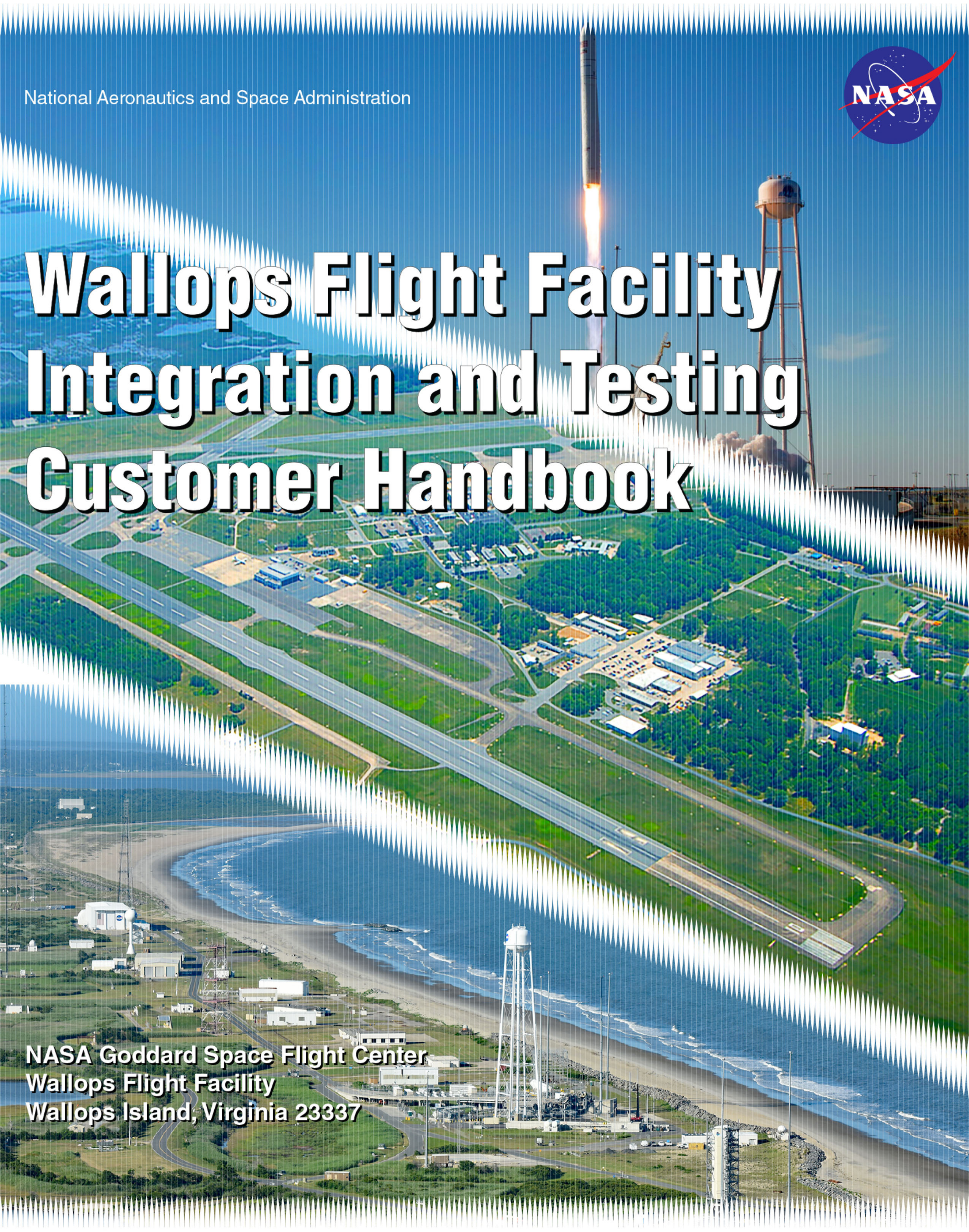
National Aeronautics and Space Administration



Wallops Flight Facility Integration and Testing Customer Handbook

NASA Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia 23337

TABLE OF CONTENTS

1 INTRODUCTION 7
1.1 Purpose 7
1.2 Facility History 9
1.3 Wallops Main Base Overview 9
1.4 Wallops Island Overview 11

2 ELECTRICAL INTEGRATION AND TESTING 13
2.1 EMI/EMC Measurement Facility (Building F-7) 13
2.2 Anechoic Chamber Facility (Building F-7) 13
2.3 GPS Simulation Lab Facility (Building E-109) 15
2.4 Radar Lab Facility (Building E-109) 15
2.5 Microwave Lab Facility (Building E-109) 16
2.6 Electrical Lab (Building E-109) 17
2.7 Telemetry Ground Stations (Building F-10) 18

3 MECHANICAL INTEGRATION & TESTING 19
3.1 Thermal Chambers (Building F-7) 19
3.2 Thermal Facilities (Building F-10) 22
3.3 Environmental Test Chamber (Building E-109) 24
3.4 Vibration Test Facilities (Building F-10) 25
3.5 Vibration Test Facilities (Building E-109) 27
3.6 Balancing Machines (Static and Dynamic) (Building F-10) 28
3.7 Mass Properties Measurement System (Building F-10) 28
3.8 Spin Deployment Facility (Building F-10) 30
3.9 Bend Test Facility (Building F-10) 31

4 PAYLOAD FABRICATION, INTEGRATION & TESTING 32
4.1 Payload Fabrication (Building F-10) 32
4.2 Attitude Control System Testing (Building F-10) 33
4.3 Sounding Rocket Payload Integration (Building F-10) 34
4.4 Solar Simulator (Building E-109) 35
4.5 SmallSat and Balloon Payload Integration (Building F-7) 36
4.6 Payload Processing Facility 37
4.7 SmallSat Multi-Payload Processing Facility (Building F-7) 37
4.8 Rideshare Mission Integration Services (Building F-7) 38
4.9 High Bays (Building E-109) 40
4.10 High Bay East (Building F-7) 40
4.11 High Bay West (Building F-7) 42
4.12 Balloon Research and Development Laboratory (Building F-7) 43

5 ENGINEERING SUPPORT 44
5.1 Overview 44
5.2 Mission Planning Lab (Building E-109) 44
5.3 Interconnect Lab (Building E-109) 45
5.4 Prototype Lab (Building E-109) 46
5.5 3-D Printer (Building E-109) 46
5.6 Machine Shop (Building E-109) 47
5.7 Software Development (Building E-109) 47

6 OTHER SUPPORT SERVICES 49
6.1 Assembly and Processing Facilities 49
6.2 Aircraft Operations Hangar (Building D-1) 50
6.3 Aircraft Hangar (Building N-159) 52
6.4 MARS/VCSFA 53
6.5 Unmanned Aircraft Systems Airfield 54

6.6 MARS Payload Processing Facility 57
6.7 MARS Port 58
6.8 Mission Operations Control Center 58
6.9 Integration and Control Facility 59

APPENDIX A: ABBREVIATIONS AND ACRONYMS 60

LIST OF FIGURES

Figure 1: Main Base and Airfield 10
Figure 2: Launch Range 10
Figure 3: Main Base and I&T Building Locations 11
Figure 4: Wallops Island 12
Figure 5: EMI/EMC Measurement Facility 13
Figure 6: Anechoic Chamber Facility Az/El Positioner Tower 14
Figure 7: Anechoic Chamber Facility Compact Range Source Feed 14
Figure 8: Anechoic Chamber Facility Compact Range Reflector 14
Figure 9: Anechoic Chamber Facility Far Field Source Feed 14
Figure 10: GPS Simulator Lab 15
Figure 11: Flight Termination Receiver System Certification Bench 15
Figure 12: Test Equity Model 115 Thermal Cycle Chamber 16
Figure 13: Microwave Lab Facility 16
Figure 14: Microwave Lab Facility 17
Figure 15: Agilent 8722ES Network Analyzer 17
Figure 16: Electrical Lab (Building E-109) 17
Figure 17: Telemetry Ground Station 18
Figure 18: Overview of Building 7 Thermal Vacuum Chamber 19
Figure 19: Thermal Vacuum Chamber 19
Figure 20. Thermal Vacuum Chamber Ports 19
Figure 21: Thermal Vacuum Chamber 20
Figure 22: Thermal Vacuum Chamber used for small spacecraft, subsystems, and components 20
Figure 23. Thermal Vacuum Chamber used for testing Balloon High Gain Antenna (HGA) 20
Figure 24: Thermal Chamber (Building F-7) 21
Figure 25. Thermal Vacuum Chamber (Building F-10) 22
Figure 26: PV/T Vacuum Chamber 22
Figure 27: Altitude Bell Jar 22
Figure 28: Espec ESZ-4CA Thermal Chamber 23
Figure 29: Vacuum Test Stand 24
Figure 30: Environmental Test Chamber Model T5ST 24
Figure 31: Building F-10 Vibration Facility 25
Figure 32: Vibration Table 26
Figure 33: UD Small Chamber 26
Figure 34: Vibration Test 27
Figure 35: Balancing Machine 28
Figure 36: Mass Properties Measurement System 28
Figure 37: Mass Properties Measurement System 29
Figure 38: Mass Properties Measurement System 29
Figure 39: Mass Properties Measurement System 30
Figure 40: Spin Deployment Facility 30
Figure 41: Bend Test Fixture 31
Figure 42: Fabrication Facility 32
Figure 43: Fabrication Facility 32
Figure 44: Magnetic Calibration Facility 33
Figure 45: Magnetic Calibration and Testing 34
Figure 46: Payload Integration and Testing 34
Figure 47: Payload Integration and Testing 34
Figure 48: E-109 Solar Simulator 35
Figure 49: Integration and Test (Building F-7) 36

Figure 50: Integration and Test (Building F-7) ... 36
Figure 51: Building F-7 Supplemental Integration Workspace ... 36
Figure 52: Payload Processing Facility ... 37
Figure 53: SmallSat Lab ... 37
Figure 54: SmallSat Lab ... 38
Figure 55: Supplemental Integration Workspace ... 38
Figure 56: Landsat 9 Integration ... 38
Figure 57: Integrated ESPA ring prior to leaving Wallops (Building F-7) ... 39
Figure 58: EFS Assembly Stand ... 39
Figure 59: Clean Room Access ... 39
Figure 60: Gowning Room Access ... 39
Figure 61: Building 7 Clean Room Gowning Area ... 39
Figure 62: Building E-109 High Bays ... 40
Figure 63: High Bay East Cleanroom Tent with ESPA ring integration ground support equipment in the foreground ... 41
Figure 64: High Bay East Cleanroom ... 41
Figure 65: High Bay West ... 42
Figure 66. Balloon Research and Development Lab ... 43
Figure 67. Balloon Research and Development Lab Mechanical Testing Facilities ... 43
Figure 68: Wallops Arc Second Pointer (WASP) ... 44
Figure 69: Mission Planning Lab ... 44
Figure 70: Interconnect Lab (Building E-109) ... 45
Figure 71: Prototype Lab (Building E-109) ... 46
Figure 72: E-109 3-D Printer ... 46
Figure 73: Software Development Lab (Building E-109) ... 48
Figure 74: Aircraft Operations Hangar (Building D-1) ... 50
Figure 75: Aircraft Operations Hangar (Building D-1) ... 50
Figure 76: Aircraft Operations Hangar (Building D-1) ... 51
Figure 77: The Northrop Grumman Antares vehicle, on its way to the commercially operated MARS launch pad ... 53
Figure 78: MARS UAS Airfield ... 54
Figure 79: 3,000-foot x 75-foot UAS Runway ... 54
Figure 80: Concrete vertical takeoff and landing (VTOL) Pad rated to 5,000 psi ... 54
Figure 81: MARS UAS Airfield HVAC Conditioned Hangar ... 55
Figure 82: Ready Room Adjacent to Hangar Bay ... 55
Figure 83: MARS UAS Airfield Ramp Area ... 56
Figure 84: Direct Access to R6604 Restricted Airspace ... 56
Figure 85: MARS Payload Processing Facility ... 57
Figure 86: MARS Payload Processing Facility Solid Motor Processing Bay ... 57
Figure 87: MARS Payload Processing Facility Secondary Payload Processing Bay ... 58
Figure 88: MARS Payload Processing Facility Control Systems ... 58
Figure 89: UUV/USV Port Upgrade Summary ... 58
Figure 90: Integration and Control Facility (ICF) ... 59

LIST OF TABLES

Table 1: Building E-109 Engineering Facilities ... 8
Table 2: Building F-7 Integration and Test Facilities ... 8
Table 3: Building F-10 Test and Evaluation Facilities ... 9
Table 4: EMI/EMC Facility Specifications ... 13
Table 5: Anechoic Chamber Facility Specifications ... 14
Table 6: Radar Lab Specifications ... 16
Table 7: Microwave Lab Specifications ... 17
Table 8: F-7 T-Vac Chamber Specifications ... 20
Table 9: Espec Thermal Chamber Specifications ... 21
Table 10: Building F-10 Thermal Chamber Summary ... 23
Table 11: Environmental Test Chamber Specifications ... 25
Table 12: F-10 Shaker Specifications ... 26
Table 13: E-109 Vibration Test Facilities ... 27
Table 14: Balancing Machine Specifications ... 28
Table 15: Mass Properties Measurement System ... 28
Table 16. Bend Test Fixture Specifications ... 31
Table 17: Magnetic Calibration Facility Specifications ... 33
Table 18: Solar Simulator Specifications ... 35
Table 19: Gimbal Specifications ... 35
Table 20: F-7 High Bay East Specifications ... 41
Table 21: F-7 High Bay West Specifications ... 42
Table 22: 3D Printer Capabilities ... 47
Table 23: Assembly and Payload Processing Facilities Wallops Island ... 49
Table 24: Building D-1 Specifications ... 51
Table 25: Building N-159 Specifications ... 52
Table 26: UAS Airfield ... 54
Table 27: UAS Hangar Bay Specs ... 55
Table 28: Ready Room Specs ... 55
Table 29: Ramp Area Specs ... 56

1 INTRODUCTION

The NASA Goddard Space Flight Center (GSFC) Wallops Flight Facility (WFF) , which will be referred to as 'Wallops' in this document, claims a heritage of low-cost operations, experienced personnel, customer-focused support, and a common-sense safety program. As an operational research site for the next generation of low-cost launch technologies, Wallops supports the development of space technologies and the dissemination of information through educational and outreach programs. Wallops is recognized as a role model for pioneering productive and innovative government, industry, and academic partnerships. Our ongoing programs and projects support all NASA centers, science, and technology focuses.

