



---

The Space Congress® Proceedings

1989 (26th) Space - The New Generation

---

Apr 28th, 3:00 PM

## Paper Session IV-B - Offshore Space Launch Developments

David P. Tuturea

*Broun & Root U.S.A., Inc. Space Operations*

Farhad Rajabi

*Broun & Root U.S.A., Inc. Space Operations*

Follow this and additional works at: <https://commons.erau.edu/space-congress-proceedings>

---

### Scholarly Commons Citation

Tuturea, David P. and Rajabi, Farhad, "Paper Session IV-B - Offshore Space Launch Developments" (1989). *The Space Congress® Proceedings*. 4.

<https://commons.erau.edu/space-congress-proceedings/proceedings-1989-26th/april-28-1989/4>

This Event is brought to you for free and open access by the Conferences at Scholarly Commons. It has been accepted for inclusion in The Space Congress® Proceedings by an authorized administrator of Scholarly Commons. For more information, please contact [commons@erau.edu](mailto:commons@erau.edu).

**EMBRY-RIDDLE**  
Aeronautical University™  
SCHOLARLY COMMONS

## OFFSHORE SPACE LAUNCH DEVELOPMENTS

by David P. Tuturaa; PE

and Farhad Rajabi, PhD, PE

Brown & Root U.S.A., Inc. Space Operations

### ABSTRACT

Studies have been performed to investigate the feasibility of launching space vehicles from an offshore platform site [1] & [2]. Constraints on the use of existing facilities at Kennedy Space Center/Cape Canaveral Air Force Station (KSC/CCAFS) and Vandenberg Air Force Base (VAFB) will make it increasingly difficult to meet future planned launch requirements for larger vehicles and more frequent launch schedules.

A universal mobile platform which can launch a variety of space vehicles from a deepwater location, provides an efficient method of reaching all these objectives, while mitigating problems with site acquisition. Costs for floating or fixed platforms used in the offshore oil industry are probably less than one half the cost of providing new, fixed, onshore launch facilities.

This paper presents the results of recent studies for offshore launch development. Several viable platform concepts are proposed and workable operational scenarios illustrated. Technical problems associated with vehicle transportation, propellant handling, storm survival, thrust plume effects and weather downtime are addressed. Also, concerns of site security, safety, logistics support and communications are discussed. Solutions to many of these problems already exist in the present state of the offshore oil industry.

### INTRODUCTION

With large new programs such as Space Station, SDI and ALS on the horizon, launch site considerations become critical.

Any new launch site must meet certain minimum requirements [3]. These are:

1. The ability to launch to all necessary azimuths through clear launch corridors;
2. Remoteness from populations and built-up areas;
3. The ability to perform launch operations without violating environmental limits or constraints;
4. Sufficient remoteness to avoid interference with existing space launch programs and operations;
5. An efficient logistic relationship to a vehicle assembly location which in turn has an adequate infrastructure of skilled labor, supply lines, utilities, etc.

Land based launch sites at KSC/CCAFS and VAFB can readily meet requirements of items 1 and 5 but, have barely managed to meet the other needs for existing launch programs. Any new major space program will greatly strain available resources at these sites.

The feasibility of establishing offshore launch sites to support new space programs has been studied from time to time since 1961 [4]. In most cases, the driving factors for moving offshore did not justify the additional costs and potential hazards. As the offshore oil industry has technically matured, equipment and methods for working offshore have improved greatly. Cost of fabricating and

installing large structures for deepwater oil & gas exploration have actually decreased in recent years. Drilling and production operations are now performed in deeper and more hostile waters with greater safety and reliability than ever before.

### SITING

At VAFB, a large investment is required for any new site. Adaptations have been shown to be as costly as new construction. Space for new construction is limited by land availability, access, terrain acoustics and local population. Operational interference is already a costly factor. Present programs are pressing Environmental Impact limits.

At CCAFS/KSC, there is a large infrastructure serving existing programs and entailing a built-in expense. New site construction is limited by space availability. Modification of existing pads is expensive due to the extensive civil work required. Many existing sites have become National Monuments and do not provide required spatial separations for large vehicle Quantity Distance (QD) and acoustics. Local populations growth has become a problem.

