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FROM THE SEAS TO THE STARS: A CASE FOR DEVELOPING OFFSHORE SPACEPORTS ON STATES' SUBMERGED LANDS

JOSEPH MICHAEL CARROLL*

INTRODUCTION

When the Space Explorations Corporation (“SpaceX”) sought a new spaceport, Texans and Floridians competed to build it,¹ because a new spaceport can bring high-tech jobs and revenue into a state.² Texas won the SpaceX competition, but companies other than SpaceX may soon want new spaceports themselves,³ so Florida and other states may soon build spaceports, too. The Federal Aviation Administration even suggests that in a “far-term [commercial space transportation] environment,” beyond the year 2025, there may be “numerous public spaceports throughout the U.S. [at] coastal and sea-based locations.”⁴

However, building spaceports on the coast raises serious land use concerns. Generally, coastal land is either developed with high economic

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¹ See Eva Ruth Moravec, Jennifer Lloyd & Peggy Fikac, *Perry Signs SpaceX Bill For S. Texas Beach Closures*, SAN ANTONIO EXPRESS-NEWS, (May 24, 2013), http://www.mysanantonio.com/news/politics/texas_legislature/article/Perry-signs-SpaceX-bill-for-S-Texas-beach-4547676.php, archived at <http://perma.cc/29B4-3DFX> (last visited Apr. 1, 2015) (discussing passage of House Bill 2623 as “a move that allows the state to remain competitive for a SpaceX launch site”); see also *Florida’s Commercial Spaceport FAQs-V. 5/2013*, SPACE FLORIDA, http://www.spaceflorida.gov/docs/shiloh-page/sfshiloh-faqfor-website-5_13.pdf?sfvrsn=2, archived at <http://perma.cc/H73E-39ER> (last visited Apr. 1, 2015).

² Alyssa Newcomb, *How SpaceX is Changing the ‘Destiny’ of Brownsville, Texas* (Aug. 5, 2014), PARABOLIC ARC, <http://www.parabolicarc.com/2013/03/01/blue-origin-shows-interest-in-shiloh-launch-site/>, archived at <http://perma.cc/YS6M-F8XT> (last visited Apr. 1, 2015).

³ Doug Messier, *Blue Origin Shows Interest in Shiloh Launch Site*, PARABOLIC ARC (Mar. 1, 2013), <http://www.parabolicarc.com/2013/03/01/blue-origin-shows-interest-in-shiloh-launch-site/>, archived at <http://perma.cc/R4A7-JD44> (last visited Apr. 1, 2015).

⁴ See Dan Leone, *Details Emerge on SpaceX’s Proposed Texas Launch Site*, SPACENEWS (Apr. 9, 2012), <http://spacenews.com/details-emerge-spacexs-proposed-texas-launch-site/>, archived at <http://perma.cc/6TAG-UY75> (last visited Apr. 1, 2015).

value⁵ or undeveloped with ecological value.⁶ Rather than building on coastal land, states should develop spaceports on submerged lands offshore for the following reasons.

First, an offshore spaceport is viable. The Italian Space Agency successfully launched nine rockets to orbit from the San Marco Range⁷—a spaceport built on a structure similar to an oil rig installed off the Kenyan coast.⁸ States already own submerged lands extending at least three miles off their coasts,⁹ so they will not have to acquire land to develop.

Second, building offshore will not destroy or degrade any coastal dunes or wetlands, which many new terrestrial spaceports will.¹⁰ And the environmental concerns unique to offshore spaceports can be mitigated.

Third, an offshore spaceport will have significant economic benefits. It should allow for wider launch corridors and better flight profiles, making it extremely competitive in the commercial launch market. And an offshore spaceport should strongly support local maritime industries.

An offshore spaceport is logistically and legally feasible, would leave land for land use, has mitigable environmental effects, and has significant economic advantages over traditional spaceports. Coastal U.S. states interested in entering the commercial launch market should strongly consider developing offshore.

Part I of this Note will explain how the San Marco Range worked. Part II will explain the legal considerations of offshore spaceport development. Part III will deal with the environmental considerations of offshore development, while Part IV will deal with the economic benefits. Finally,

⁵ See generally CHRISTOPHER MAJOR, *THE BEACH STUDY: AN EMPIRICAL ANALYSIS OF THE DISTRIBUTION OF COASTAL PROPERTY VALUES* 165 (2003), available at <http://www.gradschool.psu.edu/diversity/mcnair/papers2003/majorpdf/>, archived at <http://perma.cc/7ARG-JA8Z>.

⁶ See *Benefits of Wetlands*, WETLANDS WATCH, <http://www.wetlandswatch.org/WetlandScience/WetlandFacts.aspx>, archived at <http://perma.cc/AFL5-Q72T> (last visited Apr. 1, 2015) (“According to the 2007 Virginia Outdoors Plan ‘wetlands, both tidal and non-tidal, are among the most important natural resources found in Virginia’s landscape’”).

⁷ AIR UNIVERSITY SPACE PRIMER 20–21 (2003), available at http://www.au.af.mil/au/awc/space/primer/rest_of_world_launch.pdf.

⁸ H.N. NESBITT, *HISTORY OF THE ITALIAN SAN MARCO EQUATORIAL MOBILE RANGE* 1, 3 (1971), available at <http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19720007316.pdf>.

⁹ The Submerged Lands Act, 43 U.S.C.A. §§ 1301(a)(2) (1953).

¹⁰ Compare DRAFT ENVIRONMENTAL IMPACT STATEMENT SPACE X TEXAS LAUNCH SITE, VOLUME 1 ES-8 (2013), available at http://www.faa.gov/about/office_org/headquarters_offices/ast/environmental/nepa_docs/review/documents_progress/spacex_texas_launch_site_environmental_impact_statement/media/SpaceX_Texas_Launch_Site_Draft_EIS_V1.pdf, with CARDNO TEC, *FINAL ENVIRONMENTAL SITE REVIEW FOR THE APPROXIMATE 1,140 ACRES COMBINED STUDY AREA FOR THE SHILOH SITE* 2–12 (2013), available at http://www.spaceflorida.gov/docs/rfps/final-esr-combined-shiloh-for-public_compiled.pdf?sfvrsn=2.

Part V will deal with sites that could have viable offshore spaceports in Texas, Florida, Georgia, South Carolina, North Carolina, Virginia, California, Alaska, and Hawaii.

