Appendix C
Reliability

Launch vehicles can in principle be made very reliable by incorporating redundant components and subsystems, and by detailed testing during manufacturing and launch operations. However, it is costly to manufacture a highly reliable vehicle, and maintaining and verifying its reliability until launch imposes heavy burdens, high costs, and delays on ground operations. Yet, operating a fleet of unreliable vehicles is also costly: direct financial costs may include the replacement costs of payloads and vehicles and the costs of supporting the launch operations force during a standdown.

If only financial costs are considered, it is possible to determine the most economical reliability for a vehicle, if payload replacement costs, etc., can be estimated before the vehicle is designed. This has been done for some launch vehicles and orbital transfer vehicles.' Intangible costs may also be included if expressed in monetary terms. However, this requires subjective judgement of the value of military satellites to national security,[2] and other intangibles.

The reliabilities of currently operational launch vehicles are not known with certainty or precision. On the basis of actual launch experience, they can only be said to lie within certain confidence intervals with corresponding statistical confidence. As more launches are attempted, the confidence intervals will shrink and statistical confidence will grow. The reliability of a proposed launch vehicle or variant can only be hypothesized on a semi-analytical, semi-subjective basis. Confidence levels for the reliabilities of currently operational launch vehicles are listed in table C-[13]

'Boeing Aerospace Corp. has developed a computer program called STROP to perform such an analysis; it was first used to determine the most economical reliability for the Inertial Upper Stage.

'U.S. Congress, Office of Technology Assessment, *Anti-Satellite Weapons, Countermeasures, and Arms Control,* OTA-ISC-281 (Washington, DC: U.S. Government Printing Office, September 1985), p. 33.

[3]Confidence intervals are estimated from statistics in Harry Bernstein and A. Dwight Abbott, "Space Transportation Architecture Resiliency," (El Segundo, CA: The Aerospace Corp., March 1987), using the exact confidence bounds of Y. Fujino, *Biometrika, vol. 67, 1980,* pp. 677-681.

Table C-1 .-Launch Success Statistics (since 1976)

Vehicle	Successes /attemDts	Average success rate	Minimum reliability at eaual confidence
Delta	60/63	95.20/o	900/0
Atias E	25/28	89.30/o	81 o/o
Atlas/Centaur.	26/29	89.70/o	81 o/o
scout	14/14	100.00/0	87°!o
Titan	51/54	94.40/0	880/0
Shuttle	24125	96.00/0	870/o
Ariane	14118	77.8?40	690/o

NOTE: Forecasts (for which OTA does not vouch) of the reliabilities of proposed vehicles differ, e.g.:
S1S.1 (post-Ch#lengerj: 0.98 [Aerospace Corp.], 0.997 [GD], 1.0 [NASA HQ].
Tltm.IV: 0.98 [Aerospace Corp.], 0.98 [GD].
MLV (Delta derivative): O.M [Aerospace Corp.], 0.978 [G D].

SOURCE: Office of Technology Assessment, 1988.