Wallops' key mission elements include:

Suborbital Flight Projects—Wallops manages and implements NASA's sounding rocket, balloon, and scientific aircraft programs in support of Earth and space sciences. New technologies, such as ultra-long duration balloons, are integrated into the program.

Low-Cost Orbital Missions—Wallops manages and provides technical support for small spacecraft carriers.

Mission Operations—Wallops provides fixed and mobile launch ranges and a research airport. The range provides the services necessary for a wide variety of research, development, and operational missions, including rocket, balloon, and aerial vehicle flights. Wallops also manages and operates satellite tracking stations locally. Wallops supports all five NASA mission directorates including the Science Mission Directorate (SMD), Exploration Systems Development Mission Directorate (ESDMD), Space Operations Mission Directorate (SOMD), and the Space Technology Mission Directorate (STMD) as well as the Department of Defense (DoD), commercial, and academic organizations.

Science and Technology—Wallops Earth scientists research global climate change. Wallops engineers develop new technologies that improve capabilities of flight projects or lower costs of access to space.

Educational Outreach—Partnerships formed with industry and academia foster educational outreach programs. Wallops also carries out a wide array of education and outreach programs that support the development of future engineers and scientists.

1.1 Purpose

The Wallops Integration and Testing Handbook is a guide for planning operations at Wallops testing facilities. It provides a summary of the capabilities and technical specifications of available facilities. This handbook prescribes the information to be provided by the user that will enable the integration and testing team to effectively plan for and support the facility user's project. Note that each facility plans for availability based on current workloads/ mission schedules. For example, sounding rockets may have between 20 and 35 missions in work at one time. Also note that special training, such as cleanroom certification, electrostatic discharge (ESD) or confined space training may be required for entrance to some facilities. Contact Scott Schaire at: scott.h.schaire@nasa.gov for additional information.

1.1.1 Building E-109: Engineering

Table 1 lists the engineering facilities in Building E-109.

Table 1: Building E-109 Engineering Facilities

Facility	Refer to section
GPS Simulation Lab	2.3
Radar Lab	2.4
Microwave Lab	2.5
Electrical Lab	2.6
Environmental Test Chamber	3.3
Vibration Tests	3.5
Solar Simulator	4.4
Mission Planning Lab	5.2
Interconnect Lab (harness fabrication)	5.3
Prototype Lab (component testing)	5.4
Software Development	5.7
High Bays	4.9
Machine Shop	5.6

1.1.2 Building F-7: Integration and Test

Table 2 lists the integration and test (I&T) facilities in Building F-7.

Table 2: Building F-7 Integration and Test Facilities

Facility	Refer to section
EMI/EMC Facility	2.1
Anechoic Chamber Facility	2.2
Thermal Chambers	3.1
SmallSat Multi-Payload Processing Facility	4.7
Rideshare Mission Integration Services	4.8
High Bay East and Cleanroom	4.10
High Bay West	4.11
Balloon Research & Development Lab	4.12
Machine Shop	4.7, 4.8

1.1.3 Building F-10: Test and Evaluation

Table 3 lists the test and evaluation facilities in Building F-10.

Table 3: Building F-10 Test and Evaluation Facilities

Facility	Refer to section
Telemetry Ground Stations	2.7
Thermal Chambers	3.2
Vibration Tests	3.4
Balancing Machines	3.6
Mass Properties Measurement	3.7
Spin Deployment	3.8
Bend Test Facility	3.9
Payload Fabrication	4.1
Attitude Control Testing Facility	4.2
Sounding Rocket Payload Integration	4.3
Machine Shop	4.1

1.2 Facility History

For more than 60 years, Wallops has provided launch support for some of the highest priority research programs in the United States. Founded in 1945, Wallops was established by the National Advisory Council on Aeronautics (NACA) as a test site for aeronautics research projects. During the 1940s and 1950s, prior to the era of high-speed wind tunnels, Wallops activities focused on providing operational testing for new aerodynamic configurations aboard rockets. During the 1960s, Wallops focused on support for numerous flight projects leading to human exploration of space, such as Little Joe, which tested the ejection system for the Mercury capsule. From the 1960s through the 1980s, Wallops supported the launch of more than 40 Scout rockets. During the 1990s, Wallops evolved its mission beyond operational support to include project management and implementation of various NASA space and Earth science activities aboard suborbital and small orbital carriers. During its history, Wallops has conducted more than 16,000 launches. For a more detailed history of Wallops, visit https://www.nasa.gov/centers/wallops/home.

1.3 Wallops Main Base Overview

Wallops Flight Facility encompasses more than 6,000 acres over three different land parcels: Wallops Main Base, Mainland, and Island. The Wallops Main Base is located on Virginia’s Eastern Shore, 5 miles south of the Maryland state line.

The Main Base (see Figure 1) is home to most of NASA's administrative, engineering, fabrication, testing, and project management activities, as well as the Research Airport and Range Control Center.

Figure 1: Main Base and Airfield

Figure 2: Launch Range

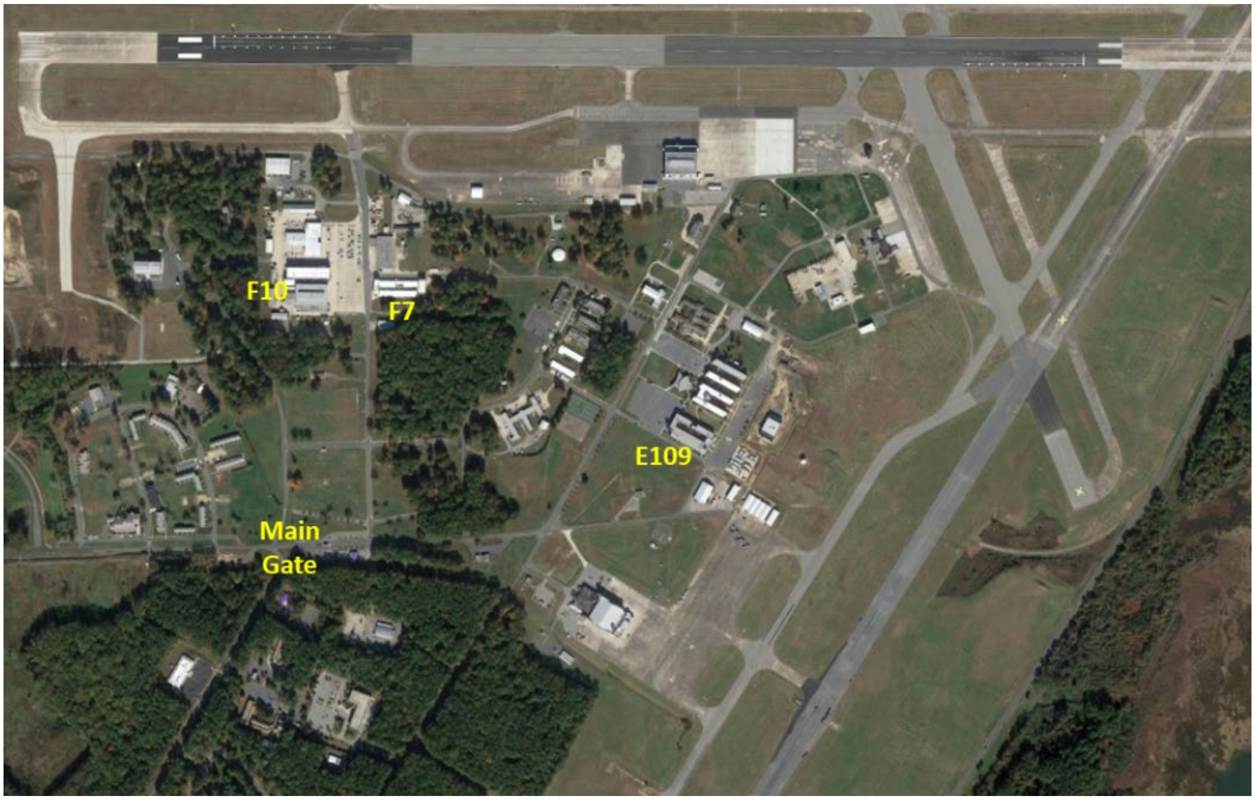


Figure 3: Main Base and I&T Building Locations

1.4 Wallops Island Overview

The mainland and Wallops Island are located approximately 7 miles to the southeast of the Main Base, adjacent to the Atlantic Ocean. Wallops Island is the site of the Wallops Launch Range (see Figure 2) and many supporting facilities. The locations of the I&T buildings are shown in Figure 3. Wallops Range has facilities for the receipt, inspection, assembly, checkout, and storage of rocket motors and other pyrotechnic devices. The Wallops Island launch site is comprised of launch pads, control rooms, blockhouses for launch control, and assembly buildings to support the preparation and launching of suborbital and orbital launch systems. Figure 4 depicts an aerial map of Wallops Island and the mainland. The top of the figure shows the mainland with supporting tracking radars. The bottom of the figure shows Wallops Island with the launch range and support facilities connected to mainland by the causeway bridge.

Figure 4: Wallops Island

2 ELECTRICAL INTEGRATION AND TESTING

2.1 aEMI/EMC Measurement Facility (Building F-7)

The electromagnetic interference / electromagnetic compatibility (EMI/EMC) Measurement Facility (Figure 5) is Military Standard (MIL-STD) 461/462-compliant and American National Standards Institute (ANSI) C63 pre-compliant for radiated emissions (RE102), radiated susceptibility (RS103), and conducted emissions (CE102). The test chamber is lined with absorbers rated to 40 gigahertz (GHz) with 100 dB shielding. The test chamber provides a low noise environment and may be used for payload self-compatibility testing and radio frequency (RF) sensitive device characterization. Two adjoining chambers house the control room and the payload support room. Electrical pass-throughs allow for connection to customer-provided ground support equipment (GSE) in the payload support room. See Table 4 for a summary.

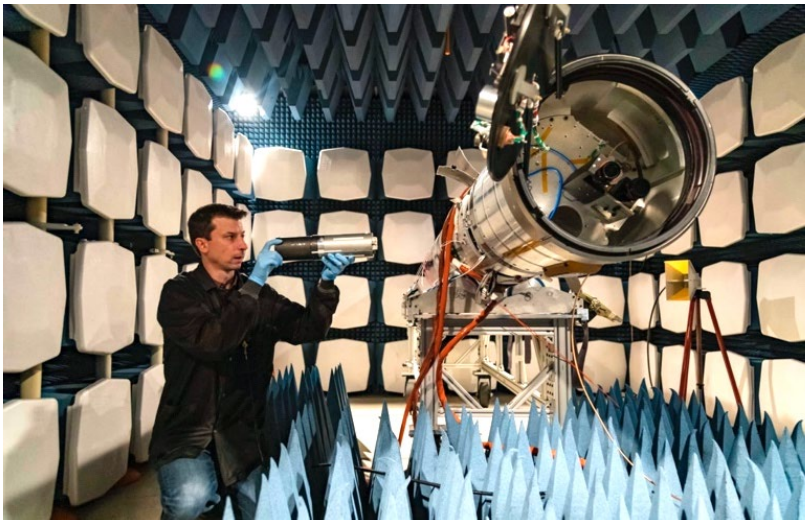


Figure 5: EMI/EMC Measurement Facility

Table 4: EMI/EMC Facility Specifications

Location	Building F-7
Measurements	12 feet wide by 18 feet long
Door Access	7 feet high by ~5 feet wide
Shielding	100 decibels (dB) to 40 GHz
Test Standards	RE102, RS103, CE102

2.2 Anechoic Chamber Facility (Building F-7)

The Anechoic Chamber facility (Figure 6 through Figure 9) is home to a shielded dual-mode far field/compact range chamber for measurement and analysis of linear and circular polarization antenna pattern. Its specifications are shown in Table 5. The Agilent PNA Orbit/FR spectrum-based automated data collection system allows both phase and amplitude pattern measurements with configurable settings for azimuth/elevation/roll range, and step sizes with source feeds in co-polarization or cross-polarization. The Anechoic Chamber maintains feeds and standard gain horns for the following bands: ultra-high frequency (UHF), L, S, C, X, Ku, and Ka.

Table 5: Anechoic Chamber Facility Specifications

Location	Building F-7
Far-Field mode	400 megahertz (MHz) to 2 GHz
Compact Range Mode	2 GHz to 100+ GHz
Shielding	90 dB to 40 GHz
Elliptic Cylinder Quiet Zone	6 feet wide by 6 feet deep by 4 feet high
Isolation Mounted Azimuth/ Elevation (Az/El) Positioner and Roll Axis	Provides angular accuracy of +/- 0.005 degrees

