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David A. Luke
Merrick & Co.

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FACILITY CONCEPT FOR NASP DERIVED VEHICLES

David A. Luke, Jr
Merrick & Co -- Denver, Colorado

As the National Aerospace Plane (NASP) development progresses the possibility of having an operational fleet of NASP derived vehicles (NDVs) becomes more of a reality. Currently facility concepts for the NDV have reflected almost exclusively its aircraft like characteristics while ignoring its rocket-like features. To meet the needs of this revolutionary type vehicle, a whole new concept in facilities, basing, and ground processing is required to ensure its rapid turnaround capability.

INTRODUCTION

NASP or the X-30 is hopefully the precursor to the NDV. While the X-30 by definition will never be an operational vehicle, it will drive most of the technologies necessary for the NDV. Since the X-30 is an experimental vehicle, it will not require a quick turnaround. It will be flown when all systems and the vehicle are ready. On the other hand, the NDV, will have very strict turnaround times for both military and commercial launches. The goal of the first generation NDV is a one day turn-around for emergencies and crisis, and about four days for routine flight. This is a revolutionary concept given the size and complexity of the vehicle. Currently, the space shuttle orbiter, which in overall size is smaller than the future NDV, requires about 6 months to turnaround. In a meeting between the director of the Kennedy Space Center, General Forest McCartney and the Air Force Scientific Advisory Board, Gen McCartney stated that the Air Force must think twice about such a quick turnaround of a manned vehicle. In manned spaceflight, if everything is not perfect we don't fly. The robustness of the NDV must be much greater than that of the Space Shuttle Orbiter if the turnaround time is to be reduced significantly. The NDV must go through the same evolution as the modern fighters of today. Aircraft reliability has gone up through many years of iterations involving, many prototypes and operational vehicles, and in some cases human fatalities occurred. There will be a high price to pay for quick turn-around SSTO vehicles. [1]

NASP DERIVED VEHICLE (NDV) TECHNOLOGY

While most of the components for the NASP are still under development, some goals for individual components have resulted in more focused work. The concept desired for NASP is to use air-breathing propulsion to reduce the need for liquid oxygen, thus reducing the vehicle's gross weight. Operational vehicles derived from NASP technology show potential for vehicle sizes of one tenth or less the take-off gross weight of the Space Shuttle. To enable air-breathing propulsion from Mach 6 to orbital velocity (Mach 24), the use of hydrogen fuel is required. No other fuel can supply the necessary combustion efficiency and vehicle cooling requirements. To reduce the fuel volume requirements, denser slush hydrogen will be used. The payload capacity of the NDV supports 40 to 50 percent of Department of Defense space traffic, nearly 90 percent of the near term SDI requirements and around 90 percent of civil and commercial launch requirements. These estimates do not account for possible new spacecraft designs optimized for NDV launch and on-orbit support, which could accommodate a larger percentage of payloads. In terms of an annual flight rate, an NDV would fly 40 to 160 flights per year, depending on the quantity of space traffic required. If the NDV lowers the cost of accessing space, a surge in commercial launch traffic is anticipated. The increased demand may range from only slight increases in launch traffic to the creation and movement of entire industries into space [2].

FACILITY DRIVERS

In examining the facility drivers for the NDV, the most significant is the quick turn-around requirements. A whole new method of ground processing must be envisioned. The current ground support for expendable launch vehicles will not provide the quick-turn capability. Some of the capabilities for the new National Launch System (NLS) must be incorporated, for example, parallel processing of the payload and the core vehicle before integration [3]. Integration of the payload on the pad can delay flights. With the NDV, processing of the payload and encapsulation must occur independent of the flight vehicle. The NDV must be processed on an assembly line with on the spot changeout of failed critical components. Moving the vehicle from facility to facility would complicate processing and cause delays, particularly during severe weather.

Currently, the NASP program is considering using slush hydrogen fuel for cooling the vehicle's skin while in the atmosphere and for propulsion. Slush hydrogen's added benefit is that its volume is 30% less than liquid hydrogen; therefore the vehicle can be smaller, saving structural mass. The disadvantages of slush hydrogen is that it's unstable. Only 13°K separate slush hydrogen from liquid hydrogen. This instability will require that slush hydrogen be manufactured near the NDV processing facilities [4].

Production of slush hydrogen will in-turn drive a requirement for clean, uninterrupted power. A dedicated power plant is required to backup the commercial feed, and possibly tertiary power backup will be required. Solid State Uninterruptable Power Supplies (SSUPS) will be required to provide power and cooling to computer equipment that controls slush hydrogen production, provides mission uplink to NDVs being prepared for launch and for maintaining NDVs manifested to fly. A large supply of both liquid and slush hydrogen will be required to meet surge requirements of a fleet of NDV vehicles supporting commercial, NASA and military

needs. If the liquid hydrogen is purchased from a commercial source for converting into slush at the NDV processing facility there is concern that commercial sources cannot supply enough liquid hydrogen to meet slush hydrogen production requirements. Consideration should be given to strengthening the industrial base of commercial liquid hydrogen production [5].