Although these issues may be major stumbling blocks for launch pad siting, both VAFB and CCAFS/KSC meet all requirements for launch vehicle assembly, check out and launch control operations. Skilled labor, laboratories, site security, payload facilities, storage yards, tracking radars, range safety control, weather services, utilities, etc. are all in place and can be expanded somewhat if needed.

The following locations have been studied as possible alternatives for a new launch site. Major findings are presented:

- o Christmas Island - 2° north latitude; in the Southern end of the Line Islands, clear launch corridors, U. S. territory, no infrastructure, requires construction of all support facilities.
- o Culebra Island - 18° north latitude, East of Puerto Rico, polar orbit requires dog legs, U. S. territory, near low priced labor source, presently 1200 residents.
- o Jarvis Island - 0° latitude, north end of Line Islands, same comments as for Christmas Island.
- o Palmyra Island - 6° north latitude, near Christmas Island, same comments.
- o Hawaii, Main Island - Cape Kuniūkahi (near eastern point) 19.5° north latitude, clear launch corridors, minimal infrastructure, active volcano nearby.
- o Hawaii, Maui Island - 21° north latitude, similar comments as for main island.
- o Kwajalein Atoll - 5° north latitude, clear corridors, some area housing and infrastructure available, U. S. territory, more distant from U. S. than any other island location, existing U. S. base, subject to growing local population desire for sovereignty.

- o San Clemente Island - 33° north latitude, near aerospace infrastructure, clear polar, but no equatorial corridor, owned by U. S. government, naval target island.
- o Ocean platform, Atlantic/Gulf - Capable of accepting Launch Vehicle (LV) elements or complete LV from Gulf or Atlantic assembly sites, transporting to desired open ocean site, clear equatorial corridor in Atlantic, must locate 1500 miles from Florida Coast for clear polar corridor.
- o Ocean platform, Pacific - Capable of accepting LV elements or complete LV from U. S. West Coast, close access to polar corridor, 3000 mile transit required for equatorial launch.

The island sites, described above, all offer good launch corridors and are sufficiently remote to avoid problems with population safety and operational interference. However, the cost associated with establishing and operating vehicle assembly and integration facilities at these locations would be excessive compared to other solutions.

Several siting options for an offshore launch platform have been investigated. As the distance offshore increases, problems associated with population safety, quantity, distance, noise and onshore environmental issues will decrease. However, other problems become more intense. These include launch control, site security, water depths, logistics support and marine equipment usage. This is illustrated in Figure 1.

Siting of launch operations on offshore platforms in the Pacific for polar launches and in the Atlantic for equatorial launches provides a reasonable solution when vehicle assembly and integration are performed at facilities with coastal access. This allows use of facilities, skilled labor and infrastructure that are readily available.

The following are possible variations of this theme:

- i. Final assembly and integration operations performed at VAFB (polar) and KSC/CCAFS (equatorial) with separate launch platforms for WTR and ETR located offshore. The distance offshore can be as required to solve problems with QD, noise, operational interference, etc.
- ii. Final assembly at a West Coast location (polar) and Atlantic/Gulf Coast location (equatorial), other than VAFB and KSC/CCAFS, with launch pads offshore West and East Coasts.
- iii. Final assembly at a single U. S. facility with separate offshore launch pads for polar and equatorial launches.

For any of the above options, a marine transport system to move the launch vehicle from the assembly site to the launch site must be provided. Marine operations are discussed later.

Using existing facilities at VAFB and KSC/CCAFS (option i above), provides the best use of available infrastructure, results in the shortest transport distance to suitable launch site, and allows use of launch control and range safety facilities already available. Our studies have found this to be the most probable scenario for offshore launch sitings.

#### LAUNCH PLATFORM ALTERNATIVES

##### General

The primary objective of an offshore launch platform (LP) is to provide a stable launch pad and associated

equipment from which a space launch vehicle (LV) can be projected into space. The most important factors considered in assessing the feasibility of an offshore launch platform are:

- Water depth capability
- Mobility
- Launch vehicle loadout method to transportation vessel (LTVT)
- Transportation survivability
- Launch vehicle transfer method to the launch pad
- Propellant transfer operation
- Launch vehicle thrust plume effects
- Launch platform motion response characteristics
- Stability of LP and survivability of LV on LP
- Launch platform maintainability
- Existing industrial experience
- Available technology
- Safety
- Security

The following oil industry platform concepts have been considered for supporting a launch vehicle at an offshore site.

