# Taurus® II

April 2010

## User's Manual

Release 1.3

Orbital

ORBITAL SCIENCES CORPORATION

**April 2010 Taurus® II User's Guide**

**Release 1.3**

| REVISION SUMMARY | | | | |
|---|---|---|---|---|
| **VERSION** | **DOCUMENT** | **DATE** | **CHANGE** | **PAGE** |
| 1.0 | TM-20831 | Mar 2009 | Initial Release for Internal Review (DRAFT) | All |
| 1.1 | TM-20831 | July 2009 | Initial Public Release (DRAFT) | Cover |
| 1.2 | TM-20831 | December 2009 | Initial Public Release | All |
| 1.3 | TM-20831 | April 2010 | Update | All |

**MEDIUM-CLASS LAUNCH SERVICES FOR THE 21ST CENTURY**

The **Taurus® II** is a two-stage launch vehicle designed to provide responsive, cost-effective, and reliable access to orbit for Medium-Class payloads weighing up to 6500 kg. The Taurus II launch system is designed to meet National Aeronautics and Space Administration (NASA) Category 3 and similar DoD mission success standards. Its initial mission is a demonstration of commercial re-supply of the International Space Station (ISS) under a NASA Commercial Orbital Transportation Services (COTS) Space Act Agreement. Follow-on ISS Commercial Resupply Services (CRS) missions are also under contract with NASA starting in 2011. Future applications include the launch of Medium-Class science, defense, and commercial launch missions. Taurus II development is internally funded by the Orbital Sciences Corporation (Orbital).

- ***Low-Risk Design***: Taurus II incorporates flight-proven components from leading global suppliers, and utilizes subsystem designs successfully deployed on other Orbital launch vehicles.
- ***Leveraging Flight-Proven Technologies***: The Taurus II first stage is powered by dual AJ26-62 engines originally developed for the Soviet N-1 vehicle. These engines have been updated by Aerojet with modern avionics and control systems. The baseline Taurus II second stage propulsion utilizes a CASTOR® 30A solid rocket motor and Orbital's latest Modular Avionics Control Hardware (MACH) technology to provide the increased capability and flexibility required by the Taurus II.
- ***Fills Medium-Class Launch Services Gap***: Taurus II fills the service gap between Medium-Light Minotaur IV-class launch vehicles and Atlas V or Delta IV offerings.

This Taurus II User's Guide describes the basic elements of the Taurus II system as well as available optional services. In addition, this document provides general vehicle performance, defines payload accommodations and environments, and outlines the Taurus II mission integration process. All data provided herein is for reference purposes only and should not be used for mission-specific analyses. Detailed analyses will be performed by Orbital based on the requirements and characteristics of each specific mission. The launch services described in this Taurus II Launch System User's Guide is intended to familiarize potential Customers with the Taurus II launch system, its capabilities and its associated services. The launch services described herein are available for commercial procurement directly from Orbital Sciences Corporation.

Readers desiring further information on Taurus II should contact us via:

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Copies of this Taurus II User's Guide may be obtained from our website at http://www.orbital.com. Hardcopy documents and electronic (CD format) are also available upon request.

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|---|---|
| 6-DOF | Six Degrees of Freedom |
| A | Ampere |
| A/D | Arm Disarm |
| AC | Air Conditioning |
| ACS | Attitude Control System |
| AFSPCMAN | Air Force Space Command Manual |
| AJ | Aerojet |
| ARAR | Accident Risk Assessment Report |
| ATK | Alliant Tech Systems, Inc. |
| atm | Atmosphere |
| ATP | Authority To Proceed |
| C | Celsius |
| C&C | Command and Control |
| CCAFS | Cape Canaveral Air Force Station |
| CCAM | Collision/Contamination Avoidance Maneuver |
| CDR | Critical Design Review |
| CG | Center of Gravity |
| CLA | Coupled Loads Analysis |
| cm | centimeter |
| CONOPS | Concept of Operations |
| COTS | Commercial Orbital Transportation Services |
| CRS | Commercial Resupply Services |
| CST | Combined System Test |
| CVCM | Collected Volatile Condensable Materials |
| DADS | Dynamic Analysis and Design System |
| dB | decibels |
| deg | degrees |
| ECS | Environmental Control System |
| EELV | Evolved Expendable Launch Vehicle |
| EGSE | Electrical Ground Support Equipment |
| EICD | Electrical Interface Control Drawing |
| EMC | Electromagnetic Compatibility |
| EME | Electromagnetic Environment |
| EMI | Electromagnetic Interference |
| F | Fahrenheit |
| FAA | Federal Aviation Administration |
| FM | Frequency Modulation |
| FMA | Final Mission Analysis |
| ft | feet |
| FTS | Flight Termination System |

| | |
|---|---|
| FTSR | Flight Termination System Report |
| g | gravitational force |
| $GN_2$ | Gaseous Nitrogen |
| GPB | GPS Position Beacon |
| GPS | Global Positioning System |
| GSE | Ground Support Equipment |
| GTO | Geosynchronous Transfer Orbit |
| He | Helium |
| HEPA | High Efficiency Particulate Air |
| HIF | Horizontal Integration Facility |
| HTPB | Hydroxyl Terminated Polybutadiene |
| Hz | Hertz |
| I/F | Interface |
| I/O | Input/Output |
| ICD | Interface Control Document |
| ID | Identification |
| in. | inch |
| INS | Inertial Navigation System |
| ISS | International Space Station |
| IVT | Interface Verification Test |
| kbps | kilobits per second |
| kg | kilograms |
| KLC | Kodiak Launch Complex |
| km | kilometer |
| kPa | kilo Pascal |
| lb | pound |
| lbm | pound(s) of mass |
| LCC | Launch Control Center |
| LEO | Low Earth Orbit |
| LEV | Launch Equipment Vault |
| Lm | Liters per minute |
| LOX | Liquid Oxygen |
| LRR | Launch Readiness Review |
| LSE | Launch Support Equipment |
| LSG | Launch Systems Group |
| LSSP | Launch Site Support Plan |
| LV | Launch Vehicle |
| lx | Lux |
| LxWxH | Length multiplied by Width multiplied by Height (i.e.; Volume) |
| m | meters |
| m/s | meters per second |
| mA | milli-Amps |
| MACH | Modular Avionics Control Hardware |
| MARS | Mid-Atlantic Regional Spaceport |
| Mbps | Mega bits per second |

| | |
|---|---|
| MCC | Mission Control Center |
| MDR | Mission Design Review |
| MDR | Mission Dress Rehearsal |
| MECO | Main Engine Cut-Off |
| MES | Main Engine System |
| MGSE | Mechanical Ground Support Equipment |
| MHz | Mega-Hertz |
| MICD | Mechanical Interface Control Drawing |
| MIL-STD | Military Standard |
| MIWG | Mission Integration Working Group |
| mm | millimeter |
| MRR | Mission Readiness Review |
| ms | millisecond |
| MSPSP | Missile System Pre-Launch Safety Package |
| mV | milli-Volt |
| N | Newton |
| N/A | Not Applicable |
| $N_2$ | Nitrogen |
| NASA | National Aeronautics and Space Administration |
| nmi | nautical mile |
| OBV | Orbital Boost Vehicle |
| OD | Operations Directive |
| ODM | Ordnance Driver Module |
| OR | Operations Requirement |
| Orbital | Orbital Sciences Corporation |
| OSP | Orbital Suborbital Program |
| PCM | Pressurized Cargo Module |
| PCM | Pulse Code Modulation |
| PDR | Preliminary Design Review |
| PI | Program Introduction |
| PID | Proportional-Integral-Derivative |
| PL | Payload |
| PMA | Preliminary Mission Analysis |
| POC | Point of Contact |
| PPF | Payload Processing Facility |
| ppm | parts per million |
| PRD | Program Requirements Document |
| psf | per square foot |
| PSP | Program Support Plan |
| RAAN | Right Ascension of Ascending Node |
| RCC | Range Control Center |
| RF | Radio Frequency |
| RP | Rocket Propellant |
| rpm | revolutions per minute |
| RWG | Range Working Group |
| S/A | Safe and Arm |
| S1 | Stage 1 |
| S2 | Stage 2 |
| SAE | Society of Automobile Engineers |
| SC | Statement of Capability |
| SCAPE | Self-Contained Atmospheric Protective Ensemble |
| scfm | standard cubic feet per minute |
| sec | second(s) |
| SIGI | Space Integrated GPS/INS |
| SINDA | Finite Element Thermal Analysis (Tool Trade Name) |
| SLV | Space Launch Vehicle |
| SM | Service Module |
| SRM | Solid Rocket Motor |
| ST ICD | Serial Telemetry Interface Control Document |
| TAA | Technical Assistance Agreement |
| TEL | Transporter Erector/Launcher |
| TLV | Target Launch Vehicle |
| TML | Total Mass Loss |
| t | Ton |
| TSP | Twisted Shielded Pairs |
| TVC | Thrust Vector Control |
| UDS | Universal Documentation System |
| UPS | Uninterruptible Power Supply |
| V/m | Volts per meter |
| VAFB | Vandenberg Air Force Base |
| Vdc | Volts direct current |
| Vp-p | Volts peak-to-peak |
| W | Watt |
| WFF | Wallops Flight Facility |
| WP | Work Package |

## 1. INTRODUCTION

The objective of the Taurus II User's Guide is to familiarize payload mission planners with Orbital Sciences Corporation's (Orbital's) Taurus II launch service. This document provides an overview of the Taurus II system design and a description of the standard launch services provided to our Customers. Orbital also offers a variety of service options to allow maximum flexibility in satisfying Customer objectives for single or multiple payloads.

### 1.1. Orbital History

Orbital has a long history of successful space launch vehicles, suborbital launch vehicles, target vehicles, and interceptor boost vehicles. Figure 1.1-1 shows the array of Orbital's major vehicles. Orbital is leveraging its 100% success rate from the Minotaur space launch vehicles and high reliability Pegasus and Taurus programs in the development of the Taurus II vehicle. Orbital's 46 years of experience includes more than 650 vehicles launched from ground-based, airborne, and seaborne platforms on every U.S. launch Range, as well as launch sites throughout the world.

### 1.2. Taurus II Launch Vehicle

The baseline Taurus II is a 2-stage, inertially-guided, ground-launched vehicle. Conservative design margins, state-of-the-art structural systems, a modular avionics architecture, and simplified integration and test capability, yield a robust, highly reliable launch vehicle design. In addition, Taurus II payload accommodations and interfaces have been designed to satisfy a wide range of potential Customer requirements.

The Taurus II launch system is composed of the launch vehicle and it's associated ground support equipment. Each element of the Taurus II system was developed to maximize payload mass to orbit, streamline the mission design and payload integration process, and to provide safe, reliable space launch services. Initially, the Taurus II will operate from the Wallops Flight Facility (WFF), VA. As Customer needs develop, the Taurus II capability will be extended to additional launch facilities and geographic locations including the Kodiak Launch Complex (KLC), AK; Cape Canaveral Air Force Station (CCAFS), FL; and Vandenberg Air Force Base (VAFB), CA.

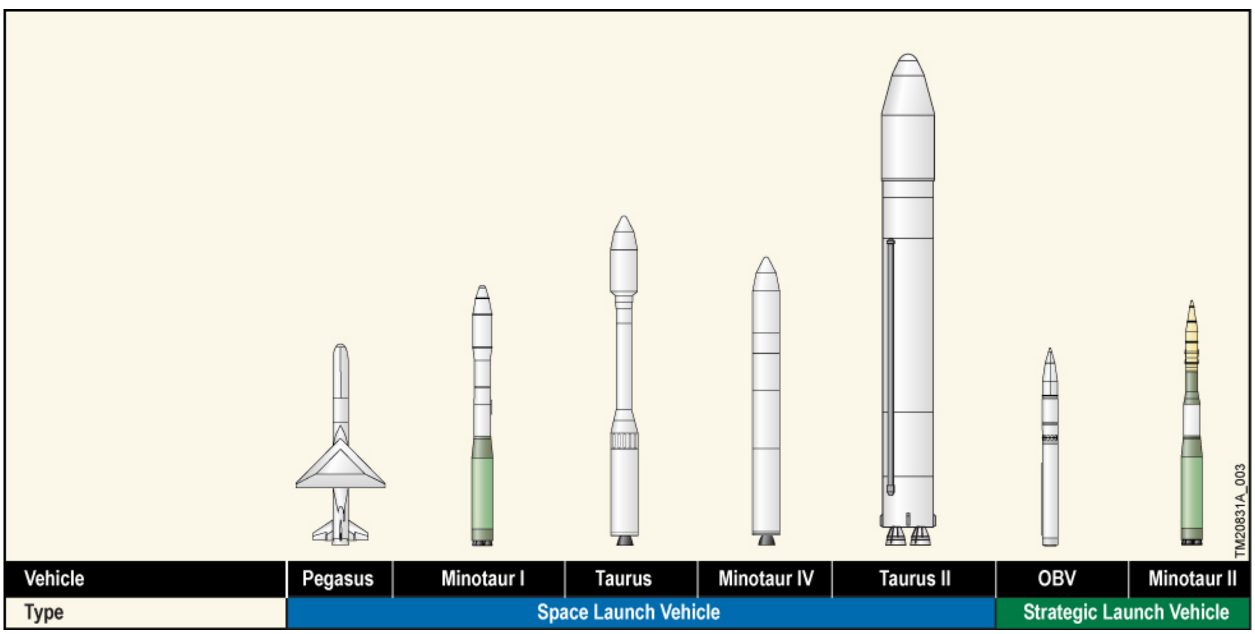



**Figure 1.1-1. Orbital Major Vehicles**

## 2. TAURUS II SYSTEM OVERVIEW

The Taurus II launch vehicle, shown in Figure 2-1, was developed by Orbital to service the Medium-Class space launch market, and to provide a cost effective, reliable and flexible means of placing Medium sized satellites into orbital and Earth-escape trajectories. Taurus II has been designed to meet the needs of government and commercial Customers through the use of existing, flight proven technologies, heritage engines and motor technology, heritage Orbital avionics architectures, and Orbital's proven integration and launch processes. The Taurus II design focuses on system reliability, transportability, minimum on-pad time and minimal fixed infrastructure.

Orbital launch vehicle designs draw on a pool of common avionics, which minimizes development costs, distributes production expenses, and provides significant test and flight operating histories for the components. The Taurus II avionics are based on heritage Orbital components flown on Minotaur, Orbital Boost Vehicle (OBV), and other orbital and suborbital launch vehicles.

The Taurus II is designed to be capable of being launched from any of the four major commercial U.S. Spaceports (California, Florida, Alaska and Virginia), as well as from existing U.S. Government facilities at VAFB and CCAFS given the appropriate fueling infrastructure and pad capability.

### 2.1. Taurus II Launch Service

Taurus II provides all of the necessary hardware, software and services to integrate, test and launch a payload into its prescribed orbit. The Taurus II mission integration process completely identifies, documents, and verifies all spacecraft and mission requirements. In addition, Orbital will complete all required agreements, licenses, and documentation to successfully conduct Taurus II launch operations.

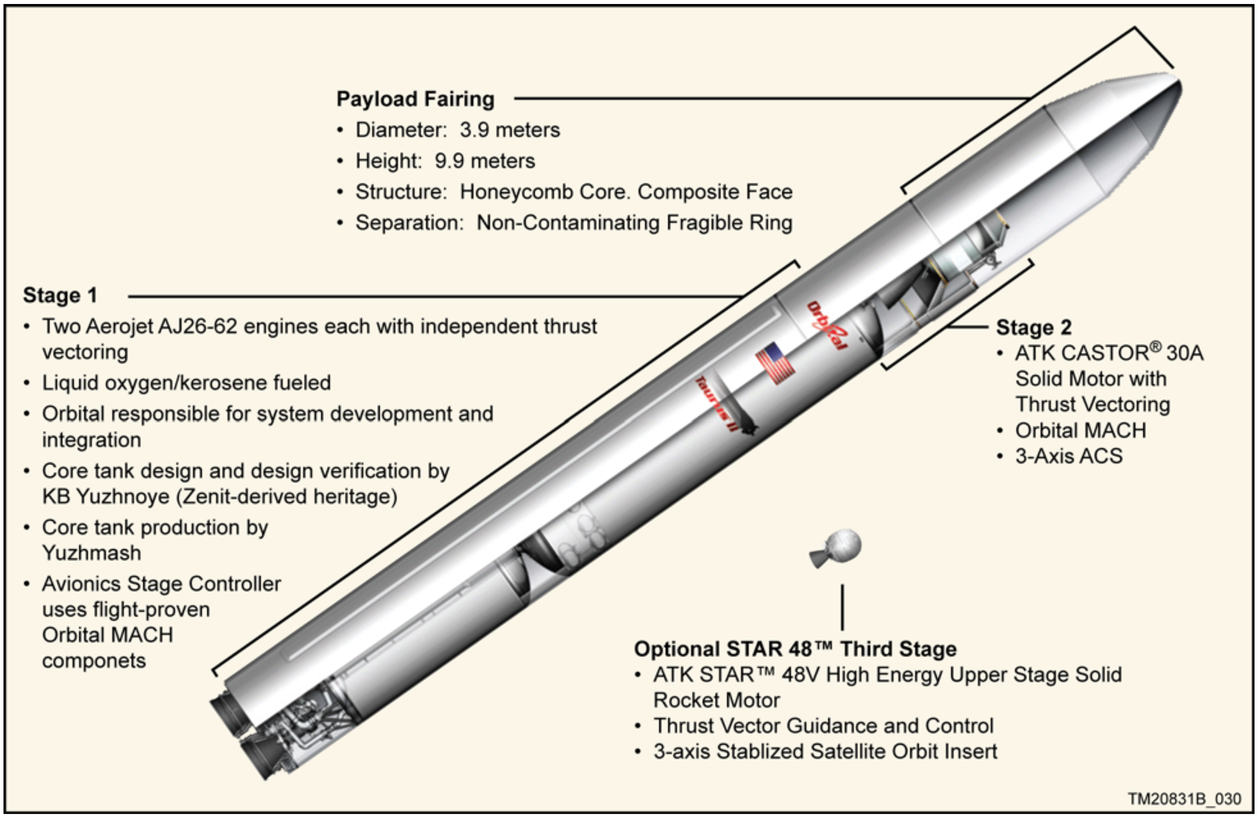



**Figure 2-1. Taurus II Launch Vehicle**

### 2.2. Taurus II Launch Vehicle

The Taurus II vehicle, shown in Figure 2-1, is a two stage, inertially-guided, ground launched vehicle. Conservative design margins, state-of-the-art structural systems, a modular avionics architecture, and simplified integration and test capability, yield a robust, highly reliable launch vehicle design. In addition, Taurus II payload accommodations and interfaces have been designed to satisfy a wide range of payload requirements.

#### 2.2.1. Stage 1 Assembly

The primary function of Stage 1 is to generate the required impulse for delivering Taurus II upper stages and payloads to the target altitude, downrange and velocity conditions for stage separation. Stage 1 is also the critical structural load path for transmitting thrust forces during early ascent, provides the structural support of the vehicle on the launch pad during ground operations, and is the primary interface between the Taurus II launch vehicle and ground systems.

The Stage 1 Assembly consists of the Yuzhnoye developed Stage 1 core structure and tanks, the AJ26-62 Main Engine System (MES), and the Range required Flight Termination System (FTS). Stage 1 establishes the 3.90 m (154 in.) diameter of the Taurus II launch vehicle and is 27.6 m (90.6 ft) long. The Stage 1 propulsion system uses Liquid Oxygen (LOX) and kerosene Rocket Propellant (RP).

***S1 Core***

The Stage 1 core provides the structural support of the launch vehicle, and all of the functionality and services required to store, manage and deliver propellants to the MES at required conditions and flow rates. The S1 core includes propellant tanks, pressurization tanks, valves, sensors, flight termination system, feed lines, tubing, wiring and other associated hardware. This equipment is packaged within five structural "bays": the inter-stage bay, the LOX tank bay, the inter-tank bay, the Rocket Propellant (RP-1) tank bay and the aft bay. The S1 core utilizes an aluminum waffle structure for the aft bay, RP-1 tank, and inter-stage bay. The LOX tank is manufactured from solid aluminum. The inter-stage bay serves as the structural interface between Stage 1 and Stage 2.

The LOX and RP-1 tank bays consist primarily of their corresponding propellant tanks. Both propellant tanks include level sensors used during propellant loading and for measuring propellant levels in flight. This in-flight measurement is used by Stage 1 avionics for calculations to determine engine mixture ratio adjustments for minimizing residuals in the propellant tanks. The RP-1 tank incorporates a tunnel to accommodate the LOX feed line through the center of the RP-1 tank instead of routing around it for packaging efficiency. The LOX feed line runs down the center of the RP-1 tank to the aft end of the stage where the MES is mounted. Helium is used for pressurizing both the LOX and RP-1 tanks. Helium pressurization gas bottles are submerged within the LOX tank for gas storage efficiency. The pressurization system, with a maximum pressure of 220 atm, operates in a blow down mode and supplies gas through a manifold of valves that are cycled open to control propellant flow rate. Liquid level sensors in the LOX tank assure the helium tanks are submerged prior to beginning helium fill operations, and emergency relief valves protect against over-pressurization events.

The aft bay contains the MES and is the primary interface between the launch vehicle and ground systems. Many of the mechanical, fluid and electrical interfaces are located at the base of the vehicle through the aft bay structure using existing liftoff connector designs derived from Yuzhnoye's Zenit launch vehicle. These connectors mate with a launch ring that is mounted to the vehicle in the integration building while the launch vehicle is horizontal.

***Main Engine System (MES)***

The MES generates thrust for launch vehicle motion and control during Stage 1 ascent. The MES consists of two AJ26-62 LOX/RP-1 rocket engines mounted on a thrust frame with individual Thrust Vector Control (TVC) systems on each engine, propellant feed lines, and fluid and electrical utilities hardware. An aft bay closure and heat shield thermal blanket are also part of the MES.

The MES thrust frame transmits thrust and gimbal loads from the engines to the S1 core structure. The feed lines that transfer propellant from the core LOX and RP-1 tanks to the engine propellant inlets incorporate flexible elements that permit relative motion between the engines and core, including commanded motion of the TVCs. The aft bay closure and heat shield assemblies span the distance between the engine and aft bay structure, providing a thermal and environmental barrier to protect components within the aft bay.

The AJ26-62 engines use a sub-cooled oxygen-rich, staged combustion cycle that can be throttled from 56% to 108% and has a variable mixture ratio valve for controlling relative flow rates of oxidizer and fuel. The engines are controlled via Orbital's engine controller in conjunction with Yuzhnoye supplied sensors and propellant utilization system. AJ26-62 engine gimbaling is controlled via a Moog hydraulic TVC system. The MES assembly generates a total of approximately 370,135 $kg_f$ (816,000 $lb_f$) of total vacuum thrust.

### 2.2.2. Stage 2 Assembly

The Taurus II Stage 2 is composed of the Stage 2 avionics module, the second stage motor & motor adapter cone, the Stage 1/2 interstage, a Stage 1/2 separation system, the fairing separation system, and an Attitude Control System (ACS).

***Stage 2 Avionics Module***

The Taurus II avionics design incorporates Orbital's latest Modular Avionics Control Hardware (MACH) design technology to provide power transfer, data acquisition, booster interfaces, and ordnance initiation. This advanced system supplies the increased capability and flexibility required by the Taurus II, providing communication with vehicle subsystems, Launch Support Equipment (LSE), and the payload, utilizing standard Ethernet links and discrete Input/Output (I/O).

MACH has exhibited 100% reliability on the Orbital Suborbital Program (OSP) Space Launch Vehicle (SLV) and Target Launch Vehicle (TLV) flights, as well as several of Orbital's suborbital launch vehicles. In addition, the Taurus II MACH system has been upgraded to provide up to 3 Mbps of real-time vehicle telemetry data with dedicated bandwidth and channels reserved for payload use.

***Stage 2 Motor***

The baseline Taurus II utilizes a CASTOR® 30A for the second stage motor, which is based on the heritage CASTOR® 120 motor used as Stage 1 for the Taurus Classic launch vehicle.

The CASTOR® 30A motor, illustrated in Figure 2.2.2-1, is built by Alliant Tech Systems, Inc. (ATK) and consists of a composite graphite/epoxy wound case, a modified mixture of TP-H8299 for its solid fuel, a CASTOR® IVB ignitor, and a flex seal design at the throat to allow for TVC motion during flight. Orbital supplies a composite sandwich structure motor adapter cone to provide a structural load path from the Stage 1 forward skirt to the Stage 2 motor aft skirt.

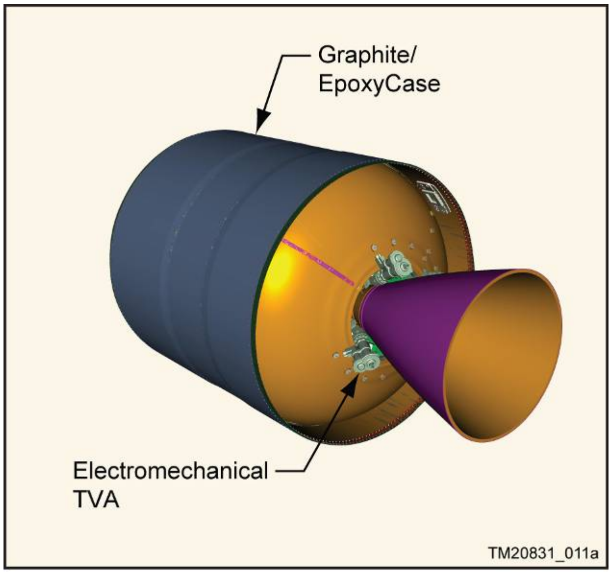



**Figure 2.2.2-1. CASTOR® 30A Motor**

The CASTOR® 30A Solid Rocket Motor (SRM) generates approximately 36,000 $kg_f$ (80,000 $lb_f$) of thrust with an Isp of 301 seconds and a burn time of 136 seconds. A 65:1 inch throat-to-exit-plane-ratio model provides the second stage performance required to meet our initial Taurus II COTS and CRS mission requirements, with an extended nozzle under development for increased performance on later flights.

***Attitude Control Systems (ACS)***

The Taurus II ACS provides three-axis attitude control throughout boosted flight and coast phases. the ACS uses the MES to provide yaw, pitch and roll control during Stage 1 powered flight. Stage 2 flight is controlled by the combination of the Stage 2 TVC and the onboard ACS system located on the avionics ring. The Stage 2 ACS employs a cold gas nitrogen system with heritage from all of Orbital's space launch vehicles.

Attitude control is achieved using a three-axis autopilot that employs Proportional-Integral-Derivative (PID) control. Stage 1 flies a pre-programmed attitude profile based on trajectory design and optimization. Stage 2 uses a set of pre-programmed orbital parameters to place the vehicle on a trajectory toward the intended insertion apse. The extended coast between Stage 1 and 2 is used to orient the vehicle to the appropriate attitude for Stage 2 ignition based upon a set of pre-programmed orbital parameters and the measured performance of the first stage. Stage 2 utilizes energy management to place the vehicle into the proper orbit. After the final boost phase, the three-axis cold-gas attitude control system is used to orient the vehicle for spacecraft separation, contamination and collision avoidance, and downrange downlink maneuvers. The autopilot design is a modular object oriented software design, so additional payload requirements such as rate control or celestial pointing can be accommodated with minimal additional development.

### 2.2.3. Optional Stages

***Enhanced Second Stage***

Currently under development for the Taurus II is an enhanced second stage engine that provides a substantial performance improvement to the Taurus II delivered payload capability. The enhanced second stage is a liquid fueled engine with restart capability, and is scheduled to fly on Taurus II in support of the NASA Commercial Resupply Services (CRS) missions in 2013. This configuration is available as an option to meet the higher performance requirements of all payloads. Additional details on the enhanced second stage are provided in section 8.0.