CONCEPTUAL LAYOUT AND PLANNING

There are three major areas that must be planned for an NDV launch complex. First, a vehicle and payload processing area must be designated. Second, an area to manufacture and store slush hydrogen, liquid oxygen, liquid nitrogen, helium and hypergolic fuels must be determined. And third a runway area must be established for take-off, landing and taxiing. A primary concern is the quantity distances (QDs) between these facilities. If an accident occurs in one area minimization of collateral damage is desired.

Processing Facility

Figure 1 shows a conceptual layout of an NDV processing facility. This drawing is not drawn to scale and is only intended to show the relationship between functional processing areas. This processing concept assumes that propellant purging has been accomplished before the vehicle rolls into the processing facility. The processing facility is made up of five distinct areas: the payload removal area, the structural and skin inspection area, the avionics and computer inspection area, the engine inspection area and the payload processing and integration area with final vehicle checkout. Each area is a separate bay with a team of individuals responsible for very specific tasks. The issue that drives this concept is a 24 hour turnaround. It is very likely there will be more than one vehicle moving through the assembly line at one time. The assembly line process reduces the wait time for individual crews to perform their tasks. The vehicles must be modular to allow changeout of large components, on the spot, during processing. This modularity will

Note: Maintenance Personnel Work in Teams on the Same Components. This Provides the Necessary Skills to Provide Quick Turn-Arounds.

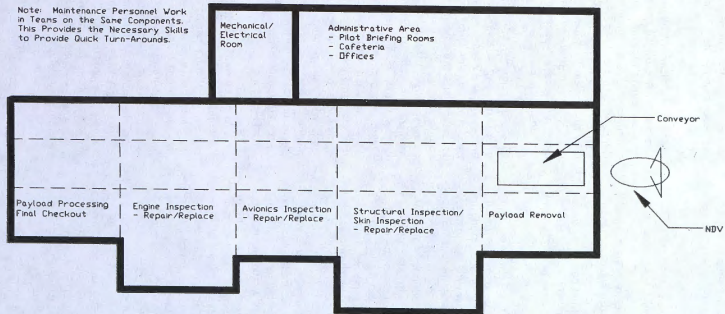


Figure 1 - Processing Facility

require robustness of the vehicle and will allow damaged parts to be repaired in a more leisurely manner while the vehicle meets its flight schedule.

The payload removal area is the first to be examined. The vehicle will be mounted to a central conveyor platform that moves it through the processing facility. Any payload that was retrieved from orbit will be removed from the payload bay and prepared for refurbishment. A drop curtain type clean room environment may be employed so the entire processing facility will not have to meet clean room standards.

A second area would be for structural and skin inspection, and include non-destructive testing. Since the vehicle is subjected to large thermal gradients, severe vibrations, and varying structural loads throughout its flight profile, it will require detailed examination. The structural inspections would include everything from landing gear, payload bay doors, internal structural members, etc. The vehicle's individual skin panels would need to be inspected and replaced if necessary. A quick method of performing this operation must be developed and proven.

The avionics inspection and repair area would be for the avionics systems, communications equipment and on board computers for mission control. The systems would be inspected for proper operation after each flight. With today's technology, the flight control systems and computer systems will be able to print out a list of potential problems for the maintenance crews on the ground before the vehicle lands, as is being done with the new C-17 and the C-5B. Each system component would be modular to make removal quick and easy for the maintenance crews. As with other components of the NDV, repairs and testing would be performed away from the NDV so the vehicle's schedule would not be interrupted. This method also requires that an adequate bench stock of replacement parts be maintained.

One of the most challenging areas for maintenance will be the engine inspection, repair and replacement bay. As in modern fighter aircraft, engine removal and reinstallation must be quick and simple. Normal preventive maintenance tasks will be performed with the engines in place during turnaround. However, if an engine requires more than just normal maintenance or minor repair, the engine will need to be removed and replaced. Major engine repairs may be performed on site or may be sent back to the factory for rebuilding. This concept also requires that an adequate number of replacement engines be kept on hand.

One of the primary inhibitors to timely launch of today's expendable launch vehicles is processing and integrating the payload on the pad. This requires large movable structures to encapsulate the payload fairing area of the launch vehicle. This structure must contain a clean room to protect the payload from the ambient atmosphere, requires strict environmental controls and strict power controls. This concept places too much ground based infrastructure close to the launch pad. When this method of payload processing is employed, the launch can be delayed by problems with the payload. These delays in payload processing not only cause delays in the launch of that particular payload, but also of the entire launch manifest for that particular booster.

