achieved through a leading position within selected areas of concentration. Tromsø Satellite Station contribute also to the development of national strategies and priorities.

Other ground infrastructure
Norwegian Telecom has earth stations for Inmarsat, Eutelsat, Intelsat, Tele-X and Thor at Eik, Nittedal and on Svalbard. These will create considerable growth in the turnover of export services during the period covered by this plan.

Eiscat (European Incoherent SCATter facility), with its installation in Ramfjordmoen near Tromsø, in Kiruna and in Sodankylä is the major research centre for studies of the polar upper atmosphere. It is decided to expand this equipment by setting up a radar station in Svalbard. This will increase the usefulness of the system, particularly in connection with the Cluster and AURIO projects. Eiscat is also of great use for rocket- and satellite-based space research projects.

The Norwegian Mapping Authority is setting up ground stations in connection with GPS (SATREF), PRARE (high-precision calculation of orbit parameters), VLBI (Very Long Baseline Interferometer) and other observation systems. This strengthens Norway's position in geophysics and geodesy, and will support long-term monitoring of environmental effects.

Norsk Romsenter
PO Box 85
Smestad
N-0309 Oslo, Norway

Data on and methodology for calculating Space Shuttle programme costs

This report presents data on the annual and total costs of NASA's Space Shuttle programme through fiscal year (FY) 1993. The total cost of the programme through FY 1993 is found to be $83.7 billion in 1992 dollars. This information has significance for pending policy decisions on the future of the Shuttle programme, its possible successors, and interrelated programmes, such as the Space Station.

Begun in 1972, the Space Shuttle programme has been the major operational component of the US manned space programme since the early 1980s. Pending decisions on the future of the Shuttle programme, and, for example, its role in the Space Station programme, are better informed by reliable information on programme experience. The General Accounting Office has recently called for better information on Shuttle costs.[1] This report presents trend data on the annual and total costs of the Shuttle programme. Programme cost data allow for reliable projection of future costs based on relevant experience. Cost data are necessary, but not sufficient, for a full policy appraisal of the Shuttle programme experience.[2] Analysis of the significance of these data goes beyond the scope of this report.[3]

Methodology

NASA budgets do not facilitate analysis because costs are not accounted by specific programmes, but rather by budget categories. Thus, the tabulation of total Shuttle costs is derived from the following four budget categories in NASA's annual budget request to Congress.

Research and Development (R & D): This category includes the costs budgeted for the development phase of the project under the line item Manned Space Flight: Space Shuttle from fiscal year (FY) 1972 to FY 1984. After 1984 there are additional costs in this category, eg, in Engineering and Technical Base, Payload Operations and Support Equipment, and Spacelab, but these are not included because they are difficult to separate and identify. Expendable launch vehicle costs, budgeted in this category, have also been excluded.

Space Flight, Control and Data Communications (SFCDC): This category includes Shuttle costs budgeted for the operational phase of the project in the following two line items: Shuttle Production and Operational Capability and Space Transportation Operations from FY 1985 to FY 1990. There are also tracking and communications costs in this category, which were not included because of the difficulty of allocating them to Shuttle.

Construction of Facilities (CoF): This category includes all costs which are explicitly labelled in the NASA budget for the Shuttle programme for the purpose of providing for repair, modification, new construction, and design and planning of facilities.

Research and Programme Management (R&PM): This category includes costs for civil service staff, ie, salaries, maintenance of facilities, and technical and administrative support. Unfortunately, within this budgetary line item costs are not broken down by programme, but rather by NASA centre. To arrive at the R&PM costs for the Shuttle programme available data are used as follows: Shuttle R&PM costs were taken to be equal to the total R&PM costs at a NASA centre multiplied by the fraction of that centre's personnel that work on the Shuttle.[4] This calculation was done for the three main centres where Shuttle work is done: Kennedy Space Center, Marshall Space Flight Center, and Johnson Space Center. Additional Shuttle R&PM costs incurred at other centres where Shuttle work is done were not included.

Table 1. Annual costs and flights of the Space Shuttle (dollars in millions).

Fiscal Year	Current dollars	Constant 1992 dollars	Cumulative current dollars	Cumulative 1992 dollars	Flights
1971	78.5	255.8	78.5	255.8	–
1972	155.9	485.8	234.4	741.6	–
1973	296.7	865.5	531.1	1610.1	–
1974	656.7	1768.3	1187.8	3378.4	–
1975	1010.7	2483.6	2198.5	5862.0	–
1976	1440.0	3328.8	3638.5	9190.8	–
TQ	373.6	863.6	4012.1	10054.4	–
1977	1652.5	3574.0	5664.6	13628.4	–
1978	1645.9	3300.0	7310.5	16928.4	–
1979	1896.5	3500.6	9207.0	20429.0	–
1980	2125.2	3583.5	11332.2	24012.5	–
1981	2254.7	3454.9	13586.9	27467.4	1
1982	3459.1	4990.5	17046.0	32457.9	3
1983	3498.7	4850.8	20544.7	37308.8	4
1984	3445.8	4578.0	23990.5	41886.8	5
1985	3120.1	3996.0	27110.6	45882.7	8
1986	3344.1	4172.4	30454.7	50055.1	4
1987	5453.2	6592.9	35907.9	56648.0	0
1988	3302.7	3843.1	39210.6	60491.1	1
1989	4214.2	4695.8	43424.8	65186.9	4
1990	4293.0	4585.0	47717.8	69771.9	5
1991	4564.4	4684.5	52282.2	74456.5	8
1992	4775.0	4775.0	57057.2	79231.5	7
1993	4495.0 (est.)	4495.0 (est.)	61551.8	83731.5	7

