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MINIMUM COST CRITERIA FOR SPS TRANSPORTATION TO GEO

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The transportation of 50 000 tons (Mg) mass to GEO — as presently estimated for a 5 GW SPS — poses a great challenge to system design and technology, especially however to economic optimization.

Required is a heavy cargo launch vehicle with more than 200 Mg payload in geosync. orbit (GEO), requiring up to some 250 launches for one SPS.

A cost—optimized vehicle of this size seems to be able to realize a range of 50 to 150 $/kg (1980) specific transportation cost to GEO. This is more than two orders of magnitude lower than the Space Shuttle plus IUS (23 000 $/kg).
However, the range indicated means 2 to 6 Billion S launch cost for one 5 GW SPS, or about one third up to the same amount as the SPS space segment will cost.

For this reason, a strict application of cost optimization has to be applied in vehicle design and not only a performance optimization as in the past.

For a minimum cost heavy cargo launch vehicle the following ground rules can be established:

(1) FULLY REUSABLE: The launch vehicle system shall not comprise any expendable components; the goal is 50 to 100 re—uses with minimum refurbishment.

(2) UNMANNED: For heavy cargo transportation man is not required. The pressurized cabin, the life support and safety systems are a payload penalty and increase cost.

(3) TECHNICAL SIMPLICITY: Minimum technical complexity is required in order to limit development, fabrication and operations cost. This means minimum number of stages and system interfaces, no deployable tanks or boosters. Performance (payload) must be achieved by adequate sizing instead of increasing technical complexity.

(4) OPERATIONS SIMPLICITY: Operations cost represent the largest cost share in case of fully reusable vehicles. Therefore, the design must take into account minimum launch, recovery and refurbishment effort.

These ground rules can be applied to the vehicle design alternatives shown in FIG. 1:

Winged vehicles are excluded because they need a flight crew and the associated equipment. This certainly decreases the payload and increases cost. Because of the lower structural efficiency only two—stage systems can be considered.

In case of unmanned ballistic vehicles a single stage system to LEO (SSTO) is feasible, however, with a lower payload than two—stage or 1 1/2—stage systems. The latter need recovery of tanks or boosters, increasing system complexity and operations cost. Two—stage systems — either to LEO or into LEO/GEO transfer orbit have a suborbital first stage. This means that the vehicle has to be recovered down—

range in the Atlantic and brought back by ship to the launch site.

The direct injection into GEO/LEO transfer orbit is unfavorable because either an expendable kick stage is required or a third stage which has re—entry and landing capability of its own.

The most simple solution both technically and from the operations standpoint seems to be the SSTO + OTV version. For verification a performance and cost analysis was performed for three types of vehic— les, as shown in FIG. 2. (This is a model comparison only for concept evaluation).

The detailed cost model includes refurbishment cost, direct operations cost (such as system manage— ment, ore—launch ops., launch and mission control, propellants, recovery and transportation) as well as the indirect operations cost (launch site administration, support and facilities).

Beside the vehicle system concept the vehicle size or payload capability has a major influence on trans— portation cost. FIG. 3 illustrates the interrelation between vehicle GEO payload capability, number of launches per year and total construction period for a 5 GW SPS.

The cost impact both of vehicle size and launch rate is shown in FIG. 4. The specific cost are reduced with increasing annual launch rate, however, increasing vehicle size is more effective for cost reduction above some 50 launches per year.

Larger vehicles require higher development investments but the difference can be amortized already after the launch of one SPS because the transportation may be reduced by a factor of two.

The economics of large size vehicles again confirm a ballistic—type system providing a large payload volume. Larger pieces of the SPS reduce the orbital assembly effort and the related cost.

However, even if the larger size means better economics, one certainly would not go straight to the final vehicle but an intermediate size in the 100 to 200 Mg GEO payload class, or 4 000 to 6 000 Mg launch mass (GLOW). This size of vehicle could also be used for nuclear waste disposal into space.