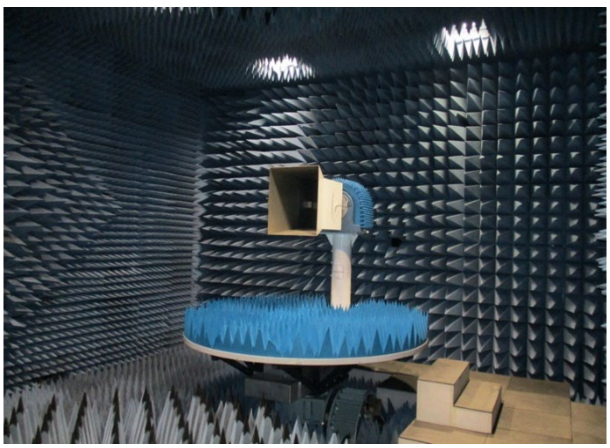


Figure 6: Anechoic Chamber Facility Az/El Positioner Tower

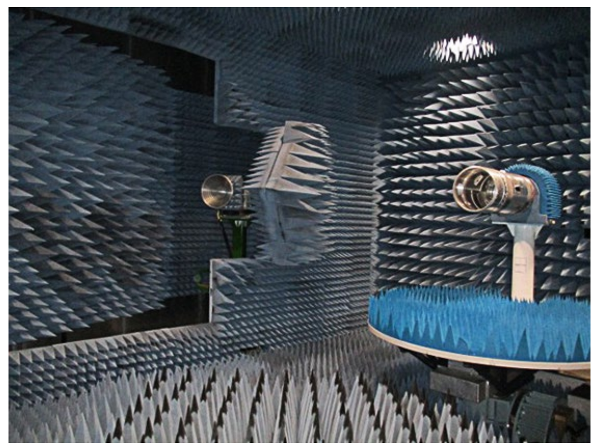


Figure 7: Anechoic Chamber Facility Compact Range Source Feed

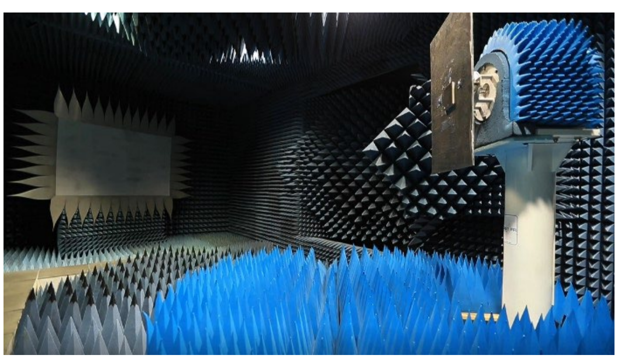


Figure 8: Anechoic Chamber Facility Compact Range Reflector

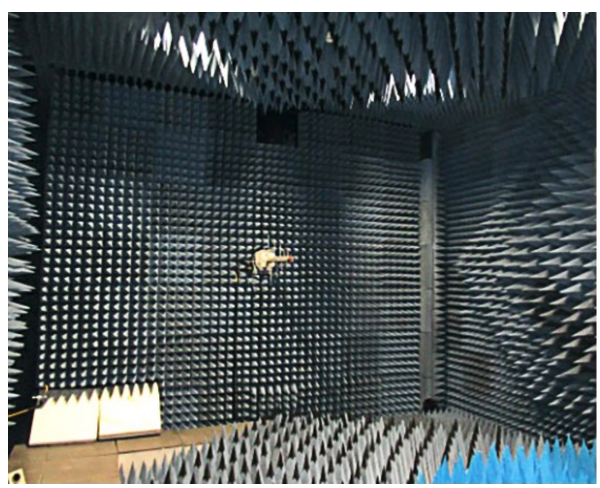


Figure 9: Anechoic Chamber Facility Far Field Source Feed

2.3 GPS Simulation Lab Facility (Building E-109)

The Global Positioning System (GPS) Simulator Facility, shown in Figure 10, is located in Building E-109 and is comprised of a 4-output Spirent GPS simulator capable of reproducing L1 and L5 RF signals. These signals would be received by a GPS receiver as it travels any trajectory at any time, with parameters such as signal strength, multipathing, antenna patterns controllable for testing of navigation and attitude receivers, a single output Spirent GSS GPS receiver programmable and transportable for use in the field, and a Navigation Laboratories Tapestry GPS/Inertial Measurement Unit (IMU) simulator.

Figure 10: GPS Simulator Lab

2.4 Radar Lab Facility (Building E-109)

The Radar Laboratory Facility contains the transponder and Flight Termination Receiver System (FTS) certification benches (see Figure 11). Table 6 lists the facility specifications. The Test Equity Model 115 Thermal Cycle Chamber is shown in Figure 12. The transponder rack and parts of the FTS bench are mobile so they can be moved for remote transponder and FTS testing. For example, these are used to perform in-vehicle testing and end-to-end (ETE) testing with the Antares vehicle at the Horizontal Integration Facility (HIF).

Figure 11: Flight Termination Receiver System Certification Bench

The portable thermal cycle chamber allows for component characterization over a wide temperature range.

Ample bench space is available for component test and measurement.

Figure 12: Test Equity Model 115 Thermal Cycle Chamber

Table 6: Radar Lab Specifications

Location: Building E-109
Radar Transponder Certification Bench
FTS Certification Bench
Test Equity Model 115 Thermal Cycle Chamber
Temperature Range: -73°C to +175°C
Control: +/- 0.2°C
Interior Dimensions: 16 inches wide x 12 inches high x 14 inches deep (1.55 cubic feet)

2.5 Microwave Lab Facility (Building E-109)

The Electrical Engineering Microwave Lab, shown in Figure 13 and Figure 14, provides instrumentation (Figure 15) and development tools for telemetry system RF communications hardware. The lab supports testing of flight and ground support hardware, as shown in Table 7.

Figure 13: Microwave Lab Facility

Table 7: Microwave Lab Specifications

Location: Building E-109
RF test and measurement capability to 30 GHz
BPSK, QPSK, 8PSK modulation and demodulation to 480 megabits per second (Mbps)
ESD Test and Assembly Benches
Keysight Advanced Design System (ADS) software
Field Programmable Gate Array (FPGA) development software

Figure 14: Microwave Lab Facility

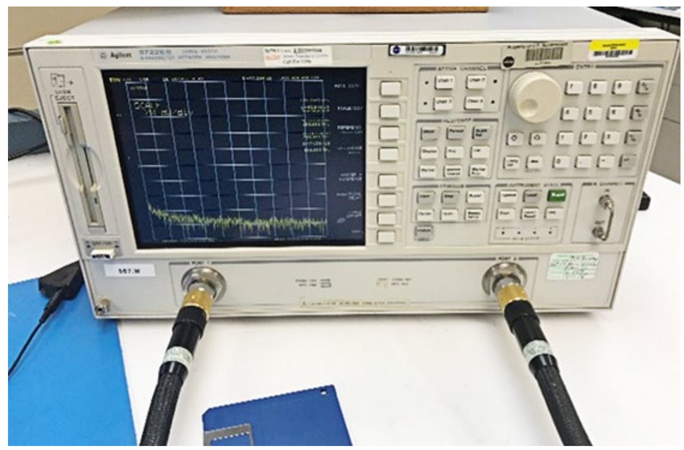


Figure 15: Agilent 8722ES Network Analyzer

2.6 Electrical Lab (Building E-109)

The Wallops Electrical Engineering Branch Electrical Lab (Room 272) supports multiple engineering and integration and testing efforts for components and small payloads. The lab, shown in Figure 16, can support class 1A to class zero missions for electrostatic discharge. A portable thermal chamber, portable laminar flow hood, and portable vacuum jar allow for environmental test capability and contamination control protections when required.

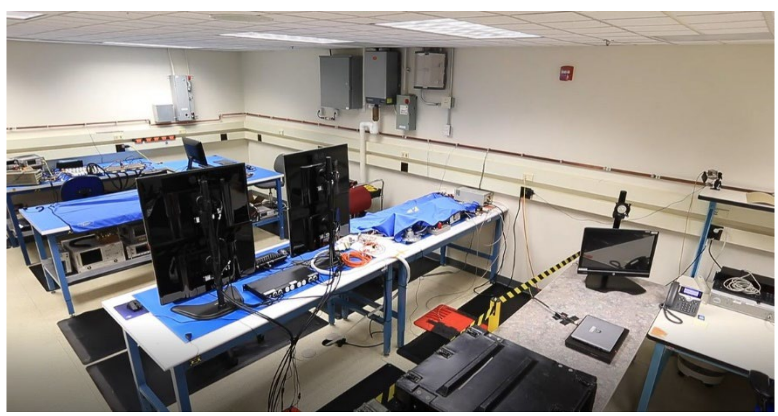


Figure 16: Electrical Lab (Building E-109)

2.7 Telemetry Ground Stations (Building F-10)

The NASA Sounding Rocket Operations Contract (NSROC) has a total of three primary ground stations with the ability to support an auxiliary testing location. Each ground station is designed to support up to eight RF links in various combinations. The typical combination is two payloads with three RF links each. The ground station can support lower S-band frequencies (2,200 to 2,300 MHz) and some upper S-band frequencies (2,382.5 MHz). Typically, most payloads are contained to lower S-band. The ground stations are in the process of being upgraded to support the C-band RF spectrum (4,400 to 4,850 MHz).

The ground stations, located in Building F-10, are configured to support multiple pulse-code modulation (PCM) links (defined by Inter-Range Instrumentation Group (IRIG) 106 Chapter 4). They can generate multiple outputs that can range from clock and data outputs to the raw demodulated signal if the customer decides to handle the data themselves. The ground stations can support both PCM and SOQPSK modulation with a maximum bit rate of 40 Mbps. They are also capable of demodulating television (TV)/frequency modulation (FM) and baseband links.

The ground stations are also capable of outputting experimenter asynchronous data embedded within the telemetry downlink. This must be the RS-232 / RS-422 asynchronous protocol and our current maximum baud rate is 230.4 kilobaud. Each ground station has a dedicated IRIG CH10 recorder that can record multiple sources both inside and outside of the ground station. Every ground station is also capable of supporting paper chart recorders with a maximum of 16 channels per chart. All ground stations can simulate a command uplink for payloads that wish to have remote control during flight. This is used in combination of an on-board payload system that allows the user to control relays and uplink asynchronous data. Figure 17 shows a typical ground station setup.

Figure 17: Telemetry Ground Station

3 MECHANICAL INTEGRATION & TESTING

3.1 Thermal Chambers (Building F-7)

3.1.1 Thermal Vacuum Chamber (Building F-7)

The cylindrical thermal vacuum (T-Vac) chamber in Building F-7 (Figure 19, Figure 20 and Figure 21) is used for thermal vacuum testing of small components. The chamber shroud is broken up into twelve panels (ten circumferential, one on the door, and one at the rear of the chamber), all controlled independently of one another. The shroud panels utilize liquid nitrogen and block heaters for temperature control, and can maintain temperatures between –100°C and +100°C. A portable 10K (International Standards Organization (ISO) 7) clean tent (12 feet by 16 feet) adjoining the chamber for test article processing can be utilized based on customer need.

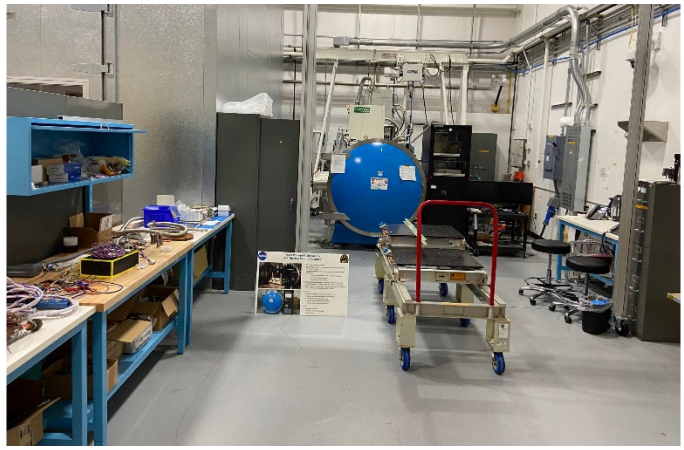


Figure 18: Overview of Building 7 Thermal Vacuum Chamber

The vacuum system consists of a two-stage pumping system. For higher-pressure tests (0.1 torr to 760 torr) such as those for balloon and aircraft tests and for initial rough pump of the cryogenic pump, the chamber utilizes an oil-free mechanical pump. For very low-pressure tests, such as those used for space flight qualification (<1x10^{-5} torr), the second stage of the vacuum system consists of a cryogenic pump.

All chamber systems (vacuum and temperature) are controlled via a personal computer (PC) with LabView and a National Instruments data acquisition system and digital input/output (I/O) card.

Figure 19: Thermal Vacuum Chamber

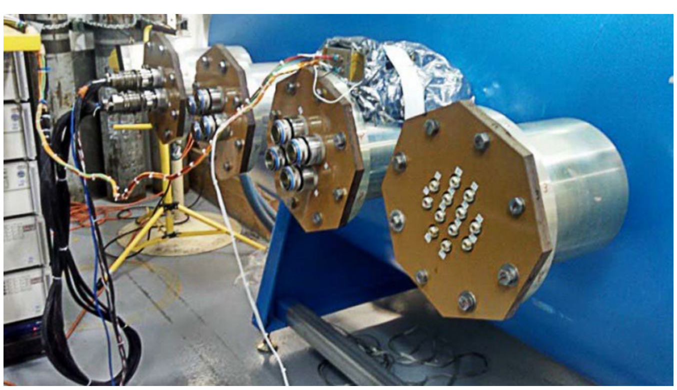


Figure 20. Thermal Vacuum Chamber Ports

Temperature measurement of test articles and associated GSE are accomplished via a Fluke 2686A data acquisition unit with Precision Analog Input (PAI) modules. The unit can read up to 120 thermo-couples (or other two-wire analog inputs). Additionally, chamber GSE includes type-T thermocouples, suitable for use in vacuum environments. These plates accommodate a variety of hermetic connectors in different configurations that accommodate

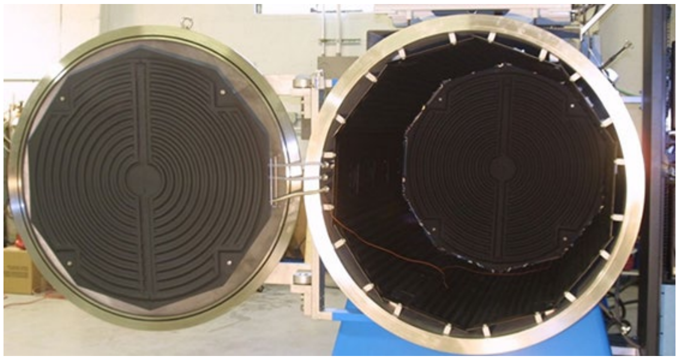


Figure 21: Thermal Vacuum Chamber

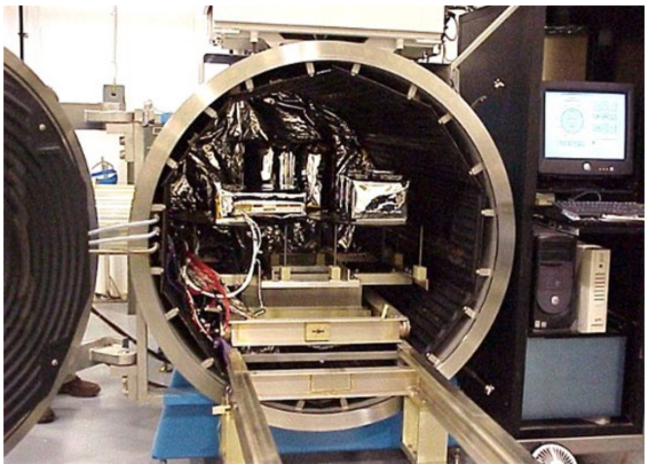


Figure 22: Thermal Vacuum Chamber used for small spacecraft, subsystems, and components

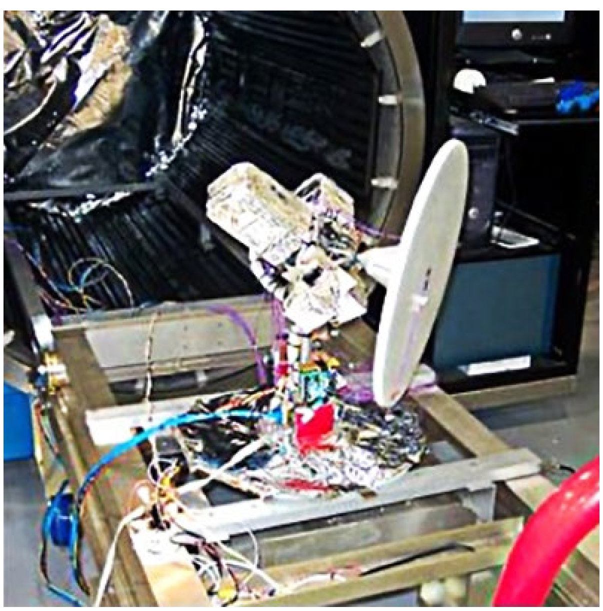


Figure 23. Thermal Vacuum Chamber used for testing Balloon High Gain Antenna (HGA)

power, signal, and RF interfaces. Plates with plumbing feedthroughs are available for external chillers, or custom feedthrough plates can be developed.

