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PERSONNEL LAUNCH SYSTEM — LAUNCH SITE PROCESSING PERSPECTIVE

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ABSTRACT

The Personnel Launch System (PLS) is currently planned to supplement the Space Shuttle in the year 2000 by transporting eight passengers and two crewmembers to and from Space Station Freedom (SSF). Alternate PLS missions include satellite servicing and on-orbit rescue. The importance of the PLS assured access to space role is supported by recommendation No. 11 of the Augustine Committee's *Report of the Advisory Committee on the Future of the U.S. Space Program*, which states: **"That NASA initiate design effort so that manned activity in the Space Station could be supported in the absence of the Space Shuttle. Crew recovery capability must be available immediately, and provision made for the relatively rapid introduction of a two-way personnel transport module on a selected expendable launch vehicle."** Winged high-lift and biconic medium-lift PLS spacecraft configurations are being studied in conjunction with several potential launch vehicles. At Kennedy Space Center (KSC), these spacecraft and booster concepts are being evaluated to determine processing requirements and attendant impacts on the ongoing Space Transportation System (STS) launch environment and infrastructure.

From these launch site studies, design recommendations are being developed. One of the primary goals in the PLS study is to design a vehicle that is easy to maintain and turnaround for launch, particularly in view of the proposed 30-year life cycle. Current KSC studies and recommendations are therefore critical in developing operationally efficient spacecraft and launch vehicle designs that minimize launch site impacts.

PLS SPACECRAFT

Two versions of PLS spacecraft are being considered (see Figures 1 and 2): High Lift-Over-Drag (L/D) Winged Configuration (HL-20); and Medium L/D Biconic Configuration. Langley Research Center has contracted Rockwell Corporation to study the winged design; Johnson Space Center has contracted Boeing Defense and Space Group to study the biconic design. Marshall Space Flight Center has provided the launch vehicle configurations.

Processing Requirements and Recommendations. PLS spacecraft subsystems should be designed to minimize ground processing and maintenance requirements. KSC recommends that spacecraft be designed using the following groundrules: •Minimize subsystem complexity; •Minimize number of subsystems; •Maximize subsystem accessibility; •Minimize number of onboard fluids; •Maximize subsystem self-test and checkout; •Share OMS/RCS propellants and tankage; and •Minimize number of hazardous propellants.

Winged PLS. The winged PLS design (Figure 1) focuses on external accessibility. Maintenance personnel can access most subsystems using removable (non-load bearing) panels. Built-in test equipment (BITE) and health monitoring will enhance launch turnaround. Rockwell baselines hydrazine as the OMS and RCS propellant, using existing engine technology. KSC prefers a hydrazine monopropellant system with shared OMS/RCS tankage, despite the weight penalty, because it reduces by one-half the number of propellant lines, valves, and tanks, compared to a bipropellant monomethyl hydrazine (MMH) and nitrogen tetroxide (NTO) system. Hydrogen peroxide (H_2O_2) and JP-4 jet fuel OMS/RCS is the designer's choice using new engine technology. KSC strongly believes non-hypergolic OMS/RCS propulsion systems such as this should be developed for future vehicles. Hypergols pose serious health hazards to launch processing personnel (0.1 to 3.0 parts-per-million exposure limits) and therefore require serial, area-cleared hazardous processing. JP-4 is a safe propellant to process, but 90 percent H_2O_2 has the drawbacks of being unstable and highly reactive with organics.

KSC agrees with each of the following major subsystem design choices for the Rockwell/Langley winged PLS. Nitrogen gas is shared for OMS/RCS pressurization, propellant line purge, and vernier thrust; this minimizes tankage and eliminates the need for gaseous helium. APUs and hydraulics are eliminated by using

