the number of shuttle flights.

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*If the demand curve were assumed to be completely unresponsive to price, which seems unlikely, and hence AB became a vertical line rather than a negatively sloped curve as shown in Fig. 1, output would be the same under all pricing rules. In this case, moving from marginal cost pricing to average cost pricing or to profit-maximum pricing would simply raise prices and thereby redistribute real income from users of the space shuttle to the general taxpayer, or to the government, without affecting the efficient allocation of resources.

We can assume that the demand schedule lies above the average cost schedule for some levels of output, as in Fig. 1.* Under these circumstances, there will be two principal ways to eliminate such a program deficit using single-part pricing: marginal cost pricing combined with government subsidy, and average cost pricing. (There are also intermediate solutions, with part of the deficit covered by a subsidy and the remainder covered by pricing between marginal and average costs.) Generally, profit-maximum pricing can be used to turn the deficit into a net surplus.** However, higher priced shuttle services would increase the cost of other government programs that used the shuttle.

Multipart pricing can be used to reduce or eliminate the deficit or turn it into a surplus while still efficiently pricing marginal launches at marginal cost to all or some users. In contrast to the pricing policies illustrated in Fig. 1, which involve charging a single price to all users, multipart pricing is illustrated in Fig. 2. AB depicts the aggregate demand curve, and SRMC depicts the short-run marginal cost curve, both as in Fig. 1. Three variants of multipart pricing are illustrated, having in common that more than a single price is charged for different units of the product or service. The three variants are: (a) perfect price discimination; (b) entry fees; and (c) market segmentation.

Perfect price discrimination is possible when each shuttle flight can be priced and sold separately. It must be impossible for one purchaser of shuttle services to resell those services to another user in a secondary market, otherwise separate prices for identical shuttle services would not be enforceable. In Fig. 2, output q_1 is sold at price p_1, output $(q_2 - q_1)$ is sold at price p_2, and so on for the subsequent outputs

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*If this assumption is not warranted, no single-part pricing scheme can eliminate the deficit. In this case, the efficient output level is zero unless externalities associated with the program make social demand greater than market demand.

**If fixed costs are high enough and demand is low enough, there may be no point at which the demand curve intersects the average cost curve. In such a case average cost pricing would be impossible and profit-maximum pricing would merely minimize the deficit. This paper assumes that average cost pricing is possible, as in Fig. 1. In practice, the actual demand situation should be investigated closely.

and prices. Each buyer is offered marginal flights at marginal cost p_6, so resources are allocated efficiently. At the same time, total payments approximate the area under the aggregate demand curve (the area $OABq_6$), so gross and net revenues are maximized. If this policy were successfully applied, the shuttle program would realize a surplus, assuming the demand and cost conditions shown in Fig. 2.*

Under entry fee pricing, all units are sold at the marginal cost, p_6 in Fig. 2, but each purchaser is required to pay an entry fee to gain access to the market. In principle, a separate entry fee would be determined for each purchaser, designed to be as high as possible without forcing him to withdraw from the market. To illustrate, the aggregate demand curve in Fig. 2 has been arbitrarily divided into two component demand curves, D_1 = DG and D_2 = AEH. Suppose these are the only two users of shuttle services. Marginal cost pricing would lead to p_6G ($=q_2$) flights for the first user and p_6H ($=q_4$) flights for the second user, a total of q_6 flights. The maximum entry fee that could be charged to each user would equal the area below the purchaser's demand curve and above the marginal cost price: that is, area DGp_6 for the first user and area $AEHp_6$ for the second user. Total entry fee collections would be the sum of the individual entry fees, equal to the corresponding area ABp_6 in the aggregate demand curve for all consumers of the service. Each purchaser, once having paid the entry fee, would have an incentive to continue buying additional units because all units would be priced at the marginal cost of the last unit purchased, thereby contributing to efficient allocation of resources.**

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*The perfect price discrimination solution could be achieved, bargaining and bluffing conditions aside, by determining the efficient number of shuttle flights per year, p_6, and then auctioning off this shuttle space at prices starting at p_1 and going down to marginal cost, p_6.

**Two-part pricing entails a variation of entry fee pricing. The first q units are sold to a particular buyer at a price greater than marginal cost, while additional units are priced at marginal cost. Since marginal units are still priced at their marginal cost, resources are allocated efficiently. Essentially, two-part pricing spreads the entry fee evenly over the first q units purchased, where q is arbitrary but must be less than the total number of units the buyer is expected to purchase.