Mechanical GSE includes large and small open-framed carts for mounting of test articles. These carts slide on rails inside the chamber (Figure 22) and provide ample view to the bottom shroud panels. Additionally, four heater plates and two heater-controlled enclosures are available for component and subsystem testing, utilizing a cold chamber as their heat sink.

Table 8: F-7 T-Vac Chamber Specifications

Location	Building F-7
Manufacturer	DVI
Usable Envelope / Test Volume	72 inches long by 48 inches diameter
Temperature Control	Liquid Nitrogen and Block Heaters
Temperature Range	–100°C to +100°C (–148°F to +257°F)
Vacuum System	Two-stage Pumping System
Oil-free Mechanical Pump	High-pressure tests (0.1 torr to 760 torr)
Operating Pressure	$<1x10^{-5}$ torr
6 Feed-through ports	Accommodate: 7.5-inch feed-through connector plates / 11-inch feed-through connector plates
Unique Capabilities	Mechanical Pump, Cryopump, Coldfinger (C/F), Scavenger Plate (SP), Thermoelectric Quartz Crystal Microbalance (TQCM) to monitor outgassing, Residual Gas Analyzer (RGA) for process control and contamination monitoring, 10K Clean Tent

Figure 23 shows an example of using the chamber to test a component or subsystem of a much larger mission, in this case a critical subsystem for large scientific balloon missions. Smaller projects, such as Small Satellites (SmallSats), can be accommodated completely inside the chamber for testing.

Specifications for the F-7 Thermal Vacuum chamber are shown in Table 8.

3.1.2 Thermal Chamber (Building F-7)

The thermal chamber in Building F-7, shown in Figure 24, provides 32 cubic feet of test volume with touch screen control, programmable thermal test profiles, data logging capability, and ethernet connectivity. A dry air purge is provided to eliminate condensation buildup on test components. The chamber offers a temperature range of -70°C to +180°C with +/-0.5°C control ability (see Table 9). This chamber is located within close proximity to the F-7 EMI and Anechoic chambers allowing for thermal conditioning of components or antennas prior to testing in those chambers.

Table 9: Espec Thermal Chamber Specifications

Model	Espec Platinous EPZ-4H
Temp Range	-70°C to +180°C
Temp Control	+/- 0.5°C
Volume	32 cubic ft. (39.4" x 35.5" x 39.4")
Purge	Dry air available

Figure 24: Thermal Chamber (Building F-7)

3.2 Thermal Facilities (Building F-10)

3.2.1 Thermal Vacuum Chamber (Building F-10)

The thermal vacuum chamber in Building F-10 (see Figure 25) has an Agilent turbopump vacuum system with an oil-free roughing pump. It includes a thermal plate for hard attachment of the test item to ensure the best thermal transfer, five available thermocouples, two 37-conductor interfaces (one twisted pair, one not), with 37 pin cannons inside and out, and multi RF connectors. Typical testing is done in two days per cycle; day one hot, day two cold, with the chamber left in vacuum overnight. Data logging captures the temperature of the test article and the vacuum level.

Figure 25. Thermal Vacuum Chamber (Building F-10)

3.2.2 PV/T Vacuum Chamber (Building F-10)

The PV/T or “White Elephant” shown in **Error! Reference source not found.** is the largest chamber at 7 feet in diameter and 12 feet long. It is primarily used for performing corona checks on subsystems that utilize high voltage components.

3.2.3 Altitude Bell Jar (Building F-10)

The bell jar is shown in Figure 27 and is used primarily for automated altitude switch testing; however, it can be interfaced for small component corona tests as well.

Figure 26: PV/T Vacuum Chamber

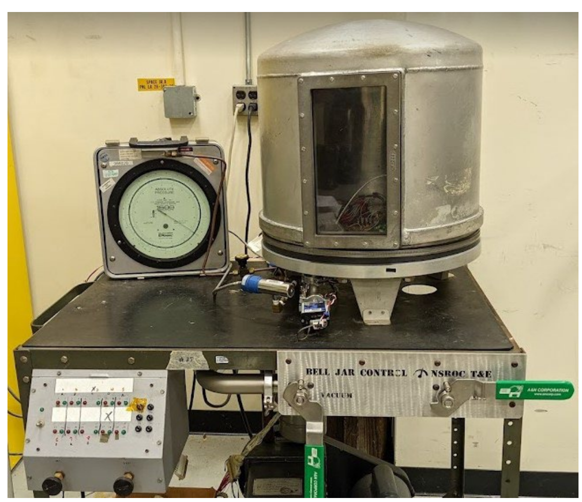


Figure 27: Altitude Bell Jar

3.2.4 Espec ESZ-4CA Thermal Chamber (Building F-10)

There are two full-time Espec thermal chambers, one of which is shown in Figure 28. They are fully automated and have Product Temperature Control, Air Temperature Control, and Soak Control functions. One of the chambers has liquid nitrogen cooling capability allowing for cooling rates as fast as 5°C per minute. Table 10 summarizes technical data on all these chambers.

Figure 28: Espec ESZ-4CA Thermal Chamber

Table 10: Building F-10 Thermal Chamber Summary

Manufacturer	Tenney Space Simulation System (3.2.1)	PV/T Inc. (3.2.2)	Altitude Bell Jar (3.2.3)	Espec ESA-4CA (Qty. 2) (3.2.4)	Vacuum Test Stand (3.2.5)
Inside Dimensions	2 feet diameter x 2 feet long	7 feet diameter x 12 feet long	1.5 feet diameter x 1.5 feet long	3 feet diameter x 3 feet long	Up to 22 inches diameter
Minimum Pressure	5×10^{-6} torr	8×10^{-2} torr	1.4×10^{-1} torr	N/A	1×10^{-6} torr
Temperature Range	-75°C to +100°C	Heat lamps used if needed	N/A	-70°C to +150°C	N/A
Pump Type	Turbo	Mechanical	Mechanical	N/A	Turbo
Clean Environment?	Yes	No	No	Yes	No

3.2.5 Vacuum Test Stand (Building F-10)

The Vacuum Test Stand is a purpose-built apparatus for testing the Sounding Rocket Program's shutter doors and sealed skin sections. Shutter doors of 22 inches and 17 inches diameter can be checked to ensure they will hold the required vacuum throughout the mission lifecycle and flight, as well as seal after opening and closing on the ground and in flight. Various sealed skins and sealed payload sections are also tested for vacuum capability on the test stand. In addition, the test stand can check for leaks; if a sealed system has an unacceptable leak rate, the test stand can be used to assist technicians by locating the source of the leak with its integrated helium leak check.

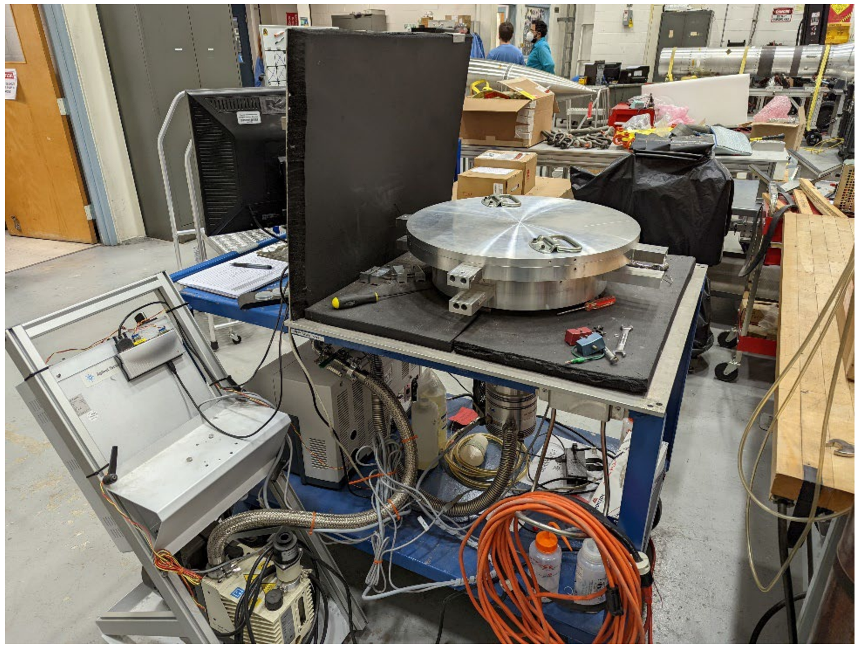


Figure 29: Vacuum Test Stand

3.3 Environmental Test Chamber (Building E-109)

The Environmental Test Chamber (Model T5ST) from Lunaire LTD Tenney Environment Inc., shown in Figure 30, is a small temperature-controlled chamber used for thermal conditioning of small components. The portable chamber loads through a front opening door that has a viewing window. The instrumented payload is installed in the chamber with no special handling or mounting fixtures and is connected to the ground support equipment via a port.

Typically, temperature is set prior to setting pressure. The payload is heated or cooled to the desired temperature with air in the chamber and remains for an hour or more. Then the pressure is set, and the temperature may change toward ambient.

The chamber uses room air. There is a manual system to add dry air to the chamber once closed to minimize the humidity in the chamber. If this is not done, frost almost certainly will appear inside the chamber at below freezing temperatures. Even with the dry air purge it is possible for a small amount of frost to form.

Figure 30: Environmental Test Chamber Model T5ST

The chamber has a 55-pin pass-through connector for users to make harnesses for inside and outside the chamber. The connectors are such that the internal and external connectors can be mated for bench testing. There is also a terminal strip with approximately 25 lines for quick and simple pass-through. There is a pass-through connector consisting of Ethernet CAT 6, FireWire, and USB-C cables, with lengths of about 4 feet inside the chamber and about 6 feet outside the chamber. All connections except the terminal strip are mounted on ISO NW100 LF plates; users can make custom pass-throughs using their own ISO NW100 LF plates. Table 11 lists the chamber specifications.

Table 11: Environmental Test Chamber Specifications

Location	Building E-109
Manufacturer	Tenney
Pressure	0.1 Torr
Temperature	-70°C to +170°C (-94°F to 338°F)
Dimensions	21 inches deep by 24 inches high by 21 inches wide
Unique Capabilities	Optical Window

3.4 Vibration Test Facilities (Building F-10)

An overview of the vibration test facility in Building F-10 is shown in Figure 31.

Figure 31: Building F-10 Vibration Facility

There are four shakers used for component and payload vibration tests at Wallops with the technical information shown in Table 12. Figure 32 shows a typical test setup. Figure 33 shows the Unholtz Dickie (UD) Small Chamber.

Figure 32: Vibration Table

Figure 33: UD Small Chamber

Table 12: F-10 Shaker Specifications

Ling Electronics Shaker B340:	
Rated Force Sine	30,000 pounds (lb.)
Rated Force Random	30,000 lb. root-mean-square (rms)
Frequency Range	5 to 2,000 Hz
Maximum Displacement Peak-Peak	1 inch
NOTE: The B340 can be rotated to mate with a Team Corporation model 482 sliding table so that it can be used for both thrust axis and lateral vibration tests. Maximum pitch moment capacity = 1,200,000 in.-lb.	
Ling Electronics Shaker B335 (2):	
Rated Force Sine	18,000 lb.
Rated Force Random	18,000 lb. rms
Frequency Range	5 to 3,000 Hz
Maximum Displacement Peak-Peak	Thrust: 2 inches Lateral:1 inch
NOTE: The B335 can be rotated to mate with a Team Corporation model 1830 sliding table so that it can be used for both thrust axis and lateral vibration tests. Maximum pitch moment capacity = 300,000 in.-lb.	
UD Shaker S452:	
Rated Force Sine	6,000 lb.
Rated Force Random	5,500 lb. rms
Frequency Range	5 to 3,000 Hz
Maximum Displacement Peak-Peak	2 inches

NOTE: The F-10 Shaker test facilities have 11-inch cube fixtures available for testing small components in all three axes by mounting the test article in different orientations. In addition, Wallops can support design and fabrication of custom vibration fixtures to interface between the test article and shaker head.

At the engineer or principal investigator's request, sensors can be mounted to components or areas of interest. F-10 Shaker test facilities have 16-channel capability; through this in-test data and the vibration control software, test profiles can be force limited to prevent damage to the test article. Specific test profiles, including reduced inputs at given frequencies (notching), can be created using the vibration control software as well.

3.5 Vibration Test Facilities (Building E-109)

There is an additional vibration test facility in Building E-109, as described in Table 13 and shown in Figure 34.

Table 13: E-109 Vibration Test Facilities

Location	Building E-109
Fixture	10 inches by 10 inches high-strength magnesium alloy mounting fixture
Shaker **Sine & Random rating** **Maximum Shock** **Frequency Range:**	 2,200 lbs. 4,500lbs. 5 Hz to 2 kilohertz (kHz)
Accelerometers:	Various sizes, single axis, tri-axis
Software	Unholtz-Dickie Corporation
Performance Applications	Sine/Random/Shock Space qualification testing Environmental testing for electronic flight hardware

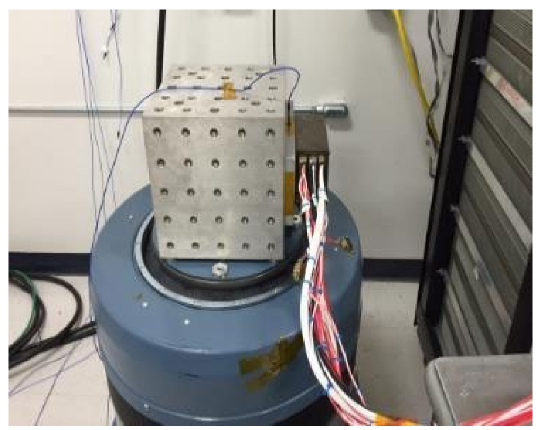


Figure 34: Vibration Test

3.6 Balancing Machines (Static and Dynamic) (Building F-10)

At Wallops, a Gisholt Rocket Balancing Machine, shown in Figure 35, is used to balance sounding rocket payloads.