- Fixed piled platform
- Gravity base offshore
- Mobile jack-up platform
- Floating barge
- Ship shaped vessel
- Semisubmersible floating vessel
- Tension leg platform
- Buoyant tower platform

Figure 2 is a simplified concept comparison matrix and shows the result of the comparison for various platform concepts against major considerations for an offshore launch platform. Based on this evaluation, the semisubmersible vessel, mobile jack-up and the fixed platform were selected for further study.

##### Fixed Piled Platform

The fixed piled platform, Figure 3, is a steel tubular truss structure which is anchored to the sea bed and which supports a working deck at a safe elevation above the sea surface. The platform is supported by a steel pile foundation designed to resist overturning moments caused by wind, wave, tide, and current action as well as seismic loads. Over 3,000 structures of this type are used to support offshore oil drilling and production operations in water depths up to 1,450 feet. In deeper water, fatigue considerations become critical to design feasibility (5).

Fixed piled platforms are designed to be installed and operated at one location. They are not moveable. They provide a stable, low motion working platform safe from wave action in design storm conditions. The oil industry has extensive experience with fixed platforms and ample data is available regarding cost, safety, operability and maintenance requirements.

##### Mobile Jack-Up Platform

Jack-up Platforms have been used for offshore oil drilling operations since 1955. With over 400 jack-ups worldwide, the oil industry has acquired a great deal of operating experience for this type of platform. A jack-up provides a relatively stable working surface above the waves by supporting itself on steel legs which extend down to the sea bed (see Figure 4). The jack-up deck structure is designed with sufficient buoyancy to float in a stable condition when the legs are fully raised. However, towing characteristics of jack-ups are very poor with towing speeds usually less than 3 knots in good weather.

Existing jack-up vessels are capable of operating in up to 400 feet water depth. This could probably be extended to about 600 feet for a new design specifically tailored to offshore launch. Structural weight and vessel size will increase substantially for greater depths.

#### Semisubmersible Floating Vessel

Over 450 Semisubmersible vessels are in widespread use in the offshore industry for exploration and production of hydrocarbons (See Figure 5).

The semisubmersible was pioneered in the late 1950's as a method of providing a stable, floating offshore platform to support drilling operations in deep water. The concept has been extensively developed since, with "semi's" today operating in water depths up to 4500 feet and able to survive in over 100 foot waves and 100 knot winds.

The semisubmersible vessel is an excellent candidate for use as an offshore launch facility because its motion response characteristics do not exceed the required limits even in rough sea conditions. They are also not sensitive to the wave direction. Semisubmersible platforms can accommodate large variable deck loads without altering motion characteristics or exceeding stability limits. Furthermore, the draft can be varied to suite the sea conditions, launch requirement, or to facilitate hull inspection offshore. The semisubmersible's greatest advantage is its mobility, stability during the tow out and launch operations, and its cost and operability which are not greatly affected by water depth.

#### MARINE OPERATIONS

Each of the launch platform alternatives described above require different marine equipment and operating procedures to transport the launch vehicle offshore and prepare for launch. After evaluating various possible marine operation scenarios, the following preferred solutions, using proven techniques, were selected.

#### Fixed Offshore Platform

1. The launch vehicle is assembled onto a Mobile Launch Platform (MLP) structure at a quayside facility.
2. The MLP and integrated LV are transferred to a ship shaped launch vehicle transport vessel (LTV) by debalasting the LTV to lift the MLP off its quayside supports, (See Figure 6).
3. The LTV, a self-propelled ship form vessel with a dynamic positioning (DP) system, transports the LV to the pre-installed offshore launch support platform.
4. The MLP/LV are transferred to the fixed platform through a mating operation involving ballasting of the LTV.
5. Liquid propellants are transferred to the launch vehicle.
6. Launch when ready.
7. The MLP is recovered by the LTV through a reverse mating operation.
8. The MLP is transported by the LTV to a suitable refurbishing facility.
9. The MLP is refurbished and returned to the Vehicle Integration Building (VIB) for assembly of another LV.

