Support for Space Launch System Core Stage Testing

Summer Internship: Stennis Space Center

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NASA Intern – Summer 2014
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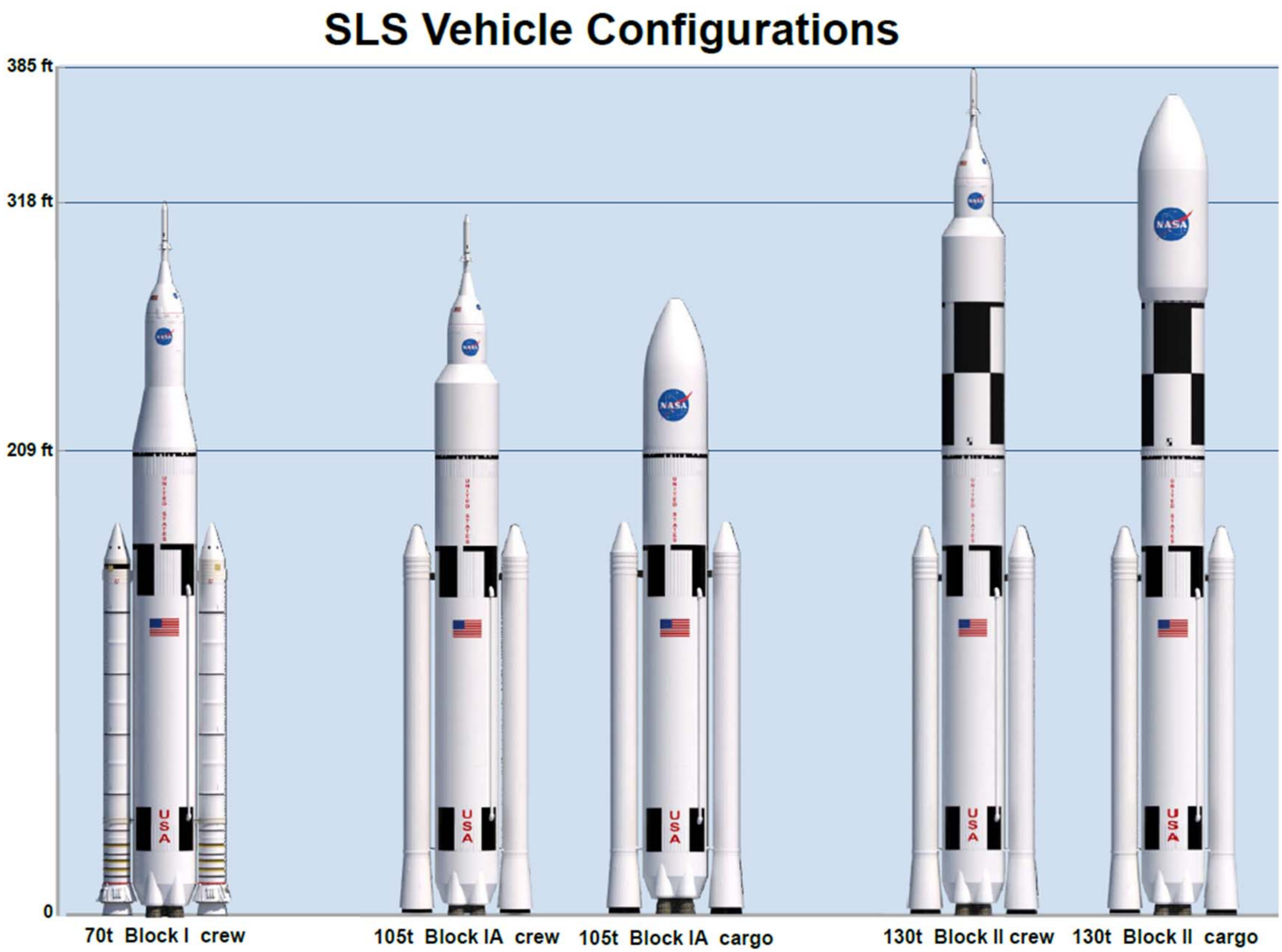
What is the Space Launch System?

- **The Space Launch System (SLS) is NASA's new heavy launch vehicle initiative.**
- **It is designed to be capable of carrying a wide range of payloads in support of the ISS, the new Orion spacecraft, and eventually a series of Beyond Earth Orbit (BEO) missions.**
  - The BEO missions could include a variety of objectives including the moon, a near earth asteroid, or Mars.
  - The SLS will have a variable payload capacity due to a modular design that will allow its functionality to be tailored to the mission.