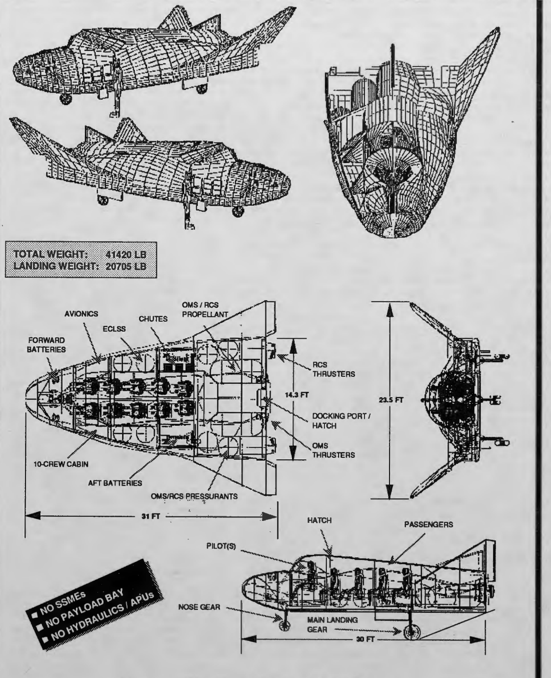


Figure 1. PLS Winged Spacecraft Configuration

electromechanical actuators (EMAs). Power and distribution is simplified by using rechargeable silver-zinc batteries and all-DC power distribution. These high power density batteries also can be used to provide forward ballast for c.g. control. Batteries can provide enough power for the SSF crew rotation 3-day reference mission. Longer missions will require the use of fuel cells. If fuel cells are used, a power/propulsion alternative is LO2/LH2 OMS/RCS with shared fuel cells/OMS/RCS LO2/LH2 tankage. Coolant fluids/loops and thermal control/heat rejection subsystems should be simplified as much as possible, despite the incurred weight penalty. KSC concurs with the design's choice of using only a water coolant loop with no avionics coldplates or freon loops. On-orbit heat rejection will be accomplished using water flash evaporators, and low altitude/landing heat rejection will utilize new technology, state-change wax thermal capacitors. The current technology alternative is a Shuttle-type ammonia spray boiler. Shuttle-type TPS can be used for the PLS spacecraft, with the exception that the FRCI-type high thermal performance (HTP) tile be "hardened" for durability, be permanently waterproof, and require no strain isolation pad (SIP) for tile attachment. No SIP will be required for the winged PLS, because it uses a flat, detachable, graphite polyimide heat shield which has a thermal expansion coefficient similar to the tile. The shield has a 650°F use temperature (compared to 350°F for aluminum); therefore, thinner tiles than the Shuttle's can be used. The heat shield is removable, which simplifies periodic structural inspections. The winged PLS requires only 2 percent of a Shuttle Orbiter's number of HTP tiles (450 vs 27407), and only 7 percent as much TPS area (840 vs 12021 sq ft). Seventy percent of the tiles are similar in shape, versus 13 percent of the Shuttle's. Solid motors located on the launch vehicle adapter will provide on-pad and inflight abort capability. Two outward-opening hatches allow normal or emergency egress and provide maximum internal accessibility for ground maintenance.

Biconic PLS. The JSC/Boeing biconic PLS (Figure 2) was designed for missions exceeding 3 days, such as satellite servicing. Fuel cells were chosen for power because of the weight penalty incurred with using batteries on longer-than-3-day missions. KSC prefers batteries for simplicity. The existing technology OMS/RCS subsystems could be simplified by using hydrazine propellant with shared OMS/RCS tankage. This will reduce the number of toxic propellants and tanks (can be reduced from 8 to 2 tanks) as baselined in the biconic vehicle's MMH/NTO systems. The biconic has four expendable OMS tanks, three expendable OMS engines, and four RCS tanks. The new technology propulsion system choice is LO2/RP-1 OMS, H2O2/RP-1 RCS, and H2O2 vernier thrusting. These non-hypergols are promising candidates; H2O2 shortcomings have been mentioned previously, and LO2 has the drawback of being a cryogen. The OMS and RCS are completely separated subsystems. A power/propulsion alternative is to use LO2/LH2 OMS/RCS and share the propellant tankage with the fuel cells. Nitrogen gas is used for the same functions as the winged PLS. The biconic design uses freon and water coolant loops with avionics coldplates. KSC recommends using a water loop only, and passive cooling for avionics. KSC also recommends using flash evaporators for on-orbit heat rejection instead of flash evaporators and expendable space radiators. The more complex cooling and thermal control systems on the biconic PLS may be driven by extended mission requirements. The biconic vehicle will require interface checkout and integration of the spacecraft with the separated adapter/radiator/OMS subsystems. The biconic PLS choice of FRCI with silicone carbide coating allows the tile to be "hardened" and waterproof. The tiles require SIP however, and KSC prefers a direct-bond tile. The vehicle uses EMAs instead of hydraulics and APUs for actuation. Health monitoring and BITE equipment will be used extensively to enhance launch turnaround. A launch escape system will provide on-pad and inflight abort capability. Two outward opening hatches allow safe normal and emergency egress, and maximize internal accessibility for ground maintenance.