***STAR™ 48 Third Stage Option***

The STAR™ 48-based third stage option mounts forward of the CASTOR® 30A or enhanced second stage, capable of providing signfiicant performance increase for spacecraft that need to achieve high energy orbits, including GTO or other high energy orbits. The STAR™ 48 series of solid rocket motors, manufactured by ATK, have extensive flight history in space launch applications on Delta and Shuttle, and are also offered on Orbital's Minotaur IV and V launch systems. The STAR™ 48V motor with vectorable nozzle combined with Orbital's heritage guidance and attitude control systems are used to allow Orbital to offer 3-axis stabilized orbit injection to customers needing orbital insertion above LEO orbits.

## 2.3. Payload Accommodations

Taurus II payload accommodations include a fairing, a variety of separation systems, and an industry standard non-separating mechanical interface.

***Payload Fairing***

The Taurus II employs a 3.94 m (155 in.) composite bi-sector fairing (Figure 2.3-1) consisting of two graphite composite shell halves, a low-shock frangible rail and ring separation system, and an actuator/hinge fairing jettison system. Further details on the fairing are provided in Section 5.

***Payload Static Envelope***

With a volume greater than 57.5 $m^3$ (2031 $ft^3$) available for users in the fairing, Taurus II provides significantly greater volume for accommodating payloads than any other Medium-Class launch vehicle in production. Further details on payload static envelopes can be found in Section 5.

***Payload Interface***

The standard payload interface for Taurus II is a 1575 mm (62.01 in.) circular bolted interface common with the Evolved Expendable Launch Vehicle

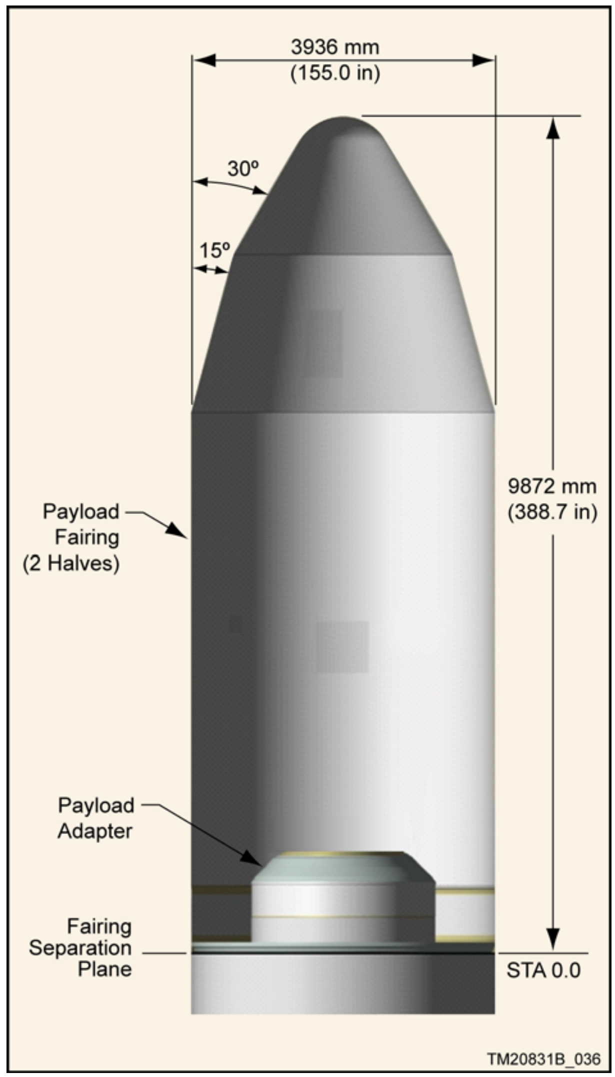



**Figure 2.3-1. Taurus II 3.9 m Fairing**

(EELV) interface standard. This standardized non-separating mechanical interface accommodates both non-separating payloads, Orbital-provided spacecraft adaptors and separation systems, as well as payload provided adaptors and separation systems.
Details of the non-separating mechanical interface and available separation systems are presented in Section 5.

### 2.4. Launch Support Equipment (LSE)

Taurus II Electrical Ground Support Equipment (EGSE), Mechanical Ground Support Equipment (MGSE), and Concept of Operations (CONOPS) were developed to be adaptable to varying levels of infrastructure at several launch sites on both the east and west coasts of the U.S.

Given that the appropriate fueling infrastructure and pad capability requirements are met, the Taurus II launch vehicle and LSE are designed to be compatible with any of the four major commercial U.S. Spaceports in Alaska, California, Florida, and Virginia, as well as from existing U.S. Government facilities at VAFB and CCAFS.

#### 2.4.1. Launch Site Infrastructure

Brief descriptions of the Taurus II fixed launch infrastructure is provided here, with a more detailed discussion in Section 7.

***Horizontal Integration Facility (HIF)***

Taurus II is designed for lean horizontal processing of the launch vehicle. Orbital performs launch site Integration and test activities of the Taurus II out of a HIF in preparation for roll-out to the pad for erection, fueling, and launch. This facility will be used to assemble and test the Taurus II launch vehicle, mate the payload to the launch vehicle, perform launch vehicle to payload checkout, and for encapsulating the payload in the fairing.

***Payload Processing Facility (PPF)***

Orbital's approach to payload processing places few requirements on the Customer. Payload processing is conducted a short distance away from the launch vehicle integration facility in an environmentally controlled PPF. Once the payload is fully assembled, checked out, and fueled (if required), the payload is transported to the HIF for integration with the launch vehicle.

***Launch Control Center (LCC)***

The LCC serves as mission control for Taurus II launches. The LCC supplies command and control capability for the payload and the Taurus II launch vehicle, and houses consoles for Orbital, Range Safety, and Customer personnel.

#### *2.4.1.1. Launch Pad*

The launch pad for Taurus II consists of the minimum equipment required to support launch vehicle erection, fueling, and launch. These fixed assets are limited to a pad consisting of a launch mount with a flame duct & lightning towers, a ramp to the top of the pad, Launch Equipment Vaults (LEVs) to house the launch vehicle and payload EGSE, cabling and fueling trenches, water storage, LOX and RP-1 fueling system and tanks, and $N_2$ and He tank skids. Taurus II pad activities are limited to erection, fueling, final checkout, and launch. These operations are streamlined to take less than 24 hours from roll-out to launch. This responsive launch operations paradigm, patterned after Sea Launch and other Ukrainian and Russian rockets, also minimizes launch pad infrastructure costs.

### 2.4.2. Mobile GSE

The primary mobile GSE that supports Taurus II launch operations include the Transporter Erector/Launcher (TEL) (Figure 2.4.2-1), the mobile Environmental Control System (ECS), lifting slings, and launch vehicle handling GSE.

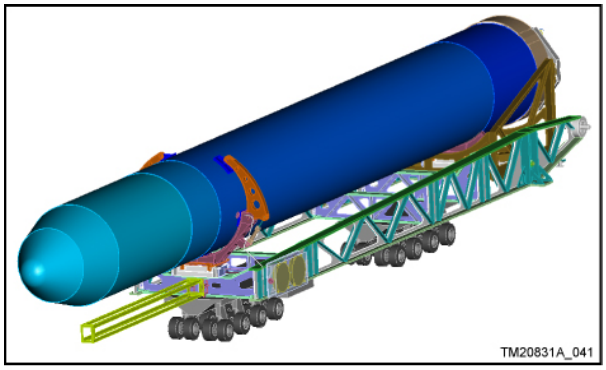



**Figure 2.4.2-1. Taurus II on TEL**

# 3. GENERAL PERFORMANCE

Taurus II can attain a range of posigrade and retrograde inclinations through the choice of launch sites made available by the readily adaptable nature of the Taurus II launch system.

## 3.1. Mission Design

Orbital provides each Taurus II launch service Customer with a mission design optimized to meet critical requirements while satisfying payload, launch vehicle, and Range Safety constraints. Launch site selection, ascent trajectory design, and post-injection deployment design are developed and verified during the Taurus II mission design process.

### 3.1.1. Mission Integration

Mission requirements are detailed in the mission Interface Control Document (ICD) which is developed as part of the payload/launch vehicle mission integration process, detailed in Section 6. The Taurus II Mission Manager works with the Customer to maximize mission success by optimizing requirements parameters to best suit both spacecraft and Taurus II launch vehicle capabilities. Special mission requirements (e.g. argument of perigee, solar exposure, etc.) are addressed on a case-by-case basis. Mission requirements defined in the ICD are used to drive elements of the trajectory design, including maximum dynamic pressure, launch azimuth constraints, free molecular heating at fairing separation, etc. The launch site is selected based on the Customer's orbit inclination requirements.

### 3.1.2. Launch Sites

The Taurus II system is designed to operate from all of the major U.S. launch facilities including Wallops, VA; Kodiak, AK; Cape Canaveral, FL; and Vandenberg, CA. (Figure 3.1.2-1). Launch Range and site selection are tailored to the mission and safety requirements of the Customer.

Initially, Orbital is basing Taurus II launch operations out of the Mid-Atlantic Regional Spaceport (MARS) at the NASA Wallops Flight Facility (WFF) in support of the NASA International Space Station (ISS) resupply missions which are currently on contract. WFF also supports other easterly launch azimuths; and high energy launches can be conducted from WFF with little performance impact.

The Taurus II can also be launched from facilities at Cape Canaveral Air Force Station (CCAFS), FL for easterly launch azimuths not supported by WFF.

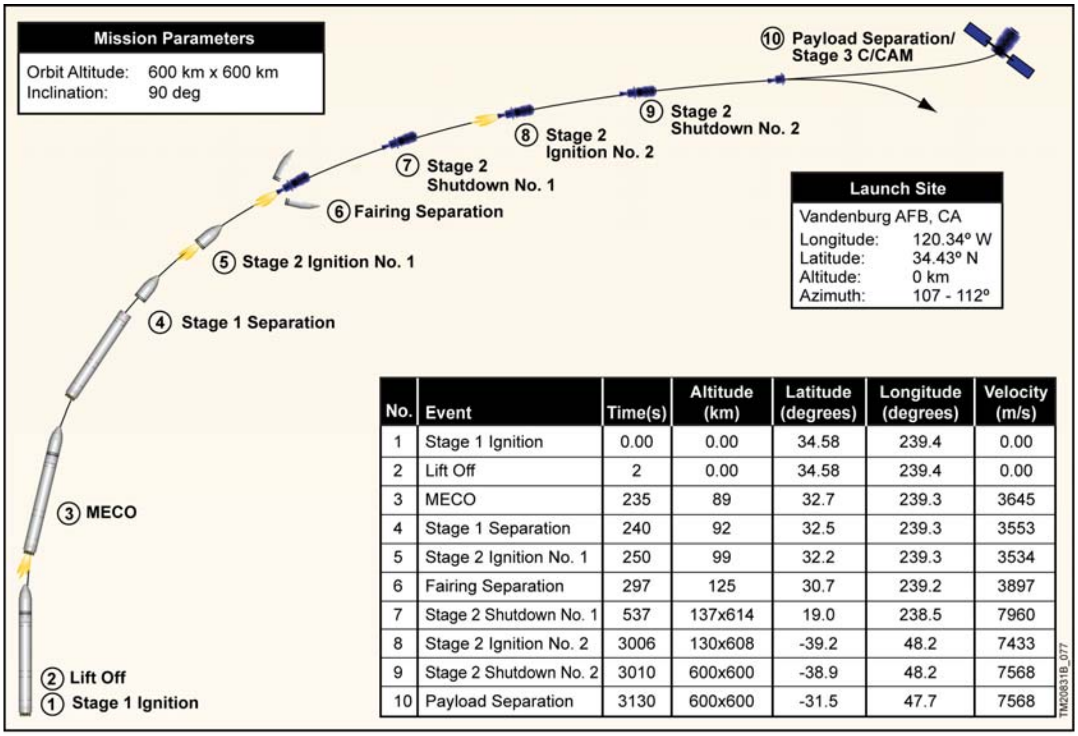
For missions requiring high inclination polar or sun-synchronous orbits, Taurus II launches can be conducted from Vandenberg Air Force Base (VAFB), CA or the Kodiak Launch Complex (KLC), AK. Overall Taurus II is designed to meet Air Force Space Command Manual (AFSPCMAN) 91-710 and Federal Aviation Administration (FAA) ground and flight safety requirements and is compatible with all U.S. Ranges.

## 3.2. Mission Profiles

A typical mission profile from WFF to Low Earth Orbit (LEO) is shown in Figure 3.2-1. The Taurus II lifts off the pad 2 seconds after Stage 1 ignition. Stage 1 burns for 235 seconds, and separates after a brief post-burn coast. The upper stage stack continues to coast for approximately 100 seconds before the fairing is jettisoned. After fairing jettison, Stage 2 is ignited for orbital insertion and circularization of the payload orbit. Stage 2 burnout occurs about 471 seconds into the flight, and the upper stack continues to coast for another 120 seconds before the payload is separated. Once the payload has separated, the Stage 2 performs a Collision/Contamination Avoidance Maneuver (CCAM) to ensure no potential exists for re-contact with the payload.

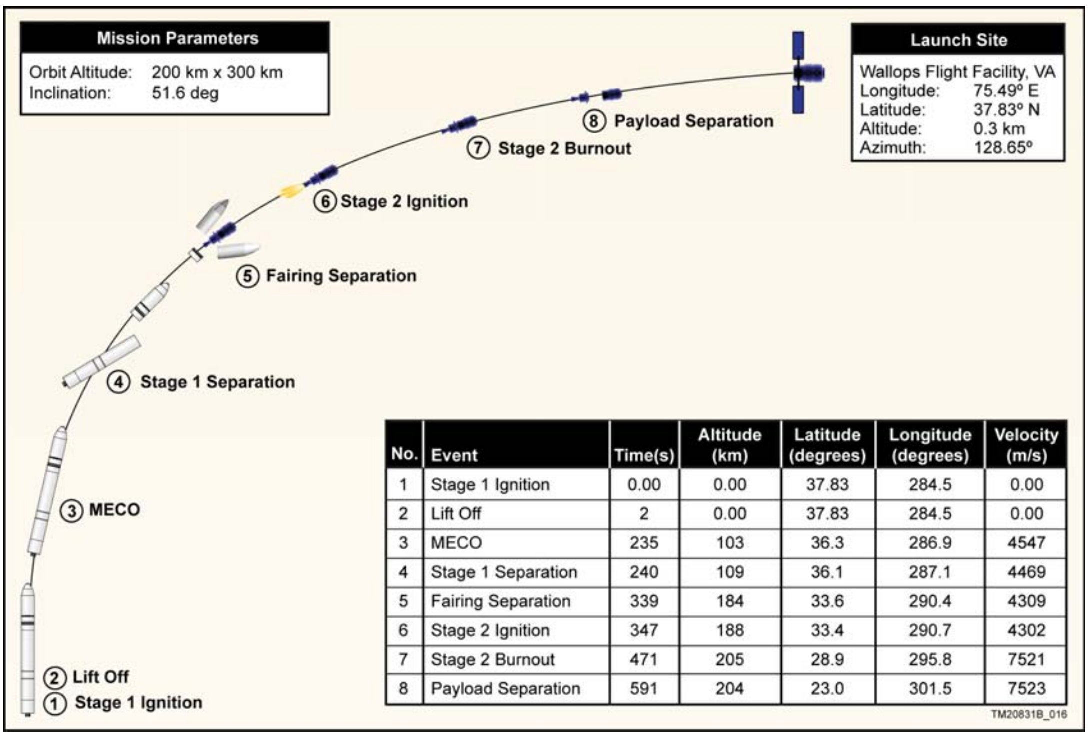

**Figure 3.1.2-1. U.S. Launch Ranges Compatible with Taurus II**

In contrast, a typical mission profile using an Enhanced 2nd Stage Taurus II launched from VAFB to Low Earth Orbit (LEO) is shown in Figure 3.2-2. The Taurus II lifts off the pad 2 seconds after Stage 1 ignition. Stage 1 burns for 235 seconds, and separates after a brief post-burn coast. The second stage ignites after a brief 10 second coast, and then ignites for the first time. The fairing separates 47 seconds into the first Stage 2 engine firing. After fairing jettison, Stage 2 continues to burn and boosts the upper stack to an altitude of approximately 137 km (74 nmi) before it is shut down. The upper stack coasts for 2500 seconds before the second Stage 2 ignition occurs. After a brief second motor firing, the orbit is circularized to its final 600 km (324 nmi) altitude. Payload separation occurs 3130 seconds into the flight. Once payload separation has been confirmed, Stage 2 performs a Collision/Contamination Avoidance Maneuver (CCAM) to ensure no potential exists for re-contact with the payload.




| No. | Event | Time(s) | Altitude (km) | Latitude (degrees) | Longitude (degrees) | Velocity (m/s) |
|---|---|---|---|---|---|---|
| 1 | Stage 1 Ignition | 0.00 | 0.00 | 34.58 | 239.4 | 0.00 |
| 2 | Lift Off | 2 | 0.00 | 34.58 | 239.4 | 0.00 |
| 3 | MECO | 235 | 89 | 32.7 | 239.3 | 3645 |
| 4 | Stage 1 Separation | 240 | 92 | 32.5 | 239.3 | 3553 |
| 5 | Stage 2 Ignition No. 1 | 250 | 99 | 32.2 | 239.3 | 3534 |
| 6 | Fairing Separation | 297 | 125 | 30.7 | 239.2 | 3897 |
| 7 | Stage 2 Shutdown No. 1 | 537 | 137x614 | 19.0 | 238.5 | 7960 |
| 8 | Stage 2 Ignition No. 2 | 3006 | 130x608 | -39.2 | 48.2 | 7433 |
| 9 | Stage 2 Shutdown No. 2 | 3010 | 600x600 | -38.9 | 48.2 | 7568 |
| 10 | Payload Separation | 3130 | 600x600 | -31.5 | 47.7 | 7568 |

**Figure 3.2-2. Taurus II Typical 3-Stage Mission Profile to LEO**




| No. | Event | Time(s) | Altitude (km) | Latitude (degrees) | Longitude (degrees) | Velocity (m/s) |
|---|---|---|---|---|---|---|
| 1 | Stage 1 Ignition | 0.00 | 0.00 | 37.83 | 284.5 | 0.00 |
| 2 | Lift Off | 2 | 0.00 | 37.83 | 284.5 | 0.00 |
| 3 | MECO | 235 | 103 | 36.3 | 286.9 | 4547 |
| 4 | Stage 1 Separation | 240 | 109 | 36.1 | 287.1 | 4469 |
| 5 | Fairing Separation | 339 | 184 | 33.6 | 290.4 | 4309 |
| 6 | Stage 2 Ignition | 347 | 188 | 33.4 | 290.7 | 4302 |
| 7 | Stage 2 Burnout | 471 | 205 | 28.9 | 295.8 | 7521 |
| 8 | Payload Separation | 591 | 204 | 23.0 | 301.5 | 7523 |

**Figure 3.2-1. Taurus II Typical Mission CRS Profile to LEO**

### 3.3. General Performance

Taurus II general performance curves for circular orbits of various altitudes and inclinations from the four primary U.S. launch sites are provided in Figures 3.3-1, 3.3-2, and 3.3-3 for east and west coast launches.

Figure 3.3-4 provides the Earth-escape energy performance for a Taurus II with STAR™ 48 third stage option.

Figure 3.3-5 provides the predicted performance for Taurus II missions with an enhanced second stage.

The Geotransfer orbit (185 km x 35,786 km) performance for a Taurus II with a STAR™ 48 third stage launched from WFF into an inclination of 38 degrees is estimated to be approximately 1,500 kg (3,307 lb). Similarly, when launched to GTO from CCAFS into an inclination of 28.7 degrees, the estimated performance is approximately 1,800 kg (3,970 lb). For Taurus II missions to GTO with an enhanced second stage, the predicted performance for launches from WFF is increased to ~1,900 kg (4,190 lb) and for launches from CCAFS the predicted performance is increased to ~2,200 kg (4,850 lb).

These curves provide the total mass to orbit available to the payload, as the mass of the Orbital-provided separation system has been accounted for in the Taurus II mass properties. The mass of any payload-unique hardware has not been accounted for and should be included in the payload mass allocation.

All performance parameters presented in this Users Guide are typical for most expected payloads. However, performance may vary depending on unique payload or mission characteristics. Specific requirements for a particular mission must be coordinated with Orbital to determine the actual performance.

### 3.4. Injection Accuracy

For a baseline Taurus II with CASTOR® 30A upper stage, typical injection accuracies are 15 km (8 nmi) on the insertion apsis, 80 km (43 nmi) on the non-insertion apsis, and 0.1 degrees in inclination. This varies greatly depending on the orbit energy management scheme used to best meet the customer needs, as well as the satellite mass properties. Using the enhanced second stage will decrease expected injection dispersions to 10 km(5 Nmi) on each apsis and 0.05 degree inclination. Taurus II attitude accuracy is summarized in Table 3.4-1. Increased accuracies are achievable for specific mission characteristics.

### 3.5. Payload Deployment

Following orbit insertion, the Taurus II avionics subsystem executes a series of Attitude Control System (ACS) maneuvers to provide the desired initial payload attitude prior to separation. This capability may also be used to incrementally reorient the upper stage for the deployment of multiple spacecraft with independent attitude requirements. An inertially-fixed or spin-stabilized attitude may be specified by the Customer.

The maximum spin rate for a specific mission depends upon the spin axis moment of inertia of the payload and the amount of ACS propellant needed for other attitude maneuvers. Table 3.4-1 provides typical payload pointing and spin rate accuracies. The actual spin rate will be determined on a mission-specific basis. The Taurus II upper stage assembly will de-spin after payload separation in preparation for the CCAM.

**Table 3.4-1. Typical Pre-Separation Payload Pointing and Spin Rate Accuracies**

| Error Type | | Angle | Rate |
|---|---|---|---|
| 3-Axis | Pitch | ±1.0° | ±0.5 °/sec |
| | Yaw | ±1.0° | ±0.5 °/sec |
| | Roll | ±1.0° | ±0.5 °/sec |
| Spinning | Spin Axis | ±1.0° | ≤10 rpm |
| | Spin Rate | | ±3 °/sec |

