SMALL LAUNCH VEHICLE
SS-88-35

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Our goal is to design a 15,000 pound Small Launch Vehicle (SLV) which can carry a 250 kg payload into Low Earth Orbit(LEO). The objective is to develop a system to provide the SLV capability at a low cost. A preliminary analysis has determined size and weight. A development plan is established for further refinement of the design. The SLV is a two stage liquid oxygen/liquid hydrogen booster. Alternative fuels and engines are being investigated.

INTRODUCTION

The Department of Astronautics, United States Air Force Academy is coordinating an 18 month research effort to design a low cost launch vehicle. The commercial applications of such a vehicle are unlimited. When one investigates how satellites are currently deployed, several questions arise. Does a $100 million dollar satellite which must have a lifetime of 3-5 years need to be launched on a $10 million dollar launch vehicle? How much of this $100 million dollars is incurred solely to ensure enough redundancy on board to enable the satellite last the full expected life time? The prime focus really should be on the size of the payload. With an SLV one tenth the cost, ten launches can be accomplished instead of one. Each individual small satellite (instead of one large satellite) now only has to last 4-6 months. How much redundancy is now required? Our premise is that each small satellite will cost much less than $10 million. The overall system cost will be decreased thereby making the operation more efficient and profitable.

This SLV analysis was started in Jan 88 as an Astronautics Independent study course. The baseline system requirements were as follows:

SLV Requirements

- 2 stage Liquid Oxygen - Liquid Hydrogen.
- 250 kg payload, 15000 lb main vehicle weight.
- Low Earth orbit (160nm, 28° inclination).
- Low g launch environment (5 - 8g's).
- Launch from 'bare minimum' pad.
- Use current hardware/technology.

SLV DESIGN

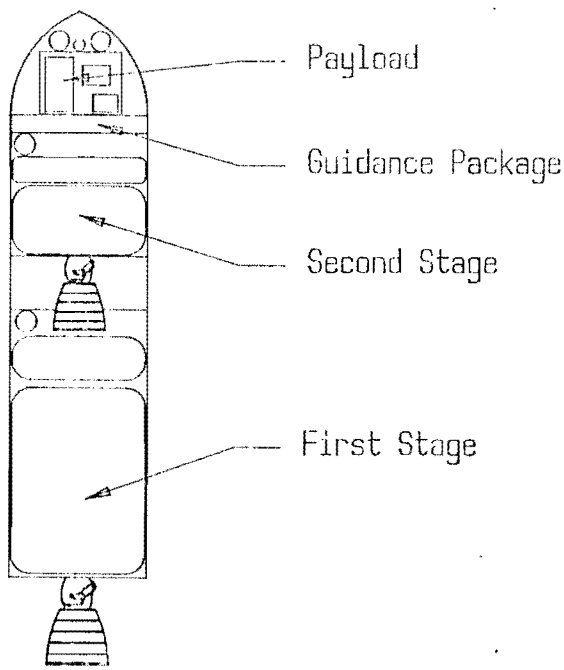

Figure 1 SLV Depiction, Current Design

The SLV Design is an iterative process highlighted by the following Flow Diagram.