I. THE SAN MARCO RANGE AND THE DEMAND FOR SPACEPORTS

The San Marco Range still exists today, though it has not launched a rocket since 1994.¹¹ The Range consists of two platforms raised out of the ocean on legs called “Texas Towers.”¹²

The San Marco Platform is the main facility, and it is named for the patron saint of navigators.¹³ Ninety feet wide, 300 feet long, 13 feet deep, and with 100 foot tall legs, it was originally a mobile floating dock used by the U.S. Army.¹⁴ Several months of renovations reconfigured the platform so that it had numerous cranes, a structure for receiving and preparing rockets, a launch pad, shelters for explosives and for crew, and other necessary features.¹⁵ The launch pad sat over an aperture in the platform “open to the sea” that absorbed “rocket exhaust.”¹⁶

The Santa Rita Platform is the secondary facility, “named for the patron saint of things impossible.”¹⁷ It was a three legged, triangular shaped mobile oil rig with 115 foot sides and 15 feet depth, and underwent renovations.¹⁸ The Santa Rita had command and control facilities for launching the rocket, and radar for tracking it.¹⁹

After renovations in Italy, ships towed the platforms to Ngwana Bay, Kenya.²⁰ The platforms’ legs lowered into the sandy bottom 30 feet below the ocean’s surface.²¹ Submarine cables connect the platforms and transmit data and electricity.²² Two additional, small platforms attached to

¹¹ AIR UNIVERSITY SPACE PRIMER, *supra* note 7.

¹² Jim Elliott, *San Marco Atmospheric Satellite Scheduled for Launch March 18*, GODDARD NEWS, Vol. 34, No. 2, Feb. 1988 (accessed at NASA Headquarters [hereinafter NASA HQ], History Office, box 006339).

¹³ *Id.*

¹⁴ NASA, SAN MARCO RANGE USER’S MANUAL, I-1, I-14, (1974) (accessed at NASA HQ, History Office).

¹⁵ *See id.* at I-14, I-15.

¹⁶ NASA, RELEASE NO. 70-203 13 (1970) (accessed at NASA HQ, History Office, box 5877).

¹⁷ Elliott, *supra* note 12.

¹⁸ SAN MARCO RANGE USER’S MANUAL, *supra* note 14, at I-20; GODDARD SPACE FLIGHT CENTER, X-724-70-19, HISTORY OF SAN MARCO, 44, 47 (1968) (accessed at NASA HQ, History Office, box 00635).

¹⁹ SAN MARCO RANGE USER’S MANUAL, *supra* note 14, at I-26.

²⁰ *See id.* at I-10. Some sources refer to this area as “Formosa Bay.”

²¹ *Id.* at I-11.

²² LUIGI BROGLIO, THE SAN MARCO PROJECT, A PROGRAM OF INTERNATIONAL COOPERATION 3–4 (1968) (accessed at NASA HQ, History Office, box 006334).

the Santa Rita in Ngwana Bay provide an electrical generator and additional radar.²³ The staff of the San Marco Range lived in a small camp onshore, with logistical, recreational, and limited storage facilities.²⁴

Rockets went to the San Marco directly by boat, where workers would lift them onto the platform using the platform's cranes.²⁵ First the rocket would go into the integration building. After personnel integrated and inspected the rocket, it shifted to the launch pad for launch.²⁶

The San Marco only launched solid-fuel rockets,²⁷ which arrive at spaceports fully fueled.²⁸ Spaceports designed on the San Marco model will likely need to add the ability to service liquid fuel rockets, which are fueled at the spaceport.²⁹ Another important change will be the addition of a flame deflector and flame trench beneath the launch pad so that rocket effluent does not contact the ocean's surface, as discussed in Part III.

II. LEGAL CONSIDERATIONS

Developing a spaceport on submerged lands should be legally viable for coastal states. Submerged lands belong to states in public trust. In most cases, state ownership extends three miles off the coast. Texas, however, owns lands extending three marine leagues from its coast. Even though states own the submerged lands discussed in this Note, federal regulations will affect spaceport development.

This section will overview the history of state ownership of submerged lands, public trust doctrine, and federal regulations likely to apply to offshore spaceports.

A. *Submerged Lands Ownership*

Ownership of submerged lands was a relatively minor issue until the 1950s,³⁰ when President Truman expanded the United States's claim

²³ SAN MARCO RANGE USER'S MANUAL, *supra* note 14, at I-21.

²⁴ *Id.* at I-28.

²⁵ *See id.* at I-14, I-21.

²⁶ *See id.*

²⁷ NASA, PROJECT SAS-B: PRESS KIT 16 (1972) (accessed at NASA HQ, History Office Box 005883).

²⁸ *See* GRAHAM A. SWINERD, HOW SPACECRAFT FLY: SPACEFLIGHT WITHOUT FORMULAE 93-99 (2008) (discussing solid and liquid rocket fuels).

²⁹ *Id.*

³⁰ *New Jersey v. New York*, 523 U.S. 767 (1998) (detailing the history of the dispute between New Jersey and New York over ownership of submerged lands under the Hudson River).

to the seabed by executive order to gain exclusive jurisdiction over submerged natural resources.³¹ States and the federal government then disputed ownership of the submerged lands.³² Then, in 1953 Congress passed the Submerged Lands Act, granting states control over submerged lands extending three miles from “the coastline,” and preserving the federal government’s claim to submerged lands extending from three miles beyond the coastline to the end of the continental shelf—the additional territory claimed by President Truman.³³

However, the Act provided an exception to the three mile grant for cases where a more distant boundary “existed at the time such State became a member of the Union,” allowing states to litigate for recognition of an extended baseline, and provided an exception for cases “heretofore approved by Congress.”³⁴ Many coastal states sued for recognition of extended baselines with mixed results.³⁵ Florida’s ownership from the baseline in the Gulf of Mexico extended to three marine leagues³⁶—but this will not benefit an offshore spaceport, as rockets would have to immediately overfly land.

Texas successfully sued for extended ownership off its baseline based on theories related to its previous status as an independent nation.³⁷ With ownership of submerged lands extending three leagues seaward of its baseline,³⁸ Texas could develop an offshore spaceport farther away from populated areas than could many other states. A particularly good site would be roughly ten miles due east of its currently proposed Brownsville site.

B. *Public Trust Ownership*

States own their submerged lands in public trust.³⁹ The Public Trust Doctrine “operates to deny states any power to convey these ‘trust

³¹ Proclamation No. 2667, 10 Fed. Reg. 12,303 (Sept. 28, 1945).

³² Kenneth G. Engerrand, *Primer of Remedies on the Outer Continental Shelf*, 4 LOYOLA MAR. L.J. 19, 20–21 (2005).

³³ Submerged Lands Act, 43 U.S.C. §§ 1301–02 (1953).

³⁴ *Id.*

³⁵ *United States v. Florida*, 420 U.S. 531 (1975); *United States v. State of Maine*, 469 U.S. 504 (1985); *United States v. California*, 381 U.S. 139 (1965); *United States v. Louisiana*, 364 U.S. 502 (1960).

³⁶ *United States v. Louisiana*, 364 U.S. 502, 503 (1960).

³⁷ *Id.*

³⁸ *Id.*

³⁹ Eric Pearson, *Illinois Central and the Public Trust Doctrine in State Law*, 15 VA. ENVTL. L.J. 713, 714 (1996).

resources,' to which they typically hold title, to private persons or entities if the transfer would diminish or defeat traditional public access to and use of those resources."⁴⁰

The public trust doctrine does not stop states from economically developing public trust land. As such, a state that independently develops and operates an offshore spaceport should not have trouble with the public trust doctrine. The public trust doctrine could only prevent a state from conveying, rather than developing, public trust lands. This could become an issue if a state chose to sell its submerged lands for an offshore spaceport to a commercial entity.