The KSC recommended subsystems for both PLS versions will result in vehicles which are heavier, but easier to process due to reduced subsystem and checkout equipment complexity.

Spacecraft Processing

Winged PLS. Preliminary results of the winged spacecraft processing analysis indicate a 21-31 day timeline, assuming 6 days/week, 2 shifts/day operations. Refer to Figure 1 for subsystem locations. The major spacecraft processing activities were derived from STS planning schedules using a pre-51L mission and operational philosophy. Shuttle SSME, payload bay, fuel cell/PRSD, hydraulics, and APU processing functions have been removed. The new activities for the winged PLS (compared to Shuttle) are battery removal, fit-check, and installation; EMA checkout; emergency parachute removal and installation; and adapter processing. The Shuttle requires approximately 450 setup and vehicle processing activities; PLS requires less than 250. The spacecraft-to-booster expendable adapter and emergency parachutes will be processed offline in separate facilities. The adapter will have electrical interfaces, stage separation devices, and abort motor interfaces which require test and checkout.

Key processing differences exist between the winged and biconic PLS. The winged PLS will have a more extensive aerosurface checkout and frequency response test than the biconic because the winged vehicle will

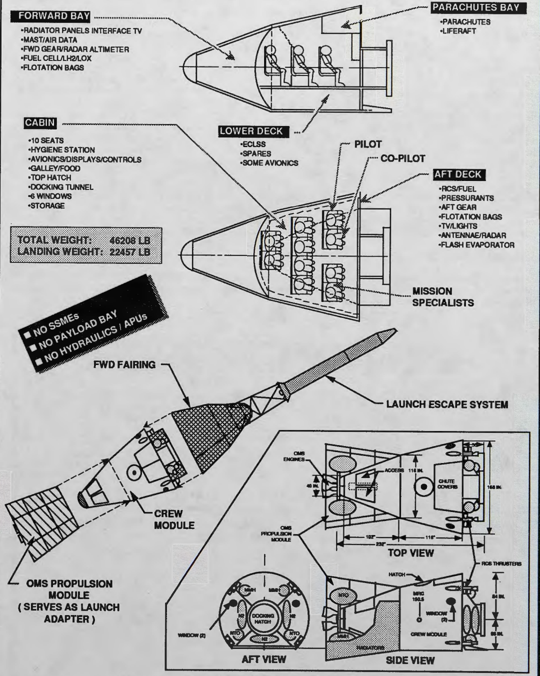


Figure 2. PLS Biconic Spacecraft Configuration

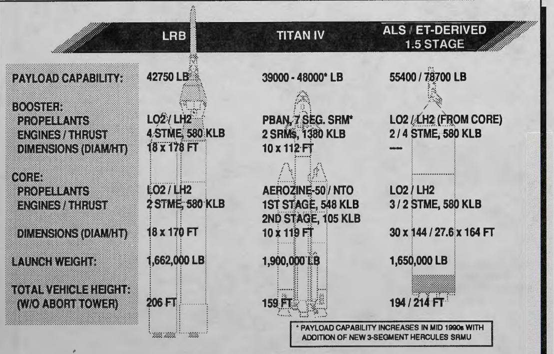
have four elevons and a body flap. Winged PLS TPS maintenance will be less than the biconic because of the elimination of SIP, and the use of a large flat heat shield on the vehicle's undersurface. The winged PLS will require less propulsion and thermal control subsystem maintenance because of the simplified design.

