LNG USE ON THE SPACE COAST

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RS&H

AAPA American Association of Port Authorities

Alliance of the Ports of Canada, the Caribbean, Latin America and the United States

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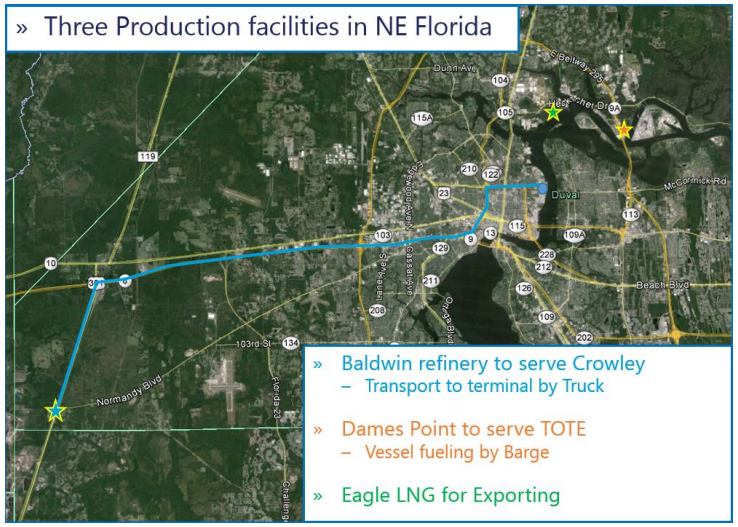
Introduction

- LNG use on the Space Coast - Port Canaveral maritime and adjacent Cape Canaveral Air Force Station rocket launch facilities will need a source of LNG for their operations.
- There are three LNG production facilities in NE Florida that can provide LNG to the Space Coast by tanker truck or “bunker barge.”
- Cruise ships will be fueled by bunker barge.
- Launch complexes have on-site storage tanks that are fueled by tanker truck.



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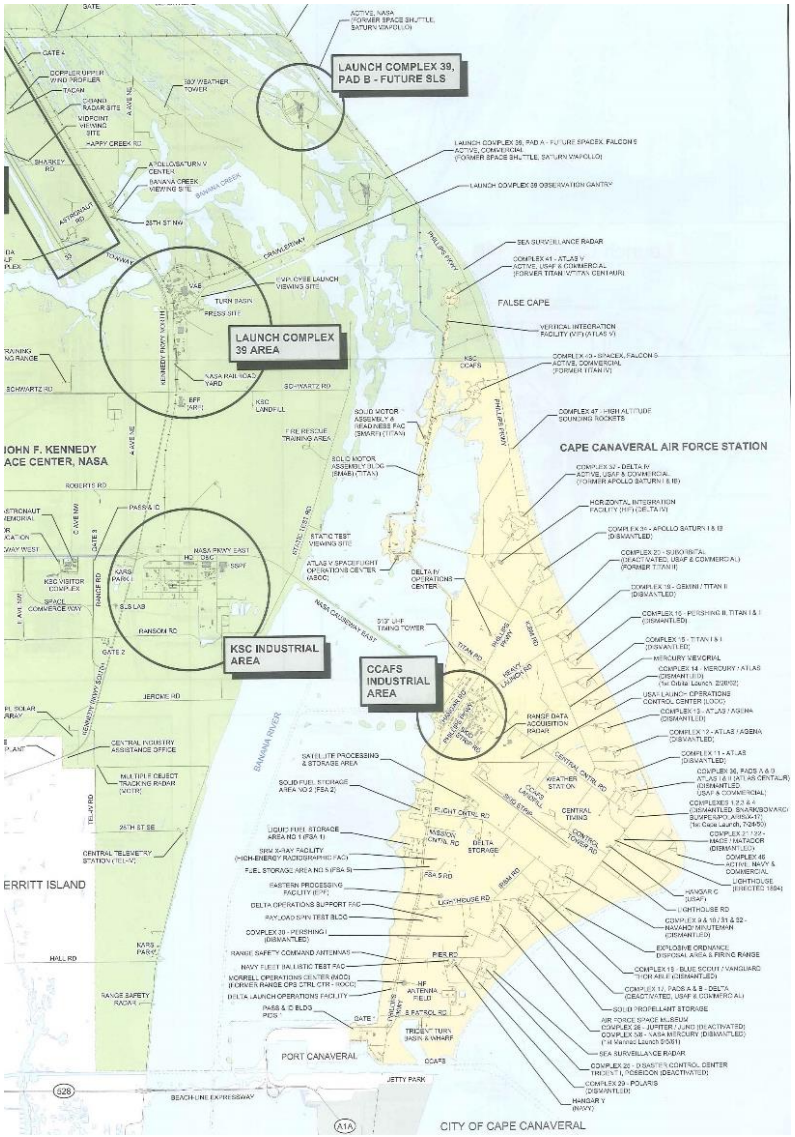
KSC and CCAFS Launch Facilities Adjacent to Port Canaveral