This machine's specifications are listed in Table 14:

Table 14: Balancing Machine Specifications

Location	Building F-10
Maximum payload weight	1,500 lbs.
Maximum height of CG above table	10 feet
Measurement accuracy	2.0 oz-in^2 at 225 revolutions per minute (RPM) or more

Figure 35: Balancing Machine

3.7 Mass Properties Measurement System (Building F-10)

The Environmental Testing and Evaluation Group at NSROC is equipped with an Airdyne Mark 8 mass properties measurement system shown in Figure 36 through 37. This unit is used for measuring center of gravity (CG) locations and moments of inertia (MOI) on sounding rocket subsystems and payload stacks. Important technical data is shown in Table 15:

Table 15: Mass Properties Measurement System

Location	Building F-10
Maximum test article weight	5,000 pounds
Maximum CG height above the table	120 inches
CG and MOI measurement accuracy	0.1%

Figure 36: Mass Properties Measurement System

Figure 37: Mass Properties Measurement System

Figure 38: Mass Properties Measurement System

Figure 39: Mass Properties Measurement System

3.8 Spin Deployment Facility (Building F-10)

Payloads with deployable booms, nose cones, doors, etc. can be tested for proper operation using the spin deployment and separation chamber located in Building F-10, as shown in Figure 40. The rotary table can spin a payload to a rate of 20 RPS while withstanding an imbalance of up to 3,000 ft-lb. 5 feet above the table surface. The chamber is equipped with a heavy-duty Kevlar® tarpaulin around the rotary table for catching deployed components. There are also video cameras mounted on the chamber walls for recording and timing the deployment events. Pyrotechnic release devices can be activated by connecting lead wires through a 20-channel slip ring that allows the table to rotate while maintaining electrical continuity.

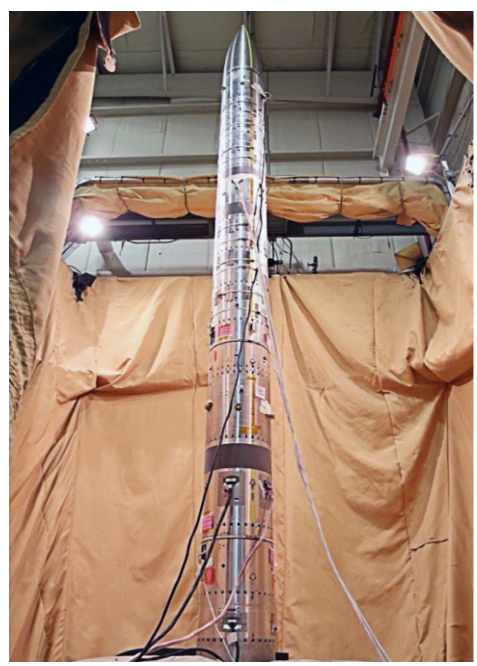


Figure 40: Spin Deployment Facility

3.9 Bend Test Facility (Building F-10)

Every sounding rocket payload is subjected to a bend test to determine the overall stiffness of the body. This information is used by the Flight Performance Group to verify payload stability during flight. The bend test fixtures in F-10 consist of a base plate mounted to the concrete floor and a pneumatic linear actuator mounted to a steel I-beam pillar. The pistons are equipped with load cells, which are used to measure and control the applied load. The aft end of the payload is fastened to a base plate, and the actuator's position along the pillar can be adjusted to the proper height on the payload being tested. Land surveying equipment is used to accurately measure the tip deflection of the payload as the actuator applies lateral loads in both directions. Table 16 lists the fixture specifications. Figure 41 shows a typical test setup.

Table 16. Bend Test Fixture Specifications

Facility	Building F-10
Maximum Load (actuator or load cell)	+/- 5,000 pounds
Maximum Actuator Height	21 feet
Accuracy of Deflection Readings	0.05 inches

Figure 41: Bend Test Fixture

4 PAYLOAD FABRICATION, INTEGRATION & TESTING

4.1 Payload Fabrication (Building F-10)

Figure 42: Fabrication Facility

Wallops has a fully equipped machine shop in Building F-10, as shown in Figure 42 and Figure 43, that can provide electronic, electrical, and mechanical support. The 26,000-square-foot machine shop includes a large selection of Computer Numerical Control (CNC) mills and lathes, manual machines, sheet metal fabrication, welding, and heat-treating facilities. Capabilities include full computer-aided design and manufacturing (CAD/CAM) implementation in developing and fabricating mechanical systems, optical instrumentation, and payload components for flight research. The fabrication area performs functions such as sounding rocket launcher refurbishment, design and fabrication of mobile telemetry and mobile radar support vans and antenna systems. The machine shop includes mechanical technician areas for assembly of scientific sounding rocket payloads. While the facility primarily supports the Sounding Rocket Program, it regularly supports other NASA and reimbursable projects. The facilities are managed through the NSROC.

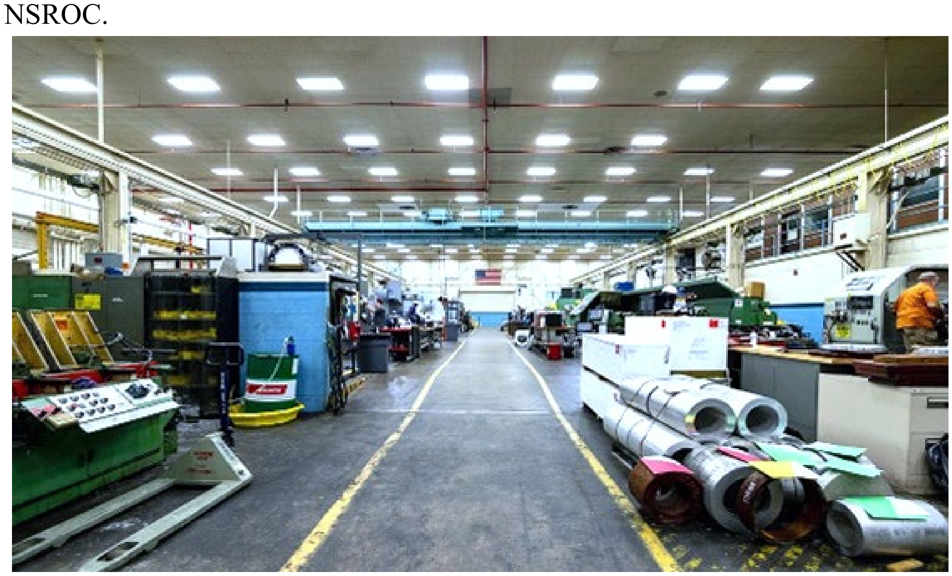


Figure 43: Fabrication Facility

4.2 Attitude Control System Testing (Building F-10)

Wallops supports Attitude Control System (ACS) testing for subsystems such as IMUs, star trackers, magnetometers, sun sensors, reaction wheels and torque rods. High intensity light sources in a clean room may be used to examine sun sensors. A star simulator is available for star tracker functional verification. A single axis rate and magnetic torque table are available with hand crank for basic verification of reaction wheels, torque rods, accelerometers, and IMUs. The Magnetic Calibration Facility in Building F-10, shown in Figure 44 and Figure 45, may be used for magnetometer and torque rod testing. The Magnetic Calibration Facility is used to conduct magnetic calibration of magnetometers on sounding rocket payloads and to perform functional tests on magnetic attitude control systems. When required, magnetic calibration tests are done – generally for all payloads with magnetometers except those in which the magnetometers are used as roll or yaw indicators. The testing equipment consists of a three axis, 40-foot square Braunbek system which can cancel the effects of the Earth's magnetic field and then generate a test field in any direction. Technical data are listed in Table 17:

Figure 44: Magnetic Calibration Facility

Table 17: Magnetic Calibration Facility Specifications

Physical Dimensions:	
Access Opening	8 feet 8 inches high by 7 feet 5 inches wide
Static Field Environment:	
Magnitude (each axis)	±100K Gamma
Step Resolution	±3.7 Gamma
Stability	±10 Gamma / minute for first 30 minutes ±3 Gamma / minute after first 60 minutes
Homogeneity	0.02% 6-foot spherical diameter
Dynamic Field Environment:	
Magnitude	+60K Gamma
Frequency	10 Hz (although 10 Hz to 100Hz @1K Gamma has been performed)
Turntable	4-foot diameter
Coil Orthogonality	1.8 arcminutes
Fields	Earth, 0 to 15 Volts direct current (DC), 0 to 25 Amps Test (3-axis), 50 Volts DC, ±8 Amps Gradient 15 Volts DC, 6 Amps
Payload Dimensions	22 inches diameter structure maximum 172 inches maximum height from fixture to upper limit of theoretical "sphere" the test instrument must fall within
Payload Mass	Orthogonality within 0.05° 800 lbs. mass limit

Figure 45: Magnetic Calibration and Testing

4.3 Sounding Rocket Payload Integration (Building F-10)

Building F-10 has three independent payload I&T areas (see Figure 46 and Figure 47 for representative facilities).

Payload integration is the first-time assembly of all the parts and pieces with experiment hardware into the launch configuration. All aspects of the design and operation are checked including mechanical fit and operation, telemetry and electrical systems operation, and systems compatibility. Pre-testing sequence tests are performed to ensure the event-programming system functions properly. Each I&T area has its own independent telemetry ground station. The telemetry ground station can support multiple links for all systems flown.

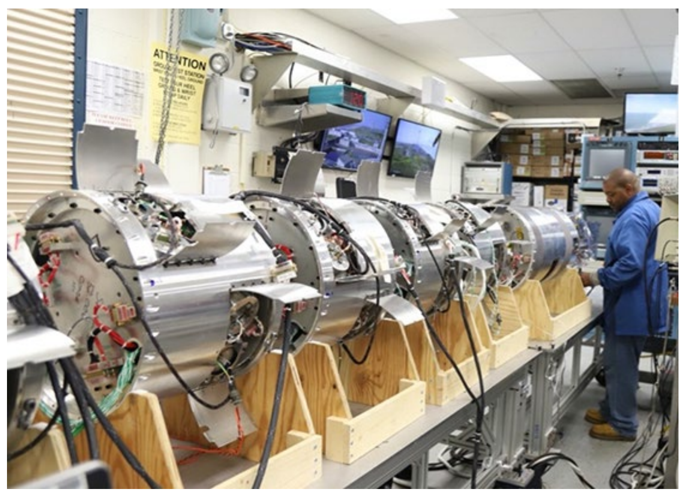


Figure 46: Payload Integration and Testing

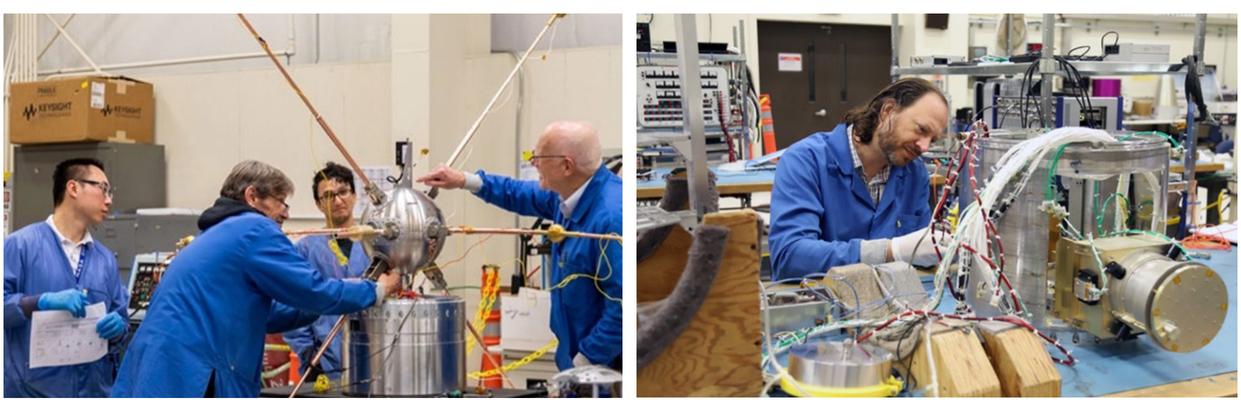


Figure 47: Payload Integration and Testing

4.4 Solar Simulator (Building E-109)

This solar simulator is based on a Fresnel lens to collimate the light beam from the 3.0 kilowatts (kW) Xenon short arc lamp source, resulting in highly collimated illumination of the target spot. The spectral distribution of the xenon light source, along with the use of specially calibrated air mass filters, closely simulates the Sun's true spectral distribution in various conditions on Earth.

This is a single star simulator, shown in Figure 48, with features described in Table 18 and Table 19:

Table 18: Solar Simulator Specifications

Location: Building E-109
Canadian optics with ultraviolet (UV)-browning plastic
3 kW Fresnel Lens, Xenon Lamp Solar Simulator
11-inch beam diameter
~1350 W/m^2 maximum output
Two-axis gimbal and linear actuators available

Figure 48: E-109 Solar Simulator

Table 19: Gimbal Specifications

Max. weight	23 kg
Max. operating torque	10.2 Nm
Range of motion	+/-90 degrees Azimuth, +/-90 degrees Elevation
Mounting	¼-20 threaded holes on a 1-inch grid pattern

4.5 SmallSat and Balloon Payload Integration (Building F-7)

Wallops Flight Facility Building F-7 (Figure 49 and Figure 50) houses the main base SmallSat and Balloon payload integration facilities.

Figure 51 shows supplemental integration workspace that supports work station setup for small mission I&T as well as thermal vacuum testing.

Figure 49: Integration and Test (Building F-7)

Figure 50: Integration and Test (Building F-7)

Figure 51: Building F-7 Supplemental Integration Workspace

4.6 Payload Processing Facility

The Payload Processing Facility (PPF), H-100, is located outside Wallops Main Gate behind the Marine Science Consortium.

Figure 52: Payload Processing Facility

There are two Class 100K clean rooms, one high bay and one low bay with adjoining work spaces supported by redundant chillers for high reliability. The spacecraft launch control center, located adjacent to the high bay, has pass-throughs for GSE cabling and tools, as well as a display for visibility during spacecraft fueling integration and launch. The PPF has an extensive flexible support capability, as shown in Figure 52, that boasts bridge cranes, scissor and fork lifts, pressurized commodity systems for clean nitrogen, helium, and air, secure access and 24-hour video surveillance, visitor area, staging pad, and other support amenities. Office space for the payload team is available with 24 cubicles, kitchen adjacent conference room with observation windows overlooking the payload bays.