The addition of Shuttle costs which could not be identified in the above categories would increase the estimates, but probably by less than 10%. Also not included is the cost-of-money. Thus, the estimates are low. Furthermore, the Department of Defense (DoD) also spent a significant amount of money on the Space Shuttle programme which is not included. By the end of 1980 DoD had spent $1.8 billion on the Shuttle programme, and in 1980 it was estimated that an additional $1.2 billion would be spent by 1984. The funding was to cover the development of the Inertial Upper Stage [IUS], construction of the Shuttle launch complex at Vandenberg Air Force Base, DoD launches, and all other DoD Shuttle-related costs.[5] NASA also receives funds for the Shuttle programme when it is reimbursed for a Shuttle flight, eg, when it flies a DoD, commercial, or foreign payload. These reimbursements represent additional resources available to the programme – they do not go to the Treasury to offset the costs of the programme. These funds were also not included in the tabulation. In FY 1990 Shuttle reimbursables were $82 million.[6] In FY 1985 when there was much more reimbursable activity (eg, DoD and commercial payloads) NASA was reimbursed about $480 million for the Shuttle.[7] Thus, again, the estimate of total cost is conservative.

Data

The total cost of the Shuttle programme through FY 1993 is found to be $83.7 billion (all costs presented in the text are in constant 1992 dollars).[8] Annual costs are converted to 1992 dollars using GNP price deflators found in the *Economic Report of the President*.[9] Table 1 shows annual and total costs of the programme in current and constant 1992 dollars (see also Figures 1 and 2). Table 1 also lists the number of flights which occurred in each fiscal year.

Programme development includes the years 1971 to 1982, as the first Shuttle launch of FY 1983 was also the first operational flight.[10] Four flights took place prior to the first operational flight. The programme flew 53 operational flights through the end of FY 1993. The costs of developing the Shuttle were $32.5 billion (1972–82). Costs since development, ie during operations, have totalled $51.2 billion (1983–93), or an average of $4.7 billion annually.

Thus, average cost per flight including development costs and flights through FY 1993 is $1.6 billion. Average cost per flight not including development costs or flights, up to FY 1992, is close to $1.0 billion.

A simple projection of average costs per flight is the projected average annual cost of the programme divided by the projected average annual flight rate. Programme experience provides reliable estimates of the first approximations to these figures. Thus, if the programme continues to average about 4.8 flights annually, and also continues to receive appropriations of approximately $4.7 billion, then $1.0 billion is the best available estimate of future average costs per flight. Estimates which deviate from this number must be justified by support for why the future average flight rate will

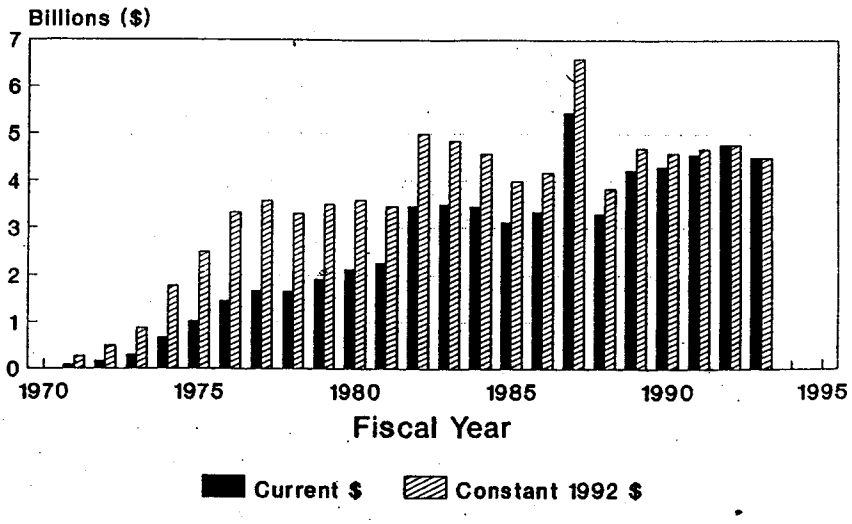

Figure 1. Annual Space Shuttle costs 1971–1993. *Source:* NASA.