- As the LNG demand increases for cruise ships and rocket engines there will be a need for pre-positioning LNG at a facility in the area.
- Port Canaveral is at the south end of this map with the launch complexes stretching to the north a total distance of approximately 15 miles.
- Least expensive way to deliver LNG to Port Canaveral is by tanker ship.



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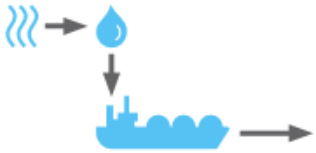
LNG: FUELING THE FUTURE

PORT CANAVERAL

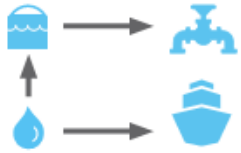
Liquefied Natural Gas (LNG) is on the rise to become the preferred marine fuel of the future. The clean burning properties of LNG means far less ship emissions to meet the global emission standard of the International Maritime Organization (IMO) effective January 2020. The new standard requires ships limit emissions that negatively affect the environment. LNG has safely been used to fuel ship engines for over 50 years. LNG is transported in specialized containers that meet all international and U.S. regulatory requirements for safe transport. Canaveral Port Authority has committed resources and is working closely with Canaveral Fire and Rescue, the U.S. Coast Guard and other federal and state agencies to ensure the safe use of LNG at Port Canaveral.

What is LNG? Liquefied Natural Gas (LNG) is a natural gas — the **same** product widely used in homes, schools, hospitals and businesses for heating, cooling, cooking and hot water.

LNG is super cooled to -260°F to become a colorless and odorless liquid.



Converting natural gas to LNG reduces its volume by 600 times, allowing for efficient transport over long distances by ship, train or truck.



LNG is warmed back to a gaseous state at its point of use before being used in a pipeline grid or as transportation fuel.

Environmental Impact LNG as ship fuel significantly reduces harmful emissions of ship operations.

Marine engines powered by LNG virtually **eliminate** sulfur oxides (SOx) and reduce nitrogen oxides (NOx) up to 85%.

Natural gas generates 27% less carbon dioxide than diesel fuel oil in combustion.

Safety LNG has been powering marine engines for more than 50 years.

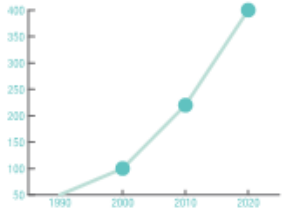
More than 151 million miles safely traveled

Insulated tank walls are specifically designed to safely store LNG at the correct pressure and temperature.

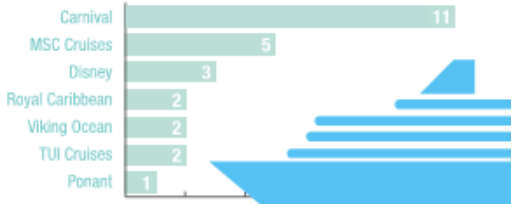
The Future LNG is the fuel of the future for commercial space and cruise industries, which requires our Port to invest in capabilities, partnerships and infrastructure to support its use.