Yet one scholar explains that the ruling in *Illinois Central v. Illinois*, the seminal public trust case, confirms "that the state could alienate submerged lands, but not if doing so was likely to result in the total obstruction of the public's right of navigation and commerce."⁴¹ No spaceport could be so large as to totally obstruct navigation and commerce, so this should not be a bar. While it may be necessary to restrict maritime activities in hazard zones emanating from a spaceport, these zones would be relatively small. So, even if a state conveyed submerged lands for an offshore spaceport, the public trust doctrine should not be a bar to the development of submerged lands.

C. *Modern Applications of the Public Trust Doctrine*

States must nonetheless consider modern applications of the public trust doctrine, which can go to resources other than land. Even broad understandings of the doctrine should allow for spaceports. The public trust doctrine can apply:

to a host of resources other than submerged lands, including marine life, wildlife, sand and gravel . . . Courts also use the doctrine to protect such time-honored public pursuits as hunting, fishing, boating . . . wildlife habitat preservation, swimming, the maintenance of ecological integrity and aesthetic beauty, and the retention of open space.⁴²

An offshore spaceport might affect any one of these protections. Fortunately, an offshore spaceport should have only a *de minimis* impact on

⁴⁰ *Id.* at 714.

⁴¹ James L. Huffman, *Speaking of Inconvenient Truths—A History of the Public Trust Doctrine*, 18 DUKE ENVTL. L. & POL'Y F. 1, 97 (2007).

⁴² Pearson, *supra* note 39, at 714–15.

these activities. Swimming does not often occur three miles beyond the baseline. Similarly, boating should only be excluded from a small area.

An offshore spaceport might even benefit public trust interests. For example, after SpaceX finishes building at Brownsville, the nearby state beach will need to be closed “to ensure safety and security during wet dress rehearsals, static fires, and launch operations.”⁴³ Beach closings would likely not be needed should Texas develop a spaceport on its boundary line with federal submerged lands, 10.36 miles from the beach. So, developing offshore would enhance a public interest protected by the public trust doctrine.

In short, the public trust doctrine should not bar development of offshore spaceports.

D. *Federal Regulation*

Federal regulations will apply to any spaceport, but offshore spaceports may deal with additional federal regulations for the marine environment. This section will briefly consider regulations by the Federal Aviation Administration and the National Oceanic and Atmospheric Administration.

1. The Federal Aviation Administration

The Federal Aviation Administration (“FAA”) licenses spaceports.⁴⁴ That will not change, whether the spaceport is offshore or on. Ensuring adequate downrange safety is important for licensure. Basically, the FAA multiplies the risk of rocket failure by the population downrange. United States spaceports have traditionally sited on the coast so that most of the downrange area is ocean, with no human population. This substantially reduces the risk of a rocket failure.

The FAA also regulates all commercial launches “pursuant to the Commercial Space Launch Act of 1984.”⁴⁵ FAA licensing for launches includes an environmental review, which “determines whether the proposed activity will have a significant environmental impact and whether there

⁴³ DRAFT ENVIRONMENTAL IMPACT STATEMENT: SPACEX TEXAS LAUNCH SITE, *supra* note 10, at ES-22.

⁴⁴ FEDERAL AVIATION ADMINISTRATION, THE ANNUAL COMPENDIUM OF COMMERCIAL SPACE TRANSPORTATION: 2012 I (2012) *available at* http://www.faa.gov/about/office_org/headquarters_offices/ast/media/The_Annual_Compndium_of_Commercial_Space_Transportation_2012.pdf (last visited Apr. 1, 2015).

⁴⁵ MATTHEW J. KLEIMAN, THE LITTLE BOOK OF SPACE LAW 12 (2013).

are ways to mitigate those effects.”⁴⁶ This makes environmental mitigation measures important.

2. The National Oceanic and Atmospheric Administration

Mitigation measures aimed at curbing noise pollution are also important for getting National Oceanic and Atmospheric Administration (“NOAA”) regulations. The Marine Mammal Protection Act protects marine mammals from “takes,’ or the harassing, capturing, killing or hunting, of a marine mammal.”⁴⁷ Harassment is further defined for civilian acts “as any act of pursuit, torment or annoyance’ that potentially injures or disrupts the behavioral patterns of a marine mammal.”⁴⁸ Noise is known to injure marine mammals and to affect their behavior.⁴⁹ This can make noisemaking a take requiring NOAA approval, if such noisemaking harms mammals.

Launching a rocket from an offshore spaceport will likely involve a take on marine mammals because rockets cause a great deal of noise when they launch. This noise seems likely to affect the behavior of whales and other marine mammals, and potentially harm them. As such, an offshore spaceport must likely obtain an “incidental take authorization.”⁵⁰ NOAA grants incidental take authorizations for takings that “would be of small numbers and have no more than a ‘negligible impact’” on marine mammals that are not endangered.⁵¹ For this purpose, “negligible impact” means “an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.”⁵²

If it turns out that the noise of a rocket launch is not powerful enough to adversely affect marine mammals, the spaceport would only require an “incidental harassment authorization,” which has less stringent standards.⁵³

⁴⁶ *Id.* at 13.

⁴⁷ Ian Boisvert, *Puget Sound Orcas, Vessel Noise, and Whale-Watching: A Licensing Program to Overcome the Problem of the ESA’s Economically-Blind “Take” Rule*, 10 OCEAN & COASTAL L.J. 117, 120–21 (2005) (quoting 16 U.S.C. § 1362(13) (2004)).

⁴⁸ *Id.* at 121 (quoting 16 U.S.C. § 1362(18)(A) (2004)).

⁴⁹ MARINE MAMMAL COMM’N, MARINE MAMMALS AND NOISE: A SOUND APPROACH TO RESEARCH AND MANAGEMENT I (2007) available at <http://www.mmc.gov/sound/fullsoundreport.pdf>.

⁵⁰ *Id.*

⁵¹ *Id.*

⁵² NOAA Fisheries, Protected Resources Glossary, NMFS.NOAA.GOV, <http://www.nmfs.noaa.gov/pr/glossary.htm#negligible>, archived at <http://perma.cc/AC8K-9QDW> (last visited Apr. 1, 2015).

⁵³ *Incidental Take Authorizations*, *supra* note 50.

Marine biologists and rocket scientists will need to help determine just how rocket launches may affect marine mammals. But considering that authorizations for takes and harassment have been issued for use of “seismic air guns,” “high energy sonars,” and “explosives detonations,” it seems likely that a rocket launch could gain approval.⁵⁴ In any case, federal regulation should not affect the legal feasibility of offshore development, but it will be crucial to mitigate noise pollution and other issues.