If necessary, the motion characteristics of ship form hulls like the LTV, can easily be tuned or attenuated through proper sizing studies and through use of proven stabilization systems.

The process of transferring the MLP and LV from the LTV to an offshore platform has been developed and performed in the oil industry for larger offshore platforms (6).

#### Mobile Jack-Up Platform

1. The LV is assembled on an MLP at a quayside integration facility with coastal access (located within 12 miles tow distance of a suitable launch site).
2. The MLP, with integrated LV, is loaded onto the Jack-up at the integration facility. Transfer is by either skidding the MLP or by raising the Jack-up on its legs to pick up the MLP onto a cantilevered support beam arrangement. The MLP/LV is then moved to the center of the Jack-up for transportation offshore. Quayside waterdepth required is about 20 feet.
3. The Jack-up is towed to the launch site using three tugs (about 7000 hp each), or two tugs in the case of a Jack-up with propulsion assist thrusters.
4. At the launch site, the legs are lowered onto pre-set foundations to ensure adequate soil load bearing. Tugs may be required for positioning control. The hull structure is raised above the water to provide an adequate air gap for wave clearance and thrust plume venting.
5. For liquid vehicles, personnel are evacuated, then propellants are transferred to the launch vehicle.
6. Launch when ready.
7. The Jack-up is reboarded, legs raised, and towed to shore for refurbishment at a suitable facility.
8. Both MLP and the Jack-up deck areas are refurbished.
9. The MLP and Jack-up are returned to the integration facility for assembly of another LV.

#### Semisubmersible Vessel

1. The LV is assembled onto the MLP at a quayside facility as for the fixed platform concept.
2. The MLP and LV are transferred to the LTV by debalasting the LTV to lift the MLP off its supporting structure.
3. The MLP/LV is transported on board the LTV to the offshore launch site.
4. At the launch site, the MLP/LV is transferred to a pre-moored semisubmersible vessel through a mating operation involving debalasting of the semisubmersible and ballasting down of the LTV.
5. Liquid propellants are transferred to the launch vehicle.
6. Launch when ready.
7. The MLP is recovered by the LTV and transported back to shore for refurbishment.

8. The MLP is refurbished at a suitable facility and returned to the Vehicle Integration Building (VIB) for LV integration.

An alternate scenario where the MLP and LV are transported offshore directly on the semisubmersible is also workable. This scenario does not require an LTVT, but requires the semisubmersible platform to be transported to and from the launch site for each launch. The semisubmersible can either be towed by tug or be self propelled. At the launch site, the platform can be held on station by conventional pre-installed moorings or by using dynamic positioning thrusters. Use of dynamic positioning will reduce the set up time required on arrival at site.

#### PROPELLANT HANDLING

For launching liquid propellant vehicles offshore, provisions must be made for loading propellants just prior to launch. Also, in case of a late interruption in the countdown, it is necessary to have the capability to download propellants into a safe holding facility.

Propellant transfer to the LV needs careful consideration. During the actual transfer, personnel should be evacuated from the platform.

Handling procedures and equipment required will vary depending on propellant type. Cryogenic fluids require insulated or vacuum jacketed, pipelines and storage vessels with boil off vents, pressure controls and circulation systems. Hypergolic propellants are at ambient temperature, but require zero leak piping systems. Hydrocarbon liquids such as Kerosene present the fewest handling problems.

A number of methods for transport, storage and loading of liquid propellants offshore have been studied. The feasible options are described below.

##### a. Pipeline to Shore

For mobile jack-up units or fixed platforms which are sitting on the seabed and are located near shore, a pipeline may be a cost effective solution. Propellants can be transferred to subsea storage tanks and then to the launch vehicle, (Figure 7). For liquid hydrogen, a vacuum jacketed (VJ) line is probably required to avoid substantial boil off loss. Subsea installation of this line will be much more expensive than for a single wall coated or insulated line. Installation costs vary but generally average about \$1,000,000 dollars a mile for common offshore oil or gas pipelines. Costs for a VJ line could be an order of magnitude higher.