The space industry plans to power launch vehicles with LNG because it's an ideal fuel for deep space missions due to its high energy content and cryogenic properties.

LNG market demand by millions of tons



Number of LNG cruise ships in service and on order through 2027 (as of March 2019)



Credit: Canaveral Port Authority
Source: U.S. Energy Information Administration, Cruise Industry News, LNG World Shipping, U.S. Department of Energy

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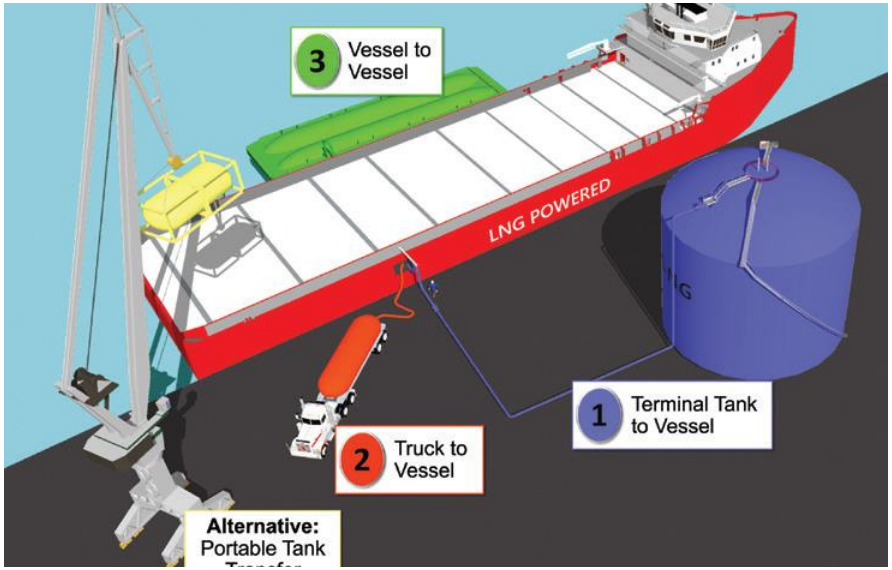
Methods of LNG Bunkering

LNG delivery to ships

1. Terminal tank to ship requirements:
   - *Land for tank*
   - *Safety/security/separation distance*
   - *Tank to ship pipe routing*

2. Tanker truck to ship (Truck Bunkering)
   - *8 hour ship dwell time*
   - *8,000 gal tanker truck and 250,000 gal ship fuel capacity, approx. 32 truck loads*

3. Bunkering Barge to ship
   - *No landside infrastructure required other than fire protection, safety and communications*



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LNG at Port Canaveral

Port Canaveral's Master Plan includes an area #19 for Potential LNG Storage

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Cryogenic Fluids – Storage and Transfer

Cryogenic Fluids Used in the Aerospace Industry:
NOTE: Absolute zero is -459°F (can't be any colder)

- Liquefied Helium (LHe): - 452°F boiling point
- Liquefied Hydrogen (LH2): -423°F boiling point
- Liquefied Nitrogen (LN2): -320°F boiling point
- Liquefied Oxygen (LO2): -297°F boiling point
- Liquefied Natural Gas (LNG): -260°F boiling point

Storage and transfer piping systems:

- LHe and LH2, the coldest of these cryogenics are stored and transferred using expensive vacuum jacketed (VJ) tanks and piping to minimize heat gain.
- LO2 and LNG can be stored and transferred in VJ tanks and piping or mechanically insulated tanks and piping depending of operational requirements and costs.
- Any boil-off gas is reliquefied and returned to tank, used as fuel or burned off in an industrial setting.