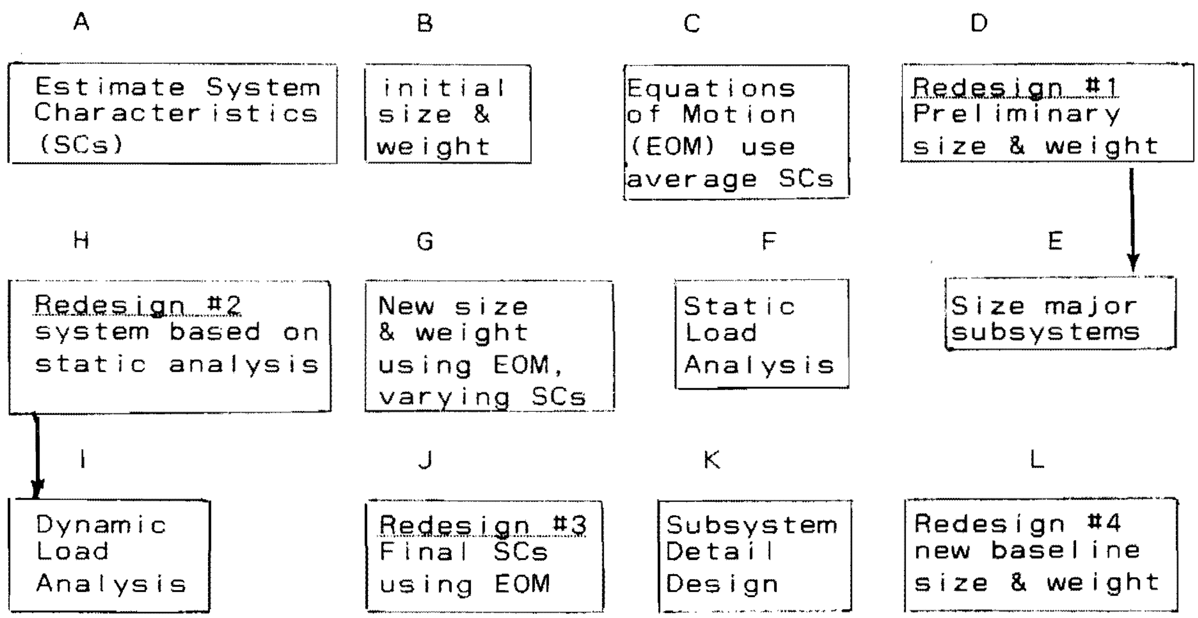

Figure 2 SLV Development Flow Diagram

Steps A through D have been completed. Step B was simply the application of general astrodynamics equations concerning staging and orbits. (Ref5) Step C used average system characteristics while numerically integrating the EOM. The preliminary analysis, Step D, determined the size of each stage. The following table provides a brief overview of the rocket design products.

TABLE 1
SLV SYSTEM PERFORMANCE (Ref 4)

STAGE	THRUST(lbf)	MASS(kg)	Isp(sec)	Propellant Fraction
1	33,000	4100	400	0.90
2	16,500	2450	440	0.87
Payload	-	250	-	-

Using the system characteristics above, in addition to providing service to LEO, a 29 kg payload can be inserted into a geosynchronous transfer orbit. Steps E and F are presently underway. The propellant tanks were designed as cylinders with spherical end caps, while the oxidizer tanks were ellipsoids. (Ref 1). The Engines selected for use on the SLV are Pratt & Whitney RL10 and its derivative, the

RL-10 Jarvis. (Ref 2). The Guidance package has yet to be determined. The static analysis for determining the structural details is in preliminary stages and is expected to be completed by December 1988. Hopefully the final system characteristics, Step J, can be determined by June 1989.

The current design, shown in Fig 1, can now be analyzed for cost.

SLV PRELIMINARY COST ESTIMATE

A preliminary cost estimate of the SLV must include several vital components. These components include: motor assemblies, guidance and control systems, vehicle structure, and environmental controls. The costs quoted here are based on preliminary data gathered from US Air Force and contractor sources.

These costs reflect only a flyaway cost. This includes nonrecurring or fixed costs allocated to the total flyaway cost of the SLV. The flyaway cost reflects a long run average cost of each SLV (100^{th} production unit). This rate of 100 units of production will allow an economic rate of production suitable for commercial purposes.

TABLE 2
THE 100TH SLV COST (FY88 DOLLARS)

Vehicle cost	$168k	
Guidance and control	35k	
Other hardware cost	8k	
Other vehicle cost*	14k	
Propulsion	430k	
		$655k

* This includes mission specific system testing, mission specific hardware and software, and miscellaneous costs.

Another cost which must be considered is ground support activities. This would include telemetry support, computer analysis, range support, and other contractor support. A preliminary cost analysis of these ground support activities is currently being undertaken. One analysis for a similar small satellite support estimated these ground support activities to cost about $750k for a transportable ground station (Ref 3). If we take the average cost over 100 flights and add operating and maintenance cost the ground support activities should not exceed more than $300k.

The profit motive can make the commercial application of the SLV successful. The actual profit margin required can only be determined by the company undertaking this venture. However, the following statement seems appropriate:

"Although the market for large capacity class satellites is occupied in the United States by established entrants (Martin Marietta, McDonnell Douglas and General Dynamics) small capacity and sub-orbital cargoes present new commercial opportunities yet to be exploited" (Ref 6, p 132)

CONCLUSION

As part of the Presidential Directive on National Space Policy, February 11, 1988, one of the overall goals of United States Space activities is "to encourage continuing United States private-sector investment in space and related activities." The Department of Astronautics is trying to contribute to the successful accomplishment of this goal through the SLV research effort. The 18 month program to design a 15,000 lb vehicle to carry a 250 kg payload into LEO for under $1 million dollars is well underway. The preliminary analysis results are positive, however, the success of this program relies on the hard work of many other individuals not named here.

LIST OF REFERENCES

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