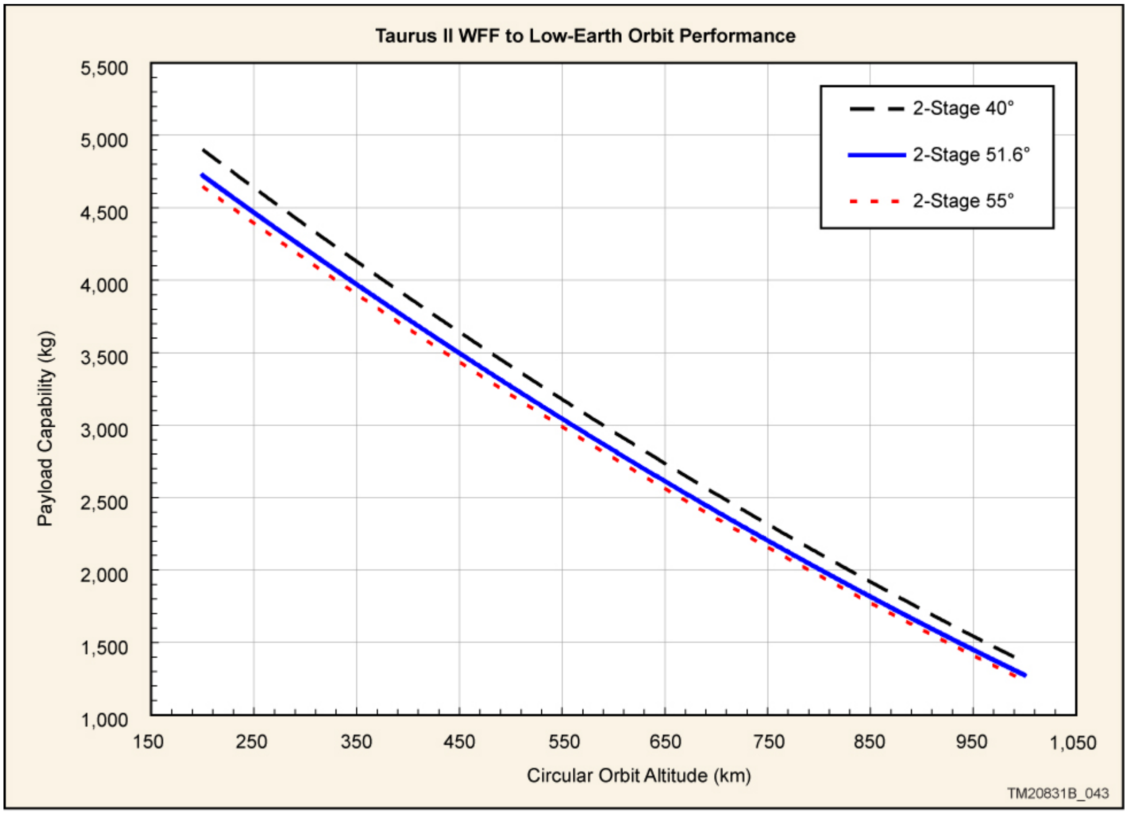



**Figure 3.3-1. Taurus II LEO Performance from WFF**

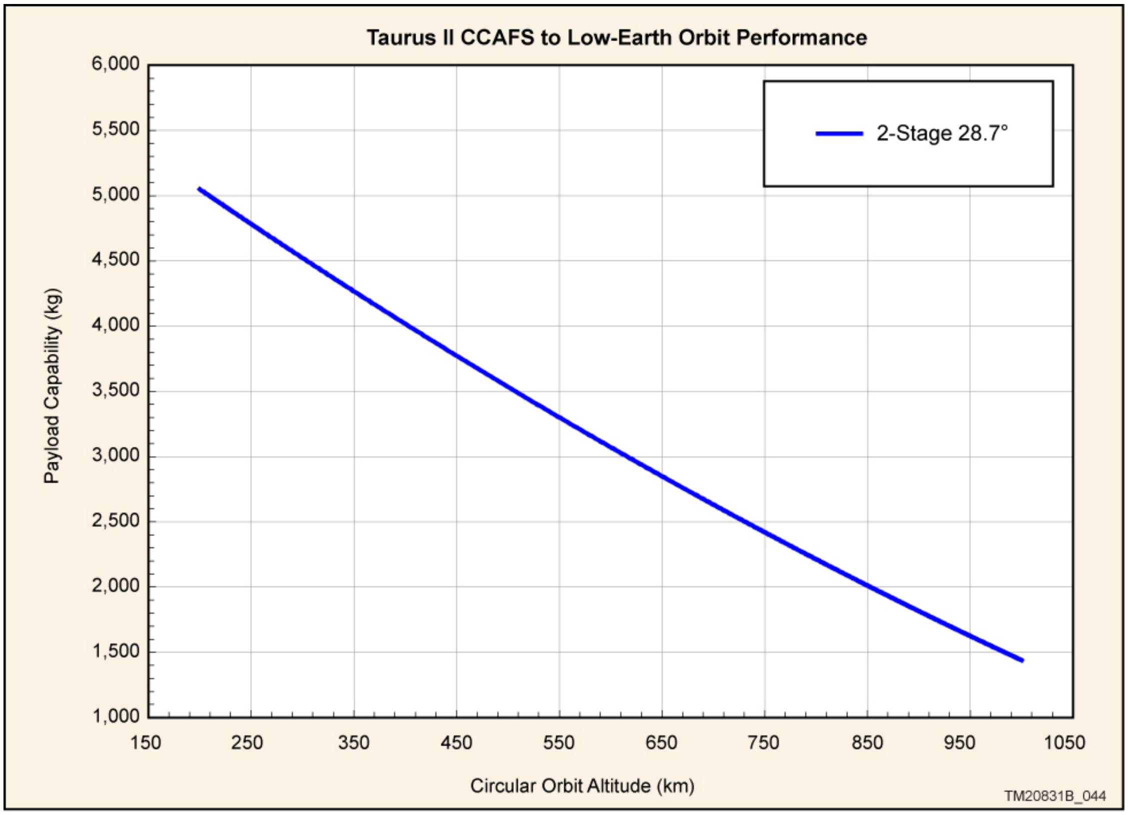



**Figure 3.3-2. Taurus II LEO Performance from CCAFS**

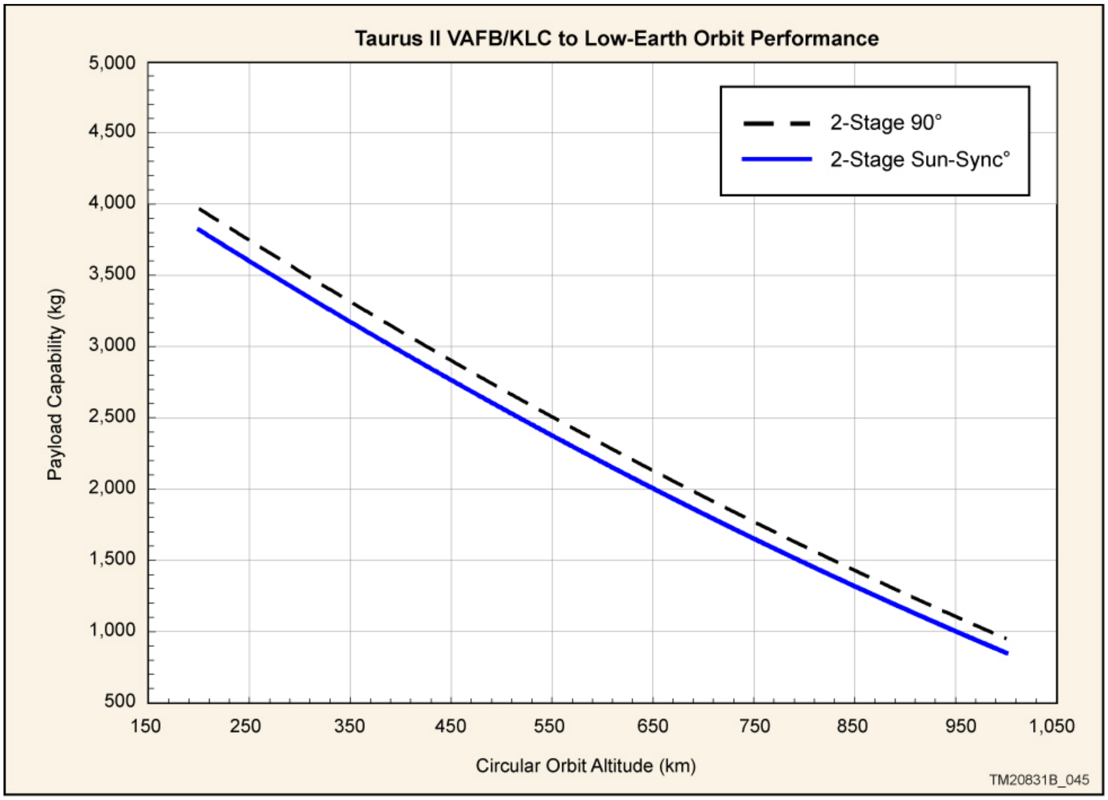



**Figure 3.3-3. Taurus II LEO Performance from VAFB & KLC**

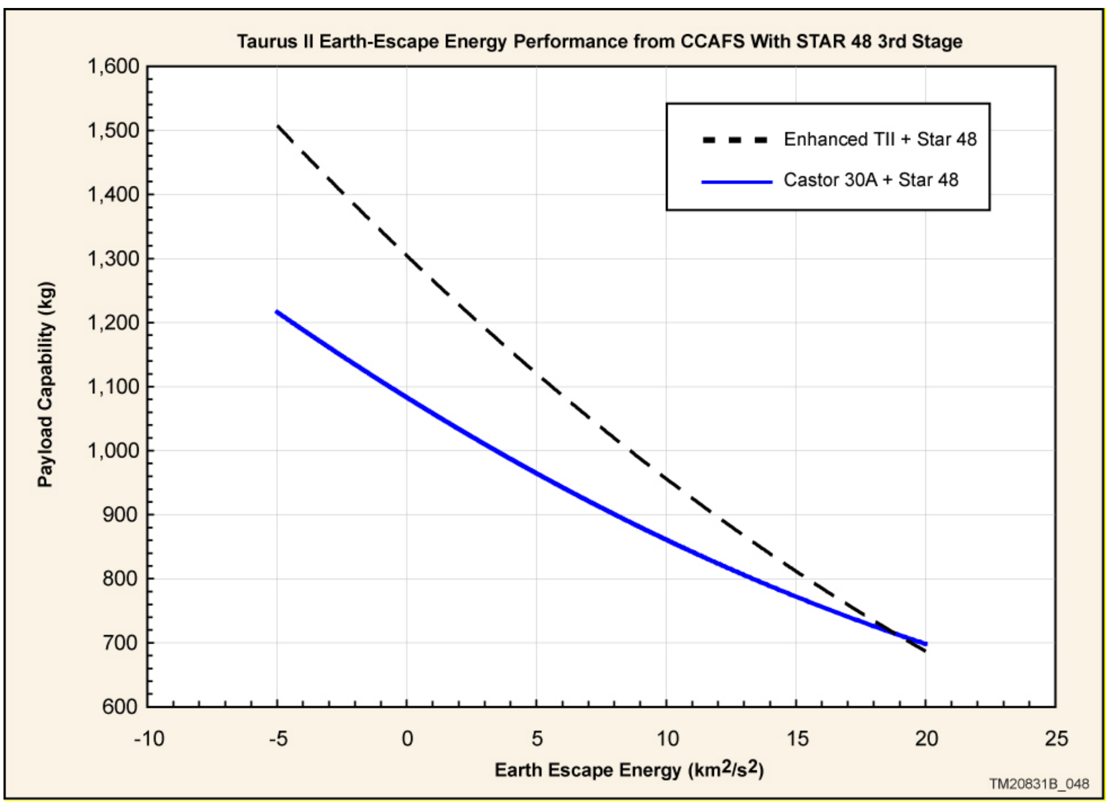



**Figure 3.3-4. Taurus II Earth-Escape Energy Performance**

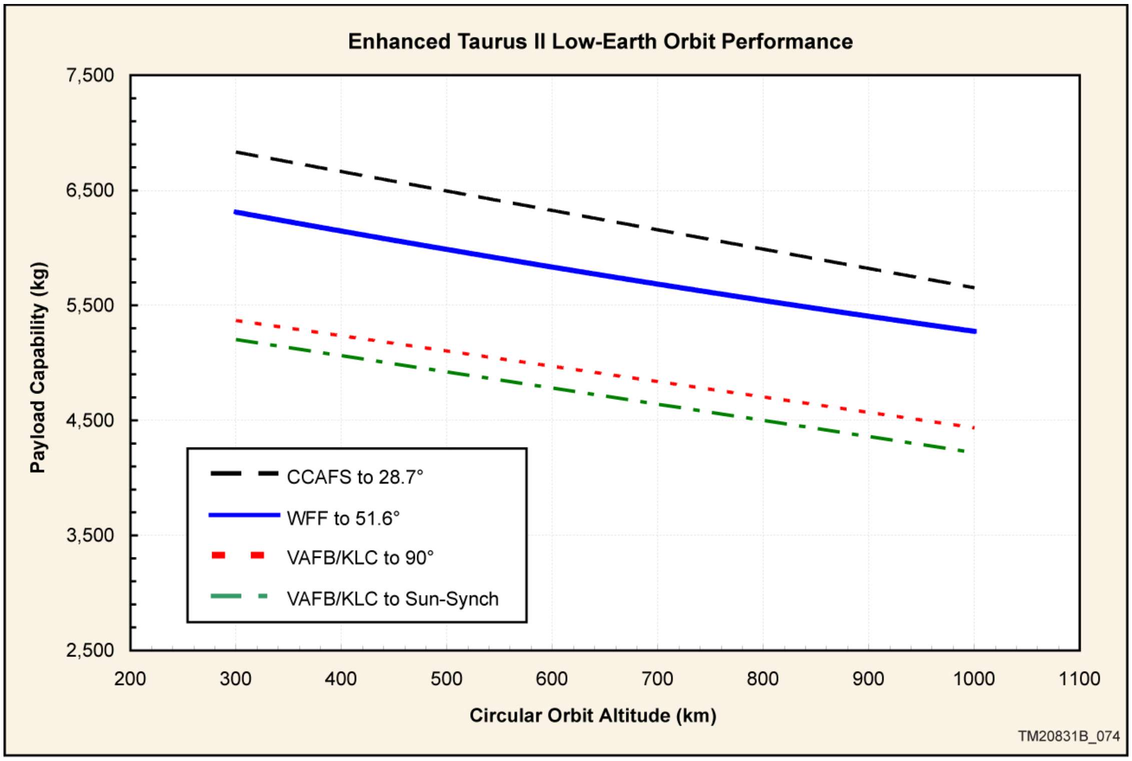



**Figure 3.3-5. Taurus II Enhanced to LEO**

### 3.6. Payload Separation Dynamics

Payload separation dynamics are highly dependent on the mass properties of the payload and the particular separation system utilized. Orbital-provided separation systems are available as a standard service to the Taurus II Customer. The available separation system options are described in Section 5. As part of the standard Taurus II launch service, Orbital performs a mission-specific payload separation tip-off analysis to determine the expected maximum payload attitude rates following separation from the upper stage. Post separation rates are a function of the pre-deployment rates described above, as well the performance of the separation system chosen and payload mass properties.

### 3.7. Collision/Contamination Avoidance Maneuver

Following orbit insertion and payload separation, the Taurus II upper stage performs a Collision/Contamination Avoidance Maneuver (CCAM). The CCAM minimizes both payload contamination and the potential for re-contact between Taurus II hardware and the separated payload. Orbital performs a re-contact analysis for post separation events for every mission.

A typical CCAM begins soon after payload separation. The upper stage performs a 90° yaw maneuver designed to direct any remaining upper stage motor impulse in a direction that increases the separation distance between the two bodies. After a short delay to allow the distance between the spacecraft and the upper stage to increase to a safe level, the upper stage begins a "crab-walk" maneuver to impart a small amount of delta velocity, increasing the separation between the payload and the upper stage of Taurus II.

Following the completion of the CCAM maneuver and any remaining maneuvers, such as downlinking of delayed telemetry data, the upper stage is passivated per best orbital debris practices.

## 4. PAYLOAD ENVIRONMENTS

This section provides details of the predicted environmental conditions that the payload experiences during Taurus II ground operations, powered flight, and post-boost operations. The environmental conditions presented in this section are intended to be representative of a typical mission. Satellite mass, geometry and structural components vary greatly resulting in significant differences from mission to mission. Mission-specific analyses are performed as part of the standard Taurus II launch service, and documented in the mission ICD.

The following environmental design and test criteria are applicable to Taurus II configurations using the standard 3.9 m diameter fairing and the CASTOR® 30A upper stage motor. Taurus II ground operations include payload integration and encapsulation, and final vehicle integration and launch activities. Powered flight begins at Stage 1 ignition and ends at upper stage burnout. Taurus II post-boost operations begin after upper stage burnout and end following post separation maneuvers. To more accurately define simultaneous loading and environmental conditions, the powered flight portion of the mission is further subdivided into smaller time segments bounded by critical flight events such as motor ignition, stage separation, and transonic crossover.

### 4.1. Acceleration Loads

Dynamic loading events that occur throughout various portions of the flight include steady state acceleration, transient low frequency acceleration, acoustic impingement, random vibration, and pyroshock events. During powered flight the maximum steady state accelerations experienced at the payload interface are as shown in Table 4.1-1.

Table 4.1-2 provides the primary dynamic loading events during Taurus II flight. Table 4.1-2 also identifies the time phasing of the Taurus II dynamic loading events, the related environments, and their significance. Pyroshock events are not indicated as they do not occur simultaneously with any other significant dynamic loading events.

**Table 4.1-1. Maximum Acceleration Loads at the Payload Interface**

| | Axial | | Lateral | |
|---|---|---|---|---|
| | Static | Transient | Static | Transient |
| Liftoff | 1.3 | ±0.5 | 0.0 | ±0.5 |
| Transonic | 2.0 | ±0.3 | 0.2 | ±1.0 |
| Stage 1 Maximum | 6.0 | ±0.5 | 0.0 | ±0.5 |
| MECO | 4.8 | ±0.3 | 0.0 | ±0.5 |
| | 0.0 | -1.5 / +3.0 | | |
| S2 Ignition | 0.0 | -1.0 / +2.0 | 0.0 | ±0.3 |
| | 1.2 | ±0.2 | | |
| Stage 2 Maximum | 3.7 | ±0.1 | 0.0 | ±0.3 |

During upper stage burnout, and prior to staging, the transient loads are relatively benign. Additional transient loads occur at both the Main Engine Cut-Off (MECO) and Stage 2 ignition events. The load factors are subject to change based on the Coupled Loads Analysis (CLA) results for each spacecraft.

**Table 4.1-2. Phasing of Dynamic Loading Events**

| Item | Liftoff | Transonic | Supersonic/ Max Q | S2 Ignition | S2 Burnout |
|---|---|---|---|---|---|
| Typical Flight Time | 2 sec | 79 sec | 90 sec | 347 sec | 471 sec |
| Steady State Loads | Yes | Yes | Yes | No | Yes |
| Transient Loads | Yes | Yes | Yes | Yes | No |
| Acoustics | Yes | Yes | Yes | No | No |
| Random Vibration | Yes | Yes | Yes | No | No |

As dynamic response is largely governed by payload characteristics, a mission-specific CLA is performed, with Customer-provided finite element models of the payload. Flight events analyzed by the CLA include liftoff, the transonic portion of flight, supersonic flight, maximum dynamic pressure (Max Q), Main Engine Cut-Off (MECO), and Stage 2 ignition. Results will be referenced in the mission-specific ICD.

It is standard for up to three (3) CLAs to be performed for each mission. Preliminary and interim CLAs are based on the analytical payload models. The final CLA is based on the updated test-verified payload model. Additional CLAs can be performed as an optional service. For preliminary design purposes, Orbital can provide initial Center of Gravity (CG) net loads given a payload's mass properties, CG location and bending frequencies.

## 4.2. Payload Vibration Environment

The Taurus II in-flight random vibration curve shown in Table 4.2-1 encompasses vibration environments seen at the payload interface, which are well below Military Standard (MIL-STD)-1540 minimum specified levels.

**Table 4.2-1. Payload Interface Sine Vibration**

| Direction | Frequency Range (Hz) | Peak Acceleration (g) |
|---|---|---|
| Axial | 10 – 20 Hz | 1.2 |
| Axial | 30 – 100 Hz | 0.5 |
| Lateral | 5 – 22 Hz | 0.3 |
| Lateral | 22 – 32 Hz | 0.4 |
| Lateral | 32 – 100 Hz | 0.3 |

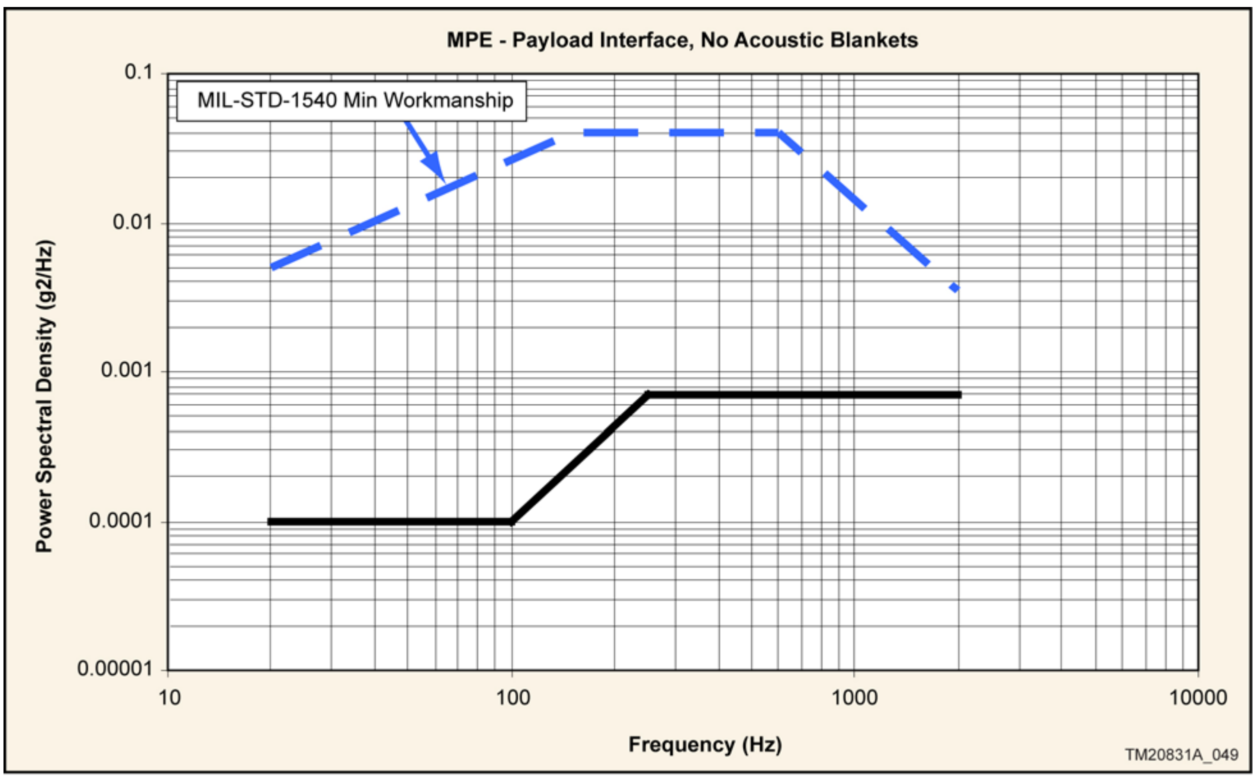



**Figure 4.2-1. Taurus II In-Flight Random Vibration at the Payload Interface**

### 4.3. Payload Shock Environment

The maximum shock response spectrum at the base of the payload from all launch vehicle events will not exceed the flight limit levels provided in Figure 4.3-1. This curve also represents the shock response spectrum at the base of the payload adapter for missions that do not separate the payload. For missions that utilize an Orbital-provided RUAG separation system, the maximum shock response spectrum at the base of the payload interface is provided in Figure 4.3-2.

If a payload-provided separation system is used, the shock delivered to the Stage 2 vehicle avionics cylinder must not exceed the limit level characterized in Figure 4.3-1 after transition through whatever payload attach fitting and joints are between the shock source and the avionics cylinder.. Shock above this level could require requalification of components or an acceptance of increased shock risk by the Customer.

### 4.4. Payload Acoustic Environment

The maximum expected acoustic levels that a payload should experience within the 3.94 m (155 in.) Taurus II fairing are illustrated in Figure 4.4-1. The acoustic levels shown in Figure 4.4-1 are with melamine acoustic blankets with an approximately 60% fill factor.

### 4.5. Thermal Environments

This section will define the thermal environments during payload processing and pad operations on the ground, as well as the thermal environment during powered flight.

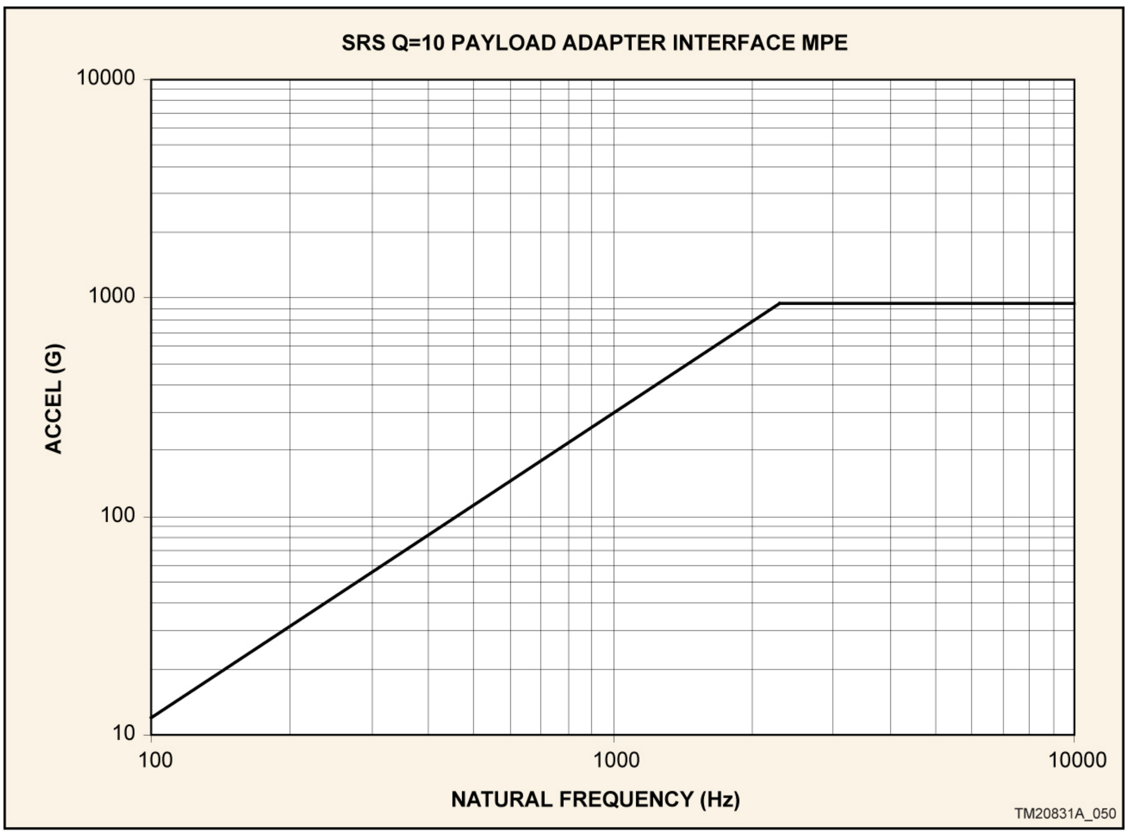



**Figure 4.3-1. Payload Interface Shock Response (Non-Separating)**

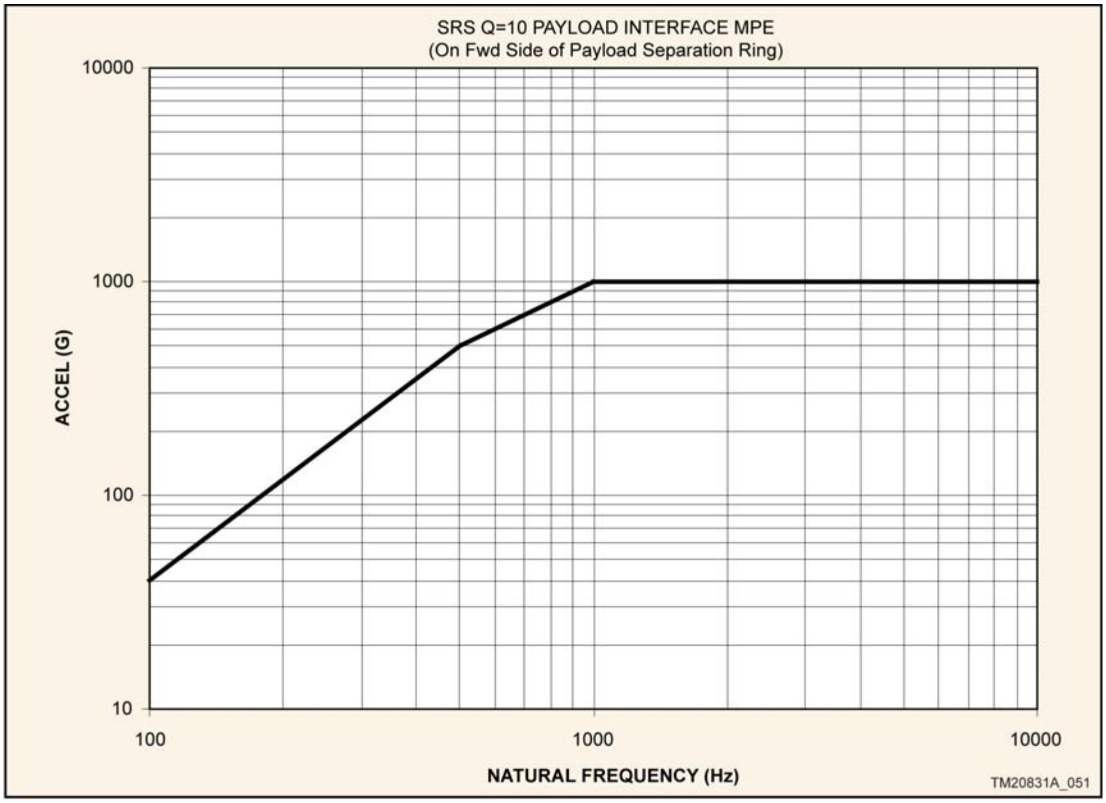



**Figure 4.3-2. Payload Interface Shock Response (Separating)**

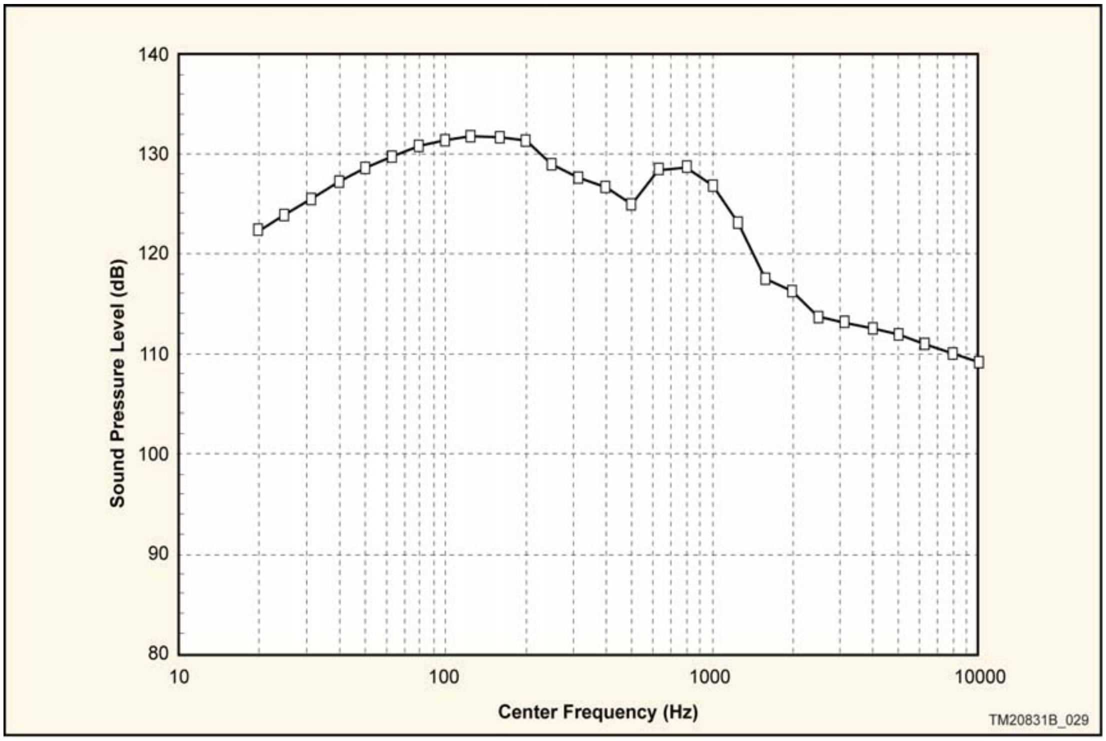



**Figure 4.4-1. Payload Fairing Internal Acoustic Flight Limit Levels**

#### 4.5.1. Ground Operations Environments

The Payload Ground Operations Environments are summarized in Table 4.5.1-1.
Prior to encapsulation, payload thermal and humidity environments will be maintained by the HIF facility Environmental Control System (ECS).