Spaceports are sprawling industrial complexes housing high explosives and hazardous materials.⁵⁵ They require extensive modification of topography within the site.⁵⁶ The Texas site is “in a sparsely populated coastal area off the Gulf of Mexico” near Brownsville on a “56.5-acre property” consisting of “wetlands and . . . sand dunes.”⁵⁷ The Florida site, named Shiloh, is within the Merritt Island National Wildlife Refuge, north of Cape Canaveral. It consists primarily of coastal land nestled between the Indian River and Mosquito Lagoon, just off the Atlantic Ocean.⁵⁸ The Shiloh site has a particularly high ecological value, providing habitats for the Wood Stork, an endangered species, and four other “federally or state listed threatened species.”⁵⁹ Destroying a habitat for these species will only serve to increase competition for remaining habitats and resources.

Even in the absence of threatened species, using wetlands and dunes for spaceports is extremely harmful. Dunes are meant to exist in a state of dynamic flux, allowing sand and sediment to naturally move from one location to another.⁶⁰ Interrupting this process by developing on sand dunes can lead to harmful sediment trapping in some areas, and sediment starvation in others.⁶¹ Likewise, wetlands are crucial for the

⁵⁴ *Id.*

⁵⁵ See CHARLES D. BENSON & WILLIAM BARNABY FAHERTY, MOONPORT: A HISTORY OF APOLLO LAUNCH FACILITIES AND OPERATIONS, ch. 1 § 4, <http://history.nasa.gov/SP-4204/contents.html> (last visited Apr. 1, 2015).

⁵⁶ *Id.* (“Planners also had to maintain a clear line of sight from the launch vehicle to the launch control center, and to . . . instrumentation sites.”); FAA Brownsville EIS, ES-5 (“Construction at this location . . . would generally involve placing fill material to elevate land levels enough to avoid frequent flooding . . . [M]ost of the land inside the proposed fence lines would be disturbed at some point”).

⁵⁷ DRAFT EIS: SPACEX TEXAS LAUNCH SITE, *supra* note 10, at ES-5.

⁵⁸ CARDNO TEC, *supra* note 10, at 2–15.

⁵⁹ *Id.*

⁶⁰ MASSACHUSETTS OFFICE OF COASTAL ZONE MGMT., Policy Guide, 20 (2011), *available at* <http://www.mass.gov/eea/docs/czm/fcr-regs/czm-policy-guide-october2011.pdf> (last visited Apr. 1, 2015).

⁶¹ See S. JEFFRESS WILLIAMS ET AL., U.S. GEOLOGICAL SURVEY, CIRCULAR 1075: COASTS IN CRISIS, 14–15 (Dep’t of the Interior, 1990), *available at* <http://pubs.usgs.gov/circ/1990/1075/report.pdf> (discussing sediment trapping and starvation influenced by manmade objects).

“numerous beneficial services” they provide “for people and for fish and wildlife [including] protecting and improving water quality, providing fish and wildlife habitats, storing floodwaters, and maintaining surface water flow during dry periods.”⁶² Attempting to remove sites from these natural processes is not only costly,⁶³ but can also have negative impacts in other areas. Spaceports will destroy the ecological value of the land they site on, which will degrade still more acreage surrounding them.⁶⁴

Additionally, spaceports seem likely to expand rather than remain static. For example, Space Florida’s proposal was for a spaceport with only one launch pad, but sought “150 useable acres in order to have the capacity to develop a variety of possible . . . needs.”⁶⁵ Space Florida specifically anticipated the possibility of constructing an additional launch pad.⁶⁶ Yet the proposal ignored the wetlands that Space Florida would need to clear and grade to connect integration and fueling facilities to this new launch pad. All of this work would be done inside a National Wildlife Refuge originally meant to act as an ecological buffer around Cape Canaveral.⁶⁷

Just as spaceports are likely to expand onto their surrounding lands, so too will oceans. The preliminary impact statements for Brownsville and Shiloh do not discuss sea level rise. Nonetheless, spaceports will not be immune to encroachments from the ocean. NOAA suggests that sea level rise around Brownsville is trending to 1’ to 2’ over 100 years.⁶⁸

⁶² VA. DEPT OF CONSERVATION AND RECREATION, GUIDANCE FOR LOCAL FLOODPLAIN ORDINANCES IN VA, 9 (2011), *available at* <https://www.rampp-team.com/documents/region3/Guidance%20for%20Local%20Floodplain%20Ordinances%20in%20VA%2010-03-2011.pdf>.

⁶³ *Wallops’ Newest Beach*, NASA.GOV, (Aug. 21, 2012), <http://www.nasa.gov/centers/wallops/news/beach.html>, *archived at* <http://perma.cc/G5W8-QU9V> (discussing the beach replenishment completed on August 10, 2012 with “3.2 million cubic yards of sand” sourced from 12 miles offshore. “The first phase of the project involved extending the island seawall about 1,419 feet. Now, with the completion of the beach, workers are in the process of installing sand fencing to help protect the beach from erosion. . . . [R]enourishment is planned every 3 to 7 years, depending on the need”).

⁶⁴ See Michael Moser et al., *A Global Overview of Wetlands Loss and Degradation*, RAMSAR.ORG, (Feb. 18, 1998), http://www Ramsar.org/cda/en/ramsar-news-archives-2002--a-global-overview-of/main/ramsar/1-26-45-87%255e16905_4000_0, *archived at* <http://perma.cc/KD9V-L8AM> (“[L]oss of part of a wetland is likely to impair the functions of the remaining wetland area”).

⁶⁵ SPACE FLA., *supra* note 1.

⁶⁶ *Id.*

⁶⁷ *Merritt Island National Wildlife Refuge*, STATEPARKS.COM, http://www.stateparks.com/merritt_island_national_wildlife_refuge_in_florida.html, *archived at* <http://perma.cc/KE9G-VRUK> (“The Refuge, which is an overlay of the John F. Kennedy Space Center, was established in August 1963 to provide a buffer zone for [NASA]”) (last visited Apr. 1, 2015).

⁶⁸ NAT’L OCEANIC AND ATMOSPHERIC ADMIN., *Sea Level Trends, TIDES & CURRENTS*,

Separate NOAA maps show that with a 1' rise, the ocean will encroach on the wetlands surrounding the proposed Brownsville spaceport and threaten its access road.⁶⁹ NOAA maps similarly suggest that with 2' sea level rise, seawater would totally inundate the wetlands west of the Shiloh site.⁷⁰ The encroaching seas will necessitate countermeasures such as seawalls that will only increase the disruption of dunes and wetlands systems.

III. OFFSHORE SPACEPORTS

An offshore spaceport based on the San Marco design will not have the land use issues of terrestrial spaceports. This section uses the San Marco Range as a model, with raised fixed platforms for activity at sea and with some facilities located onshore (but not in wetlands or dunes).