4.7 SmallSat Multi-Payload Processing Facility (Building F-7)

Figure 53: SmallSat Lab

The Multi-Payload Processing Facility (MPPF, Building F-7) includes a minimum of two dedicated lab spaces for the purpose of small satellite assembly, integration, and test, as shown in Figure 53 and Figure 54. Lab spaces include full electrostatic discharge (ESD) work-stations and clear work areas including multiple laminar flow benches, a small thermal chamber and other small-scale test equipment. One lab space includes a dedicated optical bench work area to support development and assembly, integration and test activities for optical experiments and subsystems.

Adjacent workspaces in the MPPF available to support small satellite processing include the F-7 thermal vacuum chamber, an EMI/EMC chamber, and an Anechoic chamber for antenna pattern testing. In addition, there are temporary office workspaces, as shown in Figure 55, for visiting project personnel including conference capabilities, and open work areas for larger assembly work and a small machine shop.

Figure 54: SmallSat Lab

Figure 55: Supplemental Integration Workspace

4.8 Rideshare Mission Integration Services (Building F-7)

The east end of the MPPF has been configured to provide end-to-end small mission integration services, most recently demonstrated for the Landsat-9 Expendable launch vehicle Secondary Payload Adapter (ESPA) Flight System (L9EFS) project.

Custom I&T hardware, mechanical ground support equipment (MGSE), and electrical ground support equipment (EGSE), shown in Figure 56, Figure 57, and Figure 58, developed to support L9EFS are now available for future Rideshare mission support along with similar I&T hardware and capabilities for other complex special projects such as attached International Space Station (ISS) payloads and ESPA-class spacecraft. Facilities are ideal for receipt, inspection, and preparation of ESPA hardware, integration activity (payload-to-ESPA), and integrated ESPA pre-ship checkout prior to shipment to launch vehicle site.

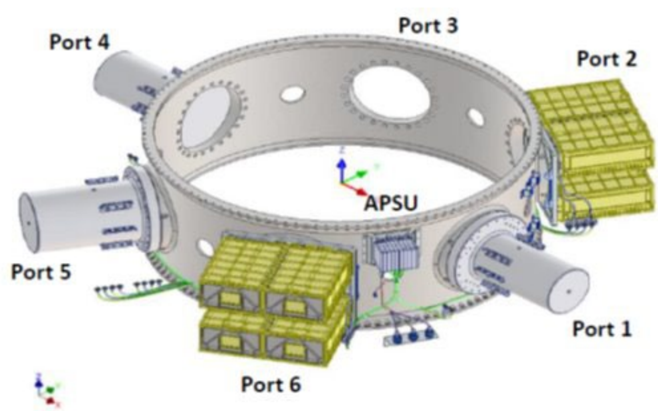


Figure 56: Landsat 9 Integration

Facility capabilities to support Rideshare/ESPA and other mission I&T include a Class 100K clean room with internal Class 10K tent, an adjacent gowning area that includes equipment and cable pass-throughs (see Figure 60 and Figure 61), a receipt/shipping anteroom with airlock, adjacent support labs for equipment not required to be in the clean roomm and other supporting workspaces. The East I&T complex is also adjacent to the F-7 thermal vacuum chamber, the EMI/EMC chamber, a small machine shop, and available office space for visiting project personnel.

Figure 57: Integrated ESPA ring prior to leaving Wallops (Building F-7)

Figure 58: EFS Assembly Stand

Figure 59: Clean Room Access

Figure 60: Gowning Room Access

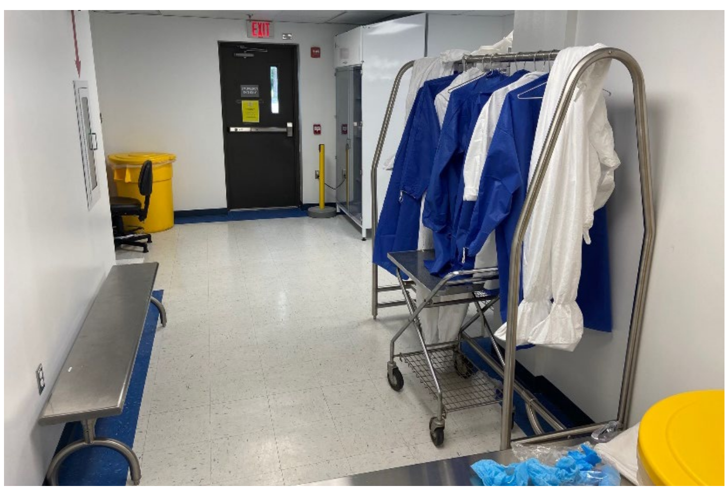


Figure 61: Building 7 Clean Room Gowning Area

4.9 High Bays (Building E-109)

Building E-109 is equipped with two integration high bays, see Figure 62, – Room 158, or East High Bay and Room 159, or West High Bay. Both rooms are approximately 885 square feet each and both have a 5-ton monorail crane with a hook height of 17 feet. The crane in Room 158 is critical, and the crane in Room 159 is non-critical. Both rooms have large roll-up doors leading to the Building E-109 loading dock for equipment loading or off-loading. There is a large interior roll-up door allowing access from one high bay to the other for projects needing the extended space of both high bay rooms. Either room can be configured for ESD operations and cleanliness requirements can be met with project-provided portable flow hoods or portable clean tents.

Figure 62: Building E-109 High Bays

4.10 High Bay East (Building F-7)

Building F-7 High Bay East holds a Class 100K cleanroom with a Class 10K clean tent, see Figure 63 and Figure 64, with a 40-foot by 60-foot cleanroom with 20-foot by 40-foot Airlock/ Ante Room, and a 5-ton critical bridge crane with a 25-foot hook height and remote controls. High Bay East specifications are shown in Table 20**.**

Table 20: F-7 High Bay East Specifications

Location	Building F-7
Cleanroom Classification	Class 100K
High Bay Dimensions	60 feet long by 40 feet wide by 30 feet high
High Bay Area	2,400 square feet
Clean Work Area (CWA)	Class 100K (Level 4)
Airlock / Ante Room Dimensions	20 feet by 40 feet by 14.25 feet
Bridge Crane	5-ton with 25-foot hook height
Clean Tent Dimensions	23.75 feet by 14.5 feet by 12 feet
Clean Tent Classification	Class 10K

Figure 63: High Bay East Cleanroom Tent with ESPA ring integration ground support equipment in the foreground

Figure 64: High Bay East Cleanroom

4.11 High Bay West (Building F-7)

Building F-7 High Bay West, Figure 65, is where balloon payloads and Wallops Arc Second Pointer (WASP) systems are typically integrated. It is 1789 square feet and approximately 34 feet by 52 feet. Please see Table 21 below for specifications:

Table 21: F-7 High Bay West Specifications

Doors	Rollup facing north and south
Cranes	Monorail with two five-ton trollies at 30-foot hook height
Compressed Air	Clean, dry, compressed air (<150 psi)
Power	110 V
High Bay Dimensions	34 feet by 52 feet
High Bay Area	1789 square feet
Location	Building F-7
Clean Work Area (CWA)	None

Figure 65: High Bay West

4.12 Balloon Research and Development Laboratory (Building F-7)

The Balloon Research and Development Laboratory (BRDL) in Building F-7, Figure 66, is a specialized facility equipped with customized and unique tools and equipment to support the testing, research, and technology needs for terrestrial and planetary balloons, as well as other lighter-than-air structures. Laboratory resources include static and servo-hydraulic mechanical testing machines, see Figure 67, equipped with customized sensors and accessories for characterizing thin polymeric films, plastics, fibers, cords, textiles, ceramics, metals, and composites. It is equipped with non-contact strain measurement equipment for testing inflatable structures and other components or subsystems using state-of-the-art equipment and accessories. Other capabilities include pressure systems equipped with various pressure gauges for characterizing inflated structures, environmental chambers for cryogenic and non-ambient testing, and an ultraviolet exposure facility for the assessment of environmental exposure effects on materials and components. The lab has a heat-sealing machine and tools for fabricating test articles as well as capabilities for testing model balloons and other inflatable structures. Staff design, test, calibrate and validate various sensors for in-flight balloon performance and related measurements. The BRDL engineers and technicians routinely design and build customized testing tools to meet specific testing or research and development activities or needs. Various drafting and analytical tools are available for design and data analysis. The BRDL supports anomaly and technical investigations as needed and has supported various projects at Wallops and agency-wide.

Figure 66. Balloon Research and Development Lab

Figure 67. Balloon Research and Development Lab Mechanical Testing Facilities

5 ENGINEERING SUPPORT

5.1 Overview

Engineering support at Wallops includes guidance navigation and control, missions systems engineering, mechanical systems, electrical, and systems software. The engineering team offers a broad range of skills in conjunction with Wallops' exhaustive array of I&T facilities. Wallops engineering provides an array of useful tools to support the life cycle of mission operations including pointing systems for balloon and ISS payloads such as the Wallops Arc Second Pointer (WASP, see Figure 68) and planning tools for small satellite and suborbital payloads in the Mission Planning Lab (MPL).

Figure 68: Wallops Arc Second Pointer (WASP)

5.2 Mission Planning Lab (Building E-109)

Figure 69: Mission Planning Lab

The Mission Planning Lab guides early-stage SmallSats through a week-long study to turn a science concept into a feasible mission that gives the science team a solid foundation on which to build a competitive proposal. Since 2014, the MPL has worked with NASA SmallSat developers and their partners to provide services in systems engineering, 3D modeling, simulation, flight trajectory formulation, and more. The MPL has served mission concepts of all kinds, from formation flying proposals to deep space missions to Mars and Venus. Additionally, MPL has sub-orbital experience and works with sounding rockets, balloons, and other platforms. Over the course of one action-packed week, engineers across a range of specialties come together to meet with a mission's science team and crunch numbers. At the end of the process, scientists gain a better understanding of how to achieve their research objectives, and they come away with a valuable packet of information describing the technical details of their mission. Figure 69 shows team members meeting at the Wallops Flight Facility to plan key mission details and better understand technical requirements.

Before the study begins, MPL engineers ask the mission's principal investigator (PI) and team to fill out pre-work forms, detailing the mission's high-level characteristics, which can include mission class, cost, target launch date, instrument and data requirements, mass, and power. MPL staff meet repeatedly with mission leadership to choose team members for the study, set expectations, and gain more insight into the mission before the study begins.

The study launches on Monday morning. By the end of Monday, the team has pulled together the basic components of the mission through brainstorming sessions and whiteboard sketches. The team has also defined the concept of operations and key requirements. On Tuesday, the engineering team drafts a preliminary baseline of the mission's components, including a computer-aided design (CAD) model. Extraneous capabilities get narrowed down, and the team streamlines the PI's wish list to the most important functionalities. Halfway through the study, engineers tackle any unexpected roadblocks and address risk as they refine subsystem models and run further analyses. Thursday brings the team together to tie up any loose ends and make sure each team member is apprised of the mission's details. With such a fast pace, it's important to regroup and review before the final day of the study. Any unfinished area of the baseline design is worked to closure by the end of the day. On Friday, the engineering team presents their completed mission design back to the science team. Beginning with a systems-level overview of the requirements and a description of the spacecraft, the presentation includes the life of the mission and a "day in the life." About a week later, the engineering team compiles the fruits of the study in a package with the presentation slides, a model of the satellite, images of brainstorming sessions from the whiteboard, charts, cost estimates, and any ancillary information the science team might find valuable moving forward.

5.3 Interconnect Lab (Building E-109)

The Wallops Electrical Engineering Branch Interconnect Lab (Room 273, see Figure 70) is responsible for fabrication, building, and testing of harnesses and circuit boards in support of multiple missions. Harness fabrication is performed by certified technicians for applications including ground support equipment, bench testing, environmental testing, flight line, and spacecraft. Harness testing may include thermal conditioning, pull tests, hi-pot tests (over 1500 V DC), and automated continuity tests. Board population and repair may be performed in this lab, along with enclosure customizations with an in-lab drill press and engraving machine.

Figure 70: Interconnect Lab (Building E-109)

5.4 Prototype Lab (Building E-109)

The Mechanical Systems Engineering Branch Prototype Lab, shown in Figure 71, provides capabilities to rapidly build prototype parts to test form, fit and function. This lab has been used on many missions ranging from large spacecraft like Global Precipitation Measurement (GPM) to small electrical boxes for test components on balloon and sounding rocket missions. The Prototype Lab hosts a 3D printer which enables large build volumes and capabilities to print various types of plastics. Small parts can be printed alone or with other small parts simultaneously to fill the volume. Larger pieces can be sectioned, and individual parts can be built and assembled to prototype larger components. After all the parts are printed, they are assembled in this area either on a shop bench or on a clean horizontal work bench.

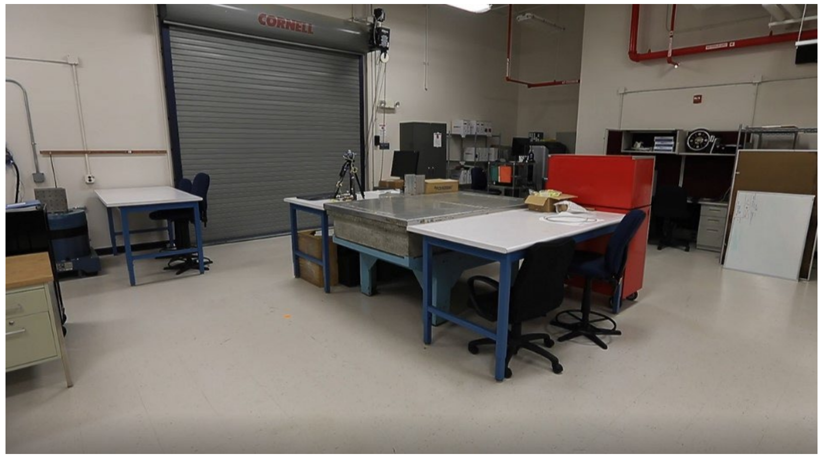


Figure 71: Prototype Lab (Building E-109)

5.5 3-D Printer (Building E-109)

The E-109 Stratasys F370 3-D Printer, shown in Figure 72, is operated by the Mechanical Engineering group and is and located in E-109. Capabilities include the use of three different build materials and their respective properties to meet the needs of the user. The F370 can provide different layer thicknesses, as the part is fabricated. The layer thickness ranges from .005” to .013” (layer thickness varies with material). Parts can be fabricated within a tolerance range of +/-.002”. The printer uses Grab CAD software to upload and select setting to ensure proper build properties and orientation for printing to capture key features of the part.