Once encapsulated payload thermal and humidity environment will be maintained by a self-contained mobile ECS, until pad ECS is connected.

After transport from the HIF to launch pad and before vehicle erection operations begin, pad ECS is connected to the fairing to maintain the payload environment until launch. The ECS duct remains attached to the fairing until launch commences. In the event of a launch abort, conditioned air continues to flow to the fairing.

Conditioned air enters the fairing at the forward cylinder section and is distributed via a diffuser/deflector along the acoustic blanket wall, to protect against any impingement velocities on the payload envelope. The conditioned air exits the fairing via vents located at the aft of the payload fairing.

Fairing inlet conditions are selected by the Customer, and are bounded as follows:

- Dry Bulb Temperature: controllable to ±3 °C (±5 °F) of setpoint
- Dew Point Temperature: 7 to 29 °C (45 to 84 °F)
- Relative Humidity: 10 to 60% determined by drybulb and dewpoint temperature selections and generally controlled to within ±15%. (Relative humidity is bound by the psychrometric chart and will be controlled such that the dew point within the fairing is never reached.)
- Max Flow: 31 to 62 scmm (1100 to 2200 scfm)
- Purity Class: 100K (ISO 8) standard

Orbital performs a thermal analysis to determine the required conditions to maintain payload environments within limits defined in the mission ICD. The analysis also determines the necessary temperature and humidity to ensure payload thermal environments are maintained.

***ECS OPTIONS:***

$GN_2$ can be provided to localized regions in the fairing as a non-standard service during ground operations up to T-0. This option are discussed in more detail in Section 8.

#### 4.5.2. Powered Flight Environments

The thermal environment of the spacecraft while encapsulated is influenced by the fairing internal temperatures prior to fairing separation. After fairing separation, the thermal environment of the spacecraft is influenced by the second stage motor temperatures and on-orbit environments prior to spacecraft separation.

##### 4.5.2.1. Payload Fairing

The ascent thermal environments of the internal fairing surfaces facing the payload are predicted histories based on correlations from Taurus II preliminary integrated thermal analyses. Temperatures are provided for all surfaces in view of the payload, as shown in Figure 4.5.2-1. Also provided are surface emissivity values for all surfaces. All temperature histories presented are based on a worst-case trajectory, ignoring expansion cooling effects of ascent. The acoustic blankets provide a relatively cool radiation environment by effectively shielding the spacecraft from ascent heating in blanketed areas.

### 4.5.2.2. Transfer Orbit Thermal Environment

The launch vehicle can be oriented to meet specific sun angle requirements, during non-powered flight of the Taurus II upper stages. A slow roll broadside to sun is used during a long coast period by the Taurus II vehicle to moderate orbital heating and cooling. The roll rate for thermal control is typically between 1 and 3 deg/sec.

**Table 4.5.1-1. Payload Ground Operations Environments**

| Event | Temp Range | | Control | Humidity (%) | Purity Class (Note 2) |
|---|---|---|---|---|---|
| | Deg C | Deg F | | | |
| Pre-payload Fairing Installation in HIF | 23 ±7 | 73 ±12 | AC | 35 to 75% | 100K (ISO 8) |
| Post-Payload Fairing Installation (measured at Fairing Inlet) | 7 – 29 ±3 | 45 – 84 ±5 | Filtered AC | 10 to 60% | 100K (ISO 8) |
| PAD Operations through T-0 | PLF Inlet | 45 – 84 ±5 | Filtered AC | (Note 1) | 100K (ISO 8) |

Notes:
1. Humidity levels may be lower than 30% depending on ambient conditions.
2. Class 10K (ISO 7) can be provided inside the fairing as a non-standard service.

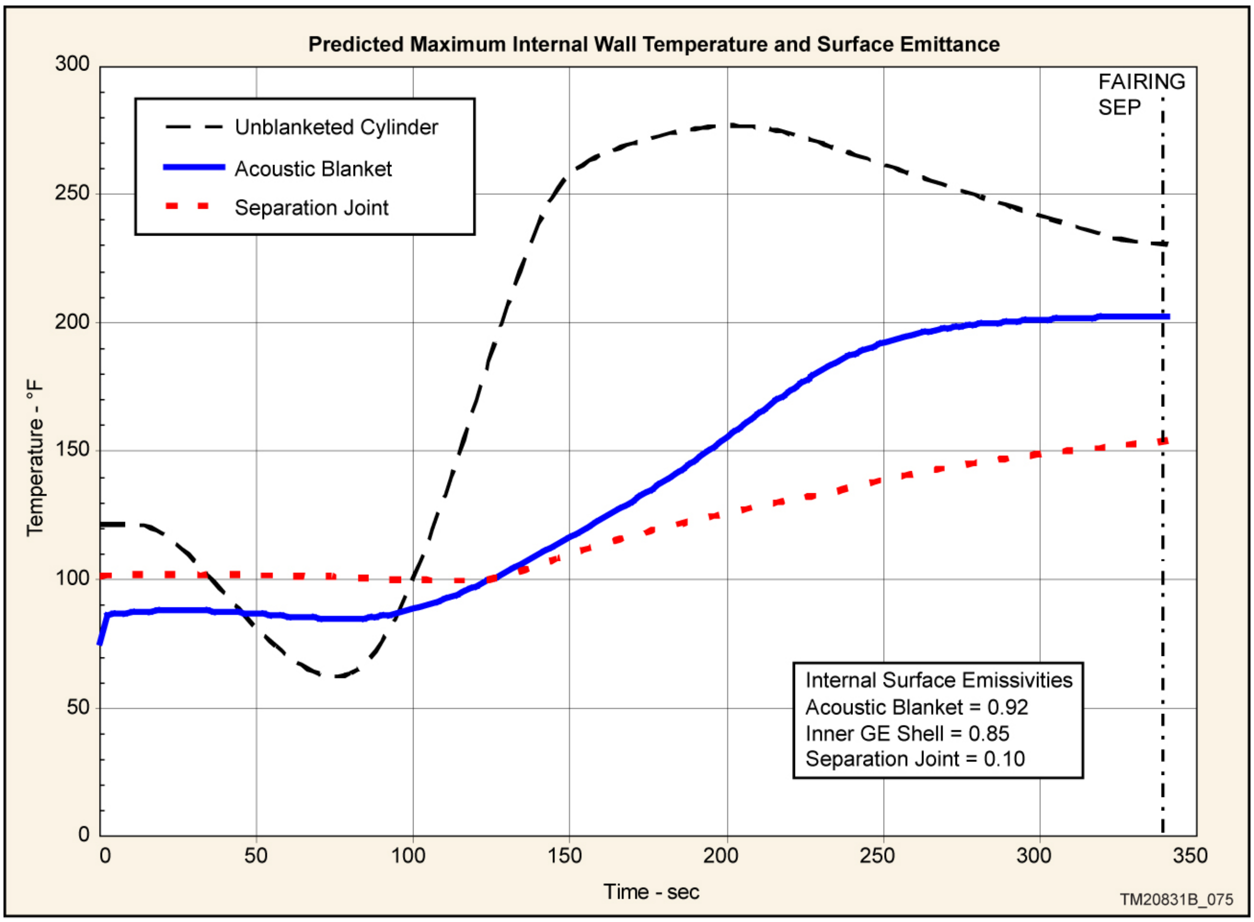



**Figure 4.5.2-1. Taurus II Worst-Case Fairing Inner Surface Temperatures During Ascent**

#### 4.5.2.3. Stage 2 Induced Thermal Environments

The maximum Stage 2 motor surface temperature exposed to the payload will not exceed 93.3 °C (200 °F), between the aft end of the payload and the forward dome of the motor assembly.

#### 4.5.2.4. Payload to Launch Vehicle Interface Temperatures

The Customer is required to provide interface geometry, thermal properties, and temperatures for the injection period assuming an adiabatic interface. Orbital will provide launch vehicle interface temperatures based on payload interface and mission-specific analysis using sun angle data.

A launch vehicle/payload integrated thermal analysis can be performed at the Customer's request as a non-standard service. This analysis would be performed for the payload's required orbit conditions. Integrated thermal analysis of worst case ground operations can also be performed as a non-standard service. In order for Orbital to perform an integrated thermal analysis, a simplified Thermal Desktop model of the payload would be required from the Customer, along with the appropriate power dissipations timelines and allowable component temperatures.

## 4.6. Contamination Control

Orbital's Taurus II contamination control program is designed to minimize the payload's exposure to contamination from the time the payload arrives at the payload processing facility through orbit insertion and separation. Orbital's Taurus II contamination control program is based on industry standard contamination reference documents, including the following:

- ISO 14644, "Cleanrooms and Associated Controlled Environments"
- IEST-STD-CC1246D, "Product Cleanliness Levels and Contamination Control Program"
- FED-STD-209E, "Airborne Particulate Cleanliness Classes in Clean Rooms/Zones"

As provided in Table 4.5.1-1, the HIF is maintained as a visibly clean, temperature and humidity controlled work area at all times. During all payload integration procedures in the HIF the payload is maintained in a Class 100,000 (ISO Class 8) or better cleanliness environment at all times.

During all encapsulated payload operations (e.g.; transportation and pad operations) the payload is maintained in a Class 100,000 (ISO Class 8) or better cleanliness environment at all times.

Orbital also ensures that materials selected for Taurus II hardware that interfaces to or is in proximity with payload hardware will not become a source of contamination for the spacecraft. Materials that are known to chip, flake, or peel are prohibited, as are cadmium-plated, zinc-plated, or materials made of unfused electrodeposited tin. Corrosion resistant materials are selected wherever practical, and dissimilar materials are avoided or protected according to MIL-STD-889B. Non-metallic materials are evaluated for outgassing properties against criteria developed from the NASA SP-R-022. Taurus II assemblies that may affect cleanliness within the encapsulated payload volume include the fairing, fairing adapter, the payload interface assembly, and the Stage 2 motor, cone, and avionics. These assemblies are cleaned such that there is no particulate or non-particulate matter visible to the normal unaided eye (i.e.; "visibly clean") when inspected from 0.15 to 0.46 m (6 to 18 inches) under 1076 lx (100 ft-candle) incident light.

Orbital ensures that launch vehicle materials within the encapsulated volume have outgassing characteristics of less than 1.0% TML and less than 0.1% Collected Volatile Condensable Materials (CVCM). Items that don't meet these levels will be masked to ensure they are encapsulated and have no significant effect on the payload.

In addition to Orbital's standard contamination control practices, the Customer can also select additional levels of enhanced contamination control as a non-standard service. (See Section 8.)

### 4.7. Payload Electromagnetic Environment

The Taurus II payload Electromagnetic Environment (EME) results from two categories of emitters:

1. Taurus II onboard antennas; and,
2. Range transmitters.

Table 4.7-1 provides a list of the emitters and receivers, as well as the frequencies and maximum radiated signal levels from all launch vehicle and Range antennas located near the payload during ground operations and powered flight.

Antennas located inside the fairing, including payload antennas, must remain inactive until after fairing deployment. All power, control and signal lines inside the payload fairing are shielded and properly terminated to minimize the potential for Electromagnetic Interference (EMI). The Taurus II payload fairing is relatively Radio Frequency (RF) opaque, which shields the payload from most external RF signals while the payload is encapsulated. Analysis details are provided upon request.

The specific EME experienced by the payload during ground processing at the HIF and the launch site depends on the specific facilities utilized as well as operational considerations of the launch site.

Field strengths experienced by the payload during ground processing once the fairing is in place are controlled procedurally and are less than 10 V/m from continuous sources and less than 20 V/m from pulse sources. Range transmitters are controlled to provide field strengths of 10 V/m or less. This EME should be compared to the payload's RF susceptibility levels (MIL-STD-461, RS03) to define margin.

**Table 4.7-1. Taurus II Launch Vehicle RF Emitters and Receivers**

| | SOURCE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **FUNCTION** | Flight Termination | Telemetry | Telemetry | Video Telemetry * | Telemetry | Range Tracking | Range Tracking | GPS |
| Receive/ Transmit | Receive | Transmit | Transmit | Transmit | Transmit | Receive | Transmit | Receive |
| Location | Stage 2 | Stage 1 | Stage 2 | Stage 2 | Stage 2 | Stage 2 | Stage 2 | Stage 2 |
| Operational Frequency Band | UHF (400 - 450 MHz) | S-Band (2.2 - 2.3 GHz) | S-Band (2.2 - 2.3 GHz) | S-Band (2.2 - 2.3 GHz) | S-Band (2.2 - 2.3 GHz) | C-Band (5.4 - 5.9 GHz) | C-Band (5.4 - 5.9 GHz) | L-Band (1565 - 1586 MHz) |
| Specific Bandwidth | 421 MHz ±45 KHz | 2288.5 MHz ±1.78 MHz | 2269.5 MHz ±1.78 MHz | 2225.5 MHz ±2.5 MHz | 2241.5 MHz ±1.78 MHz | 5690 MHz ±7.0 MHz | 5690 MHz ±7.0 MHz | 1575.42 MHz ±10.23 MHz |
| Power Output | - | 10 W | 10 W | 10 W | 10 W | - | 400 W (Peak) | - |
| Sensitivity | -107 dBm | - | - | - | - | -70 dBm | - | -90 to -134 dBm |
| Modulation | IRIG Tones | PCM/FM | PCM/FM | PCM/FM | PCM/FM | ASK | ASK | CDMA |
| Field Strength @ P/L Interfaces | - | 135.8 dB$\mu$ V/m | 135.8 dB$\mu$ V/m | 140.4 dB$\mu$ V/m | 111.6 dB$\mu$V/m | - | 153.5 dB$\mu$ V/m | - |

*NOTE: Video Telemetry (Rocket Cam) is an optional service.

### 4.8. Fairing Venting

The fairing peak vent rate is less than 4.14 kPa (0.6 psi/sec). Fairing deployment is initiated at a time in flight that the maximum dynamic pressure is less than 0.045 N (0.01 psf).

# 5. PAYLOAD INTERFACES

This section describes the available mechanical, electrical and LSE interfaces between the Taurus II launch vehicle and the payload.

## 5.1. Payload Mechanical Interfaces

As part of the Taurus II launch service, Orbital will provide all the hardware and integration services necessary to attach the payload to and separate the payload from the Taurus II launch vehicle.

### 5.1.1. 3.9 Meter Fairing

The standard Taurus II fairing is a 3.94 m (155 in.) diameter structure consisting of two graphite composite halves and a separation system. The fairing structure incorporates an aluminum honeycomb core covered by layers of graphic epoxy composite. This composite metal matrix provides a significant level of RF attenuation for the spacecraft during periods of encapsulated processing. Each composite half is composed of a cylinder and a bi-conic section. The two halves are held together with a frangible rail joint, while the base of the fairing is attached to Stage 2 using a ring-shaped frangible joint. The ordnance system employs a clean-separation frangible joint with a confined sealed stainless steel tube that fractures notched aluminum extrusions on the rails and ring. Similar fairing frangible joints are currently used on Pegasus, Taurus and Minotaur vehicles. Severing the rail/ring frangible joints allows each half of the fairing to then rotate on hinges mounted on the Stage 2 fairing cylinder. A contained cold gas generation system, based on a heritage flight proven design previously used on Minotaur is used to drive pistons that force the fairing halves open. All fairing deployment systems are non-contaminating.

### 5.1.2. Payload Static Design Envelope

The payload design envelope for the Taurus II fairing provides adequate static and dynamic clearances to the spacecraft assembly during ground operations and ascent.

Three static design envelopes have been currently defined for Taurus II payloads: the 1575 non-separating mechanical interface and the RUAG 1666 and 2624 separation systems. Details of these static envelopes are provided in Figure 5.1.2-1 for the 1575 interface, Figure 5.1.2-2 for the 1666 separation system, and Figure 5.1.2-3 for the 2624 separation system. These static design envelopes account for fairing and vehicle structural volumes only. Vertices for payload deflections must be provided with the Finite Element Model to evaluate payload dynamic deflections with the Coupled Loads Analysis (CLA). Since Orbital has accounted for deflections of the interface plane, the payload Customer should assume that the interface plane is rigid. The Customer must take into account deflections due to spacecraft design and manufacturing tolerance stack-up within the static envelope. Proposed payload static envelope violations must be approved by the Taurus II program and documented in the mission ICD and the Mechanical Interface Control Drawing (MICD). The CLA provides final verification that the payload does not violate the dynamic envelopes.

### 5.1.3. 1575 Payload Mechanical Interface

The Taurus II employs a non-separating payload mechanical interface that accommodates a variety of industry standard payload separation systems. The 1575 mm (62.01 in.) diameter circular bolted interface, shown in Figure 5.1.3-1, is common with EELV class payloads. This standardized mechanical interface accommodates both non-separating payloads, as well as a variety of Orbital-provided separation systems. The Taurus II mechanical interface also supports Customer-provided adapters and separation systems.

The 1575 mm (62.01 in.) diameter payload mounting surface provides a butt joint interface with 121 holes designed to accommodate Society of Automobile Engineers (SAE) ¼ inch fasteners. The 1575 mechanical interface is designed to handle payloads up to 6000 kg (13,228 lb) which have a CG up to 2.0 m (79 in.) above the interface flange.