What is the Space Launch System?



http://www.nasa.gov/pdf/623766main_8143_Singer-AD_industry_day-021312_FINAL3.pdf

How does SSC Feature in the Project?

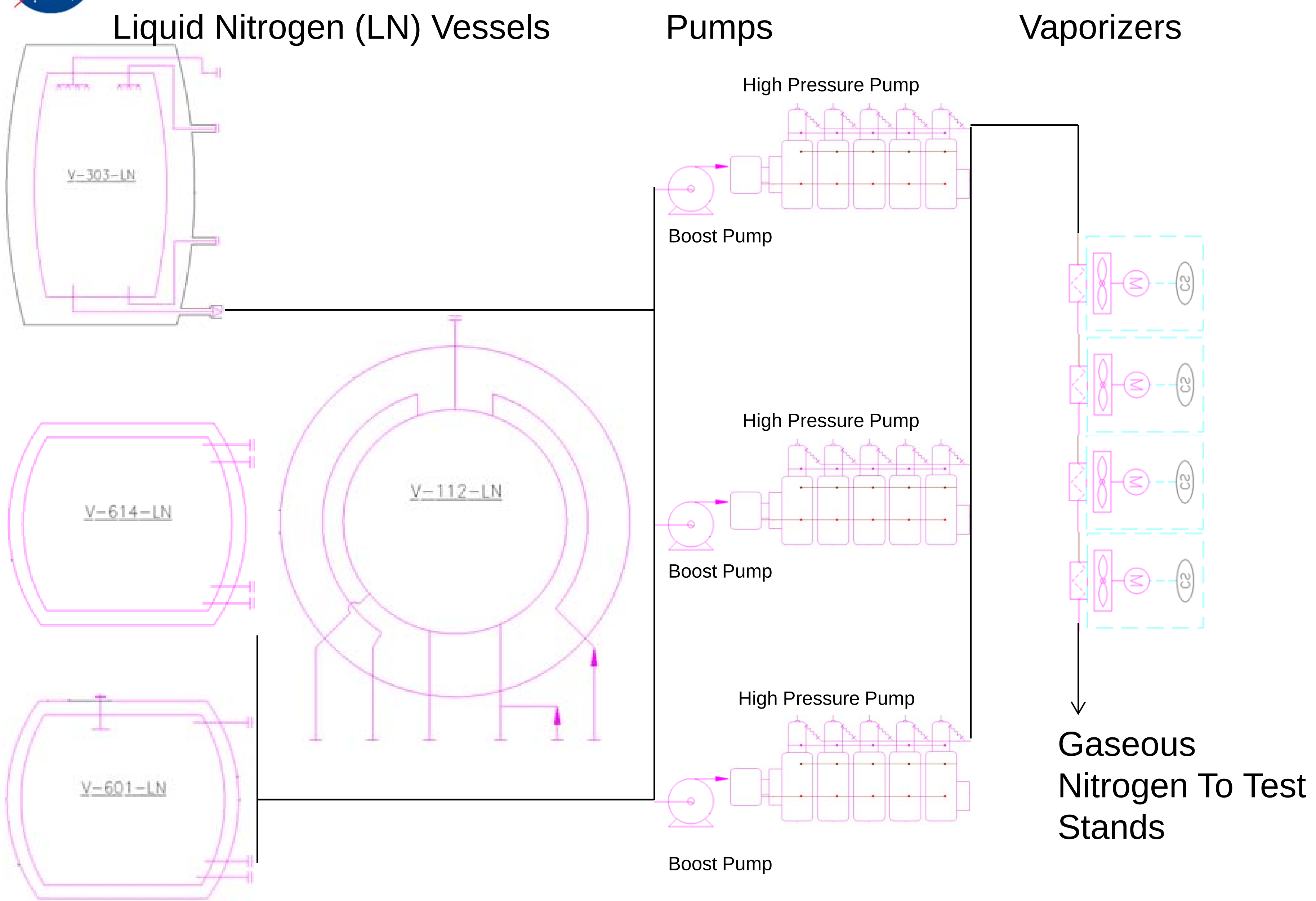
- **Stennis Space Center (SSC) is NASA's primary rocket engine testing facility.**
- **The SLS Core Stage will be one of the largest engine tests ever conducted at the facility.**
  - Only the Saturn V cluster tests rival it in size.
- **The B-2 test stand is undergoing renovations in preparation for the SLS core stage tests.**

B Test Complex

High Pressure Gas Facility

- **The High Pressure Gas Facility (HPGF) provides the test stands with the fluids necessary for testing.**
  - These fluids include hydrogen, helium, nitrogen, and air.
  - The facility includes the storage vessels, compressors, pumps, vaporizers, piping, and control systems for the distribution of the gases to the test stands.
  - During the SLS test, the HPGF will be required to supply large amounts of these fluids to the B-2 test stand.
- **Primary work involved studying various components of the nitrogen supply system for the B-2 test stand in preparation for the SLS Core Stage test.**
  - Nitrogen serves as a purge gas during testing.
  - SLS tests will have larger demand for nitrogen than standard engine tests.
  - Capabilities of the nitrogen supply system must be assessed to ensure the needs of the test can be met.