A. *Marine Noise Pollution*

Marine noise pollution can come from boat and aircraft traffic, from marine construction,⁷¹ and in the case of offshore spaceports, from the roar of a rocket's engines and the intense vibrations that such a rocket will likely generate on its launch structure.

Noise pollution can affect many types of marine life by damaging structures in their bodies or interfering with their natural processes.⁷² For cetaceans, noise damage may cause stress and affect the social interactions they require to survive.⁷³

The "constant backdrop of noise"⁷⁴ created by marine vessels is of primary concern to cetaceans, as it can distort cetacean communication and drastically limit the distances over which cetaceans are able to

<http://tidesandcurrents.noaa.gov/sltrends/>, archived at <http://perma.cc/GNX2-49ST> (last visited Apr. 1, 2015).

⁶⁹ Nat'l Oceanic and Atmospheric Admin., *Sea Level Rise and Coastal Flooding Impacts*, DIGITAL COAST, <http://coast.noaa.gov/slr/>, archived at <http://perma.cc/V5SQ-CF9Q> (last visited Apr. 1, 2015) (zoom in on Boca Chica Highway; then set sea level rise to "1").

⁷⁰ *Id.* (zoom in on the Volust-Brevard County line west of Indian River Lagoon; then set sea rise level to "2"; then use CARDNO TEC, *supra* note 10, to see map overlays of proposed Shiloh location).

⁷¹ See generally INT'L FUND FOR ANIMAL WELFARE, *BREAKING THE SILENCE: HOW OUR NOISE POLLUTION IS HARMING WHALES* (2013), available at <http://www.ifaw.org/australia/resource-centre/breaking-silence-how-our-noise-pollution-harming-our-whales>, archived at <http://perma.cc/T6NC-Z9P5> (last visited Apr. 1, 2015).

⁷² *Id.*

⁷³ *Id.*

⁷⁴ *Id.* at 9.

communicate.⁷⁵ Because water supports sound transmission while impeding visibility, whales rely primarily on their ability to sense and communicate audibly.⁷⁶ Reducing this ability has led to whales forcing an “increase [in] the volume and frequency of their calls to defeat the cacophony of vessel noise,” and scientific evidence suggests that “exposure to low-frequency ship noise may be associated with chronic stress in whales.”⁷⁷

Marine noise pollution can also result from construction methods.⁷⁸ A 2003–04 test in San Francisco Bay revealed that driving piles with hammer action can kill fish by bursting their swim bladders and causing “terrific damage” to their kidneys.⁷⁹ A marine biologist working on the project concluded that pressure waves on which sound traveled as a result of hammer actions “compressed the air in the swim bladders, which then quickly expanded again, bursting the bladder and damaging the kidneys.”⁸⁰ Mitigating sound pollution can be separated into three distinct operational phases of an offshore spaceport: (1) construction; (2) non-launch activities; and (3) launch.

Construction will primarily present sound pollution from vessels servicing construction, and from the construction activities themselves. Mitigating sound pollution from vessels supporting construction could likely be done in two ways. First, vessels supporting the construction of an offshore spaceport should be required to have the most efficient possible propeller designs.⁸¹ Ideally, the state constructing the spaceport should set a very high minimum standard for propeller efficiency.⁸² Second, vessels should be required to travel at reduced speeds.⁸³ Not only does this reduce a vessel’s “acoustic footprint,” but it also increases fuel efficiency and reduces “the risk of collisions with whales.”⁸⁴

⁷⁵ *Id.*

⁷⁶ *Id.*

⁷⁷ INT’L FUND FOR ANIMAL WELFARE, *supra* note 71, at 10.

⁷⁸ Jackson Kuhl, *Bubble Curtains: Can the Dampen Offshore Energy Sound for Whales?*, NAT’L GEOGRAPHIC DAILY NEWS, Feb. 7, 2012, <http://news.nationalgeographic.com/news/energy/2012/02/120207-bubble-curtains-to-protect-whales/>, archived at <http://perma.cc/W2XE-28V3> (last visited Apr. 1, 2015).

⁷⁹ *Id.*

⁸⁰ *Id.*

⁸¹ See INT’L FUND FOR ANIMAL WELFARE, *supra* note 71, at 11; see also WHALE AND DOLPHIN CONSERVATION SOC’Y, *Oceans of Noise*, 30–32 (2004), available at <http://www.oceanos-foundation.org/assets/Uploads/OceansofNoise.pdf>.

⁸² See INT’L FUND FOR ANIMAL WELFARE, *supra* note 71, at 11.

⁸³ *Id.*

⁸⁴ *Id.*

While vessels servicing construction provide a constant background noise, construction itself can provide the more harmful impulsive sounds that injure marine life; rather than using hammer action to drive piles, noise could be significantly reduced by “using continuous pressure or suction.”⁸⁵

Just as it is important to reduce the amount of sound generated, it is also important to reduce the distance that sound travels.⁸⁶ This can be done by two distinct but similar means: bubble curtains and balloon curtains.⁸⁷ A bubble curtain is literally a curtain of bubbles created by releasing compressed air from the bottom of a structure.⁸⁸ A balloon curtain involves placing or inflating balloons on the sides of a structure.⁸⁹

These devices work on two principles of sound transfer. First, “when a pressure wave hits an air bubble, it will compress the bubble, then [the bubble] will expand again so energy is lost.”⁹⁰ Second, because “sound travels faster through water than air,” transferring through a bubble “slows [sound] down as it hits the air bubble.”⁹¹ When deployed around hammer action driven piles, a bubble curtain slowing sound “creates a much smoother [pressure] wave, altering it from a brief percussive bang to a longer, weaker wave,”⁹² which should reduce its harm.

During non-launch operations, as during construction, service vessels will contribute noise pollution.⁹³ And, as with construction, the state should impose minimum standards on propeller efficiency for ships servicing the spaceport, and mandate travel at reduced speeds.

During launch, noise pollution will come from the rocket’s roaring engines.⁹⁴ It will be crucial to mitigate this noise as best as possible. This will likely mean employing bubble curtains and balloon curtains. If balloon

⁸⁵ *Id.* at 18.

⁸⁶ WASH. STATE DEP’T OF TRANSP., BIOLOGICAL ASSESSMENT PREPARATION ADVANCED TRAINING MANUAL 7.5, available at http://www.wsdot.wa.gov/NR/rdonlyres/448B609A-A84E-4670-811B-9BC68AAD3000/0/BA_ManualChapter7.pdf.

⁸⁷ See *id.* at 7.40; see also Karl-Heinz Elmer, Pile Driving Noise Reduction Using New Hydro Sound Dampers, <https://www.tu-braunschweig.de/Medien-DB/igb/hsd/elmer2010a.pdf> (last visited Apr. 1, 2015).

⁸⁸ Kuhl, *supra* note 78.

⁸⁹ Elmer, *supra* note 87.

⁹⁰ Kuhl, *supra* note 78.

⁹¹ *Id.*

⁹² *Id.*

⁹³ See generally WASH. STATE DEP’T OF TRANSP., *supra* note 86.