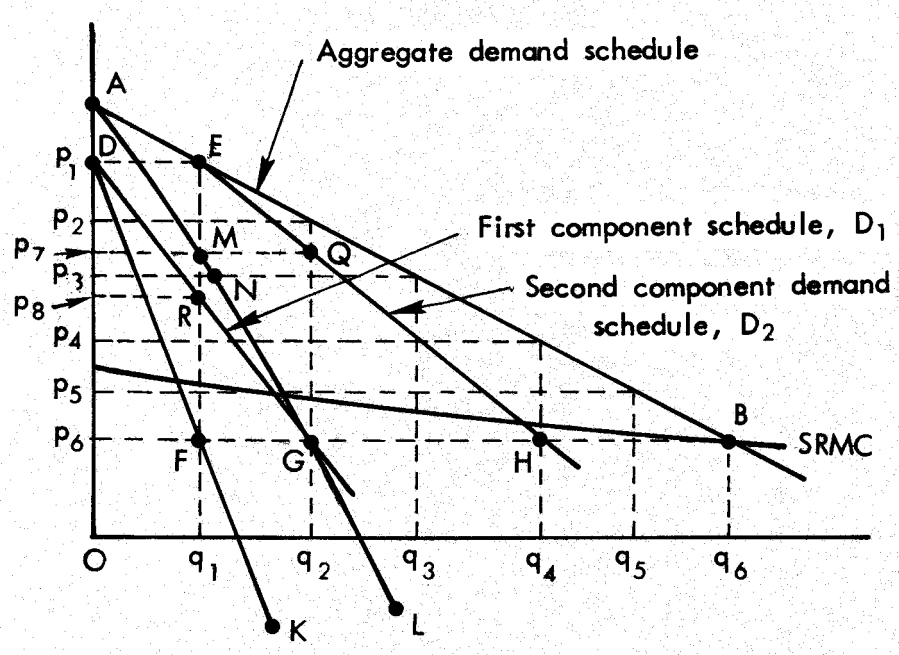

Fig. 2 — Multipart pricing policies

Perfect price discrimination and entry fee pricing can therefore *simultaneously* bring about resource efficiency and maximum net revenues. If they can be appropriately designed, these pricing schemes will yield more revenue than single-part profit-maximum (monopoly) pricing. Further, because marginal units are always sold at marginal cost, perfect price discrimination and entry fee pricing can also achieve efficient utilization of shuttle services. However, practical difficulties of implementation may offset the theoretical advantage of these pricing policies. Determining the appropriate prices in each case would require knowledge of each purchaser's demand schedule, and these may be hard to estimate, as well as subject to change. Furthermore, resolution of the bargaining problem likely to arise between buyer and seller would entail time, uncertainty, and information costs that may exceed the theoretical advantages. Moreover, substantial variation in the entry fees charged to different individuals, or in the prices charged to different users, may encounter legal problems connected with the law's rejection of "unreasonable discrimination."*

If perfect price discrimination and entry fee pricing are considered infeasible or impractical, it may still be feasible and desirable to charge different prices in different market segments. Under this pricing policy, the market would be divided into various classes of users (e.g., U.S. government, U.S. commercial, and foreign government and commercial combined) and separate prices charged to each type of user. Legal problems associated with price discrimination may be avoided since all U.S. commercial users are charged the same price, as are all foreign users. If there is concern about discrimination between U.S. commercial and foreign users, then foreign and U.S. commercial users could be combined into a single class, leaving U.S. governmental users in a second class. In general, as many classes may be defined as are enforceable and legally allowed. Market segmentation is only enforceable when shuttle users in one market segment cannot satisfy their demand by operating through a different segment. In this respect, market segmentation is analogous to perfect price discrimination. In effect, market segmentation is simply a "less-than-perfect" form of price discrimination.

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*See Wolf, Harris, Klitgaard, *et al.*, *op. cit.*, p. 112.

Three types of pricing strategies are distinguished below for markets that can be segmented. First, a single-part profit-maximum price can be determined separately for each market segment. The resulting gross revenues would exceed the gross revenues possible charging the single-part, profit-maximizing price to all users, without market segmentation. The shuttle program would earn a budget surplus intermediate between that earned under monopoly pricing without market segmentation, and perfect price discrimination (or entry fee pricing). Although the total number of flights might be greater or less than the total using single-part, monopoly pricing, it would still be true that no flights were priced at marginal cost, so there would be underutilization of shuttle services in each market segment.