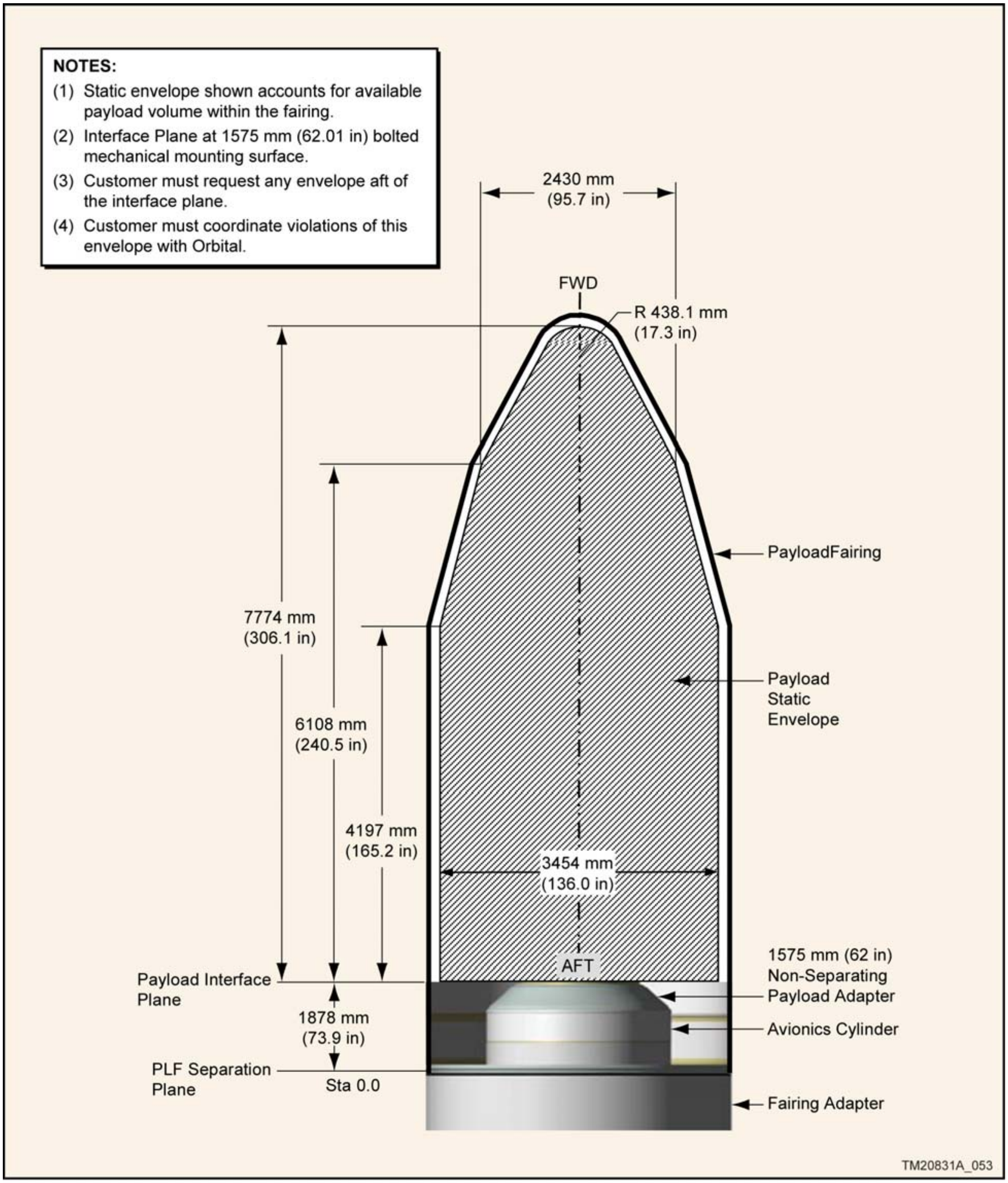



**Figure 5.1.2-1. Non-Separating 1575 Mechanical Interface Payload Static Design Envelope**

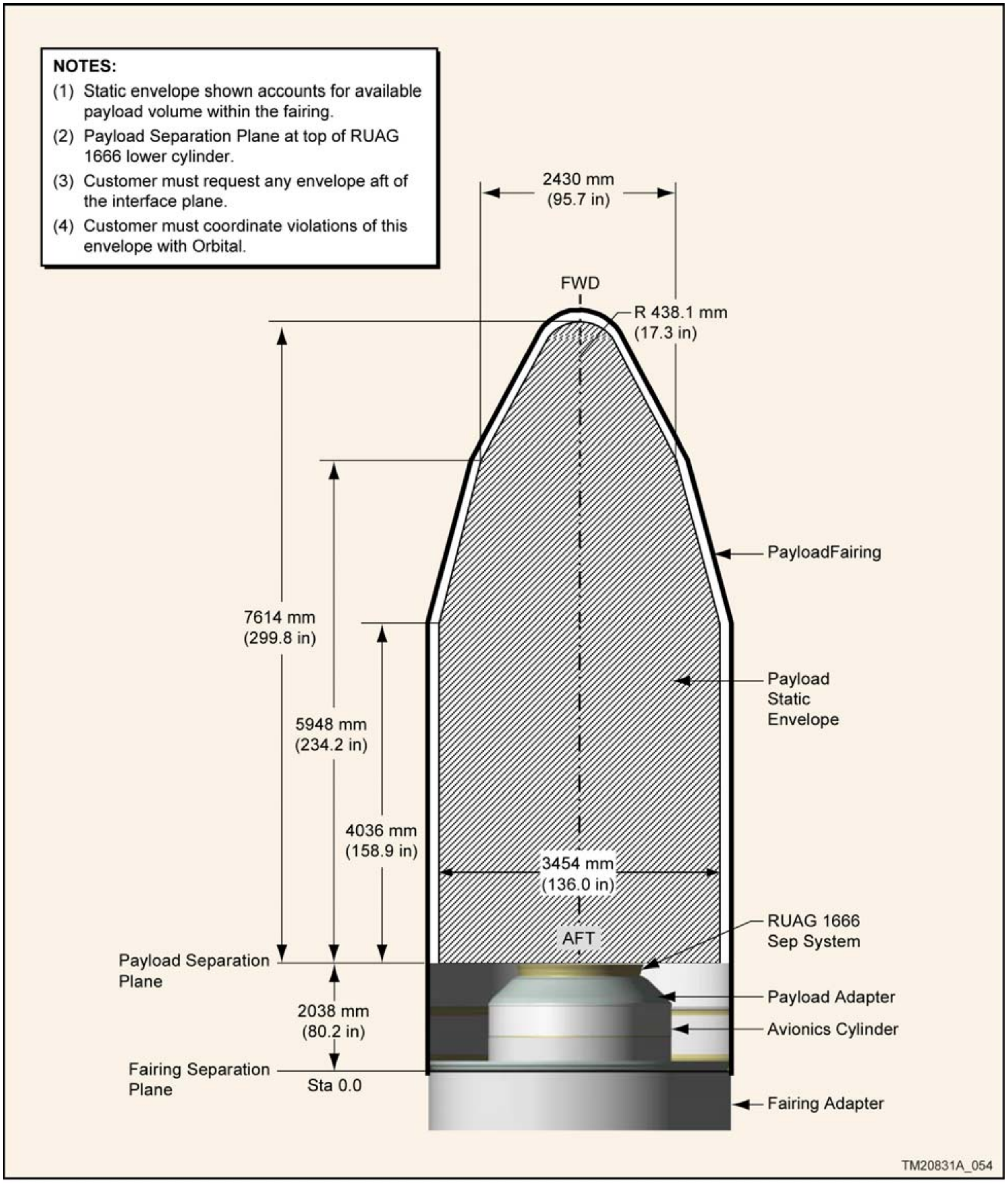



**Figure 5.1.2-2. 1666 Separation System Payload Static Design Envelope**

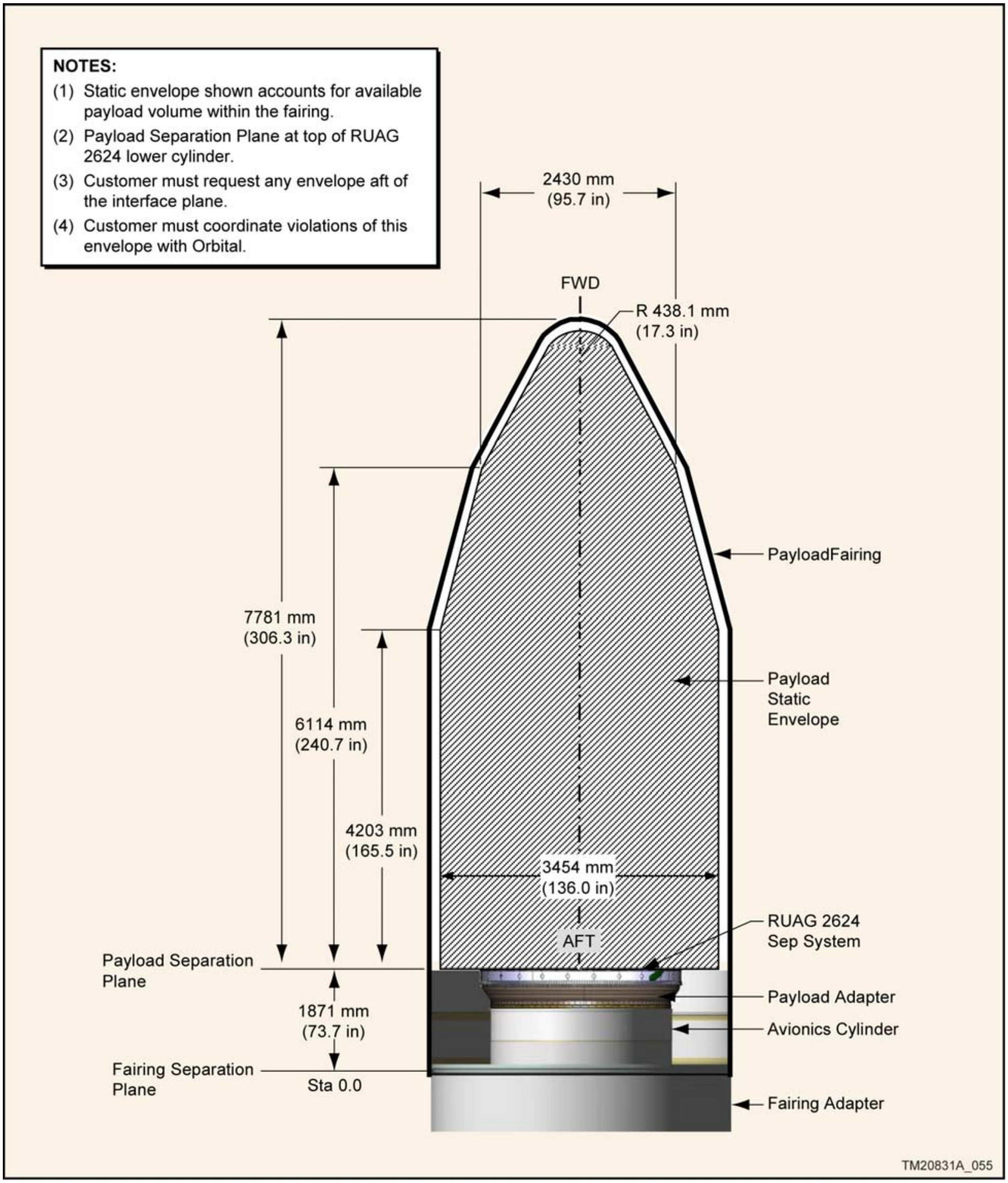



**Figure 5.1.2-3. 2624 Separation System Payload Static Design Envelope**

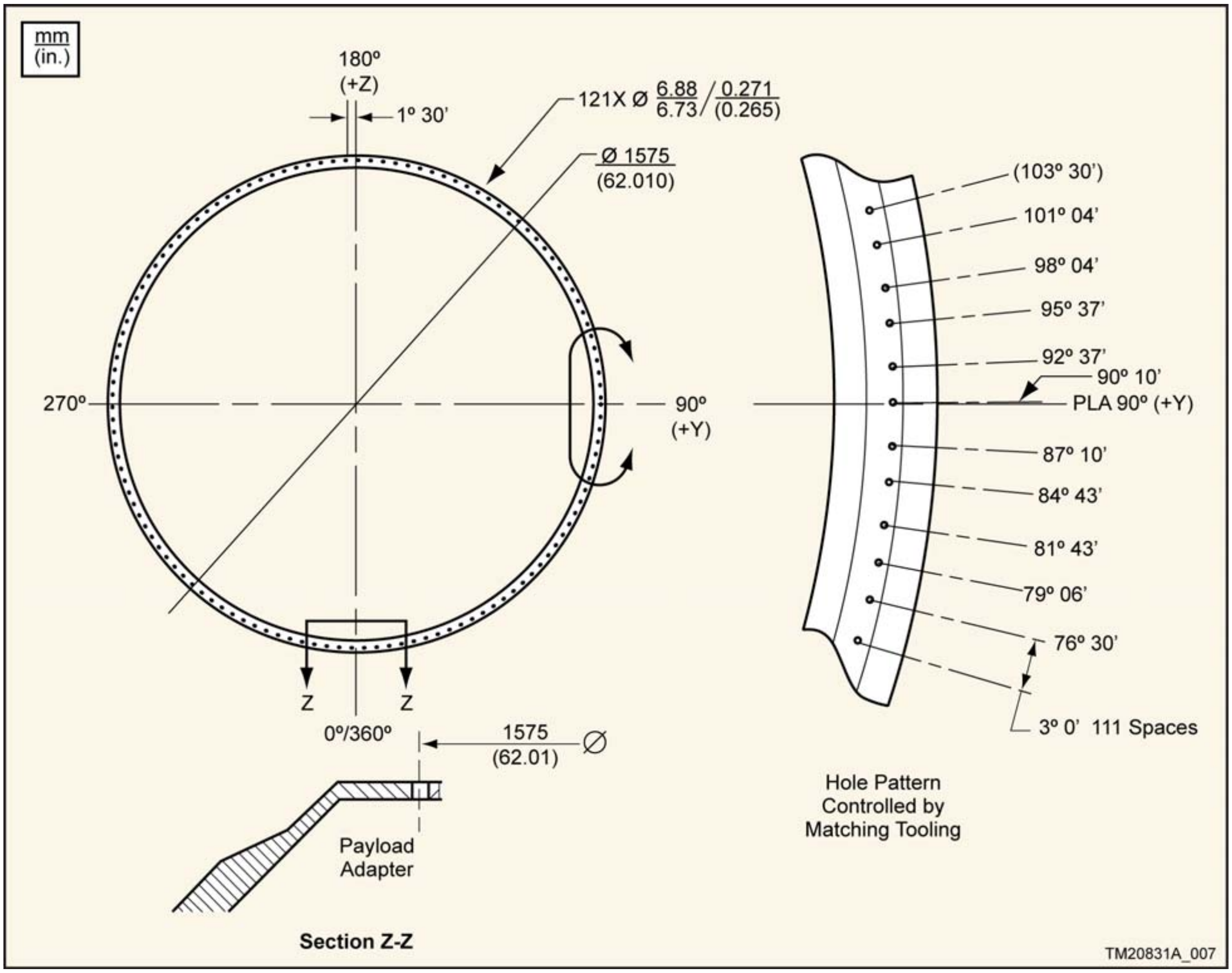



**Figure 5.1.3-1. Standardized 1575 mm (62 in.) Non-Separating Payload Mechanical Interface**

### 5.1.4. Orbital Provided Separation Systems

As part of the Taurus II launch service, Orbital provides the hardware and integration services to attach the payload to and separate the payload from the Taurus II launch vehicle.

Orbital-provided separation systems include the industry standard RUAG 937, 1194, 1666, and 2624 low shock clamp band mechanisms. One of these separation systems is provided as part of the Taurus II standard launch service. The RUAG 1666 and 2624 separation systems are illustrated for reference in Figures 5.1.4-1 and 5.1.4-2 respectively. Additional details of these separation systems can be provided by Orbital upon request, or obtained directly from the supplier, RUAG Aerospace Sweden AB.

Customers may choose one of the Orbital-provided separation systems that best fit their payload requirements, or provide an alternate solution. The payload separation system is defined and controlled in the mission ICD and Mechanical Interface Control Drawing (MICD).

### 5.1.5. Payload Provided Separation Systems

For Customers that provide their own adapter and/or separation system, the top surface of the 1575 mm (62.01 in.) diameter mechanical ring shown in Figure 5.1.3-1 is the interface point between the Customer-provided hardware and the launch vehicle.

If a Customer-provided spacecraft adapter and/or separation system is used, the maximum shock delivered to the Taurus II avionic cylinder must not exceed the limit level characterized in Figure 4.3-1. Shock above this level could require requalification of components or an acceptance of increased shock risk by the Customer. Additionally, interfaces for ground handling, encapsulation and transportation equipment must also be provided for non-standard separation systems, or must conform to existing Taurus II GSE.

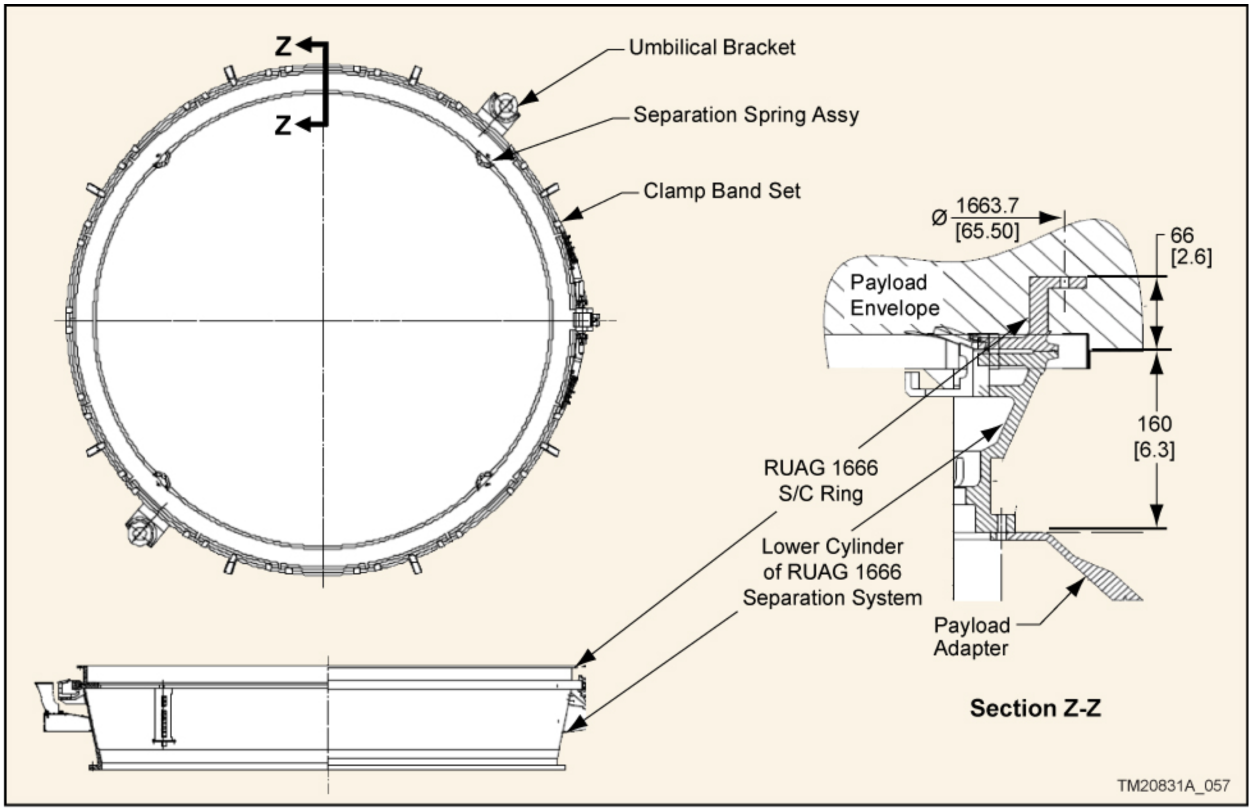



**Figure 5.1.4-1. RUAG 1666 VS Payload Mechanical Interface**

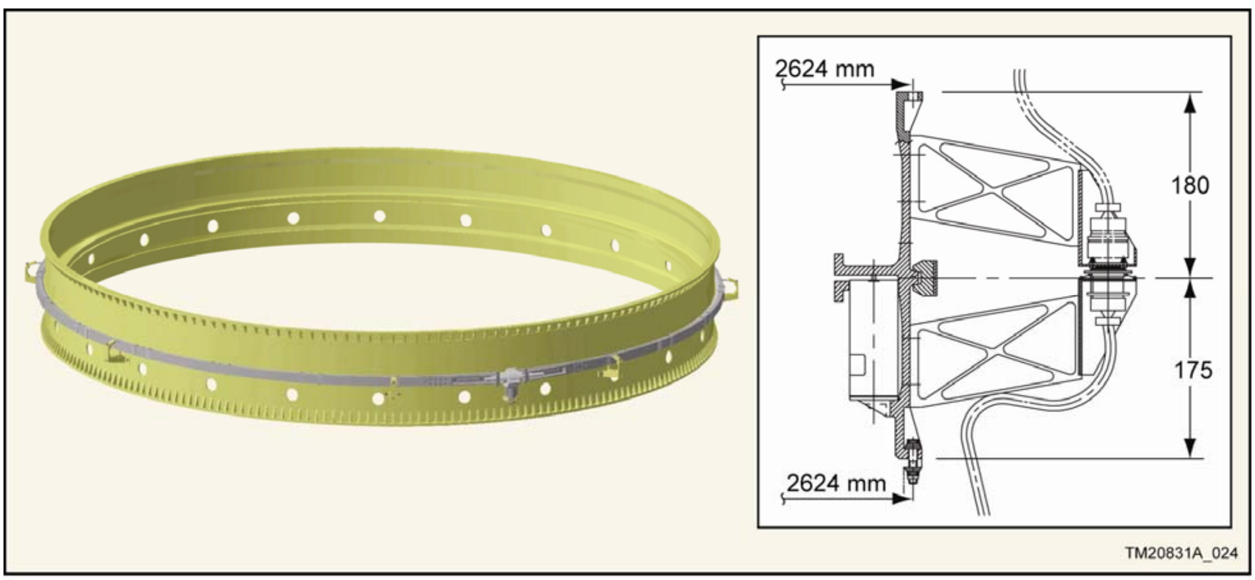



**Figure 5.1.4-2. RUAG 2624 Payload Mechanical Interface**

### 5.1.6. Payload Access Doors

Two fairing access doors per mission are provided on the Taurus II as a standard service. Taurus II fairing access doors are constructed of RF-opaque graphite material.

Taurus II standard fairing access doors are a maximum of 609 mm x 609 mm (24 in. x 24 in.). One door can be located in each half of the cylindrical section of the fairing below the first conical section and above the payload separation plane.

The Customer can position the doors anywhere within the stay-in boundary defined in Figure 5.1.6-1, however no part of any access door can extend beyond the defined boundary. The edges of the payload fairing access doors must also be at least 305 mm (12.0 in.) from the fairing joints.

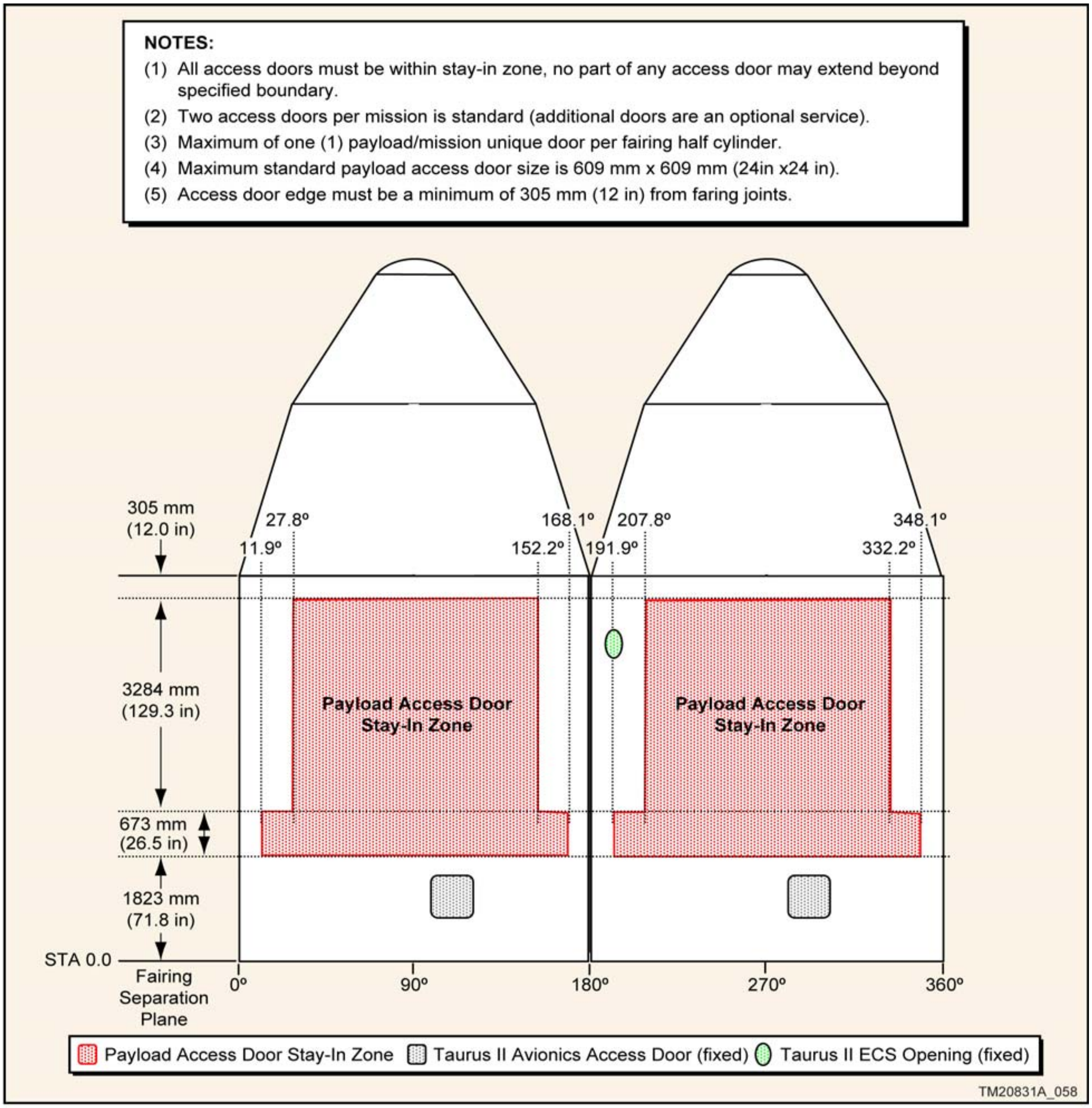



**Figure 5.1.6-1. Taurus II Fairing Access Door Placement**

Payload fairing access doors are required to be defined no later than L-8 months, and are documented in the mission ICD and the MICD. Additional access doors, doors of non-standard sizes, or doors in non-standard locations can be accommodated as a non-standard service, as discussed in Section 8.

### 5.1.7. Mechanical Interface Control Drawing (MICD)

All mechanical interfaces between the payload and Taurus II are defined in the mission ICD, and a mission-specific MICD. The MICD is a dimensional drawing that captures the payload interface details, separation system, payload static volume within the fairing, and locations of the access doors. Orbital utilizes the MICD to manufacture the fairing access doors, and also to control the mechanical interfaces between spacecraft and launch vehicle.

Orbital will provide a toleranced MICD to the Customer to allow accurate machining of the spacecraft fastener holes to the payload interface. The Orbital-provided Taurus II MICD is the only approved documentation for drilling the payload interface.

### 5.1.8. Spacecraft to Taurus II Integration

As part of the launch service, Orbital will provide all flight hardware and integration services necessary to integrate non-separating and separating payloads with the Taurus II. Non-standard or payload unique ground handling equipment is the responsibility of the payload contractor.

All attachment hardware, whether Orbital or Customer-provided, must contain locking features consisting of locking nuts, inserts or fasteners.

## 5.2. Payload Electrical Interfaces

The Taurus II launch launch vehicle to payload electrical interfaces are provided through two cable connectors supplied by Orbital. As a standard service, these two connectors are routed from the launch vehicle umbilical to the payload EGSE. The circuits that cross this interface are documented in a mission-specific Electrical Interface Control Document (EICD). The launch vehicle to payload electrical interface provides up to 20 Twisted Shielded Pairs (TSP) or 40 pass-through wires with a round trip resistance of 5 ohms or less, and 40 TSP or 80 pass-through wires with a round trip resistance of 10 ohms or less, and 38 TSP or 76 pass-through wires with a round trip resistance of 10 ohms or less. In addition to the payload umbilical pass-through capability, the connections contain redundant separation loops 4 pass-through wires) for the launch vehicle and payload on each side of the interface.

As a non-standard service in support of payload processing and operational requirements, these two connectors may also interface the payload to the launch vehicle for discrete commands, analog telemetry, and serial communications.

### 5.2.1. Electrical Interface with an Orbital-Provided Separation System

For payloads utilizing an Orbital-supplied separation system, the standard Taurus II electrical interface is located at the launch vehicle/payload separation plane. The umbilical connectors at this separating interface are dual sixty one (61) pin Deutsch MIL-C-81703 bracket mounted connectors which provide payload communication services from the ground to the payload through dedicated umbilicals within the vehicle, as shown in Figure 5.2.1-1. The payload umbilical is a dedicated pass-through harness for ground processing supported by EGSE in the Launch Equipment Vault (LEV). The LEV is the closest location for operating Customer-supplied EGSE equipment, where payload command, control, monitoring, and power services can be configured for each individual user's requirements.

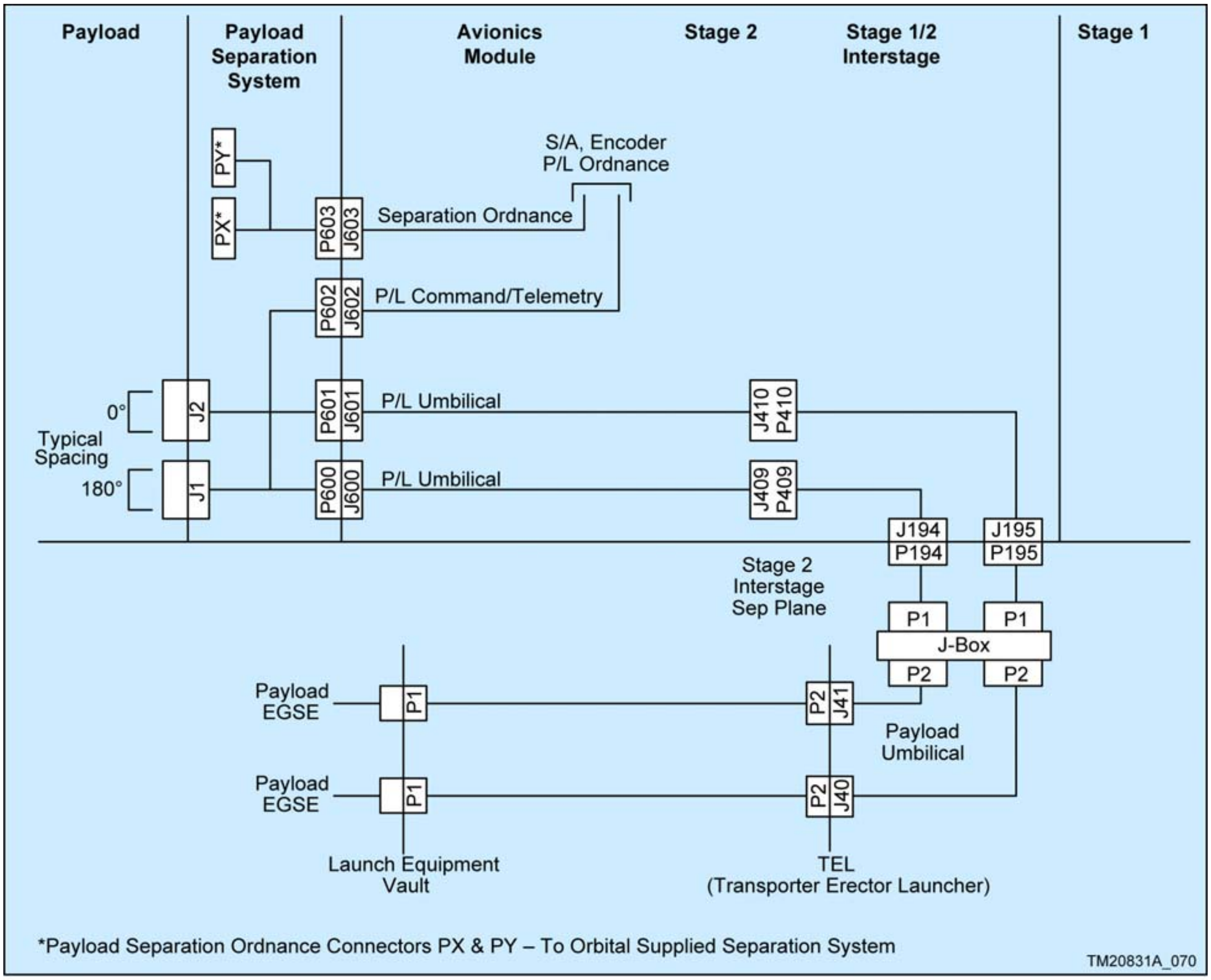



**Figure 5.2.1-1. Payload Electrical Interface with Orbital-Supplied Separation System**

A line loss analysis will be performed on mission configured cabling from the LEV to the launch vehicle to payload separation plane connectors to verify compliance to payload signal requirements.

### 5.2.2. Electrical Interface with a Payload-Provided Separation System

The Taurus II electrical interface for payloads that provide their own separation system is located at the payload to launch vehicle non-separating mechanical interface described in Section 5.1.3. The payload umbilical connectors at this non-separating interface are the same non-separating connectors as those used for the Orbital-provided separation system. A block diagram illustrating the launch vehicle electrical connections to a payload provided separation system is provided in Figure 5.2.2-1.

### 5.2.3. Payload Interface Circuitry

Figure 5.2.3-1 details the typical interface circuits for separation loopbacks, discrete commands, and serial communications interfaces with the launch vehicle avionics systems.

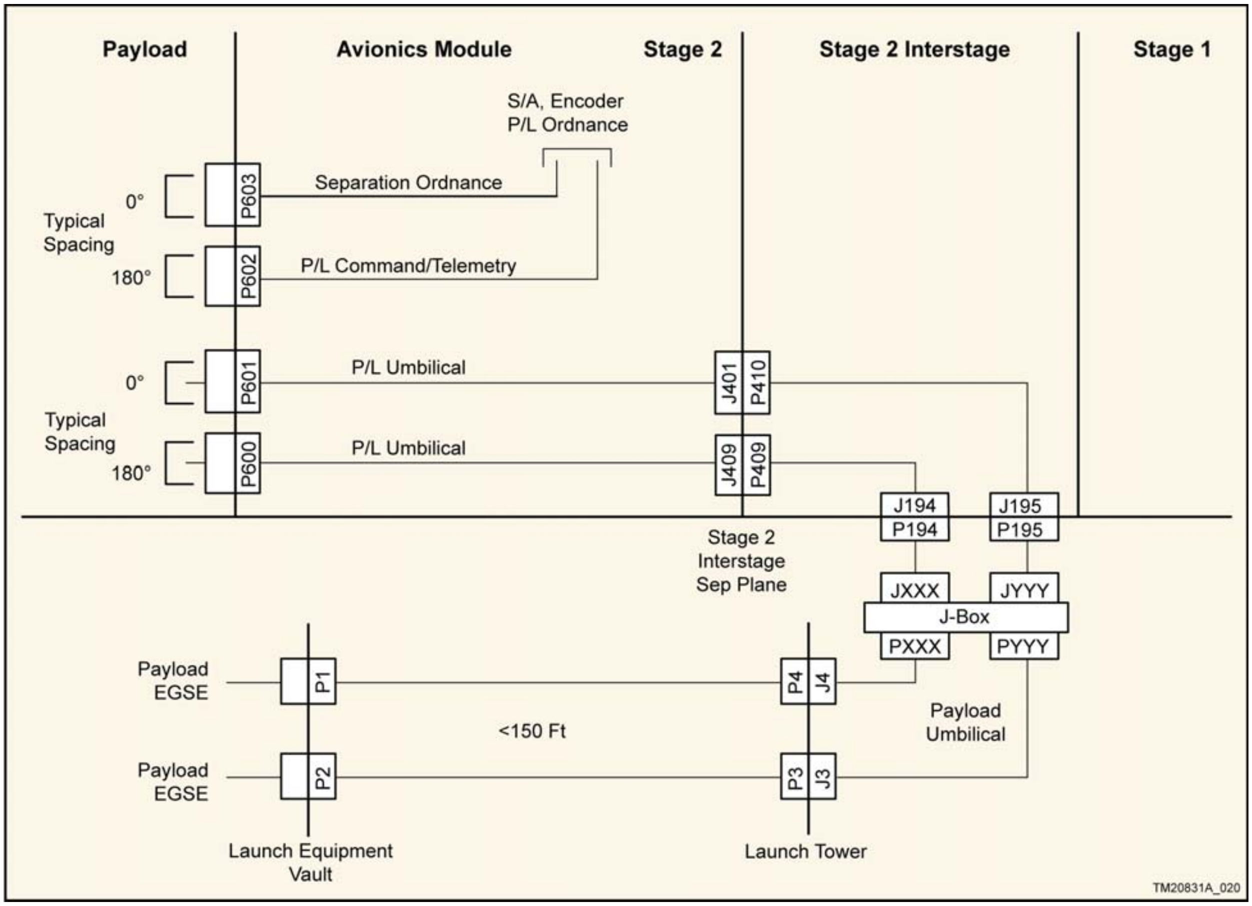



**Figure 5.2.2-1. Payload Electrical Interface with Payload-Provided Separation System**

### 5.2.4. Payload Battery Charging

Orbital provides the capability for remote controlled charging of payload batteries, using a Customer-provided battery charger. Power is provided via the dual 61 pin interface connectors through launch vehicle to payload umbilical cable and ground support wiring to the LEV. The payload battery charger should be sized to withstand the line loss from the LEV to the spacecraft. Details of battery charging requirements and the Customer-provided battery charger will be defined in the mission ICD.