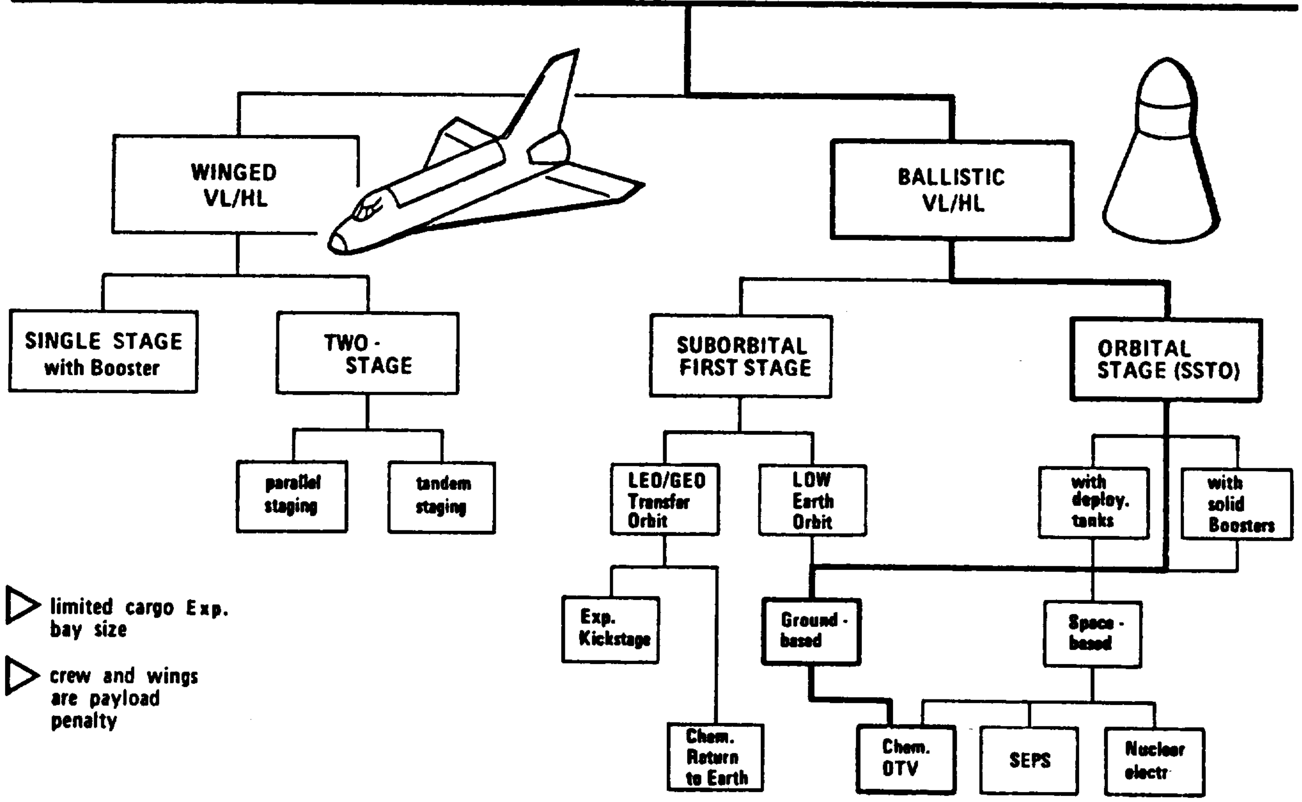
The equatorial ESA launch site Kourou (French Guyana) would probably be a good option for an international launch site, both for SPS and nuclear waste transportation. Environmental restrictions at the Kennedy Space Center as well as the 8 — 10 % higher payload recommend this.

Basically a policy decision is required for the next generation of launch vehicles whether the US will make a joint effort with Europe or go alone (may be in one direction and Europe in another).

LAUNCH VEHICLE CONCEPT SCHEMATIC

FIG. 1

Reusable Cargo Launch Vehicle System Alternatives from Earth to Geosyncronous Orbit



COST COMPARISON

FIG. 2

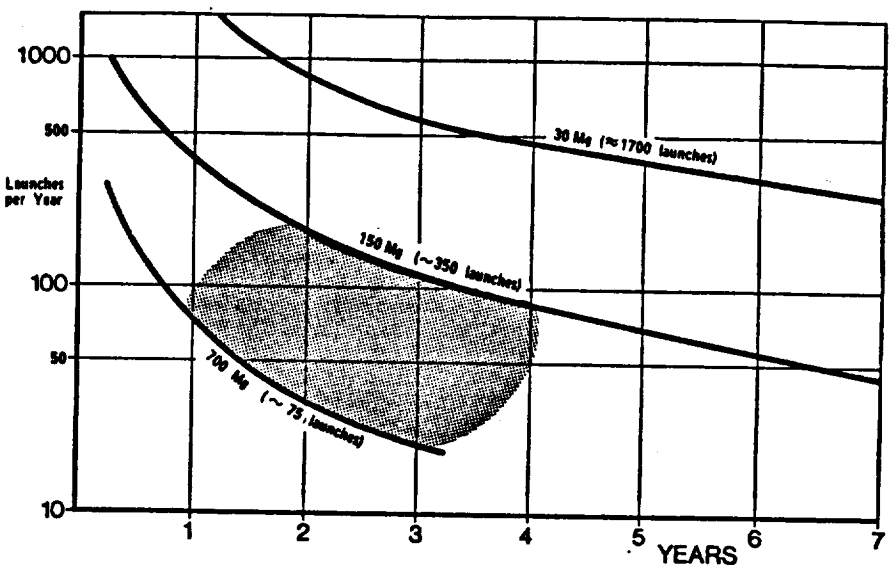
of three alternative ballistic launch vehicle systems with 30 Mg GEO Payload and a launch rate of 100 LpA

LAUNCH COST	A SSTO + OTV	B TWO-STAGE VEHICLE WITH DIRECT INJECTION AND KICK STAGE	C TWO-STAGE VEHICLE TO LEO PLUS OTV
LAUNCH MASS (GLOW)	1280 Mg	1080 Mg	770 Mg
PAYLOAD RATIO (PL/GLOW)	2.3 %	2.8 %	3.9 %
DEVELOPMENT COST	73 000 MY = 7.3 B. $ (81)	111 000 MY = 11.1 B. $ (81)	104 000 MY = 10.4 B. $ (81)
MANUFACTURING COST (1 SYSTEM WITH 100 RE-USES)	1785 MY	2040 MY + 4900 MY FOR 100 KICK STAGES	1700 MY
OPERATIONS COST (100 FLIGHTS)	6340 MY	12 695 MY	12 675 MY
SPECIFIC COST	3.6 $\frac{MY}{Mg}$	6.5 $\frac{MY}{Mg}$	4.8 $\frac{MY}{Mg}$

LAUNCH VEHICLE SIZING

FIG. 3

(GEO payload) and total number of launches for a 5 GW SPS with 50 Gg total mass



SPECIFIC TRANSPORTATION COST

FIG. 4

to geosyncronous Earth orbit (GEO) vs. annual cargo volume and launch vehicle capability (SSTO + OTV)