Figure 72: E-109 3-D Printer

The printer system consists of two extrusion heads, one for model material, and another for support material. The printer features four primary/backup material bays for build and support materials, which allow for an autonomous and continuous, build of a part within the reusable envelope. The F123 series printer utilizes four different extrusion heads that can switched out to accommodate different print material. Materials include: Acrylonitrile Butadiene Styrene Material (ABSM); Polycarbonate-ABS alloy (PC-ABS); ABS-ESD7, which combines the strength and durability of ABS material with carbon to provide electrostatic dissipative (ESD) properties; acrylonitrile styrene acrylate (ASA); Polylactic Acid (PLA); and Thermoplastic Polyurethane (TPU). See Table 22 for a summary of printer capabilities.

Table 22: 3D Printer Capabilities

Product Application	Prototype Parts
	Non-Critical/Structural Hardware
Usable Envelope	14” X 10” X 14”
Material	ABSM, PC-ABS, ABS ESD-7, ASA, PLA, TPU 92A, Diran Material Properties Link: https://www.stratasys.com/materials/search
Auto Changeover Capabilities	Switches material if bay becomes empty

Note: The E-109 vibration table (see section 3.5) is located in the Prototype Lab.

5.6 Machine Shop (Building E-109)

The mechanical fabrication shop is outfitted with various types of machining equipment to support manufacturing of test parts and rapid modification of flight hardware if needed. Hand tools and benches allow modest changes that need quick turnaround, like tapping threads or enlarging holes on mating parts. Standard manual tooling machines allow technicians to create or modify components with general tolerances. The lab is also equipped with a CNC mini-mill for higher precision parts that require tight tolerances.

5.7 Software Development (Building E-109)

Wallops develops flight and ground data systems for sub-orbital and special orbital Earth and space science missions. The software development team performs prototyping in collaboration with other NASA and Government organizations, universities, and commercial partners to advance the state of the art in implementation of its functions and related technologies.

The Systems Software Engineering Lab (Building E-109, Room 268, as shown in Figure 73) is a software development lab that also provides the capability to test range data systems prior to installation in an operational environment. In the lab are copies (hardware and software) of range data systems that are used to process range data during missions. The lab has access to data on the Range Mission Network, serial and ethernet Radar Data, and Range Data acquisition and Computation (RADAC) mission graphics data and slaving data, as well as Range Timing – including American Standard Code for Information Interchange (ASCII) time, IRIG-B and pseudo IRIG-B/Countdown time. The lab has the ability to record data for future playback. The lab also has the capability to play customer provided Chapter 10 files via telemetry systems located in the lab. An example of lab use is a range customer that utilizes software engineering personnel and the Systems Software Engineering lab to develop and test custom telemetry data display systems prior to use during their launches. The use of the software engineering lab for development and testing provides capability independent from the range and greatly reduces the stress on the range real-time operations team which may be supporting other projects or preparing for other operational support.

Figure 73: Software Development Lab (Building E-109)

6 OTHER SUPPORT SERVICES

6.1 Assembly and Processing Facilities

Wallops Island has the assembly and processing facilities described in Table 23.

Table 23: Assembly and Payload Processing Facilities Wallops Island

Bldg	Function	Sq. Ft.	Special Features
V-45	Assembly	4,933	10-ton bridge crane – critical
V-55	Assembly	2495	20-ton bridge crane – critical 100K Clean Room Hypergolic Fueling Capability
W-15	Assembly	5,165	One 3,936 square foot bay Door 13 feet high x 12 feet wide 3-ton overhead crane with 10-foot hook height Approved for explosives 6-ton bridge crane – non-critical
W-65	Assembly	13,255	6 bays: pyrotechnic storage rooms 6 assembly bays: approved for explosives Bay Doors: HxW crane(s) hook height (hh) Bay 1: 7 feet 10 inches x 23 feet 11 inches 2 x 10-ton bridge/20-foot hh Bay 2: 18 feet x 23 feet 11 inches / 2x7.5-ton monorail/18-foot hh 17 feet 10 inches x 23 feet 11 inches Bay 3: 17 feet 10 inches x 18 feet 11 inches / 2x3-ton monorail/19-foot hh Bay 4: 14 feet 11 inches x 15 feet 11 inches Bay 5: 14 feet 11 inches x 15 feet 1 inches; 2 x 3 ton monorail / 16 feet 5 inches hh Bay 6: 14 feet 11 inches x 23 feet 11 inches / 2x3-ton monorail/16-foot hh 14 feet 11 inches x 23 feet 11 inches
X-15	Payload processing	5,740	Door 19 feet 10 inches high and 18 feet 10 inches wide 3-ton overhead crane with 19-foot hook height Laboratory and office space 1-ton stationary electric chain hoist – non-critical 1-ton electric chain hoist – non-critical 5-ton bridge crane – non-critical

Bldg	Function	Sq. Ft.	Special Features
Y-15	Assembly	8,240	1 high bay (Bay 8) 7 other bays Approved for explosives Bay Doors: HxW Crane(s) hook height (hh) Bay 1 9 feet 6 inches x 17 feet 6 inches Bay 2 6 feet 10 inches x 8 feet Bay 3 6 feet 10 inches x 8 feet Bay 4 6 feet 10 inches x 8 feet / 3-ton monorail/7 feet 10-inch hh Bay 5 6 feet 10 inches x 8 feet Bay 6 6 feet 10 inches x 8 feet / 3-ton monorail/7 feet 10-inch hh Bay 7 6 feet 10 inches x 8 feet 13 feet 7 inches x 10 feet 10 inches / 2-ton bridge/15 feet 10-inch hh

6.2 Aircraft Operations Hangar (Building D-1)

The Aircraft Operations Hangar, Building D-1 (see Figure 74, Figure 75 and Figure 76) has hangar, office, and shop space of varying size and location available for approved aircraft projects. Maintenance personnel should accompany project and research and development (R&D) aircraft when engaged in flight operations at Wallops.

Figure 74: Aircraft Operations Hangar (Building D-1)

Fuel services are available for U.S. Government program aircraft during normal working hours and after hours by prior arrangement. Fuel is dispensed from trucks equipped with single point refueling fittings. The specifications for Building D-1 are shown in Table 24.

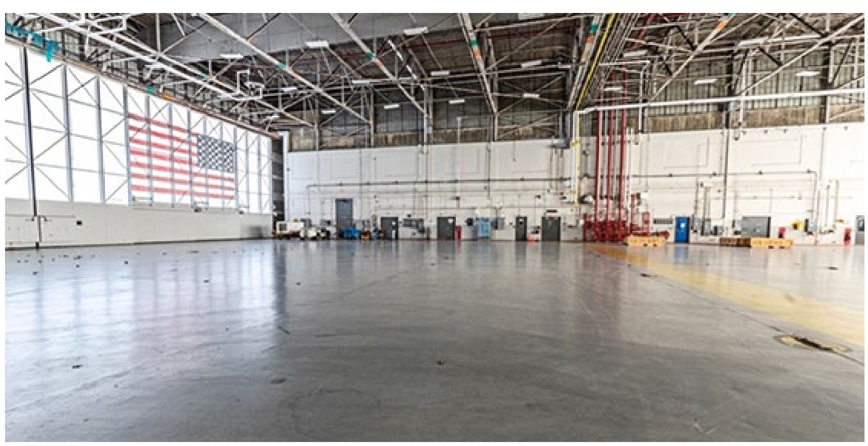


Figure 75: Aircraft Operations Hangar (Building D-1)

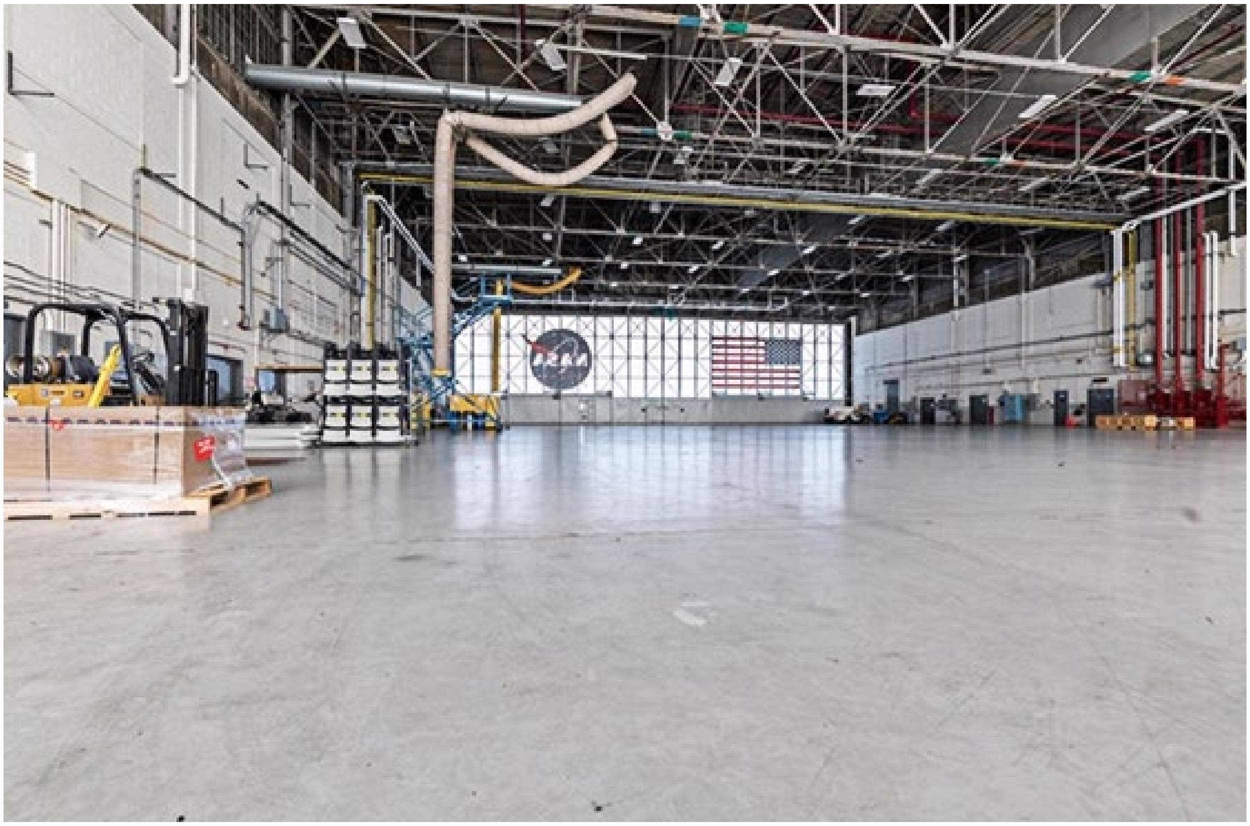


Figure 76: Aircraft Operations Hangar (Building D-1)

Table 24: Building D-1 Specifications

Space:	
Hangar Bay	185 feet long by 120 feet side by 40 feet high – 22,200 square feet.
Hangar Power	From 110 volts AC to 460 volts AC 3 phase to 200 amps
Floor Load	Aircraft rated
Adjacent Supporting Lab & Office Space	9,000+ square feet
Building D-101 may be available as a "Line Shack" for ramp personnel if required.	
Lifting Capacities:	28-ton mobile crane
	155-ton mobile crane (ramp area only)
Hangar Area Door Sizes:	4 feet 5 inches by 40 feet outside leading into the hangar from the west and east sides (D-1)

Fluids/Gases:	
Compressed Air	125 psi
Nitrogen (GN_2)	4,500 psi (mobile aircraft servicing cart)
Aviator' Breathing Oxygen (ABO) (Gas)	2,400 psi (mobile aircraft servicing cart)
ABO (Liquid)	290-gallon dewar and 50-gallon mobile cart (pre-coordination required)
Nitrogen (GN2)	Source available up to 9,000 psi
F-24 Fuel	(60,000 gallons on site), 3 fuel trucks
GSE Available:	AC and DC aircraft ground power carts
	Tugs
	Forklifts
	Navy all-bar
	Assorted tow bars (contact for type and availability)
Additional Features:	Hurricane worthiness – 120 miles per hour (mph)
	Wash apron
	Availability – High

6.3 Aircraft Hangar (Building N-159)

Hangar and office space are available for approved aircraft projects and vary in size and location. Since Wallops is equipped to support only minor or limited repairs to transient aircraft, maintenance personnel should accompany project and R&D aircraft when engaged in flight operations at Wallops. The N-159 Aircraft Hangar is primarily used to support and maintain NASA aircraft. Due to the number of NASA aircraft housed in this hangar there is limited availability to support additional aircraft.

The specifications for Building N-159 are shown in Table 25:

Table 25: Building N-159 Specifications

Space:	
Hangar Bay	140 feet wide by 140 feet long by 40 feet high – 19,600 square feet
Floor Load	Aircraft rated
Adjacent Supporting Lab & Office Space	1,558 square feet

Lifting Capacities:	No cranes available in N-159, projects must use mobile cranes for support
Hangar Area Door Sizes:	132 feet by 35 feet outside leading into the hangar from north & south sides
Fluids/Gases:	No compressed gases or fluids are available in N-159; projects must provide their own gases and fluids
Power:	280A 208V (at 4 hangar locations)
	260A 480V (at 4 hangar locations)
	140A 120V (at 4 hangar locations)
Additional Features:	Hurricane worthiness – 120 mph
	Availability – Low

6.4 MARS/VCSFA

The Virginia Commercial Space Flight Authority (VCSFA), also known as 'Virginia Space,' is a political subdivision of the Commonwealth of Virginia. Virginia Space owns and operates the Mid-Atlantic Regional Spaceport (MARS), MARS Unmanned Aircraft Systems (UAS) Airfield, MARS Payload Processing Facility, MARS Integration and Control Facility, and soon-to-be MARS Port.

Virginia Space aims to provide and is proud to offer full-service launch and drone testing facilities for commercial, government, scientific and academic users, including the Northrop Grumman Antares vehicle (see Figure 77).

The mission of Virginia Space is to serve as a driver for Virginia's New Economy by providing safe, reliable, and responsive space access at competitive prices, and secure facilities for testing of unmanned vehicles for integration into the National Air Space.