HPGF Nitrogen System Schematic



Nitrogen Supply Projections

- **Create an estimate of the amount of nitrogen that will be required to supply an SLS Core Stage Test.**
  - The SLS testing will require more nitrogen than a typical rocket engine test, placing higher demand on the High Pressure Gas Facility's (HPGF) nitrogen supply systems.
  - Testing normally requires trucks to bring in liquid nitrogen (LN); the SLS testing will require a larger number of LN trucks.
  - Consider sub-optimal test conditions such as extended test time due to holds, empty or failed nitrogen supply vessels, and system losses.

Nitrogen Truck Requirement

- **The SLS Test will require running two nitrogen pumps for 21 to 24 hours depending on test conditions.**
  - A variety of conditions and variables were considered which resulted in a number of estimates, but the minimum estimate is shown here.

Test Time (hr)	Number of LN Trucks Required
21	18
24	21

Nitrogen Supply System Testing

- **The SLS Test will require the HPGF to run two nitrogen pumps simultaneously, a test of the capabilities of the system was performed.**
  - Normal operation only requires a single operating nitrogen pump at a time.
  - The nitrogen system was tested to ensure that simultaneous operation of two nitrogen pumps can be performed safely.
  - Data from various sensors on the system were analyzed in preparation for the two pump test.
  - The results of the test showed that simultaneous operation of two nitrogen pumps can be achieved.
  - Data from the test was collected and analyzed for further recommendations on the nitrogen system.

Other Assignments

- **Test of gaseous helium system to 4700 psi system pressure.**
  - Reviewed data from the test and assembled a summary.
- **Checked helium system RV sizing calculations.**
  - Used secondary analysis method to verify results and assembled an engineering analysis report.
- **Bottle blow down analysis at the A-3 facility.**
  - Calculated the time required for a blow down of the nitrogen storage bottles at A-3.
- **Sizing of B-2 relief valves to ensure an appropriate amount of flow in the event of a regulator failure.**
  - Using an analysis tool developed by EA33 Systems Analysis & Design, the necessary orifice sizes were calculated and compared against the actual sizes of the RV orifices as published by the manufacturer, Anderson Greenwood.

PRV Sizing Tool

PRV Sizing for Gas Systems (Version 1.1)

Input			
Gas	Nitrogen		
PRV Set Pres	132	psig	
PRV Kd	0.816	(0.816 for Type 60 or 80 RV)	
Max U/S Supply Pres	150	psig	Regulator or Valve
Max Cv	0.08	gpm/psi^0.5	
Optional Input			
Facility	ER 5000 Actuation		
PRV Locator #			
PRV Model #	81SF68-6		
Analyst Name	Benton Patterson		
Date	6/26/2014		

Instructions:

1. Choose the proper system gas.
2. Enter the PRV set pressure.
3. Ensure the RV is Type 60 or 80, otherwise enter the appropriate discharge coefficient of the RV orifice.
4. Enter the maximum possible u/s supply pressure of the nearest u/s isolation valve or regulator.
5. Enter the max Cv of the valve or regulator corresponding to #4.
6. Output is the required minimum orifice size.

Notice:

This tool assumes the nearest isolation valve or regulator fails open.

The analyst is responsible for determining the validity of the failure scenario assumed by this tool and the interpretation of the results given.

This tool does not determine adequacy of PRV lines sizes.

Output

Gas	Nitrogen						Required PRV Orifice	
MW	28.0135	lbm/lbmol						
Max Relief Pres	Temp	U/S Density	Compress. Factor	Ratio of Sp. Heats	Gas Factor	Mass Flow Rate	Orifice Area	Orifice Dia.
psia	R	lbm/ft3	(-)	(-)	(-)	lbm/s	in^2	in
146.7	520.0	0.829	0.9974	1.42	358	0.005	1.97E-03	0.0500

Skills Developed

- MathCAD
- WinPlot
- Choked flow nozzle sizing
- Analysis of piping schematics
- Bottle blow down calculations
- Engineering analysis reports

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