The NLS, currently under development for DoD and NASA, has facilities for parallel processing of the payload and the core vehicle away from the pad. The encapsulated payload and the core vehicle are then mated in the vertical integration facility and placed on a mobile launch platform. The vehicle then rolls out to the pad and launches within 96 hrs. If problems with the payload are encountered on the pad, the vehicle is rolled back to the vertical integration facility for resolution. The pad is free for another launch from another vehicle [3].

This method of divorcing the encapsulation and integration of the payload from the launch pad (or runway in the case of the NDV) must be used or short turnaround times will not be realized. The various payloads that will fly on the NDV must be encapsulated off-line and queued ready for flight on the next available vehicle. Mission data must be readily available for quick upload to the vehicle and briefing to the crew. The encapsulated payload also would be integrated to an appropriate upperstage before encapsulation. The payload encapsulation structures will be a standard size and designers will have to meet the constraints of the NDV to fly on the vehicle. Redesigning the vehicle for the payload is too costly in both time and money. After the encapsulated payload is placed in the NDV payload bay, a final checkout will be performed and the vehicle will be rolled out of the payload processing facility to the vehicle fueling area.

Fuel Manufacture and Vehicle Fueling Area

This area will be one of the largest based on the clear distances required for the propellants that will be manufactured and stored. As can be seen from the overall site layout in Figure 2, the vehicle fueling area is near the take-off end of the runway. The slush and liquid hydrogen, liquid oxygen, liquid nitrogen, helium and hypergolic storage tanks must be separated by enough distance to prevent collateral damage of the various tanks in case of catastrophic accidents. The slush hydrogen manufacturing plant is located far enough from the runway to prevent damage in case of a vehicle accident during takeoff or landing and provides enough clear distance between it and the storage tanks to prevent collateral damage. One way to decrease this distance in case of a constrained site is to use earth berms around the tanks to deflect the blast up and away from the other tanks. The plant would be sized to manufacture the amount of slush hydrogen

required to support the vehicle schedule and rapid turnaround for contingency.

Handling slush hydrogen in an operational environment still has some unknowns. Slush hydrogen is 16% more dense than liquid hydrogen and has 18% more cooling capability than liquid hydrogen because of the heat of fusion. Using the slush instead of liquid reduces the projected gross liftoff weight of an NDV vehicle by 30%. The technology team working the slush issue for the NASP found that most of the work remaining is mostly engineering. There are no major technological road blocks associated with the use of slush hydrogen. Decisions must be made as to which method of producing slush hydrogen should be used, the freeze-thaw evaporative method or the refrigerative auger method. The most serious drawback to the freeze-thaw evaporative method is that it operates below atmospheric pressure, which can cause oxygen to leak into the system creating a potentially explosive mixture. Currently, this method can produce about 500 lbs of slush hydrogen in a 20 hour period. The refrigerative auger method has the advantage of operating above atmospheric pressure thus preventing oxygen contamination, but it has the disadvantage of being very expensive [4].

Another critical area of research involves the problems of storing slush hydrogen and ground operations such as rapid loading and unloading launch vehicles. Basic research must be conducted to model the thermal and fluid dynamic processes of handling the slush, and filtering and transferring technology must be developed. The slush is maintained at temperatures lower than that of liquid hydrogen so it will require better insulated storage tanks and transfer piping than is used currently to maintain the slush condition. The level of insulation will probably be similar to that used in a liquid helium handling systems. Heat leaking into the slush can cause a variety of problems; the most significant is a change in the propellant density. Heat and the resultant liquefaction of slush can cause significant density changes, up to

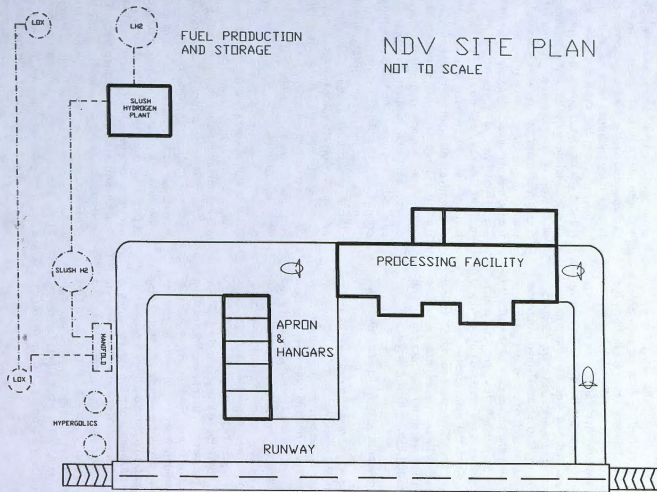


Figure 2 - NDV Site Plan

30%, in stored slush. Density changes can cause the material in a tank to oscillate, and the high-energy oscillations can cause internal tanks and transfer lines to rupture. Pumping the slush into the vehicle adds heat to the slush. If the vehicle takeoff is delayed after fueling is complete, a portable system is needed to constantly recirculate and reprocess the slush in the vehicle to maintain proper conditions [4].