Figure 77: The Northrop Grumman Antares vehicle, on its way to the commercially operated MARS launch pad

6.5 Unmanned Aircraft Systems Airfield

The Mid-Atlantic Regional Spaceport's UAS Airfield, shown in Figure 78, conducts operations including training for first responders, student outreach including ThinSat flights, NASA Langley Research Center (LaRC) test flights, numerous 14 Code of Federal Regulations (CFR) Part 107 flights involving aerial imagery; environmental and wildlife monitoring, DoD projects and FireScout Training Detachments. This airfield services both commercial and government customers regularly. Attributes of the UAS Airfield are listed in Table 26 and shown in Figure 79 and Figure 80.

Figure 78: MARS UAS Airfield

Table 26: UAS Airfield

Location	Within Special Use Airspace R-6604, partnered with the NASA Wallops Range on Wallops Island
	14/32 layout approximately 0.75° inland from the Atlantic Ocean
Magnetic Headings	135°/315°
Geo Coordinates	37°56′ North Latitude, 75°28′ West Longitude
Airfield Elevation	9 feet above Mean Sea Level

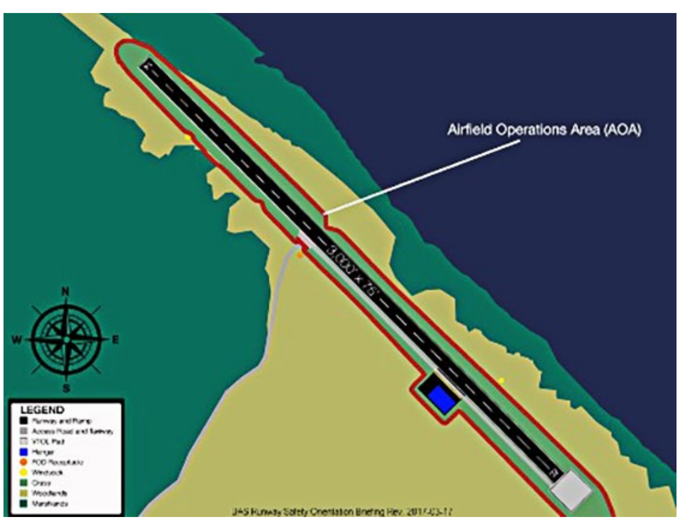


Figure 79: 3,000-foot x 75-foot UAS Runway

Figure 80: Concrete vertical takeoff and landing (VTOL) Pad rated to 5,000 psi

UAS Hangar Bay

The UAS Hangar Bay, shown in Figure 81, has attributes as listed in Table 27.

Table 27: UAS Hangar Bay Specs

95 feet x 50 feet heated, ventilated and air-conditioned hangar
70 feet by 20 feet hangar door
Full power and communications suite
Dedicated mission-planning ready room
Fire detection system
Special use airspace and frequency management

Figure 81: MARS UAS Airfield HVAC Conditioned Hangar

Ready Room Adjacent to Hangar Bay

A 'Ready Room' next to the Hangar Bay (see Figure 82) includes the capabilities described in Table 28.

Table 28: Ready Room Specs

NASA closed circuit television
Weather channels
Phone lines
Closed network airfield cameras
Conference table
Work desk area
Next Generation Land Mobile Radios (NGLRM): equipped with KWAL tower communications channel and dedicated airfield operations channel VHF/UHF common traffic advisory frequency (CTAF) capable

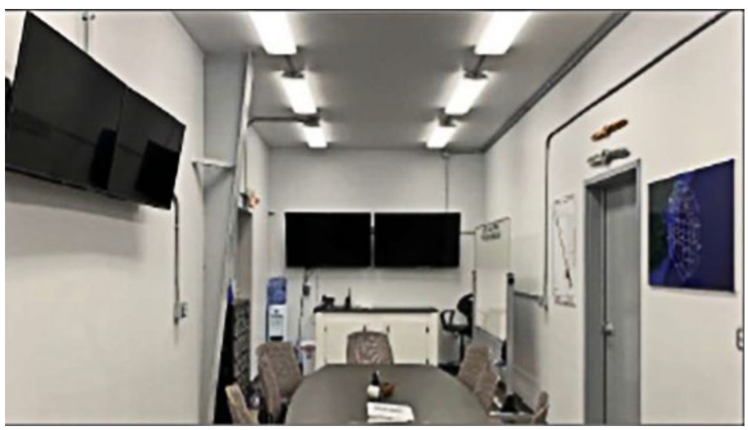


Figure 82: Ready Room Adjacent to Hangar Bay

Ramp Area

The ramp area adjacent to the UAS Airfield, as shown in Figure 83, encompasses the facilities described in Table 29.

Table 29: Ramp Area Specs

55-foot Antenna tower
Network switches with multiple cables from top to bottom, configurable
DB9, coax, Cat5 etc.
110 volts convenience power to top
240 volts at bottom
Auxiliary items
Wash-down pad capable of holding MH-60 Seahawk
550-gallon water tank
Mobile air-conditioned restroom facility

Figure 83: MARS UAS Airfield Ramp Area

Direct Access to R6604 Restricted Airspace

The Special Use Airspace (SUA) access is a NASA-controlled restricted airspace R-6604 with over 300 square nautical miles (NM) of restricted airspace (see Figure 84). The Patuxent River Atlantic Test Range (ATR) has a test track A, B, C, and D, with over 1,500 square NM of SUA. The Fleet Area Control and Surveillance Facility (FACSFAC) Virginia Capes Operating Area (VACAPES) have over 25,000 square NM of SUA. Virginia Capes offers DoD/government customers access to warning areas beyond the test track from surface to space including W-386, W-387 and W-72.

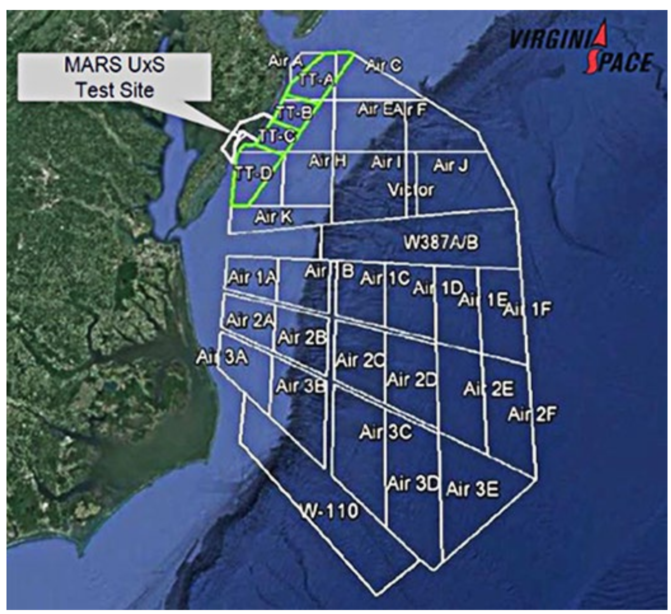


Figure 84: Direct Access to R6604 Restricted Airspace

6.6 MARS Payload Processing Facility

Figure 85: MARS Payload Processing Facility

The VCSFA Payload Processing Facility (Figure 85) shows an external overview; (see Figure 86, Figure 87 and Figure 88 for views of the interior) has capabilities such as multiple segregated processing spaces, payload integration and fueling, and stage integration. The PPF building is designed to separately process the launch vehicle (LV) and spacecraft (SC). The integration area is built to ISO 8 (100K) clean room standard as well as to Intelligence Community Directive (ICD) 705. The PPF also includes multiple overhead cranes including an overhead processing, a 30-ton crane with a 60’ hook height in the vertical integration area, and a dual 15-ton with a 30-foot hook height in the horizontal integration area.

Figure 86: MARS Payload Processing Facility Solid Motor Processing Bay

Figure 87: MARS Payload Processing Facility Secondary Payload Processing Bay

Figure 88: MARS Payload Processing Facility Control Systems

6.7 MARS Port

The MARS port is planned for construction between 2022 and 2024. Figure 89 shows a summary of proposed upgrades, which will include unmanned underwater vehicle (UUV) and underwater surface vehicle (USV) capability. It will provide opportunities for unmanned and intermodal research and continue science, technology, engineering and mathematics (STEM) outreach/workforce development in technical jobs. The MARS port will also permit the transportation of oversized and hazardous cargo via waterways versus rail and roads. Anticipated activities include inter-governmental test and operations with the Navy, DoD, National Oceanic and Atmospheric Administration (NOAA), NASA, state institutions, research partners, and the Federal Aviation Administration (FAA). The MARS port will enable classified advancements that improve interoperability, redundancy, and research in our nation's transportation system.

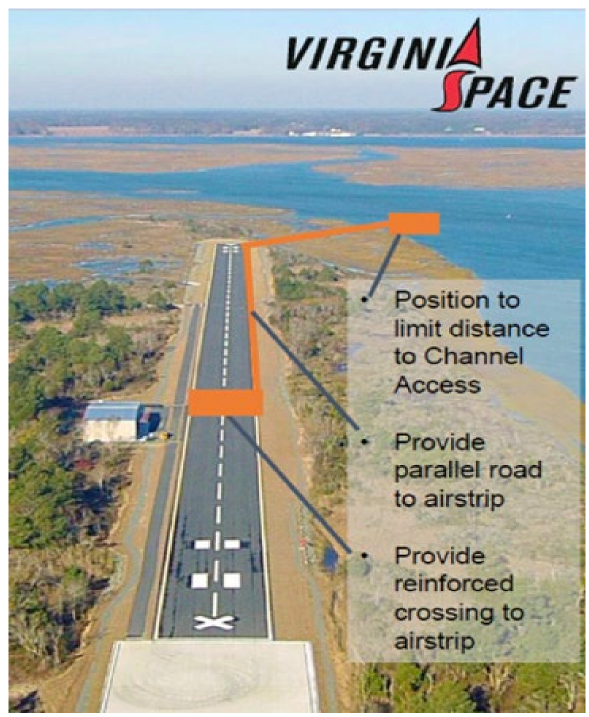


Figure 89: UUV/USV Port Upgrade Summary

6.8 Mission Operations Control Center

The Mission Operations Control Center (MOCC) is a $16 million, 14,174 square-foot building on the Wallops main base, which serves as the hub for interfacing with and controlling rockets, their payloads and associated launch pad support systems during flight operations at Wallops.

6.9 Integration and Control Facility

The Integration and Control Facility (ICF, shown in Figure 90) construction began in November 2019 and had a Certificate of Occupancy by November 2020. It is the first facility in the Wallops Business Park and sets the standard for future commercial activities in this area. It is currently leased to Rocket Lab by the VCSFA. The integration space is used for the integration of electron launch vehicles. The facility includes a mission control room as well as an office space.

Figure 90: Integration and Control Facility (ICF)

APPENDIX A: ABBREVIATIONS AND ACRONYMS

Acronym	*Definition*
ABO	Aviator's Breathing Oxygen
ABSM	Acrylonitrile Butadiene Styrene Material
ACS	Attitude Control System
ADS	Advanced Design System
ANSI	American National Standards Institute
APSU	Auxiliary Payload Support Unit
ASA	Acrylonitrile Styrene Acrylate
ASCII	American Standard Code for Information Interchange
ATR	Atlantic Test Range
Az	Azimuth
BRDL	Balloon Research and Development Laboratory
CAD/CAM	Computer-Aided Design and Manufacturing
CCTV	Closed circuit television
CE	Conducted Emissions
C/F	Coldfinger
CFR	Code of Federal Regulations
CG	Center of Gravity
CNC	Computer Numerical Control
CSBF	Columbia Scientific Balloon Facility
CTAF	Common Traffic Advisory Frequency
CWA	Clean Work Area
dB	decibel
DC	Direct Current
DoD	Department of Defense
EGSE	Electrical Ground Support Equipment
El	Elevation
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
ESPA	Expendable Launch Vehicle Secondary Payload Adapter
ETE	End-To-End
FAA	Federal Aviation Administration
FACSFAC	Fleet Area Control and Surveillance Facility
FM	Frequency modulation
FPGA	Field Programmable Gate Array
FTS	Flight Termination Receiver System
GHz	gigahertz

Acronym	*Definition*
GPM	Global Precipitation Measurement
GPS	Global Positioning System
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HGA	High Gain Antenna
HIF	Horizontal Integration Facility
Hz	Hertz
I&T	Integration And Test
I/O	Input/Output
ICD	Intelligence Community Directive
ICF	Integration and Control Facility
IMU	Inertial Measurement Unit
IRIG	Inter-Range Instrumentation Group
ISO	International Standards Organization
ISS	International Space Station
kHz	kilohertz
kW	kilowatt
L9EFS	Landsat 9 ESPA Flight System
LaRC	Langley Research Center
lbs.	pounds
LV	Launch Vehicle
MARS	Mid-Atlantic Regional Spaceport
Mbps	Megabits per second
MGSE	Mechanical Ground Support Equipment
MHz	megahertz
MIL-STD	Military Standard
MOCC	Mission Operations Control Center
MOI	Moment of Inertia
mph	Miles per hour
MPL	Mission Planning Lab
MPPF	Multi-Payload Processing Facility
NACA	National Advisory Council on Aeronautics
NGLRM	Next Generation Land Mobile Radio
NM	Nautical Miles
NOAA	National Oceanic and Atmospheric Administration
NSROC	NASA Sounding Rocket Operations Contract
PAI	Precision Analog Input
PC	Personal Computer

Acronym	*Definition*
PC-ABS	Polycarbonate-ABS alloy
PCM	Pulse-Code Modulation
PI	Principal Investigator
PLA	Polylactic Acid
PPF	Payload Processing Facility
psi	Pounds per square inch
R&D	Research and Development
RADAC	Range Data Acquisition and Computation
RE	Radiated Emissions
RF	Radio Frequency
RGA	Residual Gas Analyzer
rms	root-mean-square
rpm	Revolutions per minute
RS	Radiated Susceptibility
SC	Spacecraft
SP	Scavenger Plate
STEM	Science, Technology, Engineering and Mathematics
SUA	Special Use Airspace
TPU	Thermoplastic Polyurethane
TQCM	Thermoelectric Quartz Crystal Microbalance
TV	Television
T-Vac	Thermal Vacuum
UAS	Unmanned Aircraft Systems
UD	Unholtz Dickie
UHF	Ultra-high frequency
USV	underwater surface vehicle
UUV	unmanned underwater vehicle
UV	ultraviolet
VACAPES	Virginia Capes Operating Area
VCSFA	Virginia Commercial Space Flight Authority
VTOL	Vertical takeoff and landing
WASP	Wallops Arc Second Pointer
WFF	Wallops Flight Facility