To illustrate, suppose the market can be segmented into the two classes of users whose demand schedules are shown in Fig. 2. The first class of users is sold an output quantity q_1 (where the marginal revenue from launches supplied to this class--indicated by marginal revenue schedule DK--equals the marginal cost of an extra launch to the industry, p_6). These q_1 flights are priced at p_8, on the demand schedule of the first user class. Users in the second class are sold an output quantity q_2 (where the marginal revenue schedule for this class--the line AMNL--intersects the industry marginal cost p_6B). These q_2 flights are priced at p_7 on the demand schedule of the second user class. In total, $q_1 + q_2 = q_3$ launches are sold, and the aggregate net revenue (above marginal cost) would total $p_8RFp_6 + p_7QGp_6$. In general, this total net revenue will exceed the net revenue obtainable from charging the profit-maximizing price without market segmentation.

Second, some market segments could be charged marginal cost (e.g., the U.S. government users) and the deficit that would thereby arise covered by charging the profit-maximizing price in the remaining segments. It might be desirable to charge the profit-maximizing price to foreign users if, for example, the efficient use of foreign resources was of less concern and possible political repercussions were not an obstacle.

Additional market segments could be charged the profit-maximizing price until total monopoly profits were adequate to cover the shuttle program deficit.*

Third, prices in each segment could be raised above SRMC sufficiently to eliminate the program deficit, but not turn it into a surplus. For the cost and demand schedules illustrated here, less than the monopoly price would be necessary in each segment. To eliminate the deficit with the smallest reduction in output, prices would be increased above SRMC in each segment in proportion to the inelasticity of demand in that segment. This would reduce output by the same percentage in each market.

Thus, when the technical conditions do not preclude it, and administrative and legal considerations make it possible, multipart pricing does provide a policy option in which price can exceed marginal cost *without* causing efficiency losses. (Market segmentation can be used to impose efficiency losses selectively on only some market segments.) Efficiency losses are avoided because the marginal unit is priced at its supply cost, even though other units are charged higher prices. It is worth noting that, notwithstanding administrative and other difficulties, intricate multipart rules have been applied, usually with satisfactory results, to electricity, utility gas, and telephone pricing, and to the pricing of computer services.

Besides the principal pricing policy options we have been discussing, another option might be mentioned for completeness. NASA could charge a

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*A precedent for market-segmentation pricing can be found in value-of-service pricing for railway freight, as approved and regulated by the Interstate Commerce Commission. Lower rates per ton-mile are charged for coal than furniture than watches, thereby segmenting the market into different user classes for each value-per-ton class of freight. Such market segmentation, which might be ruled an illegal monopolistic practice in some markets, has been justified for railroads because the traffic in bulky, low-value-per-ton commodities is highly responsive to the rates charged, whereas the traffic in commodities with a high-value-per-ton, for which the same rate per ton-mile would amount to a much lower proportion of their final sales price, is correspondingly price inelastic. A uniform, non-discriminatory rate would lead to an underutilization or rail capacity by low-value-per-ton freight and a loss of traffic that could easily cover marginal costs and make a contribution to fixed costs. See Alfred Kahn, *The Economics of Regulation*, Volume 1, p. 156 and the references cited there.

single price to all non-U.S. governmental users *between* marginal and average costs, where the intermediate price is selected so that non-U.S. governmental users neither receive a subsidy from the government (such as they would receive if all infra-marginal units were priced at the cost of the last unit and marginal costs were declining) nor provide net revenues for the government (which would be the case if profit-maximizing or average costs were charged).*

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*For a fuller discussion of pricing between marginal and average cost, see Appendix C, by John Stein, in Wolf, Harris, *et al.*, *op. cit.*, pp. 164-166.

IV. THE DEFINITION OF MARGINAL COST, SPECIFICATION OF THE INCREMENTAL UNIT, AND DISTRIBUTION OF FIXED COSTS

When it comes to applying the above pricing rules, policymakers will face difficult problems, for example, in trying to calculate SRMC for particular cases. In this section, we discuss some theoretical guidelines for such calculations, leaving the more practical problems still unresolved.

