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EARTH-TO-ORBIT LAUNCH VEHICLES FOR MANNED MARS MISSION APPLICATION

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ABSTRACT

Manned Mars missions (MMMs) will require payloads to low Earth orbit (LEO) much heavier and larger than can be accommodated with the Shuttle. Three typical launch vehicles are described that could possibly satisfy the MMM needs. The vehicle concepts include Shuttle Derived Vehicles (SDVs), which are composed essentially of Shuttle components, and Heavy Lift Launch Vehicles (HLLVs), which utilize new and improved technologies and require additional development.

EARTH TO ORBIT LAUNCH VEHICLES

MMMs will create requirements for cargo sizes and weights that are greater than the current Space Transportation System (STS) can accommodate (see references 11 and 12). It may be possible to divide MMM payloads into smaller and lighter units, but with the division comes the requirements for additional launches and on-orbit-assembly. This will increase the cost and complicate the operations of the missions.

Several types of advanced, partially and fully reusable ETO launch vehicles are under study by NASA and the Department of Defense. Both manned and unmanned vehicle concepts are being studied, including multi-stage and single stage configurations. Payload delivery capabilities for these advanced concepts range from about 10,000 lb. to about 400,000 lb, and propulsion includes rocket and air breathing varieties. Vehicles at the lower end of the payload range would be primarily "people carriers" and those at the higher end would be primarily cargo vehicles. Figure 1 shows sketches of some of the concepts presently being studied.

Three classes of the heavy-lift systems are discussed in this paper, and a specific vehicle within two of those classes was selected as a reference vehicle in the study. The STS was also used as a reference vehicle, but is not discussed here.

Combinations of Shuttle components can be used to configure SDVs with greater launch capabilities than the Shuttle. New configurations using more advanced state-of-the-art technologies have been investi-

FIGURE 1. TYPICAL EARTH–TO–ORBIT VEHICLES

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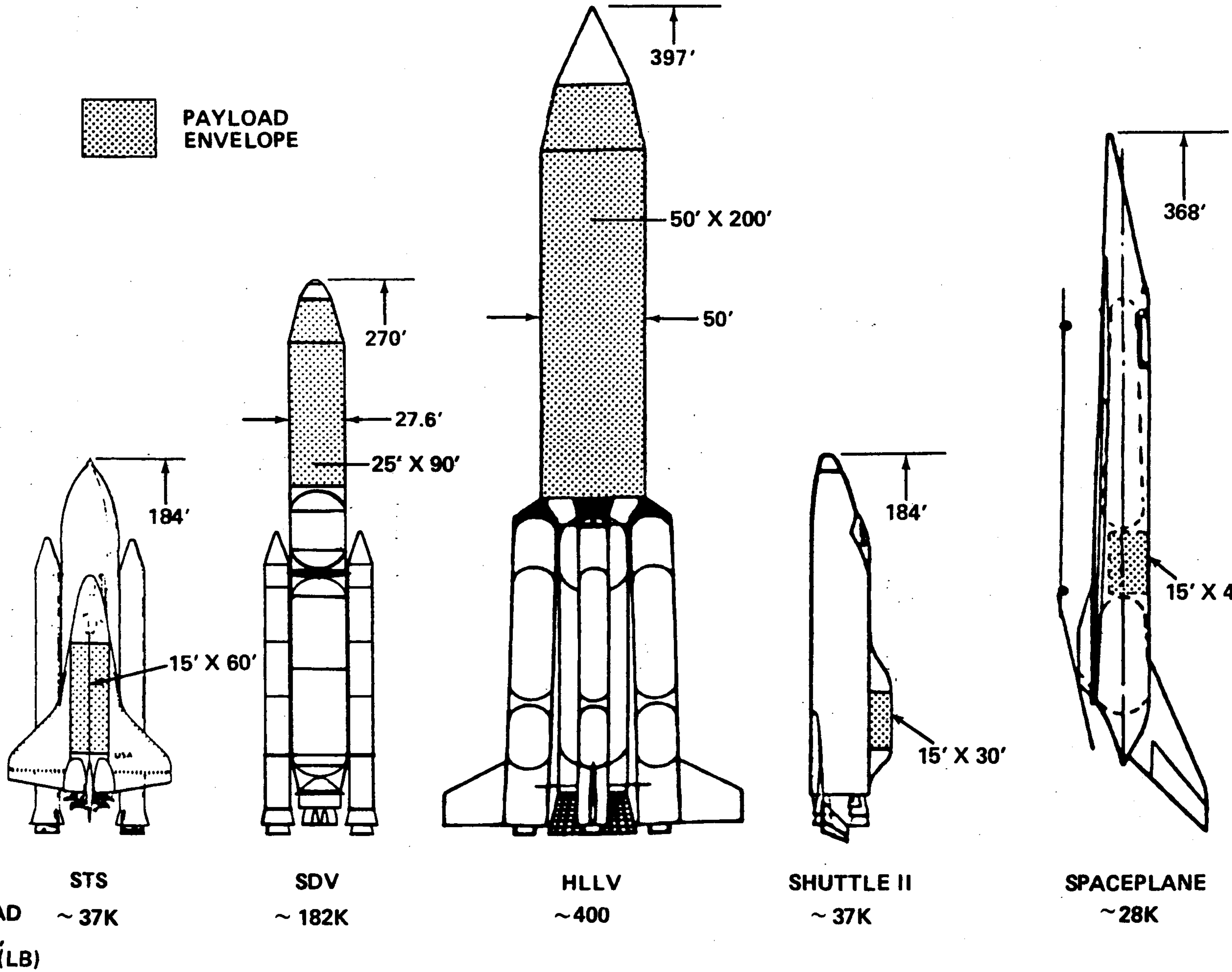