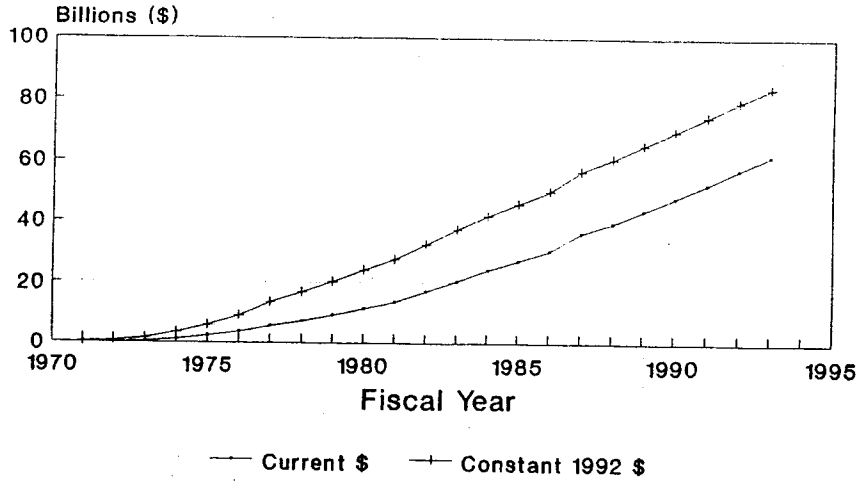

Figure 2. Cumulative Space Shuttle costs 1971–1993. *Source:* NASA. *Note:* Transition Quarter included in 1977.

be higher or lower than that of the past, or why future appropriations will be more or less than those of the past.

Conclusion

This report has provided data on the annual and total costs of the Space Shuttle programme and a methodology for calculating them. These data can be used to better inform policy decisions on the Shuttle and interrelated civil space programmes. Cost is but one criterion that should be used in a full evaluation of the Shuttle programme and its role in the US civil space programme. Other data necessary for complete consideration of the Shuttle's capabilities and constraints include schedule performance and programme capabilities. With better data, policy makers can make best use of the Shuttle programme for the remainder of its operational life.

Roger A. Pielke, Jr.
Centre for Public Policy Research
University of Colorado
Boulder, CO 80309-0330, USA

Acknowledgment:
The author wishes to thank Radford Byerly, Donald P. Hearth and Terry Dawson for constructive comments. All errors are the author's responsibility.

[1]General Accounting Office, GAO/NSIAD-93-115 (1993).
[2]In addition to cost, programme schedule and performance are necessary criteria for complete programme evaluation.
[3]This report updates and presents in greater detail cost data on the Shuttle programme that were first presented in R.A. Pielke, Jr., and R. Byerly, Jr., 'The Space Shuttle Program: "Promise versus Performance"', in R. Byerly, ed, *Space Policy Alternatives*, (Westview Press, Boulder, CO, 1992). For a complete appraisal of the Shuttle experience see R.A. Pielke, Jr., *Space Policy*, 8, 3 (1993). Cf. J. Logsdon, *Science*, 232, 1099 (1986); A. Roland, *Space Policy*, 3, 104 (1987).
[4]All input necessary to compute the algorithm is available in the annual NASA budget request to Congress.
[5]US House of Representatives, United States Civilian Space Programs: 1958–1978, Volume I, 603 (1981).
[6]NASA, Budget Estimates, FY 1992, Volume 1, 5F SUM 4 (1991).
[7]US General Accounting Office, GAO/NSIAD-87-171FS (1987), p 9.
[8]Data for FY's 1972 to 1991 are actual expenditures as reported in the annual NASA budget request to Congress. Data for FY 1992 are programme appropriations, and FY 1993 data are current estimates.
[9]Office of Management and Budget, *Economic Report of the President* (1993).
[10]The Shuttle launched four times previous to being declared operational. This analysis classifies all costs prior to the operations phase as development costs, and all since as operations costs. There are other possible classifications.

Letter to the editor

Can the USA alone put a man on Mars?

Madam

I should like to comment on 'International cooperation on Mars exploration', Louis Friedman's letter in the August 1993 issue of *Space Policy*, first by quoting statistics from 'Space industry: the scene in 1992', in the same issue, pp 236–245. The various space budgets are, then, as in Table 1, say world-wide space expenditure: $52 billion annually (roughly 50% military); of which 67.5% – or: more than ⅔! – is US!

A Manned Mars Mission based on near-present technology might cost $170 billion, to be spent over a 30 year span; hence, yearly average 5.67 billion, yearly maximum 13 billion. During these 30 years, two manned expeditions (years 18 to 21 and 24 to 27) would take place. (Those reflect my own numbers; I have studied the Manned Mars Mission since 1955.)

Table 1. World space budgets.

US	35.11	$\cdot 10^9\$^a$
CIS	7.2	$\cdot 10^9\$^b$
W-Europe	4.9	$\cdot 10^9\$^c$
Japan	1.4	$\cdot 10^9\$^d$
China	1.3	$\cdot 10^9\$^e$
Israel	0.400	$\cdot 10^9\$^f$
Canada	0.328	$\cdot 10^9\$$
India	0.224	$\cdot 10^9\$$
Brazil	0.100	$\cdot 10^9\$$
	51.6	$\cdot 10^9\$$

Notes
[a] of which: DOD 21.3, NASA 13.578
[b] Russia 7, of which 1.3 military
[c] ESA 3.3, 1 military
[d] zero military
[e] of which military: 0.8
[f] very questionable figure