Biconic PLS. The biconic vehicle processing timeline is also 21-31 days, assuming 6 days/week, 2 shifts/day operations. Shuttle SSME, payload bay, hydraulics, and APU processing functions have also been removed. Refer to Figure 2 for subsystem locations. The new activities for the biconic PLS (compared to Shuttle) are parafoil and emergency parachute removal and installation, landing gear checkout, EMA checkout, and adapter and shroud processing. The parafoil, emergency parachutes, expendable radiator, OMS, shroud, and adapter are processed offline in separate facilities. Parafoil processing may be extensive, due to the large parafoil's size (75 x 130 ft), motor drives, riser attachments, and other steering mechanisms. The expendable adapter will have space radiators, OMS tankage, propellant lines, and engines, electrical interfaces, and stage separation devices which must be checked-out. The freon coolant loops in the space radiators will need to be interfaced with the spacecraft's freon loops, filled, and leak-checked. Biconic spacecraft aerosurface checkout and frequency response test will be less extensive than the winged vehicle's, because the biconic only has a split body flap (2 surfaces). Biconic TPS maintenance may be longer because of the curved undersurface and requirement for the use of SIP in FRCI tile attachment.

The major differences between the biconic and winged PLS are separate OMS and RCS processing, radiator processing, fuel cell power reactant, storage, and distribution system testing, parafoil processing, and shroud processing. Detailed spacecraft processing timelines, including manpower and resources, will be affected by automated checkout/BITE equipment capability and operations and maintenance "philosophy".

PLS LAUNCH VEHICLES

Proposed launch vehicles for both spacecraft configurations are: •Liquid Rocket Booster (LRB); •Manrated Titan-IV; and •Advanced Launch System (ALS) or Shuttle External Tank (ET) Derived 1.5 Stage. Launch vehicle configurations and data are shown in Figure 3.



	LRB	TITAN IV	ALS / ET-DERIVED 1.5 STAGE
PAYLOAD CAPABILITY:	42750 LB	39000 - 48000* LB	55400 / 78700 LB
BOOSTER:			
PROPELLANTS	LO2 / LH2	PBAN, 7 SEG. SRM*	LO2 / LH2 (FROM CORE)
ENGINES / THRUST	4 STME, 580 KLB	2 SRMs, 1380 KLB	2 / 4 STME, 580 KLB
DIMENSIONS (DIAM/HT)	18 x 178 FT	10 x 112 FT	---
CORE:			
PROPELLANTS	LO2 / LH2	AEROZINE-50 / NTO	LO2 / LH2
ENGINES / THRUST	2 STME, 580 KLB	1ST STAGE, 548 KLB 2ND STAGE, 105 KLB	3 / 2 STME, 580 KLB
DIMENSIONS (DIAM/HT)	18 x 170 FT	10 x 119 FT	30 x 144 / 27.6 x 164 FT
LAUNCH WEIGHT:	1,662,000 LB	1,900,000 LB	1,650,000 LB
TOTAL VEHICLE HEIGHT: (W/O ABORT TOWER)	206 FT	159 FT	194 / 214 FT

* PAYLOAD CAPABILITY INCREASES IN MID 1990s WITH ADDITION OF NEW 3-SEGMENT HERCULES SRMU

Figure 3. Launch Vehicle Data

INTEGRATED VEHICLE PROCESSING

Launch site scenarios and associated preliminary schedules have been developed for processing of the integrated spacecraft and launch vehicle. These processing scenarios are shown in Figure 4 and discussed — along with processing times — in the following paragraphs.