##### b. Propellant Transfer Vessel

For longer distances, a transport vessel can be designed to carry any liquid propellant. Cryogenics can be carried in large spherical tanks using technology common to transport of Liquid Natural Gas (LNG). This vessel can be mated to the underside of the MLP and launch vehicle for propellant transfer with no relative motion, (See Figure 8).

Storage of propellants can be provided subsea or onboard the launch platform.

As an option, liquid oxygen can be generated offshore with an air separation plant onboard the launch platform. The economics will depend on vehicle size, launch frequency and distance offshore.

#### ONSHORE FACILITIES

The following facilities are required onshore to support launch operations:

- o Coastal vehicle integration facility with quayside dock for moving the launch vehicle offshore.
- o A facility for refurbishing the MLP after launch.
- o A marine fleet base.
- o Launch control and range safety facilities if not located on one of the offshore vessels.

#### SCHEDULES AND COST

The offshore launch platform concepts presented in this paper are derivatives of floating and fixed structures common in the offshore oil and gas industry. Fabrication and installation costs and schedules presented here are based on commercial rates for U.S. fabricators and shipyards. Historical data for recent projects of a similar nature has been used. Contingencies have been added to account for new development and testing of systems unique to the offshore launch concept. Costs are based on meeting United States Coast Guard and American Bureau of Shipping requirements.

Costs are dependent on platform concept, vehicle size, weight, type of propellant, design weather conditions and location of onshore support facilities. To provide some data for comparison, costs are presented for each of 3 platform concepts based on the following scenario:

Launch Vehicle:	Height	300 ft.
	Weight (Dry)	850,000 lbs
	Weight (Glow)	5 million lbs.
	VCG	105 ft. above exit plane
	Core Diameter	35 ft.
	Vehicle Diameter	80 ft. max.
Propellant:	Cryo Liquid	LOX/hydrogen
Weather:	Wave heights	55 ft. survival
		12 ft. operating
	Wind Speed	35 knots survival
		28 knots operating
Shore Facilities: ETR		at CCAFS
WTR		at VAFB

##### Mobile Jack-Up

Table 1 identifies the facilities, delivery times and costs associated with the Mobile Jack-up concept for ETR and WTR. Water depth at the ETR site is 40 feet and at WTR 600 feet corresponding to about two miles offshore. Waterdepths greater than 600 feet are probably not practical for the jack-up concept.

##### Fixed Platform

Table 2 gives costs and fabrication times for fixed platforms in three waterdepths for ETR and WTR. These waterdepths correspond to distances offshore of 2, 10 and 30 miles. Costs of other facilities needed to support the fixed platform concept are given in Table 3.

##### Semisubmersible Vessel

Costs associated with the semisubmersible vessel concept are given in Table 4.

### CONCLUSIONS

An offshore launch platform is a technically feasible and cost effective alternative to land based launch sites. Problems associated with site acquisition, spatial separation, population safety and environmental objections are mitigated. Technology developed and proven in the offshore oil industry can be directly applied to development of a sea based space launch capability.

### REFERENCES

1. Tuturea, et al, "ALS Ocean Launch System Feasibility Study", Brown & Root Space Operations Report to McDonnell Douglas Astronautics, U. S. Airforce Space Division, ALS Program office, June, 1988.
2. "Offshore Missile Launch Sites Under Study," Offshore Magazine May 1988, p. 28.
3. Payne, P., Collier, P., Watts, R., and Tuturea, D., "Considerations: New Launch Sites vs Existing Launch Sites", JDR, ICF, and Brown & Root USA, Inc. report to McDonnell Douglas for ALS 1987.
4. Hervey, D. G., "Offshore Space Center", NASA Magazine, July 1980, p. 208-209.
5. Rajabi, F., "Review of Semisubmersible and Tension Leg Platform Analysis Techniques", Brown & Root Report for NCEL on Conceptual Formulation and Feasibility of Fixed and Moored Structures in Deep Water, 2 Volumes, May 1984.
6. Tuturea, et al, "The Hutton TLP Deck/Hull Mating Operation, presented at the Offshore Technology Conference, Houston, Tx. (OCT 5048), May 1985.