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gated which could provide greater lift capacity with improved operations and costs. Evolution from the "smaller" SDVs to "larger" HLLVs have been investigated as a logical path to satisfying the 1990's and 2000's payload requirements.

SHUTTLE DERIVED VEHICLE

One potential vehicle for MMMs is the SDV-3R. The "3R" denotes three Space Shuttle Main Engines (SSMEs) in a recoverable propulsion/ avionics (P/A) module as shown in Figure 2. The SDV-3R was used as a reference vehicle in the study.

Vehicle Description

The SDV-3R consists of components and systems entirely from the present Shuttle program with the exception of the payload shroud and recoverable P/A module.

The first stage, or booster stage, uses the standard STS Solid Rocket Booster (SRB). The standard SRB uses a steel Solid Rocket Motor (SRM) case; however, a lighter weight Filament Wound Case (FWC) is being developed for the Shuttle to increase the vehicle payload capability, and can be used interchangeably with the standard steel case. The second stage, or core stage, uses the Shuttle's External Tank (ET). The ET will require slight modification to accommodate the P/A module installation at the base of the tank and the payload mounted on top of the tank. The ET is near-standard but has a flatter top to permit inline stacking of the payloads and upper stages (if required). Three standard SSMEs and the vehicle avionics are incorporated into a recoverable module located under the ET which will permit the recovery/ reuse of the SSMEs and avionics.

The SSMEs are the same as used in the Shuttle and are arranged in the same order as the Shuttle engines and use the same plumbing configuration. The engines plus the avionics are included in a recoverable P/A module that uses ballistic reentry from orbit, with ballute and parachute landing on land or water. The SSMEs, avionics, and auxiliary equipment are refurbished and reused in future flights. A Centaur G Prime third stage, which is located within the payload shroud, can be used for high energy missions such as Geosynchronous Earth Orbit (GEO) or MMM Missions. A larger stage designed specifically for the SDV-3R could