⁹⁴ ENVIRONMENTAL ASSESSMENT FOR THE SPACE EXPLORATION TECHNOLOGIES VERTICAL LANDING OF THE FALCON VEHICLE AND CONSTRUCTION AT LAUNCH COMPLEX 13 AT CAPE CANAVERAL AIR FORCE STATION FLORIDA 3-5, available at <http://www.patrick.af.mil/shared/media/document/AFD-141107-004.pdf>.

and bubble curtains deployed on the structure of a spaceport prove inadequate, then additional curtain devices could deploy off of vessels and mooring stations surrounding the launch platform. Vessels could additionally deploy buoyant, sound absorbent pads on the ocean's surface. Marine biologists, specialists in acoustics, and other scientists will need to advance these ideas further. One way or another, noise pollution must be mitigated so that environmental impacts will be substantially reduced.

B. Thermal Pollution

Mitigating thermal pollution will also be important, and should be relatively straightforward. On the San Marco platform, the launch pad was atop an aperture that rocket exhaust shot through.⁹⁵ In the initial stages of launch, the rocket's flames directly contacted the ocean.⁹⁶

Any new offshore spaceport should not allow the rocket's effluent to contact the ocean. Instead, the launch pad should site over a flame deflector leading to a flame trench.⁹⁷ The rocket's flames will be redirected into a flame trench by a flame deflector, situated directly underneath the aperture of the mobile launch pad placed on the launch structure. The flame deflector should be shaped like a wedge, allowing flames to bounce off of each side at right angles. It must be able to withstand extreme heat and could have a skin of advanced ceramic tiles, like the flame deflector used for Saturn V launches.⁹⁸ The flame trench will likewise need to be designed to withstand the extreme heat, and ceramic tiles or "special refractory fire bricks" could be used.⁹⁹ By redirecting the flames into the flame trench, no fire will directly touch the ocean's surface. Were this to happen, it is likely that some ocean water would boil over, creating significant thermal pollution, and causing extreme harm to nearby marine life.

Redirecting the flames into the flame trench also increases the ability to reduce their power. The bottom of the flame trench could be flooded with water. This water would boil over, evaporating into water vapor and absorbing tremendous quantities of energy in the process. Likewise, water could be sprayed into the flames via powerful hoses, and this water too would evaporate, absorbing energy. This would be preferable to letting water in the ocean boil because that would cause surrounding

⁹⁵ See NASA, *supra* note 16, at 14.

⁹⁶ See *id.*

⁹⁷ See BENSON & FAHERTY, *supra* note 55, at ch. 11 § 7.

⁹⁸ See *id.* at ch. 13 § 8.

⁹⁹ See *id.* at ch. 11 § 7.

water to increase in temperature via water conduction and convection in a localized area. In the case of controlled boiling, energy would transfer into water vapor, which would disperse throughout the air column, and it would transfer into the materials in the flame trench, which would radiate them back out. These materials could continue to be cooled by water pumped in via hoses.

C. Fish Aggregation

An offshore spaceport will likely act as a fish aggregation device (“FAD”). Marine biologists are divided as to the effects of FADs in the marine environment. Marine biologist Greg Brown suggests:

[T]here are two main schools of thought on the effect of FADs on fish populations. One school holds that natural feeding grounds and existing buoys would be negatively impacted, as the new device would draw fish away from their former haunts . . . The other school of thought is that the natural feeding grounds and existing buoys would be unaffected and that the increase in habitat would increase the number of fish moving into the area . . . the total fish population . . . would have increased, relieving some of the pressure of overfishing.¹⁰⁰

However, this analysis does not adequately address the effects of launch operations on marine populations attracted to the structure. Research at NASA archives yielded no information on fish aggregation at the San Marco Range, but it seems likely that fish will aggregate under such a structure and could be affected by a launch.

If it turns out that rocket launches harm creatures aggregating around a launch structure, mitigation could take an economically viable way. Teams of scuba divers could routinely clear soft corals, barnacles, and shellfish from the structure. This would make the structure a less habitable place, causing fewer fish to aggregate there. The teams of divers could transplant these creatures to artificial reefs constructed at nearby locations unaffected by launch noises. Creating such counter fish-aggregation devices could be an ecological boon; creating such sites should also help to develop or strengthen a scuba tourism industry.

¹⁰⁰ See SPACE AGE PUBL'G CO., PACIFIC ALOHA SPACEPORT FEASIBILITY STUDY 11–12 (1993) [hereinafter Pacific Aloha Study].

D. Onshore Facilities

An offshore spaceport will need onshore facilities for logistics and storage, and housing for its personnel.¹⁰¹ But all of these things could go on land already zoned for such purposes. Developing on wild coastal areas would not be necessary. In fact, these onshore facilities might benefit local economies by increasing demand on existing infrastructure.

IV. ECONOMIC BENEFITS

An offshore spaceport will have many economic benefits compared to a terrestrial spaceport. States already own the submerged lands that will support development, eliminating the upfront cost of land acquisition. Additionally, offshore spaceports should be extremely competitive in the launch market, support local maritime industries, and may increase local tourism.

A. Competitiveness in the Launch Market

An offshore spaceport would likely be very competitive in the commercial launch market due to its wider launch corridors and superior flight profiles.

1. Wider Launch Corridors

An offshore spaceport should have significantly wider flight corridors than a land-based spaceport, because a rocket launching from the ocean could stray farther from its course with less risk to populated areas. There will not be any populated areas behind or to the sides of the spaceport for many miles. Nor will there be any facilities immediately southeast or northeast of the spaceport limiting launch corridors like at Shiloh.

If a rocket strays from its designated path, then it begins approaching the limit of its spaceport's launch corridor—approaching the “so-called ‘destruct’ line indicat[ing] the maximum deviation . . . from the trajectory that could be allowed without endangering life or property.”¹⁰² Once a rocket reaches the limits of the corridor, a range safety officer must abort (destroy) the rocket.

¹⁰¹ *Id.* at 12.

¹⁰² See BENSON & FAHERTY, *supra* note 55, ch. 9 § 6.

But with a wider launch corridor, the abort decision can be delayed, which gives a rocket's guidance systems "an opportunity to recover."¹⁰³ Even without full recovery, a wider launch corridor could allow a rocket to perform an abort-to-orbit, in which the rocket puts its payload into a stable orbit, but not the one designated for the mission.¹⁰⁴ From a stable orbit, the mission might proceed on a modified basis, as it did on STS-51-F when the crew of Space Shuttle *Challenger* aborted-to-orbit.¹⁰⁵ Or, in the case of an unmanned mission, the payload could be recovered on a subsequent mission, just as the crew of the Space Shuttle *Discovery* recovered the Palapa B2 and Westar 6 satellites after they failed to reach their designated orbits.¹⁰⁶ NASA recovered those satellites on a salvage contract for Lloyd's of London after the insurance company paid out the satellite owners.¹⁰⁷ Lloyd's resold both satellites, and both relaunched into space.¹⁰⁸ An increased possibility of aborting-to-orbit and later recovering a payload is far preferable to aborting outright and losing the payload. By potentially providing wider flight corridors than land-based spaceports, offshore spaceports demonstrate an important advantage.