Two basic principles of marginal cost pricing can be stated: (1) causal responsibility determines what goes into marginal cost; and (2) SRMC (as opposed to LRMC) reflects the social opportunity cost of an additional unit of output at any given time, and therefore pricing at SRMC promotes efficient resource allocation.

The first principle implies that any future maintenance and repair of fixed facilities or hastened depreciation and replacement directly *caused* by a marginal shuttle flight should be included in SRMC. Thus, depreciation of *fixed* plant and equipment *does* enter SRMC, but only insofar as a marginal flight increases future maintenance and replacement costs. The two principles are not in conflict. The maintenance and replacement costs included in SRMC assume no change in the capacity of fixed facilities and equipment. Also, depreciation which is unrelated to the number of flights, as, for example, depreciation of administration buildings associated with the shuttle program, is not a part of SRMC, since marginal shuttle flights do not raise these costs.

The inclusion of some depreciation expenses in SRMC makes SRMC different from "identifiable additional cost," as NASA uses the term, which excludes all depreciation and includes only short-run variable costs. By contrast, NASA's measure of "full cost price" does include depreciation, but in a manner that violates both of the above principles and is inappropriate for either marginal or average cost pricing. In full cost pricing for the non-recoverable launch vehicle program, NASA calculates depreciation as a pro rata share of historic fixed costs.

This depreciation charge is removed when the historic costs have been fully depreciated. Hence, full cost decreases over time. By contrast, marginal cost increases monotonically over time, since less discounting of marginal replacement costs is involved as the date of the shuttle flight approaches the date of replacement of the fixed items. The result is that marginal cost is likely to be higher as the replacement date approaches. Thus, "identifiable additional cost" and "full cost" pricing are, in fact, very different from marginal and average cost pricing respectively, despite their superficial similarity.

Ideally, all future costs (and interest rates) should be evaluated at their expected future values. Usually current replacement cost is the best available estimate for depreciation calculations. However, it should be noted that the appropriate replacement item merely has to provide the same *service* as the replaced item. It need not be an identical item, if the state of technology has changed since the first item was built. In general, if technology has advanced, equivalent replacement service should be available at *less* than original cost. Incidentally, if future replacement of facilities and equipment is not expected to be undertaken (for example, if a set of space experiments approaches completion and no further experiments of the same sort are planned), then efficient use of the present facilities and equipment calls for charging a SRMC which excludes any allowance for replacement of fixed costs.

The incremental unit for which marginal cost is calculated should be as small as possible to provide efficient utilization of resources at the margin. For example, if a shuttle flight is scheduled with unused payload capacity, then extra payload could be efficiently added to any price above the incremental cost per kilogram or per ton launched. The marginal cost of an extra kilogram attached to an already scheduled launch with unutilized capacity will generally be much smaller than the per kilogram marginal cost of an entire launch or series of launches. As the incremental unit is increased (from an extra kilogram to an extra flight or series of flights), more fixed costs become variable and marginal and average costs increase. So pricing at the marginal cost of *the smallest possible* unit,

which would be appropriate on efficiency grounds, does not cover the cost of producing an extra flight or series of flights. In practice it is advisable to view the pricing decision in the context of a production decision--whether to produce an extra flight, series of flights, or to launch additional weight on a scheduled flight. The marginal sales unit is then equated to the marginal production unit, generally the marginal flight.

The shuttle will be able to provide various types of service, depending on the configuration of the shuttle plane, payload weight, planned orbit, and other factors. In general, SRMC will differ for each type of service, since each has specific variable and fixed costs applicable to that type of service. Variable costs (fuel, labor, etc.) can be straightforwardly identified with each service type and included in the corresponding SRMC. Some fixed items (a synchronous orbit booster, a space laboratory, the space telescope, etc.) can also be straightforwardly identified with particular service types, and marginal maintenance and replacement of these items can be directly allocated to the SRMC for the corresponding type of service. But many fixed costs will be shared among several or all services (ground support facilities, program administration, depreciation, replacement of the shuttle planes, etc.). In SRMC, such "common" fixed costs (common over various types of service) are allocated to SRMC for each service type insofar as the marginal launch of each service type increases the short-run marginal cost of that common fixed item (i.e., increases its incremental maintenance and hastened replacement cost).