If slush hydrogen can be transferred at the same rate as liquid hydrogen, information can be used from fueling the Space Shuttle to estimate fueling times. Currently, it requires 2 hours and 45 minutes to fuel the Space Shuttle with liquid hydrogen [1]. This requirement is driven by the vehicles tankage needing to be slowly chilled to cryogenic temperatures from ambient temperatures to prevent damage to the tanks. After the tankage is cooled, then the fuel flow capacity can be increased to fill the tank. This same principle will also be true with the NDV. One concept that may be investigated is to have a fuel container that is detachable from a fuel bay of the NDV. By employing this concept, a prefilled fuel container could be uploaded quickly into the fuel bay of the NDV. This concept would only need to be used if processing times limited the fueling of the vehicle to something that was greater than that allowed by the 24 hour turnaround. Normal operation of a four to seven day turnaround would not require this method.

Runways and Associated Pavements

The third major area required by an operational fleet of NDVs is runways, taxiways, aprons and hangers. While the goal for NDVs is to have them operate off of 12,000 foot runways [2] (in case of an emergency, they would be able to land at any major airport) it would be beneficial to have a much longer runway at the main operating base or launch complex supporting the NDVs. The primary reason is to allow plenty of room to stop the vehicle in case of an aborted take-off and to allow for extra stopping surface on landing in case the brakes fail. A vehicle like the NDV

will be at least as costly as the shuttle, so providing more runway surface that will potentially save the vehicle in one of these instances is a small price to pay. The runways, taxiways and aprons will have to handle a fully loaded NDV ready for take-off. The joints in the taxiways and runways will have to be of a very high quality or possibly one continuous pour. This will prevent unnecessary vibrations and unnecessary disruptions to the air flow over the lifting body of the NDV.

One area that requires a significant amount of research is developing a fire extinguishing system for the vehicle while operating on the taxiways and runways. The current method of dealing with liquid hydrogen leaks or fires is to let them burn. It is either not known how to extinguish a hydrogen fire or it is too costly. The increased number of anticipated operations leads to the possibility that catastrophic mishaps are more likely to occur. The cost of developing an agent that would neutralize the volatility of hydrogen gas mixed with air should be a development priority. The other consideration in regards to extinguishing a hydrogen fire would be the need for immediate response. Having the agent on a truck a few miles from the vehicle would not provide a timely response. In all probability the extinguishing system charged with the agent would either have to be located along the entire length of the runway, or the fire extinguishing equipment and the agent could be located on a sled vehicle that would follow along side the NDV as it travels down the entire length of the runway. Both methods would increase the probability of saving the NDV and salvaging the vehicle.

Another area requiring significant research is the possibility of an NDV alert vehicle for military uses. This vehicle could be located in a shelter, fueled and ready for taxi and take-off at a moments notice. A vehicle fueled with slush hydrogen would have to be placed inside a hardened enclosure. This example adds an entirely new dimension to explosion proof fixtures. A facility of this nature definitely would require hydrogen and

oxygen leak detection, a high volume forced air ventilation system that maintains adequate humidity and temperature limits, and a fire detection and prevention system that could extinguish a hydrogen/oxygen fire.

Acquisition Challenges

Cost estimates for providing an operational NDV with its own cryogenic plants are high. The vehicles will each cost about \$5.0 billion, and the supporting infrastructure will cost about of \$2.0 billion. Operations and maintenance costs will be about of \$60 million dollars a year [2]. This will be a large investment for a nation that currently launches only about 20 payloads per year [6]. Investing in a fleet of vehicles that can perform up to 150 missions per year per vehicle seems to be overkill, based on current projections. NASP research must continue for this nation to remain competitive in the aerospace industry. Additionally, systems like the NLS, if designed properly, will significantly decrease the cost per lb of payload to orbit and create new markets for space. This reduction in cost will drive the future requirement for high launch rates that would be best met by a fully reusable vehicle.

CONCLUSION

The technology to produce a NASP derived vehicle is near. Currently, funding is one of the major hurdles to seeing the X-30 technology demonstration. The key element that will prevent future NDVs from achieving the desired goals in turn-around capability will be a lack of investment in the supporting infrastructure. It's time the nation began addressing the supporting infrastructure in parallel to the vehicle. Then, some of even the most ambitious goals for vehicle capabilities might be met.

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