PLS / LRB. The total PLS/LRB integrated vehicle flow (see Figure 4, top left) is 52 days. The LRB booster and core vehicles are checked out in parallel in the same LRB HPF. Processing functions are the same for the two vehicles, except the booster has 4 STME engines and the core has 2 STME engines. The processing time is 18 days, which concurs with previous KSC STS/LRB Study results. Next, the LRBs are moved to the VIF and mated to the MLP during the next 5 days. Concurrently, the spacecraft, parachutes, and adapter are processed in their respective facilities. Spacecraft checkout (31 days) is approximately as long as booster checkout and MLP mate. After booster/core mate, the adapter is mated to the launch vehicle (1 day). When adapter/vehicle mate is complete, the PLS spacecraft is moved to the VIF and mated to the vehicle. Spacecraft mate and integrated checkout requires approximately 5 days. This duration depends on shroud (biconic only) and abort motor installation requirements. The integrated vehicle is then moved to the launch pad. Pad operations comprise 16 days, and include booster/core/engine final checks, propellant loading, launch countdown, and launch. This duration concurs with previous KSC STS/LRB Study results, excluding STS payload-unique pad processing requirements.

PLS / Titan-IV. The Titan-IV booster will be processed at CCAFS ; the PLS spacecraft and adapter at KSC (see Figure 4, center). Total flow time is estimated at 168 days based on five 10-hour shifts per week. At CCAFS, the first 91 days involve assembly and checkout of the first and second stages of the core vehicle in the VIB. Concurrently, the lower 5 segments of the SRMs are stacked in the SMAB. The SRM lower segments and core vehicle are then mated in the SMAB during the next 7 days, then moved to the launch complex. At the launch pad, buildup and checkout of the upper 2 segments of the SRMs is accomplished during the next 21 days. The spacecraft, parachutes, and adapter are processed at KSC concurrent with the CCAFS booster activities. Parachute and adapter processing is accomplished in 15 days in their respective facilities, and spacecraft processing is completed in 31 days in the spacecraft HPF. The adapter is transported to CCAFS and mated to the core vehicle after it is aligned and checked-out. Next, the spacecraft is transported to CCAFS and installed above the adapter. These 1-day activities occur toward the end of SRM buildup and checkout. Finally, abort motors and shroud (biconic only) are installed on the integrated vehicle. The last 49 days of the flow involve integrated vehicle testing, pad operations, launch preparations, propellant loading, and launch. The 168-day total flow time may be reduced in the mid 1990s with processing improvements at CCAFS. These include an expanded SMAB, Titan-IV launch capability at LC-40 and -41, and a 3-segment SRMU. The flow time will also be shortened if no Centaur or IUS-type upper stage is used for PLS. The problems remain of manrating the Titan-IV, and sharing the CCAFS facilities with competing DoD and commercial customers.

PLS / ALS (or ET-derived) 1.5 Stage. The total PLS/ALS 1.5 Stage integrated vehicle flow (see Figure 4, bottom left) is the same as PLS/LRB — 52 days. Since ALS and ET-derived core flows are assumed to be the same, and for the sake of convenience, only ALS is used in the following discussion.

The ALS is assumed to use a recoverable propulsion and avionics (P/A) module on the booster and/or core stage. The 1.5 stage ALS uses a 3 STME engine core with a 2 STME engine Atlas-type half stage booster. After the P/A module(s) are ready, they are integrated horizontally with the core and checked-out in the CSPF. This 25-day activity includes 18 days of LRB-type processing, and another week of P/A module/core vehicle integration. Next, the core is moved to the VIF where it is mated to the MLP (3 days). Concurrently, the spacecraft, parachutes, and adapter are processed in their respective facilities. Spacecraft checkout (31 days) takes approximately as long as the ALS booster checkout and MLP mate. After booster/core mate, the adapter is mated to the launch vehicle (1 day). When adapter/vehicle mate is complete, the PLS spacecraft is moved to the VIF and mated to the vehicle. Spacecraft mate and integrated checkout comprises approximately 5 days. This duration depends on shroud (biconic only) and abort motor installation requirements. The integrated vehicle is then moved to the launch pad. Pad operations require 16 days and include booster/core/engine final checks, propellant loading, launch countdown, and launch. This duration concurs with previous KSC STS/LRB Study results, excluding STS payload-unique pad processing requirements.