If the proportion in which the various service types are sold is variable, then marginal common fixed costs for each service type can be conceptually determined by adding a marginal launch of a particular type, holding all other types of service at constant levels, and examining the resulting increase in common costs. But when various types of service are provided in fixed proportions (e.g., perhaps, up-trips and down-trips, assuming these are different service types and scheduling is not a problem), then the combined services are a joint product and the SRMC of the common fixed items cannot in general be observed. However, if

one type of service is underutilized (e.g., some down-trips are empty but all up-trips are full), then all common SRMC for the joint service are allocated to the fully utilized service (up-trips) and none to the underutilized service, since additional units of the underutilized service can be supplied with no increment in joint common cost.

To what extent can the foregoing guidelines and principles be applied? Probably, to only a quite limited extent. For example, in practice it is virtually impossible to know marginal cost *ex ante*, at the time when prices must be set. Marginal cost depends on future demand conditions that influence capacity utilization and marginal expected replacement costs. Also, marginal cost will vary from month to month as the price of included items changes. A useful approximation to SRMC may be expected average marginal cost for a large block of shuttle flights, including both variable costs per flight and incremental maintenance and replacement costs averaged per flight.

Although SRMC pricing promotes efficient allocation of present resources, a reasonable argument can be made that pricing should be used to recoup a portion of sunk fixed costs, such as the large start-up costs for R&D, facilities, and equipment undertaken in the initial development years of the shuttle program. Although this approach appears to violate the principles of marginal cost pricing, it may be reasonable if the pricing decision is viewed in the perspective of a long-run production decision. A long-run time frame is appropriate when a long-run production decision is involved, even though the shortest possible time frame is ideal for promoting efficient allocation of variable resources at the margin. The situation is similar to that in the earlier discussion of the appropriate sales unit. A similar conflict arose there between the ideal and the practical, and was resolved by placing the pricing decision in the context of a production decision. When Congress originally appropriated start-up costs for the shuttle program, all costs were variable, and marginal cost involved what appears in the subsequent sequence of "short-runs," to be fixed costs. If the original Congressional appropriation was predicated on the assumption that a price would be charged above SRMC and closer to LRMC, then the

shuttle pricing decision may be viewed as having occurred in the context of that long-run production decision. When viewed from this perspective, LRMC promotes efficient allocation of the original start-up costs. It is true that once the fixed costs are sunk, SRMC becomes the pricing policy that promotes efficient allocation of resources that are still variable, but if the relevant production decision is long-run, then the long-run perspective should dominate the pricing decision as well.* Since Congress probably expected to subsidize non-governmental shuttle flights somewhat, a price lower than LRMC would be appropriate. Thus, less than a full share of sunk R&D expenses and other start-up costs would be included in marginal cost, even if pricing is viewed in a long-run context.

The "bottom line" to this discussion is both important and ambiguous: The marginal cost that is appropriate to use in establishing pricing policies for the shuttle will vary over a considerable range, depending on the production decision and the time horizon that applies; and the latter is apt to differ depending on whether the decisionmaker's perspective is that of the Congress, the Space Agency, or the operator of a particular shuttle service.

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*The complexity, as well as ambiguity, of this issue extends even farther. In general, the difference between LRMC and SRMC depends on costs that are fixed in the short run. Similarly, the difference between SRMC and SRAC consists of costs that are fixed in the short run. Consequently, SRAC $\tilde{=}$ LRMC, and the SRAC pricing rule that is *in*appropriate in the short run may be appropriate in the long run!

V. EVALUATION OF PRICING POLICIES

How do the various pricing policies stand up to evaluation in relation to the criteria of allocative efficiency, on the one hand, and distributional equity, on the other?

Policies (1) marginal cost pricing and, among the multipart pricing options, policies (4a) perfect price discrimination and (4b) entry fee pricing, meet the strict test of allocative efficiency mentioned earlier, while policies (2) average cost pricing, and (3) profit-maximum pricing do not. Policy (4c), market segmentation pricing, may be efficient in some market segments. The efficiency losses associated with profit-maximum pricing and market segmentation pricing may be greater or less than those associated with average cost pricing, depending on the precise location of demand and cost functions. But, within fairly wide bounds of the relevant parameters for the cost and demand curves, the efficiency losses associated with average cost pricing are not as large as those associated with profit-maximum pricing.