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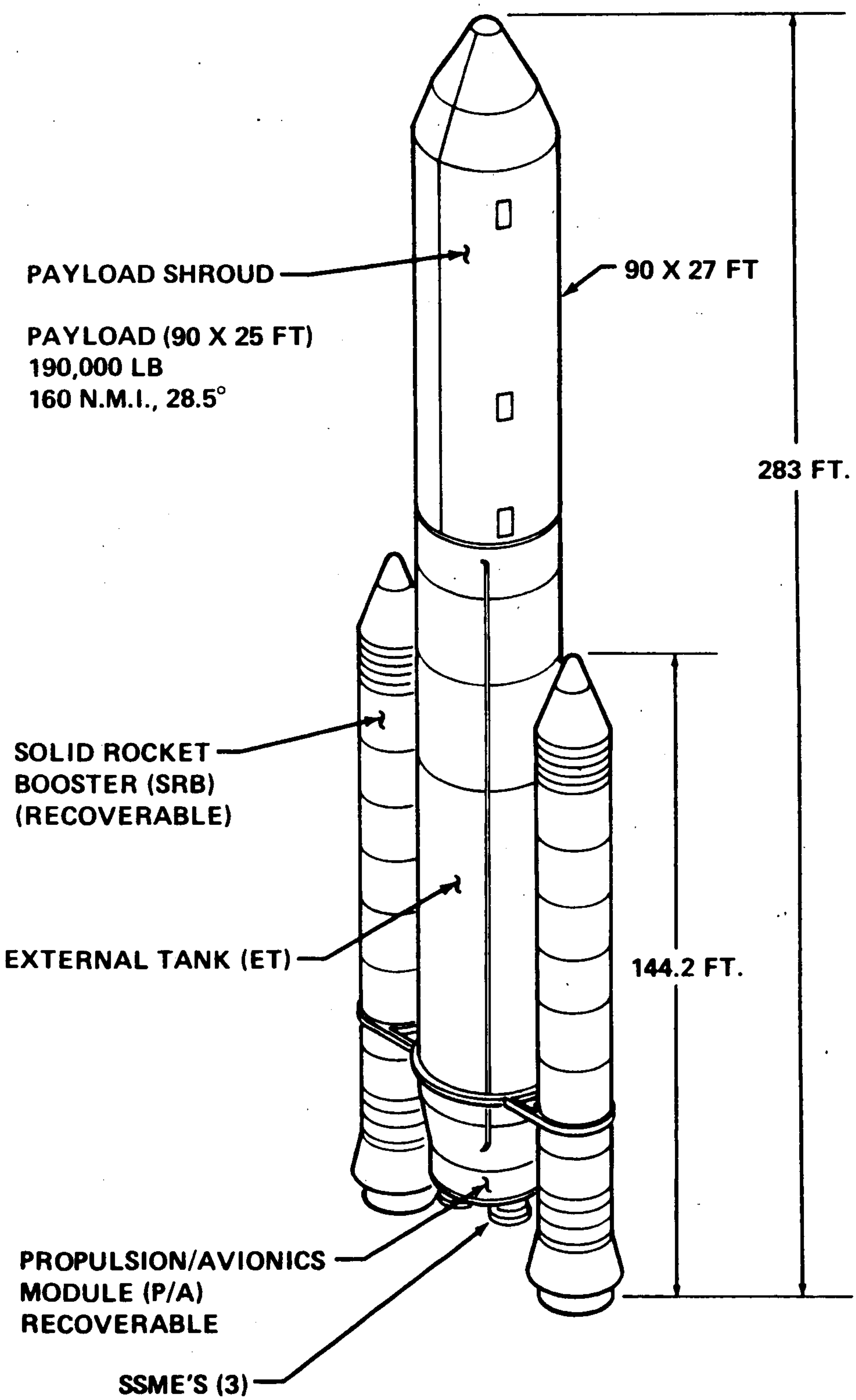
FIGURE 2
SHUTTLE DERIVED VEHICLE
THREE SSME'S, RECOVERABLE
(SDV–3R)



also be used with more than twice the performance of the Centaur G Prime.

Performance

The SDV-3R offers a wide range of performance. The two-stage vehicle has the capability of placing 190,000 pounds into a 160 n.mi., 28.5 degree inclination orbit, 182,000 pounds into a 270 n.mi, 28.5 degree orbit (that presently planned for the Space Station), and 159,000 pounds into a polar orbit. The SDV-3R can place 19,000 pounds into GEO by using the Centaur G Prime as a third stage. This payload weight is the maximum that a Centaur G Prime can take from LEO to GEO. A larger upper stage for the SDV-3R could permit payloads to GEO to increase to 50,000 pounds.

Launch Facilities/Operations

The SDV-3R will use the STS assembly and launch facilities with slight modifications. A new Stacking Integration Building (SIB) and Mobile Launch Tower (MLT) may be located at Kennedy Space Center (KSC) to provide redundancy in facility capabilities, where redundancy does not already exist in basic Shuttle facilities. This combination of existing and new facility elements can greatly enhance launch assurance and can be made available as an option. Additional facilities requirements will depend upon the launch rate required to meet the needs of MMMs.

Schedule

First flight of the SDV-3R vehicle can occur after a five (5) year development program.

