Appendix E

Economics of the Space Shuttle

by James A. Van Allen

In April 1982, James A. Van Allen of the University of Iowa presented to a meeting of Tau Beta Pi a paper entitled "Applications of Space Research to Modern Day Society." In preparation for the May 5 OTA workshop in which he participated, Van Allen sent a copy of that paper to OTA. Included here is the section of that paper in which he treats the economics of the space shuttle. Van Allen's analysis, which differs markedly from NASA's, is included in order to show how the space shuttle may have, more or less directly, affected the funding for space science. It is included with only minor explanatory comments. The reader should note that Van Allen includes overhead costs* in his calculations; these costs are not included when calculating marginal costs.[1]

The opinions expressed by Van Allen are his own and do not necessarily reflect those of OTA.

> There were many . . . weaknesses in the famous forecast of $100 per pound into orbit . . . I have prepared several (charts) analyzing the economics of the shuttle. The summary of this analysis is that there is no prospect whatever of bringing shuttle launch costs below some $5,000 per pound (1982 dollars). Even this figure is optimistic because my assumed payload of 60,000 lb per flight includes the mass of upper stages and other equipment that is not properly classified as useful payload.
>
> Hence, for realistic missions during the next 20 years or so, the shuttle system is actually much more expensive than are conventional, expendable boosters as exemplified by Delta, the Atlas-Centaur, the Titan-Centaur, and the French-German Ariane, all of which are in the advanced state of development and available for frequent use.

*Overhead costs are defined to be the fixed costs of the Federal establishment and associated contractors for maintaining the full operational capability of conducting a program of space shuttle flights, whether or not such flights actually occur.

[1]See, for example, Engel, Rolf, 1982, *Interavia* vol. 2, No. 177.

Table E-1 A.—Shuttle Economics (Federal Government)

N = Number of flights per year
O = Annual overhead
A = Out-of-pocket costs per flight
P = Cost per payload
M = Mass of payload
C = Cost per flight
L = Launch cost per pound of payload

$$C = \frac{O + N(A + P)}{N}$$

$$L = \frac{O + NA}{NM}$$

OTA'S comments: Table E-1A gives Van Allen's basic equation in which the quantity C, the cost per flight, Is expressed as a function of overhead costs, the number of flights per year, the out-of-pocket costs per flight, and the cost per payload.

Table E-1 B.—Shuttle Economics (Federal Government)

Examples:
O = $2,000,000,000 per year
A = $40,000,000 per flight
P = $100,000,000 per payload
M = 60,000 lb

N	Annual total	C	Launch cost per lb of payload
1	$2,140,000,000	$2,140,000,000	$34,000
	2,420,000,000	806,700,000	11,780
10	3,400,000,000	340,000,000	4,000
50	9,000,000,000	180,000,000	1,300

OTA'S comments: Table E-l B uses Van Allen's basic formulas of table E-1A to compute values of launch cost per pound of payload as a function of the number of flights per year N for assumed values of O, A, P, and M as listed at the head of table E-18.

Van Allen's comments: This analysis Ignores overhead during the lo-year *developmental* period; amortization of the investment for development of the vehicle and for facilities; and Interest on the Investment during the developmental and amortization periods.

Note that often quoted "marginal" or Incremental launch cost per flight is the quantity A, a grossly unrealistlc representation of the true cost. For the examples given here the "marginal" launch cost per pound of payload Is $670, irrespective of the number of flights per year.

Note: "Payload" Includes upper stages, if they are necessary, plus other equipment not properly considered useful payload.

Table E4A.-Shuttle Economics
(Private enterprise/Federal Government)

Van Allen's comments:

Assumed: That the Space Transportation System including facilities had been developed by private enterprise and then had been taken over by the Federal Government.

I = direct investment costs accrued linearly as a loan over a period of 10 years

The direct investment costs plus interest over the developmental period are then amortized linearly over an operational period of Y years by the Federal Government.

X = annual interest rate over (10 + Y) years

In this case the *additional* annual cost averaged over the Y years of operational use is given by

$$Z = (1 + 51X)\ (1/y + x/2)$$

Numerical examples are given in table E-2B for N = 1,3, 10, and 50 launches per year.

Table E-2B.—Shuttle Economics
(Private enterprise/Federal Government)

Examples:

I = $15,000,000,000

Y = 15 years

X = 0.1 (10%)

z = $2,625000000

N	Annual total	C	Launch cost per lb of payload
	$4,765,000,000	$4,765,000,000	$77,750
	5,045,000,000	1,681,700,000	26,360
10	6,025,000,000	602,500,000	8,360
50	11,625,000,000	232,500,000	2,270

Van Allen's comments: "Payload" includes upper stages, If they are necessary, plus other equipment not property considered useful payload.

Assumed values of O, A, P, and M are the same as In table E-l B.

All estlmatsd cost flguras In tables E-1A, 1B, 2A, and 2B are given In 1982 dollars.

OTA'S comments: Table E-2B uses the formula of table E-2A to calculate four specific examples of the launch cost per pound of payload. Taking a developmental cost of $15 billion amortized over 15 years at an Interest rate of 10 percent, Van Allen calculate that for 1,3,10, or 50 flights per year, the total (not marginal) launch cost per pound of payload will be $77,750, $26,360, $8,380, or $2,270, respectively.

Van Allen's calculations are Intended to call Into question the assertion that the shuttle will be able to bring the launch cost par pound of payload down to $100 to $30/lb. It should be noted, however, that this figure is the *rnarginal* launch cost per pound of payload, and that Van Allen's calculations are baaed on the total launch cost per pound of payload. It Is, of course, the total cost of the shuttle which has had an Impact on the space program.