In general, the more elastic is the demand schedule and the larger are short-run fixed costs relative to short-run variable costs, the greater will be the efficiency losses associated with pricing policies other than (1), (4a) and (4b). *Therefore, ascertaining or at least trying to estimate more accurately (i) the elasticity of demand for space shuttle services by type of user and (ii) the magnitude of short-run fixed costs relative to short-run variable costs, should be of considerable importance to NASA in choosing among alternative policies.*

It is important to note that these conclusions with respect to the relative efficiency of alternative pricing policies depend on an assumption that the implementation costs, as well as the externalities, associated with the several policy alternatives are not so different as to alter the conclusions. In fact, as we have already suggested, implementation costs may be quite different among the alternatives: for example, the practical problem of implementing multipart pricing may more than offset its theoretical efficiency.

If one believed that there are likely to be considerable positive or negative externalities associated with expanded use of space shuttle services (e.g., positive externalities through the advancement of science and technology, and the discovery of new resources in planetary space, or negative externalities associated perhaps with a stimulus to international arms competition), then one might want, respectively, to choose a policy *below* marginal cost, or move toward an average cost or profit-maximizing price, respectively.

Also, for the foregoing conclusions to hold, distortions introduced by inefficient pricing in closely related markets must not be important (i.e., the problem of "second best" can be neglected). If the price of a related service, for example the service of non-recoverable launch vehicles, were priced below SRMC because of a market distortion such as a government subsidy, then shuttle services also should be priced below marginal cost so as not to exaggerate the demand for conventional launch vehicles. The opposite would apply if non-recoverable launch vehicle services were inappropriately priced above SRMC.

Evaluating the several pricing policies according to distributional criteria is still more difficult. Distributional criteria, which consider who benefits and who pays, entail a large number of issues easy to identify, hard to quantify in general, and hard to apply to the specific case of choosing an appropriate pricing policy for the space shuttle. In general, it can be said that pricing policy is an inefficient mechanism for redistributing income among types of users. A conceptually preferable system can always be devised using marginal cost pricing and side payments.

The principal distributional considerations include the following:

1. Should Cost Burdens be Redistributed from Taxpayers to Users?

It can be argued that those who benefit most from NASA's activities--the aerospace and telecommunications industries, for example--should be obliged to help defray NASA's costs, thereby reducing some of the burden on the general taxpayer. Hence, pricing policy should be used to shift

part of the burden from taxpayers to users. On this ground one might argue for a pricing policy that moves from what is allocatively efficient (e.g., marginal cost pricing), to a pricing policy that yields larger revenues (e.g., profit-maximum pricing or market segmentation pricing).

Insofar as the choice of a pricing policy generates revenues for the Treasury, it is a form of taxation. Consequently, pricing policy should be considered as part of the question of whether such government projects as the space shuttle ought to be funded through "general" or "specific" taxation. General taxes (e.g., income, excise, and real estate taxes) single out specific economic activities (work, consumption and use of land, respectively) for taxation, but they do not charge for the use of a specific government service, while specific taxes (such as road tolls or postal charges) do. None of these taxes is "neutral," since each singles out some economic activity for taxation.

As a major means of collecting revenue, general taxes are preferable to specific taxes because of the difficulty, and frequent impossibility, of collecting specific taxes from those who actually benefit from a particular government service. In many cases, it is precisely the impossibility of identifying or singling out beneficiaries (such as the beneficiaries of military preparedness, or space exploration) that calls for government programs and expenditures in the first place. One person's consumption of military preparedness or space exploration cannot be provided without simultaneous enjoyment (or dislike) of the same benefits by everyone else. So no individual would be willing to purchase these "public" goods, and specific taxation to finance them would be impossible.

The question remains, if most government projects must be funded from general tax revenue, should some projects still be funded from specific taxes, to the extent possible? The answer depends on both distributional and efficiency considerations in specific cases.

If, for example, charging a price greater than marginal cost for a wide range of government services used by a wide range of beneficiaries, were to result in a payment burden whose incidence would be similar to

that of a general tax, then no distributional advantage would be gained, regardless of its apparent distributional equity in a particular case. So if some government services benefit certain individuals while other services benefit different individuals, and if the aggregate effect is only a small redistribution of the tax burden, then the redistributive benefits resulting from the excess of price over marginal cost are probably not worth the effort.

Looking just at the case of NASA activities rather than government services in general, a pricing policy of charging above marginal cost would be hard to justify on distributional grounds if the economic sectors that benefit from these NASA activities broadly serve the entire economy. In this instance, the paying and benefitting groups would be roughly coterminous. However, if the particular NASA service disproportionately benefits a particular sector of the economy, there may be a valid argument for a specific charge on these beneficiaries, i.e., for charging a price above marginal cost (assuming the alternative of a side payment cannot be arranged). It might be argued, for instance, that telecommunications more broadly benefits society than does aerospace. If the premise is correct, the distributional argument for charging a price above marginal cost would be stronger with respect to NASA's aerospace activities than to its telecommunications activities.