LANDING AND RECOVERY

PLS landing and recovery issues are being identified and analyzed. Refer to Figure 5 for a landing/recovery scenario. The *biconic PLS* currently uses a steerable parafoil parachute for routine landings. Landing accuracy

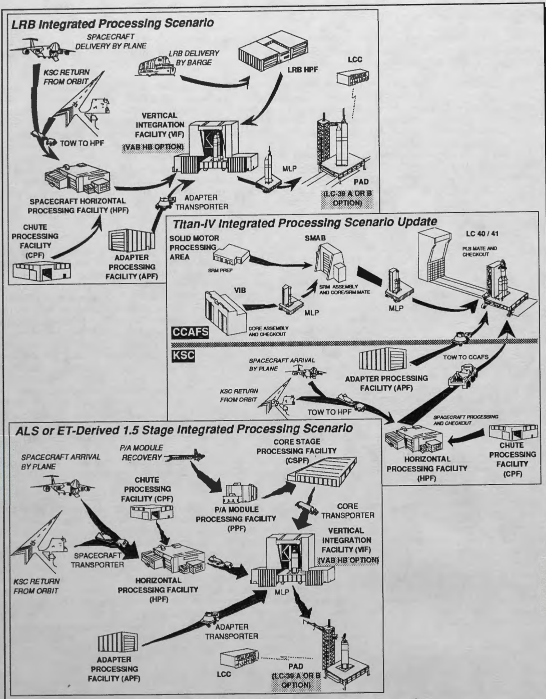


Figure 4. PLS Launch Site Processing Scenarios

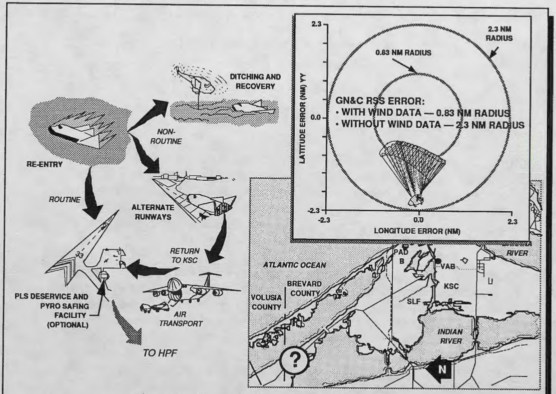


Figure 5. PLS Landing and Recovery Scenario

requires that a 1.7 to 4.6 nautical mile diameter landing area (see Figure 5, top right) be cleared and the surface be conditioned for a landing skid/nosewheel touchdown at 10—22 fps vertical velocity (unless landing rockets are used). This routine landing area would preferably be located at or near KSC, with alternate CONUS sites in Florida or Texas. Boeing has identified a potential site north of KSC near the Brevard/Volusia county borders. Environmental concerns, land availability, and costs will present a challenge in siting a landing area of this size. The *winged PLS* will use the existing SLF at KSC (see Figure 5, bottom right), or other alternate 10,000—15,000 ft runways that are within the spacecraft's crossrange. Both spacecraft can be transported to KSC from alternate sites by using a C-5 or C-17 air transport. Both spacecraft will probably be able to perform RTLS, TAL, and AOA inflight aborts. The winged spacecraft will be able to use current Shuttle landing sites (KSC, Edwards, White Sands, Ben Guerir, Moron, Banjul, etc.); new sites will need to be planned for the biconic spacecraft.

Both spacecraft will have Apollo-type on-pad abort capabilities. In such an abort situation, a launch escape tower or adapter rockets will be used to propel the spacecraft away from the pad area. Emergency parachutes will deploy and the vehicle will splash down 1 mile off the coastline. Flotation bags will stabilize and properly orient the vehicle in the ocean. KSC will require a search-and-rescue force as well as a spacecraft recovery ship to be readied during each PLS launch.

CONCLUSION

The need for assured manned access to space, coupled with ambitious manifests for SSF, lunar, and Mars missions indicate the need for a PLS-type spacecraft. To maximize operational efficiency and minimize KSC impacts, launch site evaluations and subsequent recommendations are vital early in the spacecraft design phase.