2. Better Launch Profiles

Similar to allowing rockets to fly on wider launch corridors, offshore spaceports could also allow rockets to achieve better flight profiles. Rockets do not ascend straight into space—instead, they follow a carefully calculated flight profile:

[On] an optimized trajectory . . . the [rocket] will climb vertically for a relatively short period to escape the denser part of the atmosphere (to minimize drag loss), and then roll over into a shallow climb (to minimize gravity loss).¹⁰⁹

¹⁰³ GENE KRANTZ, *FAILURE IS NOT AN OPTION: MISSION CONTROL FROM MERCURY TO APOLLO 13 AND BEYOND* 40 (2000).

¹⁰⁴ *Aborts*, NASA, <http://spaceflight.nasa.gov/shuttle/reference/shutref/sts/aborts>, archived at <http://perma.cc/49Q6-GCUA> (last visited Apr. 1, 2015).

¹⁰⁵ NASA, *STS-51F*, SPACE SHUTTLE MISSION ARCHIVES, http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/archives/sts-51F.html, archived at <http://perma.cc/HUS2-WVTK>.

¹⁰⁶ KLEIMAN, *supra* note 45, at 28–30.

¹⁰⁷ *Id.*

¹⁰⁸ *Id.*

¹⁰⁹ SWINERD, *supra* note 28, at 104.

Climbing vertically not only increases gravity loss, it also presents range safety problems; NASA officials had to abort the unmanned Mercury-Atlas 3 rocket when it went:

[I]nexplicably flying straight up, threatening the Cape and the surrounding communities. The worst-case scenario would be for it to . . . explode. The higher up it flew before it exploded, the wider the “footprint” of debris scattered all over the Cape and surrounding area would be.¹¹⁰

From an offshore facility, a near vertical climb could not risk damage to the surrounding area, because the surrounding area would be ocean. The one concern would be protecting the offshore spaceport itself. Once a rocket clears away from the spaceport, it could proceed practically vertically until it became truly optimal to pitch over. This more optimal flight trajectory will allow any given rocket to use less fuel or carry a heavier payload. In either case, it should prove an economic boon for each launch from an offshore spaceport.

B. Support for Maritime Industries

A working spaceport is known to create jobs for the local economy, and Florida's interest in developing at Shiloh is partly motivated by retaining and promoting jobs on the “space coast,” which were jeopardized with the end of the shuttle program.¹¹¹ An offshore spaceport should provide all the usual jobs associated with spaceports, but should also promote local maritime industries “in a way no other spaceport proposal does.”¹¹²

The authors of the Pacific Aloha Spaceport Feasibility Study noted that an offshore spaceport would require “tugboats and various other seafaring support.”¹¹³ Boats would be needed to transfer workers to and from the spaceport on a daily basis. Additional boats might be needed during launch for flame suppression and sound control. All of these vessels would need crews, fuel, maintenance, and dock space. This increase in demand could strongly support local maritime industries.

¹¹⁰ KRANTZ, *supra* note 103, at 40.

¹¹¹ Jeff Harrington, *Space Coast Jobs Face Uncertain Future After End of Shuttle Program*, TAMPA BAY TIMES, <http://web.tampabay.com/news/science/space/space-coast-jobs-face-uncertain-future-after-end-of-shuttle-program/1177218>, archived at <http://perma.cc/9WKD-K4XE> (last modified July 13, 2011).

¹¹² SPACE AGE PUBL'G CO., *supra* note 100, at 11.

¹¹³ *Id.*

It also seems likely that an offshore spaceport would need a team of professional scuba divers for underwater maintenance and other activities. This would provide still more jobs, while possibly promoting a local scuba diving industry, which might itself promote tourism to the area.¹¹⁴

V. SITES FOR OFFSHORE SPACEPORTS

Many U.S. states have sites that may be viable for offshore spaceports. This section will analyze sites for spaceports servicing eastbound launches, and sites for spaceports servicing polar-orbit launches. It will treat Hawaii separately because a Hawaiian spaceport could service eastbound and polar-orbit launches.

A. *Sites for Eastbound Launches*

Most rockets launch on eastward trajectories. Launching in this direction helps achieve orbit, because it makes use of the earth's rotational speed. The closer a spaceport is to the equator, the greater this "launch bonus" is.¹¹⁵

At least six continental U.S. states could launch eastbound rockets from their submerged lands. Table 1 details these sites, noting depths at the sites,¹¹⁶ launch bonuses relative to existing U.S. spaceports, and other benefits and issues.

¹¹⁴ Ghazali Musa & Kay Dimmock, *SCUBA Diving Tourism: Introduction to Special Issue 8 TOURISM IN MARINE ENV'TS* 1, 1 (2012) ("Scuba diving is an important component of marine tourism . . . and a 21st century scuba diving environment is economically important to tourism destination") available at http://epubs.scu.edu.au/cgi/viewcontent.cgi?article=1747&context=tourism_pubs, archived at <http://perma.cc/8FQT-2S92> (last visited Apr. 1, 2015).

¹¹⁵ See SWINERD, *supra* note 28.

¹¹⁶ NOAA, *BookletChart: Southern Part of Laguna Madre*, 15 http://ocsdata.ncd.noaa.gov/BookletChart/11301_BookletChart.pdf (showing depths off Brownsville); NOAA, *BookletChart: Charleston Light to Cape Canaveral*, 17 http://ocsdata.ncd.noaa.gov/BookletChart/11480_BookletChart.pdf (showing depths off Canaveral); NOAA, *BookletChart: St Mary's Entrance—Cumberland Sound and King's Bay*, 6, 11, 12 http://ocsdata.ncd.noaa.gov/BookletChart/11503_BookletChart.pdf (showing depths off Cumberland Island); NOAA, *BookletChart: St. Helena Sound to Savannah River*, 10, 11, http://ocsdata.ncd.noaa.gov/BookletChart/11513_BookletChart.pdf (showing depths off Hunting Island); NOAA, *BookletChart: Approaches to Cape Fear River*, 6 http://ocsdata.ncd.noaa.gov/BookletChart/11536_BookletChart.pdf (showing depths off Bald Head Island); NOAA, *BookletChart, Cape Henry to Currituck Beach Light*, 10 http://ocsdata.ncd.noaa.gov/BookletChart/12207_BookletChart.pdf (showing depths of False Cape); NOAA, *Booklet Chart: Chincoteague Inlet to Great Machipongo Inlet*, 6 http://ocsdata.ncd.noaa.gov/BookletChart/12210_BookletChart.pdf (showing depths of Chincoteague); NOAA, *BookletChart: Fenwick Island to Chincoteague Inlet*, 9, 13, http://ocsdata.ncd.noaa.gov/BookletChart/12211_BookletChart.pdf (showing depths of Chincoteague).