In the particular case of the space shuttle, it is therefore highly important in evaluating the alternative pricing options for NASA to try to identify the precise composition of the consuming and benefitting public. Are the principal users expected to be in aerospace, telecommunications, mining and mineral exploration, or other fields? *Identification of the particular industries or sectors expected to benefit from the space shuttle is important in considering the redistributive argument for charging a price above marginal cost.*

Note that this argument still leaves open the question of which among several pricing policies should be chosen, since average cost pricing, monopoly pricing, and multipart pricing all have in common this characteristic of specifically taxing shuttle users. To choose among these latter alternatives, one might argue further that the redistributive

issue should be pushed as far as possible; that is, the goal of net revenue maximization should be sought. However, as noted earlier, if multipart pricing is impractical, then the efficiency losses associated with a pricing policy that pushes toward monopoly pricing may be considerably greater than those associated, for example, with average cost pricing. In the final analysis, to be justifiable, a price yielding net revenues must lead to redistributional gains that are considered to outweigh efficiency losses--an outcome which, as noted earlier, is more likely if the demand for the space shuttle is inelastic (or fixed costs are not too large).

2. Should Pricing Policy Attempt to Eliminate Excess Profits?

A second distributional argument relates to the elimination or capturing of excess profits earned by firms that directly benefit from NASA's activities. Whether or not these companies narrowly or broadly serve the entire economy, they may in any case be able to extract excess profits in the process. Charging suitable shuttle fees, it is argued, can help correct this situation.

However, the government generally has other mechanisms for regulating profits of telecommunications firms and other firms working on government contracts, the likely users of most space shuttle services. If these firms, nonetheless, manage to earn excessive profits, it would seem preferable to change regulatory practices and federal contracting procedures, rather than to rely on shuttle pricing for this purpose.

In general, this argument would not seem to provide much justification for choosing an inefficient pricing policy.

3. Should Pricing Policy be Used to Tax Foreign Buyers?

A variant of the argument that pricing policy should be used to shift part of the burden of space shuttle costs from taxpayers to users of the shuttle applies to potential foreign buyers of shuttle services. Foreign buyers will not usually have contributed to the general tax revenues of the U.S. Treasury, and efficient utilization of foreign

resources may not be of major concern to the United States. Hence, the case for a redistributive use of pricing policy is stronger in this case because the benefitting and the paying groups are clearly different.

The most efficient way to tax foreign shuttle users (assuming perfect price discrimination is ruled out) would be to charge an entry fee or similar side contribution to NASA's overhead costs, while selling marginal shuttle flights at SRMC. Price discrimination against foreign users through market segmentation (i.e., charging a uniform but higher price to foreign than domestic users) would not raise as much revenue for the shuttle program, as would entry fee pricing, appropriately carried out. Also, market segmentation would reduce the number of foreign launches, thereby raising SRMC to the industry as a whole and to domestic users in particular. Furthermore, if competing French and Japanese non-recoverable launch programs provide substitutable service, then foreign demand for shuttle services may be fairly elastic. In this case, charging a high price to foreign shuttle users through market segmentation might increase net profits only slightly while reducing foreign use of the shuttle substantially. Nonetheless, both entry fees and market segmentation pricing could yield net profits from foreign users and thereby entail distributive benefits from a U.S. standpoint.

The principal arguments against such a policy are political rather than economic or distributional. They include, too, the risk of retaliation by other countries which could entail economic as well as political losses for the U.S. Yet these economic losses might be less than the gains for two reasons: foreign governments probably already apply such pricing policies on their sales abroad of government-subsidized technology to a greater extent than does the United States; and the volume of such sales by foreign countries is currently and prospectively less than those by the United States. However, even if retaliation by foreign countries did not occur, or the impact of such retaliation inflicted costs on the U.S. less than the gains that such a pricing policy for space shuttle

services would entail, the foreign policy consequences might be undesirable. NASA has a responsibility for promoting technological cooperation with other countries, both in the interests of technological progress and of advancing U.S. foreign policy relationships with other countries. A pricing policy that charges foreign users more for space shuttle services than domestic users might be expected to provoke resentment, especially among NATO allies and Japan, and a resulting penalty for U.S. interests and relationships with these countries in other realms quite apart from aerospace technology. Furthermore, a discriminating pricing policy might induce potential foreign users to develop further their own launch capabilities. Because economies of scale are so pronounced in shuttle services, foreign competition in launch services should not be unwittingly encouraged.