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Cryogenic Fluids – Storage and Transfer

SLC-41 LO2 VJ Storage Tank

- LC-39B LH2 Vacuum Jacketed (VJ) Storage Tank – 850,000 gallon capacity (originally built for Saturn V rocket). Outer shell pressure design conditions: Full vacuum on annular space, 5 psig exterior (rocket over-pressure)
- Note cross country VJ piping in the foreground.

SLC-41 LH2 VJ Horizontal Storage Tank

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Cryogenic Fluids – Typical LNG Storage Tank

Chicago Bridge & Iron Company LNG 28,000 cubic meter (175,000 barrel) capacity tank developed in 1968.

Smaller capacity horizontal and vertical tanks are also commonly used

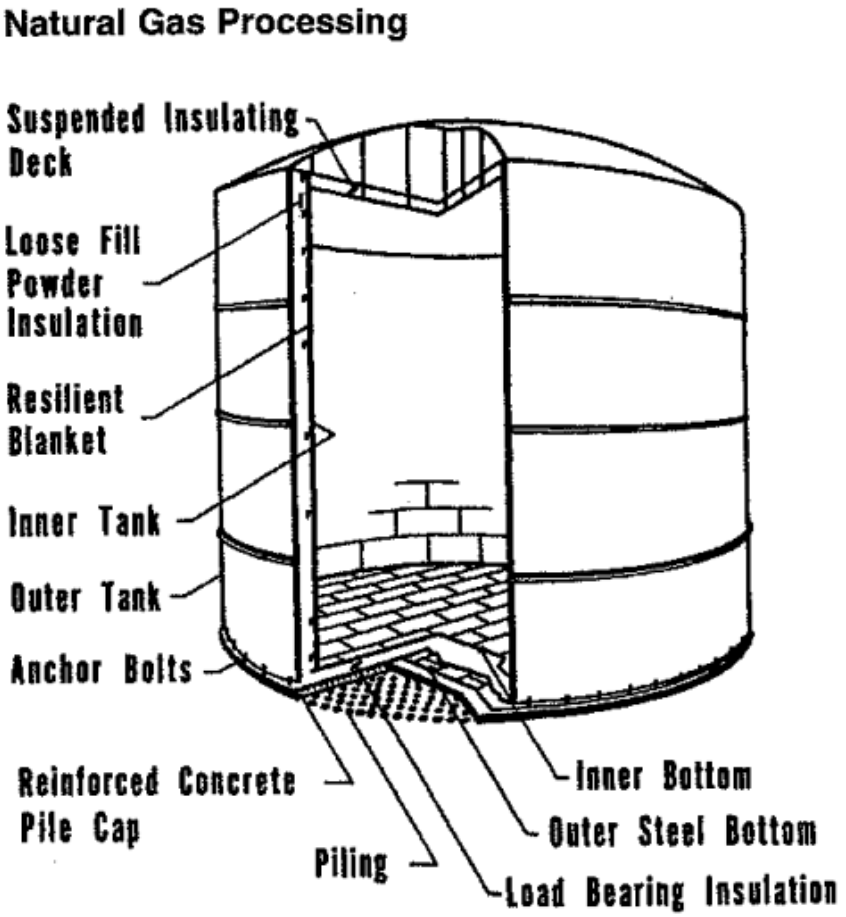

Figure 10.25 Above-ground metal tank for LNG.