TABLE 1—CONTIGUOUS U.S. SITES FOR EASTBOUND ROCKETS

State	Site	Depth	Relative Launch Bonus	Other Benefits	Issues
Texas	10.3 miles east from the baseline at Brownsville	87'–91'	Bonus over Cape Canaveral	Best launch bonus in Texas	Narrow flight corridor, flights may need to dogleg ¹¹⁷
Florida	Outside Cape Canaveral's hazard zones, 3 miles east from the baseline	60'–92'	Bonus over Wallops Island	Adjacent to Cape Canaveral	
Georgia	3 miles east from the baseline at Cumberland Island	17'–45'	Bonus over Wallops Island	Best launch bonus in Georgia	
South Carolina	3 miles east from the baseline at Hunting Island State Park	19'–35'	Bonus over Wallops Island		Close to Hilton Head
North Carolina	3 miles east from the baseline at Bald Head Island	31'–40'	Bonus over Wallops Island		Close to Frying Pan Shoals
Virginia	3 miles east from the baseline at False Cape State Park	27'–47'	Bonus over Wallops Island	Best launch bonus in Virginia	
Virginia	Outside Wallops Island's hazard zones, 3 miles east from the Chincoteague baseline	29'–59'	No relative launch bonus	Adjacent to Wallops Island	

The sites for Texas and Georgia are the southernmost sites in their respective states, giving the largest possible launch bonus. Florida cannot likely construct a spaceport south of Cape Canaveral because of

¹¹⁷ See BENSON & FAHERTY, *supra* note 55, ch. 1 § 2 (discussing launch penalties of dogleg flights).

overflight risks from the Bahamas. However, building near Cape Canaveral may be a significant benefit because this would add new activity to Florida's existing space coast.

The southernmost possible site in South Carolina is off of Hilton Head, which is a major tourism destination. To reduce nuisance to Hilton Head, it seems practical to site a spaceport just north, off Hunting Island State Park. The reduced launch bonus from this move should be negligible.

Virginia may have two highly viable sites. False Cape State Park affords the largest possible launch bonus in Virginia. But building off Wallops Island in the north would consolidate launches to Virginia's existing space coast. Sites north of Virginia would have a launch penalty relative to Wallops Island and therefore seem unviable for new spaceports servicing eastbound orbital launches.

All the sites listed in Table 1 are shallower than 93 feet. Planners for the San Marco Range set 100 feet as "the maximum water depth in which an operational setup would be attempted."¹¹⁸ With a view only to depth, these sites all seem adequate. San Marco's planners considered additional features such as the "shear value" of "soil bottoms."¹¹⁹ This Note does not consider such factors.

B. *Sites for Polar-Orbit Launches*

Rockets bound for polar-orbits have traditionally launched due south from two U.S. sites: Vandenberg Air Force Base in California, and the Kodiak Launch Complex in Alaska. Launch bonuses do not apply to polar-orbit launches, so a spaceport servicing polar-orbit launches can be competitive on any latitude.¹²⁰ But such spaceports must have ocean to their south in order to reduce risk in a rocket failure.

California and Alaska could both increase their share of the commercial launch market with offshore spaceports. Many sites on the California coast could support polar orbit launches. But it might be best to site off of Vandenberg Air Force Base so as to consolidate launch activities on California's existing space coast. Depths three miles west of Vandenberg range from 33 to 47 feet.¹²¹ Similarly, much of Alaska's coast could support polar orbit launches, but it might be best to site near the Kodiak Launch

¹¹⁸ See NESBITT, *supra* note 8, at 15.

¹¹⁹ *Id.*

¹²⁰ See SWINERD, *supra* note 28, at 104–06.

¹²¹ NOAA, *BookletChart: Santa Cruz Island to Purisima Point*, 5, 11 http://ocsddata.ncd.noaa.gov/BookletChart/18721_BookletChart.pdf.

Complex in order to consolidate launch activities. Depths three miles off Kodiak Island generally range from 37 to 47 feet.¹²²

C. *Hawaii*

The State of Hawaii could support a strong offshore launch facility servicing both eastbound and polar orbit launches. The idea of a Hawaiian spaceport began in the earliest days of space travel,¹²³ and found supporters in astronaut Deke Sleyton¹²⁴ and author Arthur C. Clarke, who thought “Hawaii would be an excellent site from almost all points of view.”¹²⁵

The best offshore site in Hawaii would likely be off of Ka Lae, the southernmost point on the Island of Hawai'i, which is southernmost and easternmost island in the archipelago. In fact, Ka Lae is “the southernmost point in the USA”¹²⁶ and would have a launch bonus over Cape Canaveral.

There is a relatively wide submerged promontory extending due south of Ka Lae, with depths of just 65 feet at the 3-mile line.¹²⁷ From that site, a rocket could fly due south for 2,600 miles before passing over the sparsely inhabited islands of French Polynesia.¹²⁸ A rocket launching eastward would travel over 5,000 miles before overflying Ecuador.¹²⁹ The FAA would have to decide if such flight paths are acceptable. If they are, Hawaii could have an excellent spaceport.

CONCLUSION

U.S. states interested in entering—or increasing their share of—the commercial launch market should strongly consider developing offshore. An offshore spaceport is viable for several states. The Italian Space Agency successfully operated an offshore spaceport for years. States can

¹²² NOAA, *BookletChart: Kodiak Island*, 11 http://ocsddata.ncd.noaa.gov/BookletChart/16580_BookletChart.pdf.

¹²³ BENSON & FAHERTY, *supra* note 55, ch. 5 § 4, (“During the month of July, the NASA-Air Force team considered eight sites [including] South Point on the island of Hawaii.”) NASA.GOV, <http://www.hq.nasa.gov/office/pao/History/SP-4204/ch5-4.html>.

¹²⁴ SPACE AGE PUBL'G CO., *supra* note 100, at 6 (“[F]ormer astronaut Donald K. ‘Deke’ Slayton in May 1982 . . . expressed an interest in establishing a commercial launch facility. Local opposition and a lack of state government support doomed the project.”).

¹²⁵ *Id.* at 3–4.

¹²⁶ *Id.* at 4.

¹²⁷ NOAA, *BookletChart: Hawai'ian Islands—Southern Part 9* http://ocsddata.ncd.noaa.gov/BookletChart/19010_BookletChart.pdf.

¹²⁸ See generally SPACE AGE PUBL'G CO., *supra* note 100.

¹²⁹ *Id.*

develop a spaceport similar to the San Marco Range on their submerged lands, and should be able to comply with federal regulations.

An offshore spaceport will not destroy or degrade any coastal dunes or wetlands, unlike spaceports built on land. And the environmental concerns unique to offshore spaceports can be mitigated.

An offshore spaceport will be extremely competitive in the commercial launch market, and it will strongly support local maritime industries. In short, many U.S. states have good sites for offshore spaceports, and should strongly consider developing offshore.