Sometimes the line between distributional and efficiency considerations is not entirely clear. We referred earlier to the possibility that implementation costs associated with an otherwise efficient pricing policy, namely multipart pricing, might make that policy more costly, hence less efficient, to adopt than one of the other options. This is particularly likely to be the case for multipart pricing options because they require a fairly complete knowledge of the relevant demand functions of different space shuttle users. But implementation problems also arise in connection with other pricing options as well, particularly where distributional considerations enter prominently into the Congressional authorization and appropriation for government programs in general, and for the space shuttle in particular. To an appreciable extent, launch services in the past and the space shuttle program currently and prospectively, have been "sold" to the Congress on grounds that they would have positive and substantial commercial payoffs.* Hence, Congressional backing for the program, for various possible

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*Wolf, *et al.*, *op. cit.*, pp. 22-24.

reasons,* may have been predicated on the understanding that some considerable part of the R&D and other historic and current fixed costs attendant to the space shuttle program would be met from the prices charged for shuttle services. Under these circumstances, a policy of charging prices greater than the *ex post* short-run marginal costs can be justified, and the justification can be made on efficiency as well as distributional grounds. As noted earlier, a portion of the costs that are fixed *ex post* are marginal *ex ante*, from the standpoint of the original Congressional backing and authorization for the program. The observer's viewpoint can influence what comprises "extra" costs. And from that of the Congress, it is not inappropriate to relate the extra investment required for the shuttle to the package of shuttle services expected from that investment, and hence to spread the investment costs over the services themselves.

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*These reasons may include Congressional interest in obtaining more reliable information concerning the alleged benefits from the shuttle or other R&D programs to the private sector than is involved in the usual testimony presented by interested companies at Congressional hearings. Although net revenues above marginal costs are at best only a lower-bound estimate of such commercial value, Congressional concerns may be more directed toward reducing the risks of overestimating such private sector spinoffs rather than underestimating them. See, for a fuller discussion, *ibid.*, pp. 24-26.

VI. CONCLUSIONS

Economic theory is helpful in providing an analytical framework for structuring and thinking about the problems, possibilities, and issues relating to the choice of a pricing policy for the space shuttle. However, the framework does not, in this case as in many other policy contexts, lead to an unequivocal conclusion. Resolution of the preferable tradeoffs between efficiency and distributional considerations depends, in the first instance, on clarifying and specifying what the tradeoffs are, but in the final analysis depends on the relative weights and emphasis that policymakers choose to give these conflicting considerations.

The following guidelines can be drawn from the preceding discussion with respect to the choice of a preferred pricing policy for the space shuttle:

1. In determining pricing policy, it is important to try to estimate the elasticity of demand for space shuttle services among each class of users. The more highly price-elastic is the demand, the more likely are substantial efficiency losses to result from a policy that sets price greater than marginal cost. (Incidentally, if the cost of a nearly equal-effectiveness payload launch by the Titan 3C is in the neighborhood of $30 million, then charging a price for shuttle services in that neighborhood is likely to encounter a highly elastic demand.)

2. In evaluating the elasticity of demand, NASA should also be concerned with the *composition of demand*, in order to ascertain how generally and broadly representative of the taxpaying public are the potential users of space shuttle services. Clearly, the more broadly-based are the users and beneficiaries of shuttle services, the less decisive is the argument for charging a price above marginal cost on grounds of equity and redistribution.

3. In considering the composition of shuttle services demand, attention should also be directed toward the impact of alternative pricing policies on *foreign users*, for example on their incentive to develop their own launch capabilities (which is likely to be enhanced

the higher is the price charged for the shuttle by NASA), as well as the impact on U.S. political relationships with other countries, especially NATO allies and Japan.

4. The more clearly does the *legislative history* accompanying the space shuttle indicate that promises and commitments were made to the Congress that the program's deficits would be limited because of revenues derived from commercial sales, the more reasonable it is to consider a part of the initial or investment costs associated with the program as "marginal," and hence an appropriate part of the price to be charged to shuttle users.