TABLE 1

#### MOBILE JACK-UP COST

Item	Cost \$M		Shipyard Fabrication Duration	On-Site Erection Schedule
	ETR	WTR		
Mobile Jack-Up Vessel 320' x 320' x 35' Comp.	93	98	16 months	
Mobile Launch Platform	6	6	6 months	
Guayside Slip & Docks (One Unit)	25	25		18 mos.
MLP Refurb Facility	29	40		12 mos.
Shore Base & Receiving Docks	6	8		8 mos.
Propellant Pipelines (2 miles)	20	24		8 mos.
Propellant Shore Facil.	32	45		12 mos.
Total	211	246	16 months	18 mos.

TABLE 2

#### FIXED PLATFORM COST

Distance Offshore	Water Depth Feet	Platform Cost Installed	FAB & Install Duration
2 Miles	40 (400)	\$15M (110m)	4 mos.
10 Miles	80 (900)	\$30M (240m)	6 mos.
30 Miles	150(3000)	\$60M "	9 mos.

(WTR) in parentheses

\*Fixed Platforms have not yet been installed in depths greater than 1,500 feet.

TABLE 3  
SUPPORT FACILITIES ASSOCIATED  
WITH FIXED PLATFORMS

Item	Cost \$M		Shipyard Fabrication Duration	On-Site Erection Schedule
	ETR	WTR		
Mobile Launch Platform	8	8	9 months	
Guayside Slip & Docks (One Unit)	37	51		18 mos.
MLP Refurb Facility (One Unit)	29	40		12 mos.
Shore Base & Receiving Docks	6	8		8 mos.
Propellant Vessel	60	60	21 months	12 mos.
Propellant Shore Fac.	32	45		12 mos.
Launch Vehicle Transport Vessel	74	74	19 months	12 mos.
Total	246	286	21 months	18 mos.

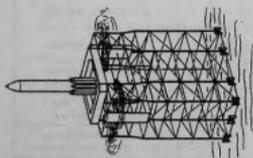
TABLE 4  
SEMI-SUBMERSIBLE PLATFORM CONCEPT  
FACILITIES COST

Item	Cost \$M		Shipyard Fabrication Duration	On-Site Erection Schedule
	ETR	WTR		
Semisubmersible Vessel	46	46	24 months	
Guayside Slip & Docks	30	45		18 mos.
MLP Refurb Facility	29	40		12 mos.
Shore Base & Receiving Docks	6	8		8 mos.
Propellant Vessel	60	60	21 months	
Propellant Shore Fac.	32	45		12 mos.
Launch Vehicle Transport Vessel	74	74	19 months	12 mos.
Total	277	318	24 months	18 mos.

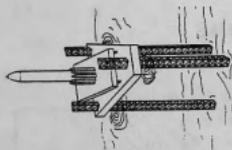
#### Notes:

- 1) Excludes AGE, VIB, Payload Facilities and associated site civil works.
- 2) Excludes platform cost from Table 2
- 3) A pipeline is more economic than the propellant vessel for 2 miles offshore.
- 4) Shore facility is not required if propellants can be purchased from a supplier with coastal access for the propellant vessel.
- 5) Launch vehicle transport vessel is not required if the semisubmersible can perform this function.

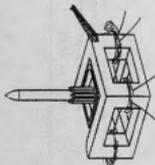




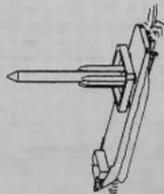
FIXED PILED PLATFORM CONCEPT  
FIGURE 3



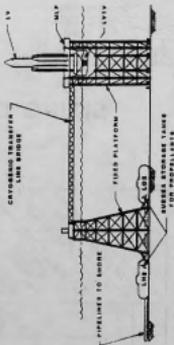
MOBILE JACK UP CONCEPT  
FIGURE 4



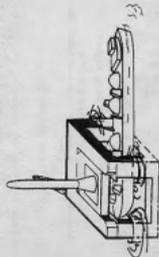
SEMISUBMERSIBLE CONCEPT  
FIGURE 5



LAUNCH VEHICLE  
TRANSPORT VESSEL  
FIGURE 6



PIPELINE PROPELLANT TRANSFER  
FIGURE 7



PROPELLANT TRANSFER  
VESSEL  
FIGURE 8