### 5.2.5. Payload Command and Control (C&C)

The Taurus II electrical interface can, as a non-standard service, provide discrete sequencing commands to the payload. These are typically available to the payload as closed circuit opto-isolator command pulses of 5 A in lengths of 40 ms minimum. Discrete sequencing commands generated by a launch vehicle Ordnance Driver Module (ODM) can be used for any combination of (redundant) ordnance events and/or discrete commands depending on the payload requirements. Payload C&C requirements are specified in the mission ICD and the Serial Telemetry Interface Control Document (ST ICD) and should not change once the final telemetry format is released at approximately L-6 months. Details of the mission-specific C&C signal wiring will be documented in the mission-specific EICD.

#### 5.2.6. Telemetry Interfaces

The standard Taurus II payload interface provides a 16 Kbps RS-422/RS-485 serial interface for Customer use. The serial telemetry interface has the flexibility to support a variety of payload channel and bit rate requirements, signal conditioning, Pulse Code Modulation (PCM) formatting, and data transmission bit rates. The number of channels, sample rates, etc. are defined in the mission ICD and the ST ICD.

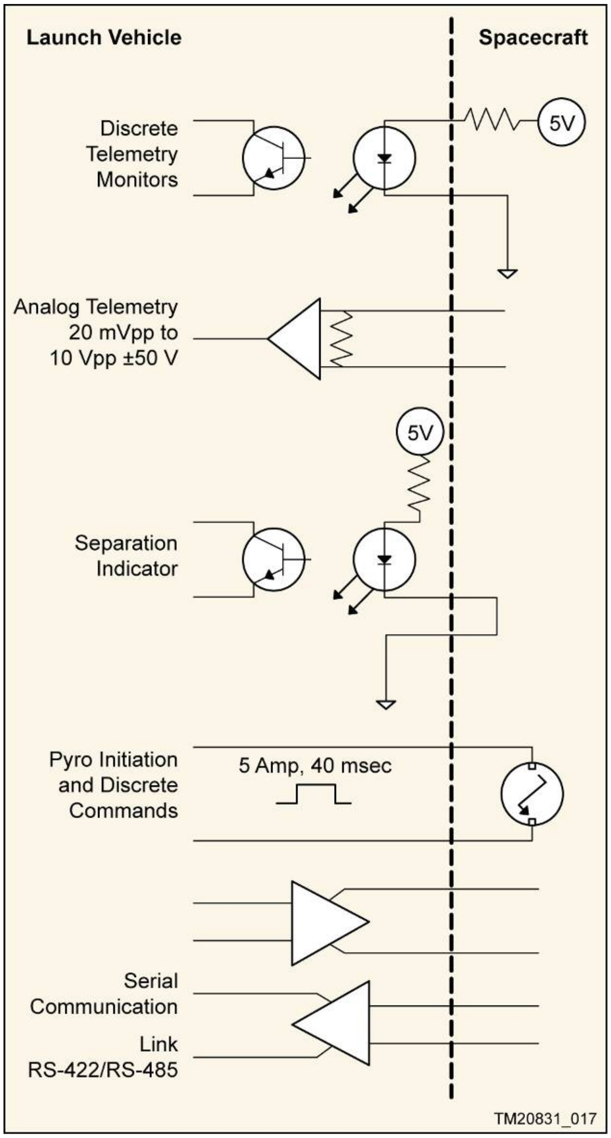



**Figure 5.2.3-1. Typical Taurus II Payload Electrical Interface Circuits**

##### 5.2.6.1. Payload Discrete Telemetry

Standard Taurus II electrical services provide up to five (5) discrete (bi-level) telemetry monitors through dedicated channels in the vehicle encoder. The Customer is required to provide Orbital with the payload 5 Vdc source and the return path details. Current at the payload interface will be less than 10 mA. Payload discrete telemetry requirements, source and return path details, and sampling characteristics are specified in the mission ICD, the ST ICD, and the EICD, and should not change once the final telemetry format is released at approximately L-6 months.

##### 5.2.6.2. Payload Analog Telemetry

Standard Taurus II electrical services provides up to six (6) analog telemetry monitors through dedicated channels in the vehicle encoder. Analog telemetry signal characteristics are 20 mVp-p to 10 Vp-p, ±50 V. Payload analog telemetry requirements and signal characteristics are specified in the mission ICD, the ST ICD, and the EICD, and should not change once the final telemetry format is released at approximately L-6 months.

##### 5.2.6.3. Payload Separation Monitors

Separation breakwire monitors are required on both sides of the payload separation plane. Taurus II requires two (2) separate loopbacks on the payload side of the separation plane. These loopbacks are used for telemetry indication of separation and for initiation of the Stage 2 CCAM maneuver. The loopbacks must be wired into different separation connectors for redundancy. Taurus II separation systems can provide multiple separation loopbacks on the launch vehicle side of the separation plane for positive payload separation indication if required.

### 5.2.7. Non-Standard Electrical Interfaces

Non-standard electrical services, such as the selection of separation system and unique serial command and telemetry interfaces to the payload, may be negotiated between Orbital and the Customer on a mission-by-mission basis, and are defined in the mission ICD, the ST ICD, and the EICD.

### 5.2.8. Electrical Launch Support Equipment

Orbital provides space for Customer supplied EGSE in the LEV. The equipment interfaces with the launch vehicle/spacecraft through the dedicated payload umbilical interconnect, as depicted in Figure 5.2.8-1. The payload Customer is responsible for providing cabling from the EGSE location to the launch vehicle umbilical interface in the LEV. Separate payload ground processing harnesses that mate directly with the payload are accommodated through the payload access door(s) as defined in the mission ICD and the MICD.

### 5.2.9. Electrical Interface Control Drawing (EICD)

Orbital provides an EICD to the payload that captures details of electrical interfaces between the payload and launch vehicle. The Orbital-provided EICD is the only approved documentation for electrical connections to the payload interface and is used to control the electrical interfaces between Taurus II and the spacecraft.

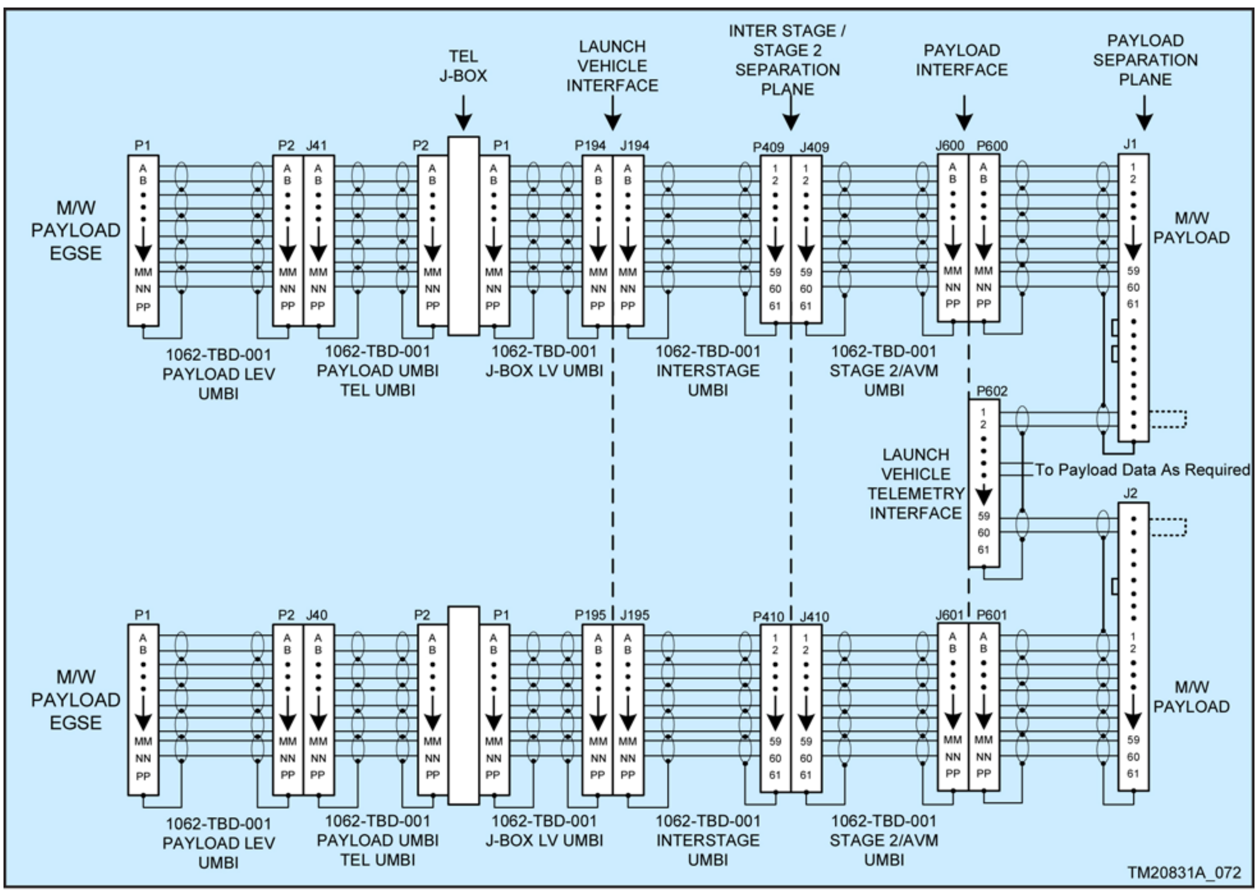



**Figure 5.2.8-1. Payload Umbilical Interconnect**

### 5.2.10. Serial Telemetry Interface Control Document (ST ICD)

Orbital provides a ST ICD to the Customer that captures details of command and telemetry interfaces between the payload and launch vehicle. The Orbital-provided ST ICD is the only approved documentation for telemetry and command requirements between the payload and the Taurus II launch vehicle.

## 5.3. Payload Design Constraints

The following sections provide design constraints to ensure payload compatibility with the Taurus II system.

### 5.3.1. Payload Center of Mass Constraints

Along the Y and Z axes, the payload CG must be within 51 mm (2.0 in.) of the vehicle centerline and no more than 2000 mm (78.7 in.) forward of the payload interface for the standard configuration (within the accuracy listed in Table 5.3.1-1). Payloads with a CG that extends beyond the 51 mm (2.0 in.) lateral offset limits will require Orbital to verify that the specific offsets can be accommodated.

### 5.3.2. Final Mass Properties Accuracy

The final mass properties statement must specify payload weight to an accuracy of at least 10 kg (22 lbm), the payload center of gravity to an accuracy of at least 6.4 mm (0.25 in.) in each axis, and the products of inertia to an accuracy of at least 0.7 kg-m$^2$ (0.5 slug-ft$^2$). In addition, if the payload uses liquid propellant, the slosh frequency must be provided to an accuracy of 0.2 Hz, along with a summary of the method used to determine slosh frequency.

### 5.3.3. Pre-Launch Electrical Constraints

All payload electrical interface circuits are constrained from lift-off through payload separation to ensure there is no current flow greater than 10 mA across the payload electrical interface plane. The primary structure of the spacecraft must be electrically conductive to establish a single point electrical ground.

### 5.3.4. Payload EMI/EMC Constraints

Taurus II avionics share the volume inside the fairing with the payload such that radiated emissions compatibility is paramount. Orbital places no specific radiated emissions limits on the payload other than the prohibition against RF transmissions while encapsulated within the Taurus II fairing. The Customer should provide evidence of single fault tolerance (dual inhibits) for prevention of inadvertent RF transmissions.

All payload RF transmission frequencies must be coordinated with Orbital and Range officials to ensure non-interference with Taurus II and other Range transmissions. Additionally, the payload must schedule all RF tests at the processing facility with Orbital in order to obtain proper Range clearances and frequency protection.

Prior to launch, Orbital requires review of the payload radiated emission levels to verify overall launch vehicle EMI safety margins in accordance

**Table 5.3.1-1. Payload Mass Properties Measurement Tolerance**

| Measurement | Accuracy |
|---|---|
| Mass | ±22 lbm (±10 kg) |
| Principle Moments of Inertia | ±5% |
| Cross Products of Inertia | ±0.5 sl - ft² (±0.7 kg - m²) |
| Center of Gravity X, Y, and Z Axes | ±0.25 in (±6.4 mm) |

with MIL-E-6051. Payload RF transmissions are not permitted after fairing mate and prior to an ICD specified time after separation of the payload. An EMI/Electromagnetic Compatibility (EMC) analysis may be required to ensure RF compatibility.

### 5.3.5. Payload Dynamic Frequencies

Liftoff and transonic flight dominate the dynamic excitations produced by the Taurus II launch vehicle. These dynamic events combined with launch vehicle steady-state accelerations should be used in the design of spacecraft structures.

To avoid dynamic coupling of the payload with the natural frequency of the vehicle, the payload should be designed with a structural stiffness to ensure that the spacecraft structure first mode fundamental frequency is greater than 20 Hz axially (thrust axis), and above 8 Hz in the lateral axis. Further, to prevent dynamic coupling of the payload with launch vehicle modes, the frequencies of spacecraft secondary structures should be designed to be greater than 35 Hz. These values are affected significantly by other factors such as the coupled dynamics of the spacecraft, any isolation system used, and/or the separation system employed; therefore, the final determination of dynamic compatibility of the payload must be made on a mission-specific basis. The Customer should contact the Taurus II Program Office to ensure that more detailed dynamic analyses are performed in order to determine the unique loading conditions for their payload.

### 5.3.6. Payload Propellant Slosh

Slosh models at 1, 3, and 6G are required for payloads with liquid propellant. The model provided must be either a NASTRAN or Craig/Bampton model. Data on first sloshing mode is required and data on higher order modes is desirable. The slosh model should be provided with the payload finite element model submittals.

### 5.3.7. System Safety Constraints

Orbital considers the safety of personnel and equipment to be of paramount importance. Safety design criteria for Taurus II payloads is outlined in a number of government documents, such as the Range Safety Manual and AFSPCMAN 91-710. These are compliance documents and must be strictly followed. The Range Safety Users Manual (AFSPCMAN 91-710) outlines the safety design criteria for all Taurus II payloads. It is the responsibility of the Customer to ensure that the payload meets all Taurus II, Orbital, and Range imposed safety standards.

All Taurus II Customers are required to conduct at least one dedicated payload safety review prior to arrival of any payload hardware at the integration facility and/or launch site. All Customers are also required to submit all required safety documentation to Orbital as summarized in Section 6.

NOTE

> Customers designing payloads that employ hazardous subsystems, processes, or hardware are advised to contact Orbital early in the design process to verify compliance with system and Range Safety standards.

### 5.3.8. Payload Testing and Analysis

Sufficient payload testing and/or analysis must be performed to ensure the safety of ground crews and mission success. To verify that the payload can meet safety and mission success criteria, the payload organization must provide Orbital a list of the tests, test levels, and test results to which the payload was subjected prior to payload arrival at the integration facility and/or launch site.

## 6. MISSION INTEGRATION

Orbital's established engineering, production, testing and quality assurance approaches are designed to provide a successful mission with an absolutely safe and reliable launch service for our Customers. Another of Orbital's top priorities is to ensure timely launch services, with emphasis on maintaining high schedule confidence and flexibility. Orbital's active production lines and proven launch vehicle operations capability, coupled with management attention to potential risk areas, minimizes the risk of launch delays. Orbital is committed to providing all of our Customers with launch services that meet or exceed their mission requirements.

### 6.1. Mission Management Approach

A mission-unique organizational structure is established for each Taurus II launch service to manage and execute key mission roles and responsibilities. Taurus II missions are managed through Orbital's Taurus II Mission Management Office. The integrated Taurus II organizational structure, as shown in Figure 6.1-1, provides open communication between the Orbital Taurus II Mission Manager and the Customer, emphasizing timely transfer of data and prudent decision-making, ensuring efficient launch vehicle/payload integration operations.

#### 6.1.1. Orbital Mission Responsibilities

As the launch service provider, Orbital is the primary communication path with support agencies, which include—but are not limited to—the various Range support agencies and U.S. Government agencies such as the U.S. Department of Transportation and U.S. State Department. Orbital's mission responsibilities fall into four primary areas: Taurus II Program Management, Mission Management, Mission Engineering, and Launch Site Operations.

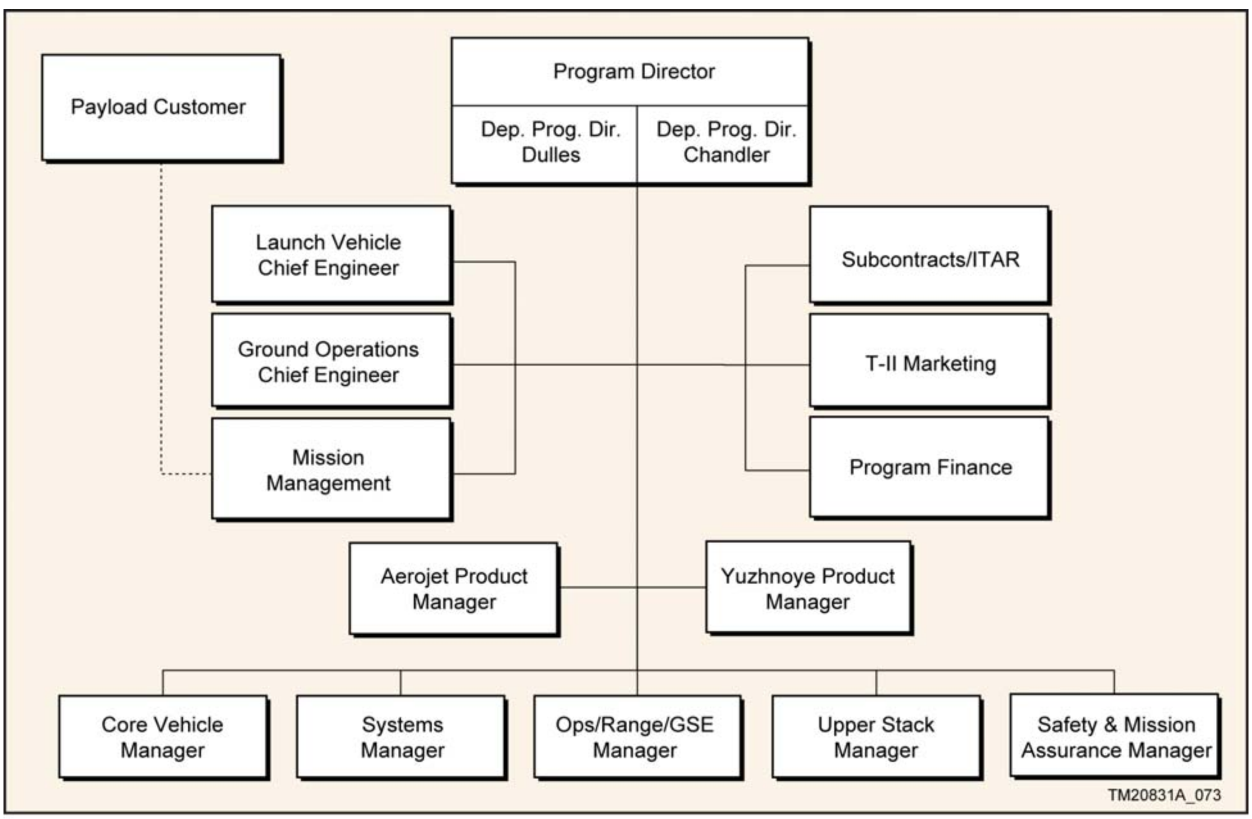



**Figure 6.1-1. Taurus II Program Structure**

### *Taurus II Program Management*

The Taurus II Program Director has primary responsibility and accountability for the Taurus II Program including all elements required to provide a reliable and timely launch service and to ensure Customer satisfaction. The Program Director is assisted by Deputy Program Directors at each of the primary manufacturing sites in Dulles and Chandler. The Program Director's responsibilities include management of schedules, budgets and deliverables; the Customer interface; vehicle engineering; change control; manufacturing; and integration and launch operations.

### *Taurus II Mission Management*

Orbital assigns a Mission Manager over the technical and programmatic interfaces for each Taurus II mission. The Taurus II Mission Manager is the single Point of Contact (POC) for all aspects of a specific mission, and has overall program authority and responsibility to ensure that payload requirements are met and that the appropriate launch services are provided. The Taurus II Mission Manager chairs the Mission Integration Working Group (MIWG) which is the primary forum for Customer and launch vehicle technical interchanges. The Mission Manager's responsibilities include oversight of detailed mission planning, payload interface definition, documenting payload requirements, mission-peculiar systems engineering, design and analyses coordination, launch site and Range coordination, integrated scheduling, launch vehicle production coordination, payload launch site processing, and payload unique flight operations.

### *Taurus II Mission Engineering*

The Taurus II Mission Engineer reports to the Taurus II Systems engineering lead and ensures that all mission-specific engineering is incorporated into the baseline Taurus II design and properly tested. The Mission Engineer supports the Taurus II Mission Manager to ensure that vehicle preparation is on schedule and satisfies all payload requirements for launch vehicle performance.

The Taurus II Mission Mechanical Engineer is responsible for the mechanical interface between the satellite and the launch vehicle. This person works with the Taurus II Mission Engineer to verify that mission-specific envelopes are documented and environments, as specified in the ICD, are accurate and verified. The Mission Mechanical Engineer ensures Payload fairing provisions are incorporated and the mechanical interfaces are properly designed and tested.

The Taurus II Mission Electrical Engineer is responsible for the electrical interfaces between the spacecraft and the launch vehicle. This person works with the Taurus II Mission Engineer to verify that mission-specific electrical and communication requirements are documented and the electrical interfaces, as specified in the EICD, are accurate and verified. The Mission Electrical Engineer ensures payload serial, telemetry and commanding provisions, as specified in the ST ICD, are incorporated and the electrical and software interfaces are properly designed and tested.

The Taurus II engineering support organization is responsible for supporting mission integration activities for all Taurus II missions. Primary support tasks include mission analysis, software development, mission-unique hardware design and testing, vehicle integration procedure development and implementation, and flight operations support.

### *Taurus II Launch Site Operations*

The Launch Site Manager is directly responsible for launch site operations and facility maintenance. All work that is scheduled to be performed at the Orbital launch site is directed and approved by the Taurus II

Launch Site Manager. This includes preparation and execution of work procedures, launch vehicle processing, and control of hazardous operations. All hazardous procedures are approved by the appropriate Launch Site Safety Manager, the Range Safety representative, the Taurus II Launch Site Manager, and the Taurus II Safety Manager prior to execution. In addition, Taurus II Safety and Quality Assurance engineers are always present to monitor critical and hazardous operations. Scheduling of payload integration with the launch vehicle and all related activities are also coordinated with the Launch Site Manager.

#### 6.1.2. Matrixed Support

In addition to the full-time mission specific assignments, each Taurus II mission receives significant matrixed support from Orbital's Flight Assurance, Safety and Mission Assurance, Technical Operations, and Business Operations organizations.

The Flight Assurance organization ensures that Mission Assurance requirements for a given mission are met. This organization is augmented by Orbital's Safety and Mission Assurance organization in completing this task. The Manager of Flight Assurance is responsible for implementing the mission assurance program, reports to the Taurus II Program Director's office on a daily basis, and reports administratively to Orbital's Vice President of Safety and Mission Assurance. The Manager of Flight Assurance is supported by multifunctional quality engineers and inspectors from the Safety and Mission Assurance organization in meeting the mission assurance requirements of the program. The Manager of Safety is in turn supported by a safety engineering group, and is responsible for the System and Range Safety program. All work performed at the integration and launch site is reviewed and approved by a safety engineer. This includes work procedures associated with launch vehicle integration, test, and launch as well as the control of hazardous operations. Safety engineering performs hazard analyses on system changes (including payload systems and subsystems) to assess their impact on ground and flight safety. Safety engineering updates and maintains the Flight Termination System Report (FTSR), the basic vehicle Accident Risk Assessment Report (ARAR), as well as the mission-specific annex to the ARAR.

Orbital's Technical and Business Operations organizations provide engineering standards, training, accounting, financial, marketing, and other engineering and business resources to augment the dedicated Taurus II program staff. Technical Operations provides a broad technical pool of highly trained engineering professionals available on an as needed basis. Staff associated with very specialized analyses is managed as a functional group, providing consistent support to all programs within Orbital's Launch Systems Group (LSG).

### 6.2. Mission Integration Process

The core of the mission integration process consists of a series of Mission Integration Working Groups (MIWGs) and Range Working Groups (RWGs). The Mission Manager has overall responsibility for both the MIWG and the RWG.

#### 6.2.1. Mission Integration Working Group (MIWG)

The MIWG is the forum for defining all launch services provided to the Customer and physical interfaces between the payload and the Taurus II launch vehicle. The MIWG is chaired by the Taurus II Mission Manager and membership includes representatives from Taurus II engineering and operations organizations, as well as their counterparts from the Customer organization. The membership of the MIWG creates and implements the mission Interface Control Document, Mechanical Interface Control Drawing (MICD), Electrical Interface Control Drawing (EICD), and the Serial-Telemetry Interface Control Document

(ST ICD). The MIWG members also ensure that all mission-unique analyses, hardware, software, and integrated procedures are performed on schedule. The MIWG is also responsible for coordinating launch site operations; Range interfaces; safety reviews and approval; and flight design, trajectory and guidance for the specific mission.

#### 6.2.2. Range Working Group (RWG)

The RWG is responsible for the areas of launch site operations; Range interfaces; safety review and approval; and flight design, trajectory, and guidance. Documentation produced by the RWG includes all required Range and safety submittals.

#### 6.2.3. Mission Planning and Development

Orbital assists the Customer with mission planning and development associated with Taurus II launch vehicle systems. These services include launch vehicle to payload interface design and configuration control, development of integration processes, launch vehicle analyses, facilities planning, launch campaign planning, Range services and special operations, and integrating launch vehicle, payload, and Range schedules. The procurement, analysis, integration and test activities required to place a Customer's payload into orbit are conducted over a 26 month long standard sequence of events called the Mission Cycle. This cycle normally begins 24 months before launch, and extends to eight weeks after launch. Figure 6.2.2-1 provides an overview of the nominal Taurus II Integrated Master Schedule, and provides insight into how the mission cycle is integrated into the Taurus II launch vehicle production schedule, as well as the launch site integration and launch operations schedules. A detailed Integrated Master Schedule is developed by the Mission Manager after the mission kickoff meeting. The Integrated Master Schedule documents all payload and launch vehicle integrated activities and milestones leading up to launch, with agreed to dates for all deliverables and milestones. The typical Integrated Master Schedule interweaves the following Mission Cycle activities:

a. Mission management, document exchanges, meetings, and formal reviews required to coordinate and manage the launch service.
b. Mission analyses and payload integration, document exchanges, and meetings.
c. Design, review, procurement, testing and integration of all mission-unique hardware and software.
d. Range interface, safety, and flight operations activities, document exchanges, meetings and reviews leading up to launch.

Once contract Authority to Proceed (ATP) is received, the Mission Cycle is initiated. The contract option designates the payload, launch date, launch vehicle configuration, and basic mission parameters. In response, the Taurus II Program Director designates a Taurus II Mission Manager who works with the payload Customer to develop the Integrated Master Schedule and ensure that the launch service is supplied efficiently, reliably, and on-schedule.

A typical Mission Cycle is based on a 24 month interval between mission authorization and launch. This interval reflects the Taurus II contractual schedule and has been shown to be an efficient schedule based on Orbital's OSP, Taurus, and Pegasus program experience. However, Orbital has the flexibility to negotiate either accelerated cycles, which may take advantage of the Taurus II multi-Customer production sets, or extended cycles required by unusual payload requirements, such as extensive analysis, complex payload-launch vehicle integrated designs, tests or funding limitations

#### 6.2.4. Mission Reviews

In addition to the MIWG and RWG, a number of mission reviews are conducted as required to ensure the launch service and payload integration activities are progressing according to schedule. During the integration process, mission reviews are held to provide coordination with mission participants and management who do not participate in either of the Working Groups. Due to the variability in complexity of different payloads and missions, the content and number of these reviews are tailored to Customer requirements.