Credit: "Cryogenic Engineering", second edition, Thomas M. Flynn

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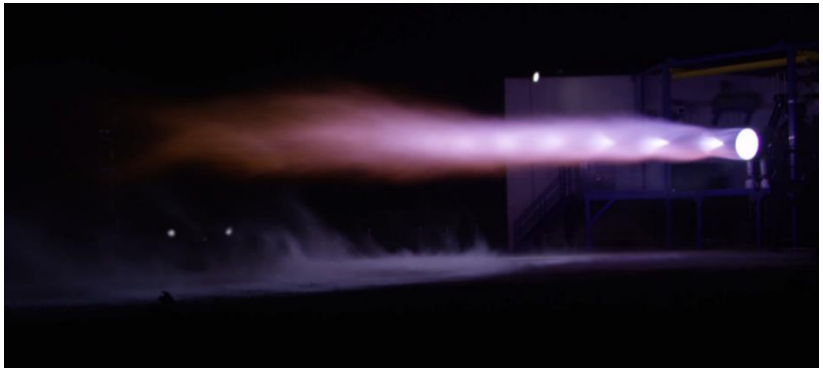
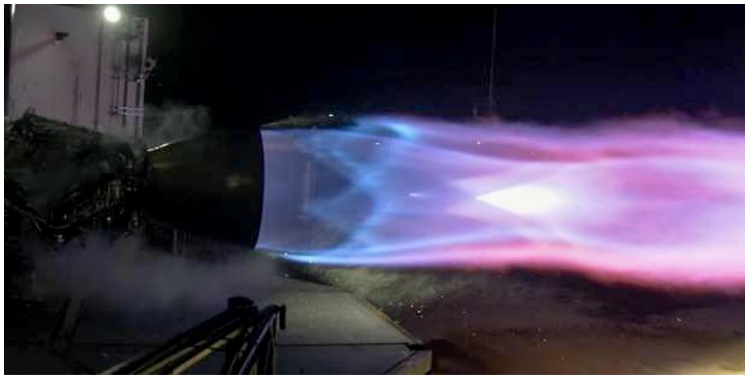
LNG Fueled Rocket Engines





Photos of LNG / LO2 rocket engine test fire. There are several commercial aerospace companies that are developing LNG engines.

There are numerous videos of LNG rocket engine test firings online.

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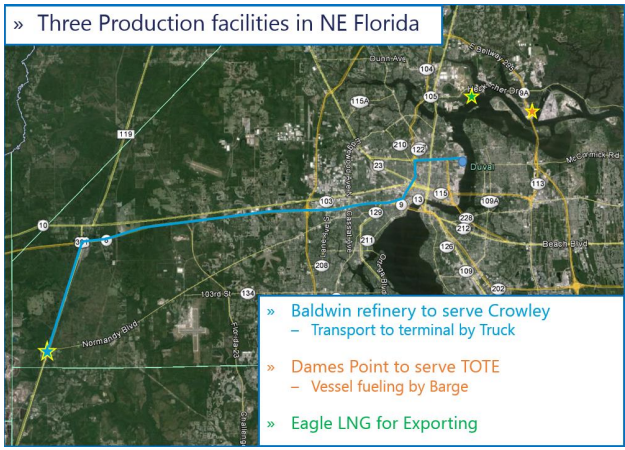
RS&H LNG Expertise

- LNG Cape Canaveral Air Force Station (CCAFS)
  - Designed a launch facility which is currently under construction for vehicle using LNG and LO2, performed all siting of propellants
- Explosive Site Survey expertise
- Cryogenics Expertise
  - Extensive use of Cryogenics for NASA and Commercial Aerospace Processing and Launch Complexes
    - *Applications include: fuel storage and handling systems, valve skids, vaporizers, pumping, flare stacks, fuel conditioning systems, compressors, cooling towers*
- Strategic Planning support for JAXPORT
  - LNG facility/site location
  - Long-term Terminal Planning & Design
  - Engineering Services 15+ years



RS&H Cryogenic Experience (cont.)

- Testing LH2 and LO2 Tail Service Masts at NASA's KSC Launch Equipment Test Facility (LETF)
- Newly installed LOX Vaporizers at Pad 39B
- Cold Shock Test of LOX vaporizer component at Vendor's Facility
- LH2 and LO2 Storage Tank and Piping Inspection and Refurbishment at Pad 39B
- LH2 and LO2 system design for Atlas V SLC-41 project
- ASME B31.3 Process Piping Flexibility (Thermal) Analysis and Pressure Vessel design per ASME Boiler Pressure Vessel Code Div. 1 and 2