SHUTTLE DERIVED/HEAVY LIFT VEHICLE (SD/HLV)

Requirements for payload weights to LEO greater than the capability of the SDV-3R will require a larger SD/HLV. This larger vehicle could evolve from the SDV-3R through normal growth or could be developed as the basic launch vehicle of the MMM. If the vehicle is developed directly for MMMs, the components/systems inherited from the SDV-3R will require development under the HLLV program, thereby adding to the development time.

Growth from the SDV-3R type of configuration to larger-lift capability could be achieved by any one or more of several means. The one shown in Figure 3 uses reusable liquid rocket boosters in lieu of the

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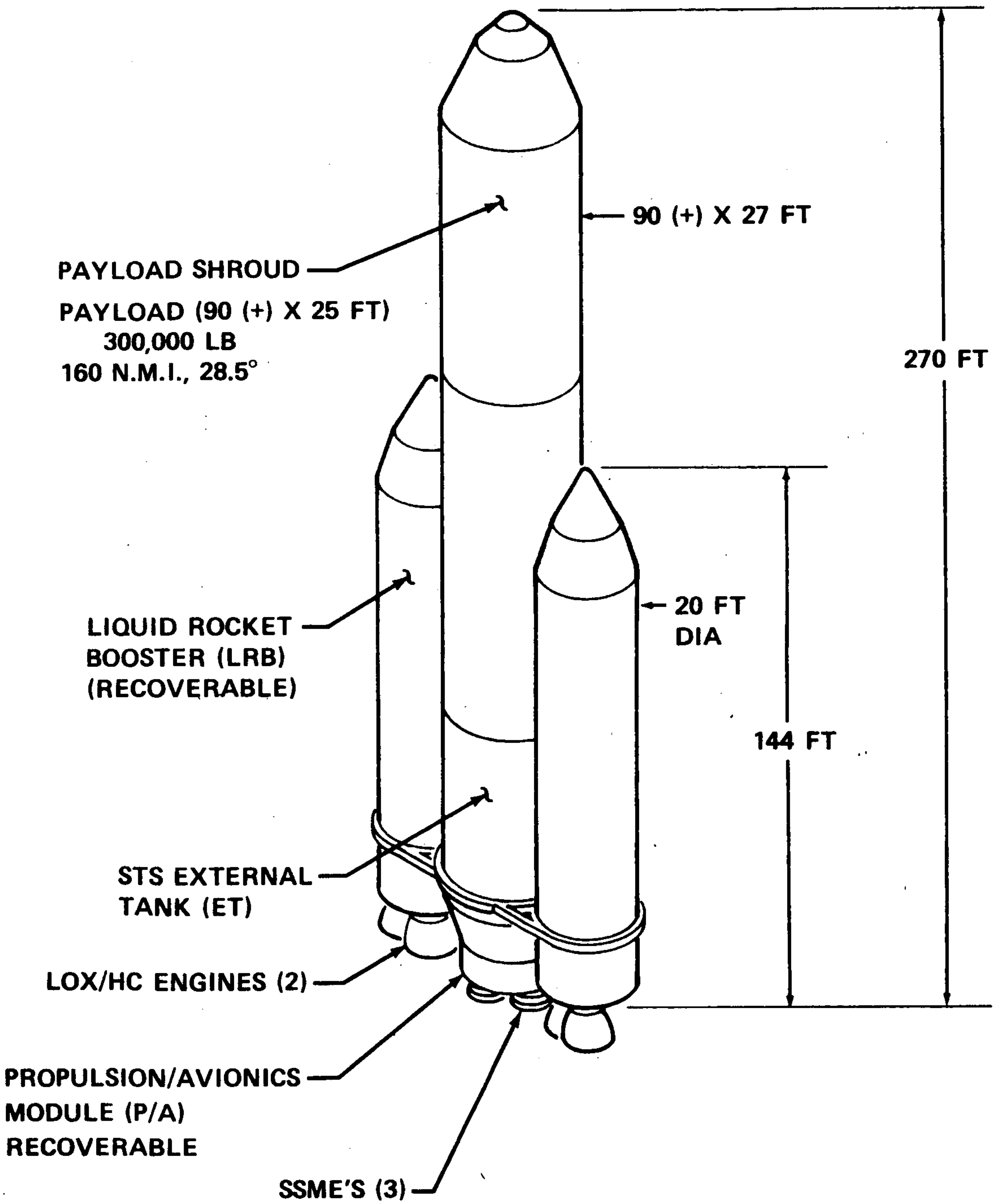
FIGURE 3
SHUTTLE–DERIVED HEAVY LIFT VEHICLE (SD/HLV)



current solid rocket boosters. The "core stage" is retained essentially as utilized in the SDV-3R vehicle.