##### 6.2.4.1. Mission Design Reviews

Typically two mission-specific design reviews are held to determine the status and adequacy of the launch vehicle mission preparations. They are designated MDR-1 and MDR-2 and are held at 6 months and 13 months, respectively, after ATP. They are each analogous to development program Preliminary Design Reviews (PDRs) and Critical Design Reviews (CDRs), but focus primarily on mission-specific elements of the launch vehicle effort.

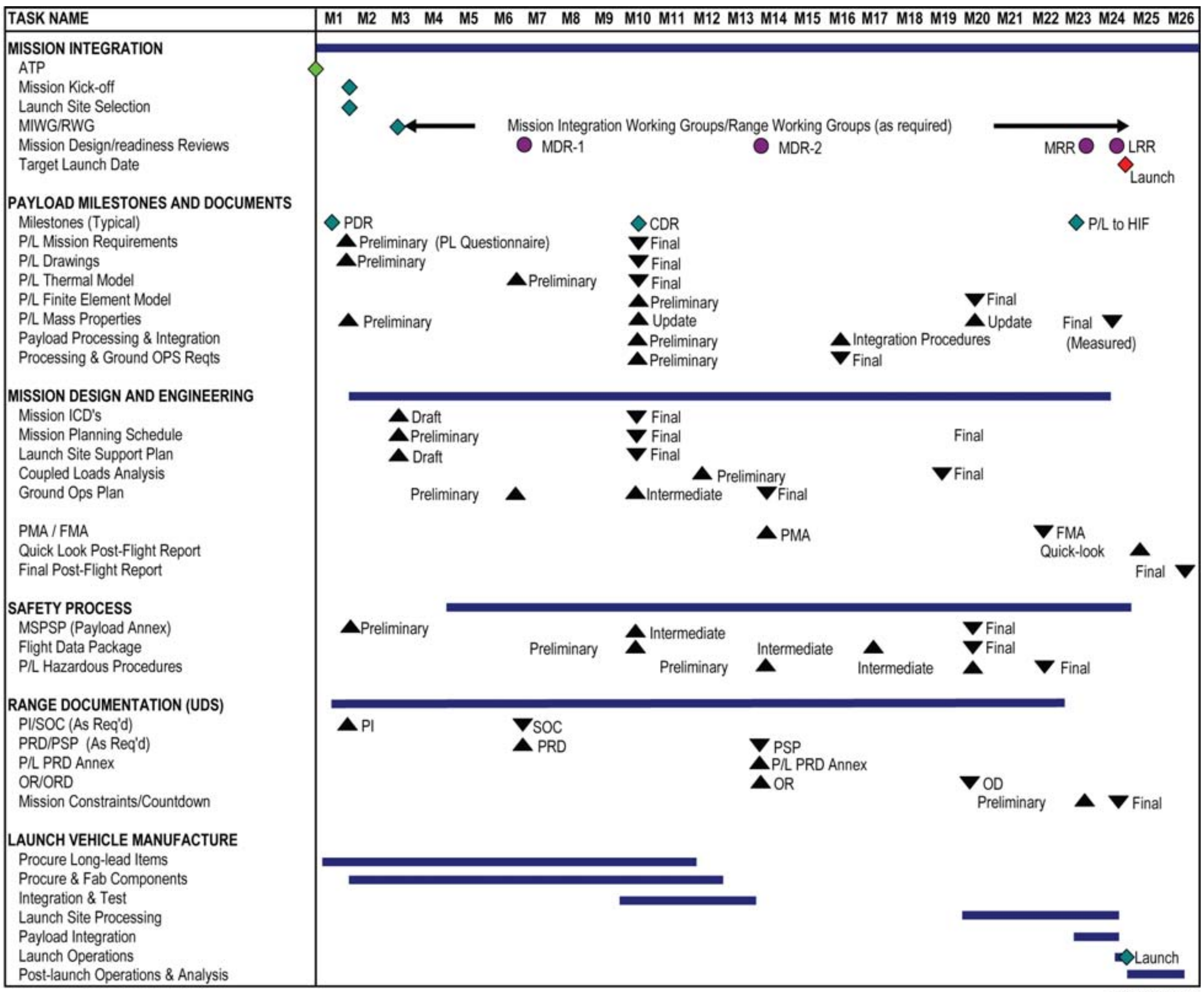



**Figure 6.2.2-1. Integrated Master Schedule (Top Level)**

#### 6.2.4.2. Readiness Reviews

As a baseline, Orbital conducts two readiness reviews as described below.

***Mission Readiness Review (MRR)*** — The MRR is conducted within one month of launch, and provides a pre-launch assessment of integrated launch vehicle and payload readiness prior to committing significant resources to the launch campaign.

***Launch Readiness Review (LRR)*** — The LRR is conducted at L-1 day and serves as the final assessment of mission readiness prior to activation of Range resources on the day of launch.

### 6.2.5. Customer Responsibilities

The Customer mission responsibilities are summarized in Figure 6.2.5-1. The payload Mission Manager is responsible for ensuring that the interests of the mission are best served. The payload Mission Manager is the primary Customer interface to the Taurus II program, and is the Customer counterpart of the Taurus II Mission Manager. The payload Mission Manager is a key member of the MIWG and RWG, and helps develop the mission ICD and launch service requirements, and ensures that all payload documentation, data, models, and drawings are provided according to the agreed to schedule.

In return, the payload Mission Manager is provided with insight into the mission integration analyses and tests that are performed by Orbital. Once the payload is delivered to the launch site, all activities are controlled by an integrated processing schedule that is developed through the MIWG.

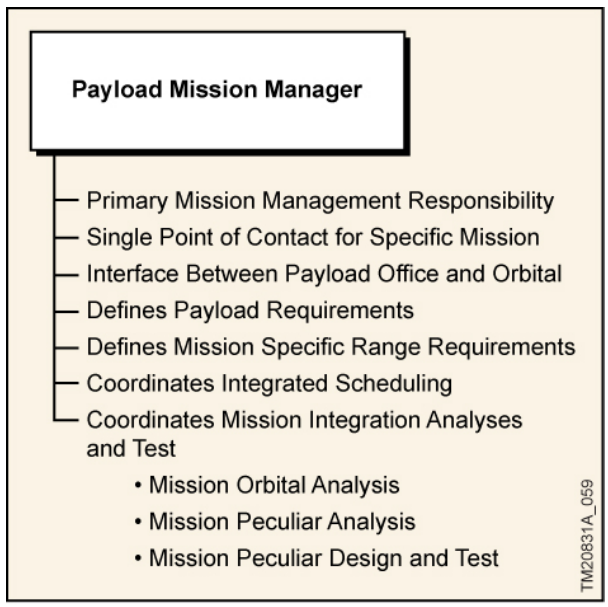



**Figure 6.2.5-1. Customer Responsibilities**

#### 6.2.5.1. Customer-Provided Documentation, Data, Models, and Drawings

Integration of the payload requires detailed, complete, and timely preparation and submittal of interface documentation, data, models, and drawings.

Customer-provided documents represent the formal communication of requirements, safety data, system descriptions, and mission operations planning. The major products and submittal times associated with these documents are divided into two areas: those products that are provided by the Customer, and those produced by Orbital. Documentation produced by the Customer as detailed in the following paragraphs, is critical for enabling the Orbital team to perform their functions, and prepare for and manage the Taurus II launch of the payload. Typical timing of Customer-provided deliveries are indicated in Figure 6.2.2-1.

***Payload Questionnaire***

The payload questionnaire is designed to provide the Taurus II program with the initial definition of payload requirements, interface details, launch site facilities requirements, and preliminary safety data. The Customer provides a completed payload questionnaire form (Appendix A of this Taurus II Users Guide), in time to support the mission kickoff meeting. The Customer's responses to the payload questionnaire define the most current payload requirements and interfaces and are instrumental in Orbital's preparation of numerous documents including a draft of the mission ICD, preliminary mission analyses, and drafts of the launch Range documentation. Additional pertinent information, as well as preliminary payload drawings, should also be included with the response. Orbital understands that a definitive response to some questions may not be feasible, and that these items will be defined during the normal mission integration process.

***Mission ICD Inputs***

The Taurus II-to-payload mission ICD details all mission-peculiar requirements agreed upon by Orbital and the Customer. The mission ICD contains the payload description, electrical and mechanical interfaces, telemetry and command communications, fairing requirements, orbital parameters, description of the mission-peculiar vehicle, and a description of specialized and/or payload unique Ground Support Equipment and facility services required. This key document is used to ensure compatibility of all launch vehicle to payload interfaces, as well as defining all mission-specific and payload unique requirements.

The Taurus II Mission Manager and the payload Mission Manager, have primary responsibility for developing the content of the mission ICD. A draft version of this document will be developed by the Taurus II Mission Manager from the payload questionnaire and provided to the Customer. The mission ICD is then matured via the MIWG forum.

***Launch Site Support Plan (LSSP) Inputs***

For each mission, Orbital develops a LSSP to specify the Range support needed to meet the specific mission requirements of the Customer. The LSSP includes all payload requirements as well as any additional Taurus II requirements that may arise to support a particular mission.

A draft of the LSSP is produced by the Taurus II Mission Manager based on the payload questionnaire. The payload Mission Manager provides updated information through the MIWG and RWG forums to ensure that all payload-unique mission requirements are captured in the LSSP. Orbital then uses the LSSP to develop the mission Program Requirements Document (PRD) annex which is provided as a key requirements document to the Range, as described in Section 6.2.5.2.

***Payload Drawings***

Payload configuration drawings should be provided to Orbital as soon as they are available after the Mission Kickoff Meeting. Orbital will work with the Customer to define the content and desired format for the drawings.

***Payload Mass Properties***

Payload mass properties must be provided to Orbital by the Customer to support efficient launch vehicle trajectory development and dynamic analyses. Preliminary mass properties should be submitted at launch vehicle ATP. Updated payload mass properties are provided at predefined intervals identified during the initial mission integration process. Typical timing of these deliveries are as indicated in Figure 6.2.2-1.

Accurate payload mass properties are required at least four months prior to launch so that Orbital may perform the final trajectory analysis, and submit the results to the Range no later than 45 days prior to launch. Since the "final" spacecraft mass properties may not be determined until after propellant loading or other operations at the launch site, the requirement for the mass properties provided to Orbital is that they be within the specified ICD tolerances to those mass properties measured after final launch site operations.

***Payload Finite Element Model***

A payload mathematical model is required for use in Orbital's coupled loads analyses. Acceptable forms include either a Craig-Bampton model valid to 120 Hz or a NASTRAN finite element model. For the final coupled loads analysis, a test verified mathematical model is desired.

***Payload Thermal Model for Integrated Thermal Analysis***

A payload thermal model is required from the payload organization for use in Orbital's integrated thermal analysis. Thermal models must be provided in SINDA format. The analysis is conducted for three mission phases:

a. Prelaunch ground operations
b. Ascent from lift-off until fairing jettison
c. Fairing jettison through payload deployment

***Payload Launch Site Integration Procedures***

For each mission, Orbital requires detailed spacecraft requirements for integrated launch vehicle and payload integration activities. With these requirements, Orbital will produce the integrated procedures for all launch site activities. In addition, all payload procedures that are performed at the launch site must be presented to Orbital for review prior to first use.

***Payload Integrated Test Procedure Requirements***

For each mission, Orbital requires detailed spacecraft requirements for integrated launch vehicle and payload testing activities. With these requirements, Orbital will produce the integrated test procedures.

***Mission ICD Verification Documentation***

Orbital conducts a rigorous verification program to ensure all requirements on both sides of the launch vehicle to payload interface have been successfully fulfilled. As part of all mission ICDs, Orbital includes a verification matrix that indicates how each ICD requirement will be verified (e.g., test, analysis, demonstration, etc.). As part of the verification process, Orbital will provide the Customer with a form to complete for each interface requirement that is the responsibility of the payload to meet. The form clearly identifies the documentation to be provided as proof of verification. Likewise, the Taurus II Mission Manager will ensure that the Customer is provided with similar data for all interfaces that are the responsibility of Orbital as the launch provider.

***Safety Documentation***

For each Taurus II mission Orbital acts as the interface between the mission and Range Safety. To fulfill this critical role Orbital requires payload safety information from the Customer. For launches from any of the U.S. Ranges (i.e.; WFF, CCAFS, VAFB, and KLC), the Flight Facility Range Safety Manual, applicable NASA documents, and AFSPCMAN 91-710 provide detailed Range Safety regulations. Orbital provides the Customer with coordination and guidance regarding applicable safety requirements.

All hazardous procedures to be conducted at the launch facility must be documented and provided to Orbital for submission to Range Safety for approval. To obtain approval to use the launch site facilities, specific payload safety data must be prepared by the Customer and submitted to Orbital. This information includes a description of each payload hazardous system and evidence of compliance with safety requirements for each system. Drawings, schematics, and assembly and handling procedures, including proof test data for all lifting equipment, as well as any other information that will aid in assessing the respective systems and procedures should be included.

Major categories of hazardous systems include ordnance devices, radioactive materials, propellants, pressurized systems, toxic materials, cryogenics, and RF radiation. Procedures relating to these systems as well as any procedures relating to lifting operations or battery operations should be prepared for safety review submittal. Orbital provides this information to the appropriate Taurus II and Range Safety offices for approval.

NOTE

> It cannot be overstressed that the applicable safety requirements should be considered in the earliest stages of spacecraft design. Launch sites discourage the use of waivers and variances. Furthermore, approval of such waivers cannot be guaranteed by Orbital.

#### 6.2.6. Range Documentation

All U.S. Launch Sites utilize the Universal Documentation System (UDS), established by the Range Commanders' Council, for documenting mission requirements with the Range. The UDS provides a common language and format for stating mission requirements and preparing support responses to promote effective communication between a Range user and the launch site. The UDS provides a flexible and dynamic system that meets the support requirements of simple or complex, small or large programs. The types of documents used in the UDS are briefly described in the following paragraphs.

NOTE

> Range documentation is tailored for each mission and launch site, therefore all of described documents may not be required for every mission.

***Program Introduction (PI)***

The PI is a mission planning and approval document that initiates Range support planning. The PI provides the Range manager with an overview of Range user requirements (i.e.; data, processing and office space, aircraft, security, type of instrumentation, display requirements, logistics, etc.). The PI also lists the Range user's primary point of contact (which is the Taurus II Mission Manager), timelines, project description, and security guidelines.

***Statement of Capability (SC)***

The SC is the Range response to the PI. The SC confirms that a mission has been accepted for support by the Range. The PI and SC complement each other in establishing the scope of the Range's mission support activity.

***Program Requirements Document (PRD)***

To obtain Range support, a PRD must be prepared by the Taurus II Mission Manager. This document describes Range requirements needed to generally support the Taurus II at the launch site.

***Program Support Plan (PSP)***

The PSP is the Range response to the requirements submitted in the PRD. The PRD and the PSP complement each other in finalizing the scope of Taurus II the launch service mission support when required.

### PRD and PSP Mission Annex

For each launch, a PRD annex is submitted to specify the Range support needed to meet the specific mission requirements. This PRD annex includes all payload requirements as well as any additional Taurus II requirements that may arise to support a particular mission. The payload Mission Manager provides input to the PRD mission annex via the LSSP, as well as through the MIWG and RWG forums to ensure that all payload unique mission requirements are captured in the PRD. The Range then provides a PSP Mission Annex in response.

### Operations Requirements (OR)

To obtain Range support for the launch operation and associated rehearsals, an OR document is prepared by the Taurus II Mission Manager. The OR is operationally oriented and specific in describing the requirements and support associated with one or more operations within the scope of the mission defined in the PRD.

### Operations Directive (OD)

The OD is the Range response to the OR and commits specific Range support to the operation. The OR is used by the Range and Taurus II Mission Manger to schedule specific equipment, communications links, and operations and maintenance personnel to support the mission at the launch site. The Customer provides all payload pre-launch and launch day requirements for incorporation into the mission OR. These inputs are typically provided initially through the payload Questionnaire, updated via the MIWG and RWG forums, and coordinated through the Taurus II Mission Manger.

## 6.2.7. Orbital Produced Documentation, Data, and Analyses

Mission documentation produced by Orbital is detailed in the following paragraphs.

### Mission ICD

The launch vehicle to payload mission ICD details all of the mission-unique requirements agreed upon by Orbital and the Customer. The mission ICD is a key document that is used to ensure compatibility of all launch vehicle to payload interfaces, as well as defining all mission-specific requirements. The mission ICD contains the payload description, electrical and mechanical interfaces, environmental requirements, orbital parameters, description of the mission-peculiar vehicle, and a description of special GSE, and facilities required. As a critical part of this document, Orbital provides a comprehensive matrix that lists all ICD requirements and the method in which these requirements are verified, as well as who is responsible.

The Taurus II Mission Manager has primary responsibility for developing the content of the mission ICD. A draft version of the mission ICD will be produced by the Taurus II Mission Manager from the payload Questionnaire. This document is then matured via the MIWG with significant inputs from the payload Mission Manager and the Customer's technical team. The initial draft of the mission ICD is provided prior to the first MIWG. The ICD is then matured and updated as required. The payload Mechanical Interface Control Drawing (MICD), Electrical Interface Control Drawing (EICD), and Serial-Telemetry Interface Control Document (ST ICD) provide additional detail on critical Taurus II-to-payload interfaces defined of the mission ICD, and are described in the following paragraphs.

### Mechanical Interface Control Drawing (MICD)

The MICD is generated by Orbital using Customer-provided configuration drawings of the payload. The MICD is a fully dimensioned set of drawings that depict all Taurus II components and GSE that interfaces to or interacts with the payload, and graphically illustrates all mechanical interfaces between the launch vehicle and payload and the payload and Taurus II GSE. As a minimum, the MICD will define and document the payload static and dynamic envelopes within the fairing, payload access door locations and other fairing structural and mechanical interface details, GSE interfaces, and mechanical interface details of the Electrical GSE (e.g.; connectors and brackets). The MICD will be formally accepted by Orbital and the Customer through the MIWG forum. The Orbital-provided MICD is the only approved documentation for structural and mechanical interfaces between the launch vehicle to payload and between the payload and Taurus II GSE.

***Electrical Interface Control Drawing (EICD)***

The EICD is produced by Orbital using Customer-provided information on the payload electrical interface requirements. The EICD illustrates all electrical interfaces between the launch vehicle and payload and between the payload and Taurus II EGSE. As a minimum, the EICD will define and document a wiring diagram of the electrical interfaces and a table of pin assignments for all power, command & control, telemetry, monitoring, and EGSE interfaces required to support the payload. The EICD is formally accepted by Orbital and the Customer through the MIWG forum. The Orbital-provided EICD is the only approved documentation for electrical interfaces between the launch vehicle to payload and between the payload and the ground.

***Serial Telemetry ICD (ST ICD)***

Orbital provides a ST ICD to the Customer that captures details of command and telemetry interfaces between the payload and launch vehicle. A draft version of the ST ICD is developed by the Taurus II Mission Manager with requirements provided in the payload questionnaire. This document is then matured via the MIWG. The ST ICD is formally accepted by Orbital and the Customer through the MIWG forum. The Orbital-provided ST ICD is the only approved documentation for telemetry and command communication between the launch vehicle to payload and between the payload and the ground.

***Mission ICD Verification Documentation***

Orbital is responsible for providing verification documentation for all Taurus II interface requirements. This documentation is used as part of the team effort to complete a thorough verification that all ICD requirements have been met.

***Preliminary Mission Analysis (PMA)***

Orbital performs the PMA to determine the compatibility of the payload with the Taurus II launch vehicle and to provide succinct, detailed mission requirements, such as performance capability, accuracy estimates and preliminary mission sequencing. The results of these analyses are incorporated in the mission ICD. The analyses results are used to verify mission requirements.

***Coupled Loads Analyses (CLA)***

Orbital has developed and validated finite element structural models of the Taurus II vehicle for use in CLAs with Taurus II payloads. Orbital will incorporate the Customer-provided payload model into the Taurus II finite element model and perform a preliminary and updated CLAs to determine the maximum responses of the entire integrated stack under transient loads. Once a test validated spacecraft model has been delivered to Orbital, a final CLA load cycle is completed. Through close coordination between the Customer and the Taurus II Program Office, interim results can be made available to support the Customer's schedule critical needs.

### *Payload Fairing Venting Analysis*

Orbital performs a venting analysis for Taurus II to properly size the fairing cavity vent orifice for the mission unique trajectory. The analysis will determine the peak venting rate and the residual pressure at fairing deployment. The results of the venting analysis are included in the mission ICD.

### *Fairing Clearance Analyses*

Orbital will verify the clearance between the fairing and the payload through preliminary and final clearance analyses. These analyses will account for the effects of fairing and spacecraft deflections and fairing tolerances. Information regarding the volume the payload displaces will be required to properly perform this analysis. The locations and magnitudes of the critical clearance points will also be identified.

### *RF Link and Compatibility Analysis*

Orbital will perform an RF link analysis for each mission to ensure that a sufficient RF link margin exists for the telemetry system and for the flight termination system from launch through payload separation or Range telemetry loss of signal.

### *Integrated Thermal Analysis*

Orbital performs a an integrated thermal analysis utilizing the Customer-provided payload thermal model. Orbital in-turn provides the Customer with mission-specific boundary conditions as an input to the Customer's payload thermal analysis. The analysis is conducted for three mission phases:

a. Prelaunch ground operations
b. Ascent from lift-off until fairing jettison
c. Fairing jettison through payload deployment

### *Final Mission Analysis (FMA)*

The FMA presents a detailed trajectory analysis for the payload using revised analytical mass property inputs and the NRTSIM analysis tool. The FMA includes results from a Six-Degrees of Freedom (6-DOF) simulation; a separation analysis for the spacecraft separation events; and results of a Monte-Carlo analysis defining dispersions for the orbit insertion parameters.

### *Payload Processing Requirements*

Orbital will prepare the necessary documentation to secure the use and required services of an appropriate Payload Processing Facility (PPF). The PPF requirements are based on inputs received from the Customer through the payload Questionnaire and such forums as the MIWG and RWG.

### *Integrated Launch Site Procedures*

For each mission, Orbital prepares integrated procedures for various operations that involve the payload at the processing and launch site. These include, but are not limited to: payload mate to the Taurus II; fairing encapsulation; flight simulations; final vehicle closeouts, and transport of the integrated payload/launch vehicle to the launch pad. Once Customer inputs are received, Orbital will develop draft procedures and submit them to the MIWG for review and comment. Once concurrence is reached, final procedures will be released prior to use. Draft hazardous procedures must be presented to the appropriate launch site safety organization 90 days prior to use and final hazardous procedures are due 45 days prior to use.

### *Missile System Pre-Launch Safety Package (MSPSP Annex)*

The MSPSP Annex documents launch vehicle and payload safety information including an assessment of any hazards which may arise from mission-specific vehicle and/or payload functions, and is provided as an annex to the baseline Taurus II MSPSP. The Customer must provide Orbital with all safety information pertaining to the payload. Orbital assesses the combined vehicle and payload for hazards and prepares a report of the findings. Orbital will then forward the integrated assessment to the appropriate launch Range for approval.

### *Mission Constraints Document*

This Orbital-produced document summarizes launch day operations for the Taurus II launch vehicle as well as for the payload. Included in this document is a comprehensive definition of the Taurus II and payload launch operations constraints, the established criteria for each constraint, the decision making chain of command, and a summary of personnel, equipment, communications, and facilities that will support the launch.

### *Final Countdown Procedure*

Orbital produces the launch countdown procedure that readies the Taurus II and payload for launch. All Taurus II and payload final countdown activities are included in the procedure.

### *Payload Separation Analyses*

Orbital performs preliminary and final separation analyses that are unique for each payload. There are two programs used by Orbital to complete this task. A Monte Carlo simulation is performed using a multi-body re-contact analysis program to demonstrate analytically that adequate separation distances exists between the payload and the upper stage after deployment, and Dynamic Analysis and Design System (DADS) software is used to analytically determine payload tip-off and separation velocity. Nominal and 3-sigma rates are determined to verify tip-off and separation velocity requirements are met. The analyses includes the effects of residual thrust and dispersions, Inertial Navigation System (INS) accuracy and dispersions, and RCS minimum impulse error.

### *Post-Launch Analyses*

Orbital provides post-launch analyses to the Customer in two forms. The first is a quick-look assessment provided within five days of launch. The quick-look data report includes preliminary trajectory performance data, orbital accuracy estimates, system performance preliminary evaluations, and a preliminary assessment of mission success.

The second post-launch analysis is a more detailed final report of the mission, and will be provided to the Customer within eight weeks of launch. Included in the final mission report is the actual mission trajectory, event times, significant events, environments, orbital parameters and other pertinent data from on-board telemetry and Range tracking sensors. Photographic and video documentation, as available, is included as well.

Orbital also analyzes telemetry data from each launch to validate Taurus II performance against the mission ICD requirements. In the case of any mission anomaly, Orbital will conduct an investigation and closeout review.

***Export Compliance***

Customers who are not U.S. citizens can be accommodated as part of a non-standard service. Information and services provided by Orbital to non-US Customers will be limited by the rules set forth in the Technical Assistance Agreement (TAA), which Orbital is required to produce for the U.S. State Department in compliance with U.S. Export laws, rules, and regulations, prior to acceptance of a formal launch services agreement with a non-US Customer.

# 7. GROUND AND LAUNCH OPERATIONS

Ground and launch operations are conducted in three major phases:

a. Launch Vehicle Processing/Integration: Includes receipt and checkout of the launch vehicle components, followed by assembly and test of the Taurus II vehicle.
b. Payload Processing/Integration: Includes receipt and checkout of the payload, followed by integration with Taurus II and verification of interfaces.
c. Launch Operations: Includes transport of the launch vehicle to the launch pad, arming, erection, checkout, fueling, and launch.

## 7.1. Taurus II Launch System Processing and Integration Overview

The Taurus II launch system is designed to minimize vehicle and payload handling complexity and launch site integration effort. The Taurus II program utilizes horizontal integration to simplify integration procedures, increase safety, and provide improved access for the integration team.

The Taurus II vehicle is designed to reduce the time between spacecraft integration and launch operations. The concept of operations for the launch vehicle maximizes processing and testing done in parallel to spacecraft operations reducing the duration and complexity of joint operational requirements. In addition, Orbital's standardized mechanical and electrical interfaces and checkout procedures reduce vehicle and payload integration times, increase system reliability and minimize vehicle demands on payload availability.

Payload to launch vehicle integration and test is performed inside the HIF with the vehicle located on the mobile assembly mating dollies with supporting shroud rings. Once the Upper Stack and Aft Bay are integrated to the Stage 1, the vehicle is lifted onto the Transporter Erector/Launcher for final integration and checkout. The Transporter Erector/Launcher enables the Taurus II to be moved to the launch pad, erected to vertical, fueled and launched within 24 hours.

### 7.1.1. Planning and Documentation

Taurus II integration and test activities are controlled by a comprehensive set of Work Packages (WP) that describe and document every aspect of integrating and testing of the Taurus II and the payload. In addition to standardized launch vehicle mechanical and electrical WP procedures, mission-specific WPs are created for mission-unique or payload-specific procedures. During execution of a WP, any discrepancies encountered are recorded on a Discrepancy Report and dispositioned as required. All activities are in accordance with Orbital's AS 9100 certification.

## 7.2. Launch Vehicle Processing

The major vehicle components and subassemblies that comprise Taurus II processing include the Stage 1 Main Engine System (MES), Stage 1 core, S1/S2 interstage structures, and the Stage 2 structures, motor, avionics assembly, and fairing assembly. The Taurus II major components and subassemblies are delivered to the Horizontal Integration Facility (HIF) at the launch site.