Vehicle Description

The first stage consists of two reusable liquid rocket boosters, each equipped with two LOX/hydrocarbon rocket engines of approximately 1.6 million pounds thrust. These boosters are 20 feet in diameter, approximately 150 feet in length, and would be recovered by parachute/paraglider types of devices of advanced design, in a manner similar to SRB recovery on the Space Shuttle. The LOX/hydrocarbon boost engine would be developed for this and other applications and could be described as an advanced technology version of the F-1 engine used in the Saturn-Apollo program.

The core stage or second stage consists of an ET with the main engines and avionics installed at the base of the ET in a recoverable P/A module. This stage is retained in essentially the same form as used in the SDV-3R vehicle. A payload shroud of the same diameter as the ET (as shown in the illustration) would allow accommodation of payloads up to 25 ft. x 90 ft. Payloads of larger dimensions can be accommodated without placing undue demands upon vehicle control and dynamics.

A third stage using a single SSME can be employed for intermediate destination orbits beyond the efficient range of the basic two-stage vehicle.

The lower turnaround cost for the reusable liquid rocket booster, due to refurbishment and lower propellant cost than for the SRMs, combined with P/A modules recovery and reuse, will allow per flight costs even lower than an SDV-3R type vehicle of comparable size. The ET and payload shroud are the only expendable items with this arrangement.

Inheritance

The ET for the core stage will be inherited directly from the Space Shuttle and the SDV-3R vehicle, along with production, test, and logistics support capabilities. The recoverable P/A module will likewise be retained directly from the SDV-3R vehicle and SSMEs from both predecessor vehicles. The payload shroud for payloads up to 25 ft. x 90 ft. could be used as is from the SDV-3R vehicle; shrouds for larger payloads can be developed and built as they are needed. The LOX/hydrocarbon booster engines and the booster stages share heritage from F-1 engines and Saturn V boosters, as well as vehicle arrangement and booster recovery methods from the Space Shuttle.

HEAVY LIFT LAUNCH VEHICLE (HLLV)

Advancement in technologies and state-of-the-art may make it advantageous to design and develop a HLLV that is independent of the Shuttle. This "new design" HLLV could use the LOX/HC Booster Engines employed in the SD/HLV and new LOX/LH_2 Engines for upper stages. Techniques involving propellant cross-feed from Booster to Center Core Stage during the boost phase of the flight would enhance the performance of the vehicle. A new advanced recovery system, advanced avionics/software and improved operations could make a new advanced configuration economical.

Vehicle Description

Since this vehicle definition is still in the early stage, only basic concepts and descriptions are possible at this time. Figure 4 shows a typical HLLV concept. The first stage could consist of two to four reusable liquid rocket boosters or of boosters with reusable P/A modules similar to that used for the SDV-3R core stage. Each booster is equipped with two LOX/Hydrocarbon rocket engines of approximately 1.6 million pounds thrust or two of the boosters are equipped with two LOX/Hydrocarbon engines and the other two boosters are equipped with one LOX/Hydrocarbon engine. The LOX/Hydrocarbon boost engines would be developed for this and other applications and could be described as an advanced technology version of the F-1 engine used in the Saturn-Apollo program. The booster or the booster boat-tail containing the engines and avionics would be recovered and reused.

The core stage or second stage consists of a propellant tank and a recoverable P/A Module containing five LOX/LH_2 engines. The boosters and core stage use engines which are burned in parallel. The boosters include an auxiliary liquid hydrogen tank which permits cross feed of LH_2 and LOX into the core LH_2 and LOX tanks, which permits the core stage to have a full complement of propellant at booster separation, resulting in higher vehicle performance.

A third stage using SSME or an Advanced Cryogenic Engine (ACE) can be employed for intermediate or high energy missions beyond the efficient range of the basic two-stage vehicle. The payload shroud to accommo-

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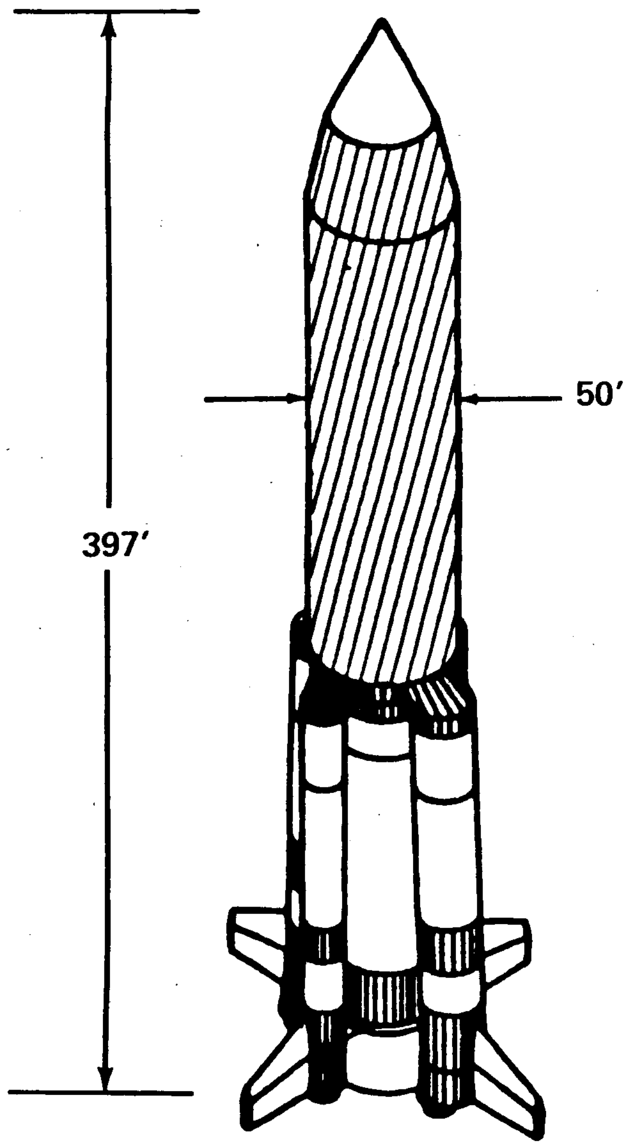
FIGURE 4. HEAVY–LIFT LAUNCH VEHICLE (HLLV) (RECOVERABLE PROPULSION AND AVIONICS (P/A) MODULE)



- REUSABLE P/A MODULE
  - 5 X STME'S @ 100%
- 4 X LIQUID BOOSTERS (RECOVERABLE)
  - 2 W/2 X 1.616 MLBF ENGINES
  - 2 W/1 X 1.616 MLBF ENGINE
- 33 FT. DIA. EXPENDABLE CORE STAGE TANKAGE
- USABLE P/L ENVELOPE – 45′ X 200′
- PERFORMANCE*
  - 270 NM/28.5° – 401K
  - 160 NM/28.5° – 418K
  - 540 NM/90° – 302K
- IOC 1995

* ORBITS CIRCULARIZED WITH KICK STAGE

date payloads of about 45 feet in diameter by about 200 feet in length will require development.

Performance

The basic two-stage vehicle can place approximately 408,000 pounds to a 160 n.mi., 28.5 degree inclination orbit, approximately 401,00 pounds into a 270 n.mi., 28.5 degree orbit, and approximately 302,000 pounds to a 540 n.mi., polar orbit.

Payloads of approximately 120,000 pounds to high energy orbits or to GEO are possible depending on the size of the third stage.

Launch Facilities/Operations

New launch facilities and launch sites must be investigated. Specifics will be dependent upon vehicle configuration, logistics, launch rates expected and mission requirements.

Schedule

The schedule will, of course, be dependent on the mission requirements. Ten to twelve years is normally required for a new vehicle development.

SUMMARY

Manned Mars missions will require launch vehicles with considerably larger capability than the present STS. Launch vehicles evolving from the Shuttle can be made available in the early years to meet MMM goals. Also, larger vehicles can be made available in the later years using new and improved techniques. Economic analyses need to be made to determine the best vehicle for the mission and the time period the mission is accomplished.

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