Once the major vehicle components and subassemblies are delivered to the HIF, the vehicle is horizontally integrated and tested prior to the arrival of the payload. Integration is performed on platforms set at convenient working heights, which allows relatively easy access for component installation, inspection and test. GSE scaffolding and 'diving boards' are used as needed to provide access to difficult to reach areas of the launch vehicle.

Orbital's team of skilled engineers and technicians perform the following major integration and processing functions on the Taurus II Stage 1 (S1) in the HIF prior to arrival of the payload:

- Receive and inspect all S1 structures, assemblies, engines, sub-assemblies and vehicle components
- Integrate mechanical and electrical components and sub-assemblies onto the S1 core
- Integrate Main Engine System (MES) onto the MES Thrust Frame
- Perform electrical and systems functional & verification testing of the integrated MES
- Integrate MES with the S1 core
- Perform electrical and systems functional & verification testing of the S1 integrated core

In parallel, work on the Taurus II Stage 2 (S2) upper stack is also performed in the HIF prior to arrival of the payload. The following major integration and processing functions are performed on the S2:

- Receive and inspect all S2 structures, assemblies, motors, sub-assemblies, upper stack components, and fairing
- Integrate CASTOR® 30A motor assembly with the S2 upper stack avionics ring and motor cone
- If a third stage option is employed, integrate third stage motor assembly with the S2 upper stack and third stage motor cone (if required)
- Integrate mechanical and electrical components and sub-assemblies onto the S2 upper stack
- Perform electrical and systems functional & verification testing of the S2 integrated upper stack

Once the Taurus II S1 core and S2 upper stack are assembled and checked out, interstage integration can proceed:

- Perform open configuration testing of the S1 and S2 prior to physical integration
- Physically and electrically mate and integrate the S2 upper stack to the S1 core
- Perform integrated S1/S2 Flight Simulation
- Hoist integrated launch vehicle onto Transporter Erector/Launcher
- Integrate launch vehicle to Transporter Erector/Launcher and install umbilicals

### 7.3. Launch Vehicle Testing

Several key Taurus II launch vehicle systems tests are utilized to verify proper integration and operation of the launch vehicle subsystems, systems, and stages. System tests are conducted prior to system and stage mating to ensure each stand alone system is fully functional. For each of these tests specialized test software is loaded into the EGSE in the HIF and/or at the pad. After each test, the configuration of the vehicle remains unchanged until a full and complete review of the test data has been completed and approved.

***Functional Verification Testing***

Functional verification testing is performed on each assembly, subsystem, and system both before and after they are integrated into the launch vehicle. Typical functional verification tests include pre-systems integration testing (i.e.; continuity, isolation and grounding tests) of all components and subsystems, EGSE checkout, major subsystem and system functional checkout, leak checks of pressurized and propellant systems (e.g.; MES leak check, S1 LOX tank leak check), MACH software load verification, power systems tests, post-mate checkouts, communications and telemetry testing, RF testing, FTS receiver/transponder and end-to-end testing, ordnance system testing, premature stage separation tests, fueling system testing, Space Integrated GPS/INS (SIGI) operational testing, and Flight Control Verification and Phasing tests of the S1 and S2.

***Flight Simulation Testing***

Flight Simulation Tests use the flight software to simulate a "fly to orbit" scenario using simulated Inertial Navigation System (INS) data. Flight Simulations are performed after each major change in vehicle configuration (i.e.; after S1/S2 stage mate, after the payload is electrically connected, after the payload is mechanically integrated, and before roll-out to the pad for launch). After each flight simulation test, a complete review of the data is undertaken prior to proceeding.

After the S1/S2 launch vehicle integration and testing has been successfully completed, payload integration can proceed. The Customer nominally participates in Flight Simulations after electrical and mechanical mate of the spacecraft to the launch vehicle.

### 7.4. Payload Processing/Integration

Orbital's approach to payload processing places few requirements on the Customer. Payload processing is conducted a short distance away from the launch vehicle integration facility in an environmentally controlled Payload Processing Facility (PPF). Once the payload is fully assembled, checked out, and fueled (if required), the payload is transported to the Horizontal Integration Facility (HIF) 12 days before launch, and integrated to the launch vehicle.

#### 7.4.1. Payload Propellant Loading Option

For spacecraft that intend to utilize integral propulsion systems with propellants such as hydrazine, Orbital can provide propellant loading as an optional service. Since payload propellant loading is a hazardous non-standard service, the payload propellant loading requirements must be communicated to and coordinated with Orbital well in advance of payload delivery to the launch site. The payload use of Range propellant loading facilities at the launch site can then be coordinated and secured through Orbital.

NOTE

> Customers designing payloads that employ propellant loading, or utilize other hazardous subsystems, processes, or hardware are advised to contact Orbital early in the design process to verify compliance with system and Range Safety standards.

#### 7.4.2. Payload Hazardous Operations

As discussed in Section 6, any payload specific hazardous operations and/or procedures should be coordinated through Orbital, and a draft of the procedures must be provided to the launch Range no later than 120 days prior to first use and finalized 45 days prior to first use.

#### 7.4.3. Payload to Taurus II Integration

After arrival at the HIF, the payload completes its own independent verification and checkout prior to beginning the integration process with Taurus II. Taurus II integrated launch processing activities are designed to simplify final launch processing while providing a comprehensive verification of the launch vehicle to payload interface. The systems integration and test sequence is engineered to ensure all interfaces are verified.

#### 7.4.4. Payload Pre-Mate Interface Testing

If required, the electrical interface between Taurus II and the payload is verified using a mission unique Interface Verification Test (IVT) to jointly verify that the proper function of the electrical connections and commands. These tests, customized for each mission, check bonding, electrical compatibility, communications, discrete commands and any off nominal modes of the payload.

After completing the IVT, a Flight Simulation is performed with the payload electrically (but not mechanically) connected to Taurus II to demonstrate the full sequence of events in a simulated flight scenario. Once the Flight Simulation is successfully completed, the payload is mechanically mated to the launch vehicle. For pre-mate verification of the mechanical interface, the separation system can also be made available before final payload preparations.

#### 7.4.5. Payload Mating and Verification

Following the completion of the open configuration Flight Simulation, the jumpers between the payload and Taurus II are removed and payload closeouts are completed, and the payload is both mechanically and electrically mated to the Taurus II. Following mate, the flight vehicle is ready for the final integrated systems test and Flight Simulation.

### 7.5. Final Processing and Fairing Closeout

After successful completion of integrated launch vehicle/payload Flight Simulation, all launch vehicle consumables are topped off and ordnance is connected. Similar payload operations may occur at this time.

#### 7.5.1. Payload Encapsulation and Fairing Closeout

Once consumables are topped off, final launch vehicle to payload closeout is complete, the fairing is positioned over the payload, the payload is encapsulated inside the fairing and the fairing is integrated with the launch vehicle. Fairing integration to the launch vehicle includes installing the fairing to the separation system, installing the tip-off hinges, and integrating the mechanical/electrical mates between the fairing and upper stack.

Once fairing installation and payload encapsulation is complete, the environmental control system is then attached and initiated to ensure the required payload environments are maintained inside the fairing until launch. Following payload encapsulation in the fairing, the Customer will coordinate with Orbital's Taurus II Mission Manager for any further access to the payload.

#### 7.5.2. FTS and ACS Closeout

After vehicle checkout and integration of the payload to the Taurus II launch vehicle is complete, the flight termination system batteries are activated, conditioned, and installed in the vehicle and an end-to-end FTS test is performed to certify the FTS system. Once the payload is encapsulated in and the fairing installation is complete, the ACS and separation systems are pressurized to final flight pressure, final vehicle preparations are accomplished and a safe and arm verification test is performed to assure proper Safe and Arm (S/A) and Arm/Disarm (A/D) switch operation. The vehicle and launch team are then ready for roll-out to the pad in preparation for countdown and launch.

### 7.6. Launch Operations

After the LV and payload are fully assembled, checked out, and tested as an integrated system, launch operations begin, which includes transporting the integrated launch vehicle out to the pad, erection and installation of the launch vehicle on the launch mount, launch vehicle to pad integration of umbilicals and fueling lines, integrated system testing, launch countdown, automated fueling operations, and launch.

#### 7.6.1. Launch Control Organization

The Launch Control Organization is split into two groups: the Management group and the Technical group.

##### 7.6.1.1. Launch Control Management

The Launch Control Management group consists of senior Range personnel and Mission Directors/Managers for the launch vehicle and payload. The Management group has overall responsibility for launch operations and success of the launch.

##### 7.6.1.2. Launch Control Technical

The Launch Control Technical group consists of the personnel responsible for the execution of the launch operation and data review/assessment for the payload, the launch vehicle and the Range. The payload members of the technical group are engineers who provide technical representation of the Customer in the control center. The launch vehicle members of the technical group are engineers who prepare the Taurus II for flight, review and assess data that is displayed in the Mission Control Center (MCC) and provide technical representation in the MCC and in the Launch Control Center (LCC). The Range members of the technical group are personnel that maintain and monitor the voice and data equipment, tracking facilities and all assets involved with RF communications with the launch vehicle. In addition, the Range also provides personnel responsible for the Flight Termination System (FTS) monitoring and commanding.

#### 7.6.2. Launch Rehearsals

Launch rehearsals are conducted prior to each mission to prepare Taurus II, Customer, and Range personnel for a successful launch. Both Customer and Range personnel involved with launch day activities are required to participate in both launch rehearsals.

##### 7.6.2.1. Launch Site Dress Rehearsal

A launch site dress rehearsal is conducted one month prior to launch (L-1 month) to train and certify the launch team with launch site MCC and LCC consoles and communications systems, procedures for reporting issues, problem solving, launch procedures and constraints, and the decision making process. The launch site dress rehearsal is typically a full day in duration and consists of a number of countdown simulations performed using abbreviated timelines. All aspects of the team's performance are exercised, as well as simulated holds, scrubs, and recycle procedures. The operations and team performance are critiqued and lessons learned are incorporated prior to the Mission Dress Rehearsal (MDR).

##### 7.6.2.2. Mission Dress Rehearsal (MDR)

The MDR is performed 2 days before vehicle roll-out to the pad to train and certify the launch team's readiness for launch. The MDR is the final rehearsal prior to entering countdown operations, and ensures that any issues encountered during the launch dress rehearsal have been resolved. The MDR is typically a half day in duration and is a key criterion for approving launch readiness.

### 7.6.3. Launch Countdown

Following Taurus II closeout operations, the final countdown to launch begins. Orbital's launch countdown operations are designed to methodically transition the vehicle and launch site from a safe state to that of launch readiness. Payload tasks are integrated into the launch countdown operations, as required, as coordinated by the Taurus II Launch Conductor. Launch countdown operations begin 24 hours prior to launch (L-24:00), after positive readiness response from Taurus II and Range personnel.

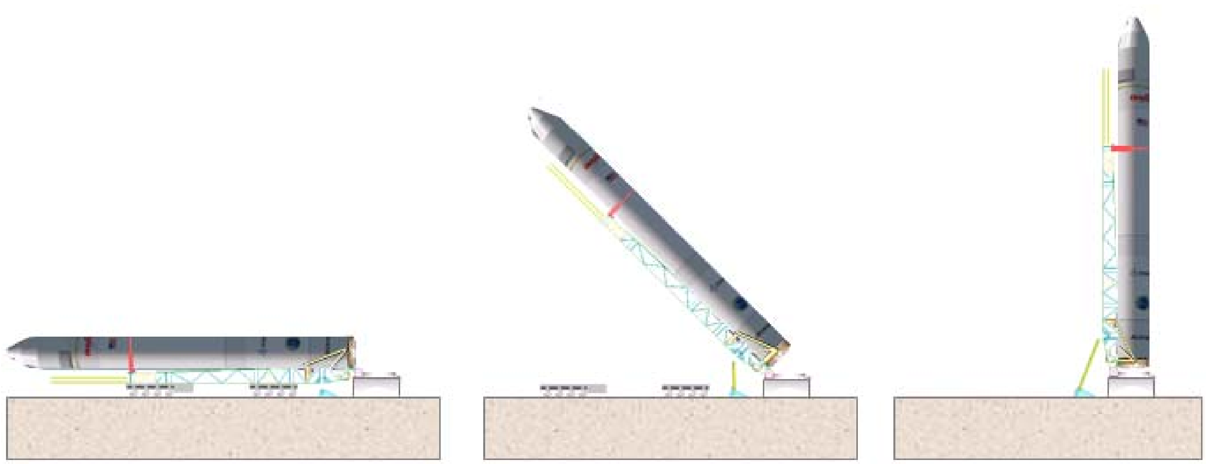
#### 7.6.3.1. Launch Vehicle Roll-out to the Pad and Erection

Upon initiation of launch operations, the Taurus II launch vehicle is transported to the pad on the Transporter Erector/Launcher. Once at the pad, the launch vehicle is erected, secured to the launch mount, and fuel and electrical connections are installed (Figure 7.6.3.1-1). The following major operations occur during the Roll-out and Erection Launch Countdown sequence:

L-24:00: Roll-Out Readiness Poll
- Transport launch vehicle to Launch Pad
- Align/Integrate Transporter Erector/Launcher to Erection Fixture
- Switch to Pad ECS
- Verify Safe-to-Erect

L-18:30: Vehicle Erect Readiness Poll
- Erect launch vehicle
- Integrate to launch mount
- Verify launch vehicle to Ground Safe-to-Mate
- Connect launch vehicle fuel and umbilical lines
- $GN_2$ Purge
- Final launch system closeout
- Pad evacuated of all personnel

Once evacuation of all personnel has been verified, the launch vehicle can be powered and final Taurus II launch system testing can begin.



### 7.6.3.2. Combined System Testing (CST)

After the vehicle is fully erected and integrated with the pad, final launch system tests are completed to verify vehicle integrity and to exercise all interfaces to the Range. CST at the pad begins 7 hours prior to launch (L-07:00), when a positive Power-On readiness response from Taurus II and Range personnel initiates the Hot-Pad operations.

***Combined System Test (CST)***

The Combined System Test is performed after the vehicle is fully erected and integrated with the pad. CST is performed to verify vehicle integrity and to exercise all interfaces to the Range. CST includes launch vehicle and payload health system checks, power systems tests, SIGI alignment and navigation tests, fueling and telemetry tests, and open-loop tests to verify the C-Band, S-Band, and FTS RF systems. A final mission simulation test is then performed on the integrated launch system. The following major operations occur during the CST Countdown sequence:

L-07:00: Power-On Readiness Poll
Apply power to launch vehicle
Combined Launch System Test
Fueling GSE chill-down

Fueling GSE chill-down is performed at the end of the CST sequence. The vehicle and launch team are then ready to being fueling operations.

### 7.6.3.3. Propellant Loading

The propellant loading operations begin at the end of CST with positive propellant loading readiness response from Taurus II and Range management. Propellant loading is an automated process that includes loading both LOX and RP-1 into the launch vehicle. The following major operations occur during the propellant loading portion of the Launch Countdown sequence:

L-02:00: Propellant Loading Readiness Poll
LOX transfer line Chill-Down
LOX/RP-1 Propellant Loading (automated)

### 7.6.3.4. Launch

After the vehicle is fully fueled, and approved for launch by Taurus II and Range management, the final countdown to launch is initiated:

L-00:30: Launch Readiness Poll
Terminal Countdown begins
Engine Low-Flow Chill-down
Switch FTS to Battery Power
Engine Medium-Flow Chill-down
Switch Avionics & Telemetry to Battery Power

T-00:03: Command Auto-Sequence Start

T+00:00: Ignition
Throttle Up to 108%
Actuate LOX/RP-1 Fuel Line Pyros
Actuate Hold-Down Pyros

T+00.00.2 LAUNCH


**Figure 7.6.4.4-1. Taurus II Launch**

### 7.7. WFF Range Facilities

Initially, Taurus II will be launched from the NASA Wallops Flight Facility (WFF), VA. As discussed in Section 3, Orbital is currently on contract with NASA to provide eight cargo re-supply missions to the International Space Station (ISS). Orbital has contracted with the Mid Atlantic Regional Spaceport (MARS) to develop the Taurus II processing and launch facilities at WFF. The facilities Orbital will utilize at WFF are shown on the site map in Figure 7.7-1 and discussed below.

#### 7.7.1. Taurus II Processing Facilities at WFF

The primary WFF facility used for Taurus II processing is the Horizontal Integration Facility (HIF) located on Wallops Island, approximately 1.2 miles from the launch pad.

#### 7.7.1.1. Horizontal Integration Facility (HIF)

The Taurus II launch vehicle and the payload will be fully integrated and tested in the HIF, which has been designed and built to meet the processing and integration requirements of the Taurus II program.


**Figure 7.7-1. Taurus II Facilities at WFF**

The HIF, located on Wallops Island approximately 1.2 miles from Pad 0A, is the primary WFF facility used for Taurus II processing. The WFF HIF, shown in Figure 7.7.1.1-1 boasts a 245 feet long and 90 feet wide footprint that is capable of supporting parallel integration of two Taurus II launch vehicles.

The Vehicle Integration and Test area has two bridge cranes, one 25-ton capacity and the other with 70-ton capacity, each with a 45' maximum hook height. The cranes can also be electrically connected to provide tandem crane lift capability. There are two 25'W X 35'H roll up doors on the South end of the building and one of the same dimensions on the North end. The HIF has lab areas in the Crew Support Area. One of the labs is set up as a Battery lab with ESD grounding and low pressure Nitrogen connections, and the other can be used for small component testing.

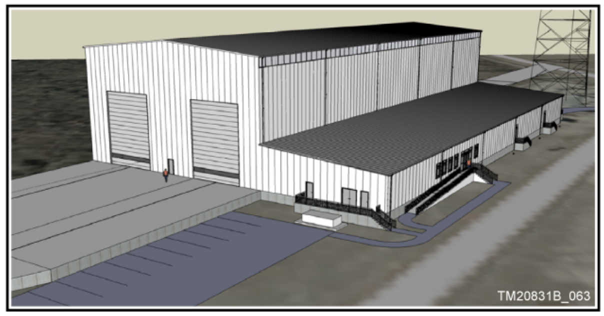



**Figure 7.7.1.1-1. WFF HIF**

The HIF provides compressed gasses ($GN_2$, GHe, and air), HVAC, security, power, water, phone, data, and fiber-optic networks. The HIF has warehouse space for storing Taurus II components and equipment between launches, and incorporates fiber optic lines for data communications between the HIF/LCC/Launch Pad and MCC on the main base.

The temperature in the HIF can be selected between 18 °C to 29 °C (64 °F to 84 °F) and held within that setting by a few degrees. Humidity in the HIF will be maintained between 35% and 75% relative humidity.

The HIF is classified as a 'visibly clean facility' Class 100K (ISO 8). Orbital performs launch site Integration and Test activities of the Taurus II in the HIF in preparation for roll-out to the launch pad. This facility will be used to assemble and test the Taurus II launch vehicle, mate the payload to the launch vehicle, perform launch vehicle and payload checkout, and for encapsulating the payload in the fairing.

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**Figure 7.7.2.1-1. WFF PPF**

**7.7.2. Payload Processing Facilities at WFF**

There are two existing WFF facilities that will initially be used for payload processing and fueling to support Taurus II launches.

**7.7.2.1. Payload Processing Facility (PPF)**

WFF Building H-100 (Figure 7.7.2.1-1) has been designated the PPF for Taurus II launches. The PPF will prepare the Cygnus Pressurized Cargo Module (PCM) for integration to the Service Module, and load NASA supplied cargo into the PCM interior. The PPF is located on the WFF main base, near the airfield, providing the capability to support both ground and air transported payload hardware.

The 80 ft x 40 ft x 62 ft PPF high bay has a 3200 sq ft cleanroom capable area with 20 ft x 60 ft exterior roll-up doors at either end. The high bay is also equipped with a 22 t crane, which has a hook height of 60 ft.

The 80 ft x 40 ft x 40 ft PPF low bay has 3200 sq ft which is also cleanroom capable area, and has 35 ft x 40 ft exterior roll-up doors at either end. The low bay is equipped with two 20 t cranes, with hook heights of 30 ft. Both high and low bays of the PPF are maintained as Class 100K (ISO 8) facilities, with 10K (ISO 7) capability in specific clean rooms.

The PPF also provides 400 cycle, 3 phase power with emergency generator backup, power system grounding grids and lightning protection, 125 psi air system and 6000 psi $GN_2$ system, Global Positioning System (GPS) feeds from exterior antennae, a HVAC system, and over 1300 sq ft of conference rooms and office space.

#### 7.7.2.2. V-55 Fueling Facility

WFF Building V-55 (Figure 7.7.2.2-1) has been designated as the fueling facility for Taurus II launches. V-55 will be used for loading the hypergolic fuels into the Cygnus spacecraft service module.


**Figure 7.7.2.2-1. WFF Payload Fueling Facility**

Since fueling is a hazardous operation, V-55 is located at the north end of Wallops Island and is isolated from the HIF and other launch site facilities. Building V-50, located 450 ft to the south of V-55, provides a remote location for monitoring and control of the fuel loading operations. V-50 also provides a Self-Contained Atmospheric Protective Ensemble (SCAPE) suit up area, and a covered walkway runs between V-50 and V-55.

V-55 provides a 60 ft x 40 ft x 40 ft work area, which sits on an 8" reinforced concrete slab with a hydrazine compatible topcoat and spill control pond. Two 19 ft x 24 ft exterior roll-up doors are located at either end, and a personnel access door is located at the front of V-55. The high bay is equipped with a 20 t crane, which has a hook height of 33 ft.

V-55 provides 4160 VAC 3 phase power @ 60 Hz, with separate feeds for 480 VAC, 240 VAC, and 100/115 VAC power. Power system grounding grids including an ESD floor and lightning protection, are also provided. The HVAC system is a 15 ton DX systems with hydronic coil, and the air system provides 125 psi compressed air. Two PTZ cameras provide full coverage of V-55 interior. All power system hardware and PTZ cameras are explosion proof. V-55 is currently maintained as a Class 300K (ISO 9) visibly clean environment.

### 7.7.3. Launch Facilities at WFF

Launch Day activities will be conducted from five major facilities at WFF, including the launch pad, the Launch Control Center (LCC), the Mission Control Center (MCC), the Range Control Center (RCC), and payload/Customer Mission Control.

#### 7.7.3.1. Taurus II Launch Pad at WFF

The launch pad that will be used for all Taurus II launches out of WFF will be Pad 0A, illustrated in Figure 7.7.3.1-1. The Taurus II fixed infrastructure at WFF launch pad 0A provides the minimum necessary for erection, fueling, final checkout, and launch. WFF launch pad 0A fixed assets are limited to a raised pad consisting of a launch mount with a flame duct & lightning towers, a ramp to the top of the pad, cabling

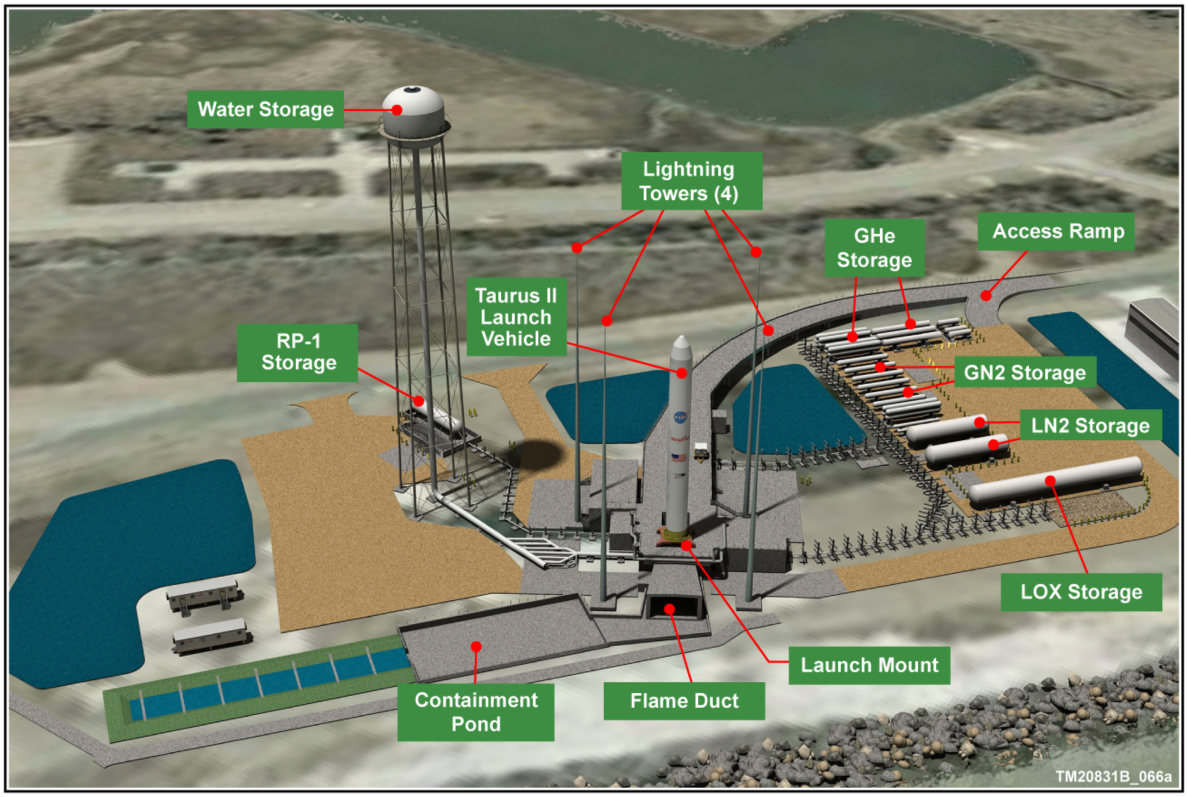


**Figure 7.7.3.1-1. WFF Launch Pad 0A**

and fueling trenches, a 250,000 gallon water storage tank and containment pond for noise suppression, Launch Equipment Vaults (LEVs) for protection of portable Taurus II and Customer EGSE, LOX and RP-1 fueling systems and tanks, and $N_2$ and He compressed gas storage tank skids. Taurus II launch pad 0A operations are streamlined to take less than 24 hours from roll-out to launch. This responsive launch operations paradigm also minimizes Taurus II launch operations and infrastructure costs.

### 7.7.3.2. Launch Control Center (LCC)

The LCC provides launch control for Taurus II launches. Building W-20 is an existing Wallops Island "blockhouse" type facility (Figure 7.7.3.2-1) that Orbital utilizes for Taurus II launches from WFF. The LCC houses the launch systems C&C and telemetry consoles for the payload and Taurus II launch vehicle, and provides consoles for Orbital, Range Safety, and Customer personnel. Since Taurus II EGSE is reconfigurable and mobile, it will be moved into WFF building W-20 and configured prior to a launch, and then moved into storage after the launch campaign is complete.


**Figure 7.7.3.2-1. WFF Launch Control Center**

The LCC provides launch C&C primary and backup positions for Taurus II launch vehicle control, Taurus II fueling control, payload control, Range Safety, and WFF site control (i.e., propellant farm, ECS, and telemetry, power, and network support equipment).

### 7.7.3.3. Mission Control Center (MCC)

The MCC (Figure 7.7.3.3-1) serves as the launch authority center for Taurus II launches. Building E-106 is an existing WFF facility on the main base that Orbital utilizes for mission control of Taurus II launches. The WFF MCC houses the Taurus II, Yuzhnoye, and Customer launch teams and provides consoles for Orbital, Range Safety, and Customer personnel. The MCC provides hardline and RF telemetry consoles, voice net communications, and launch Pad 0A live video. Observation and VIP guest accommodations are also provided at the MCC.

### 7.7.3.4. Range Control Center (RCC)

The RCC serves as the command and control and launch authority center for the WFF Range Safety personnel. The RCC is co-located with the Taurus II MCC in WFF Building E-106. The RCC houses the WFF Range Safety, WFF launch team, FAA, and WFF Launch Authority personnel.

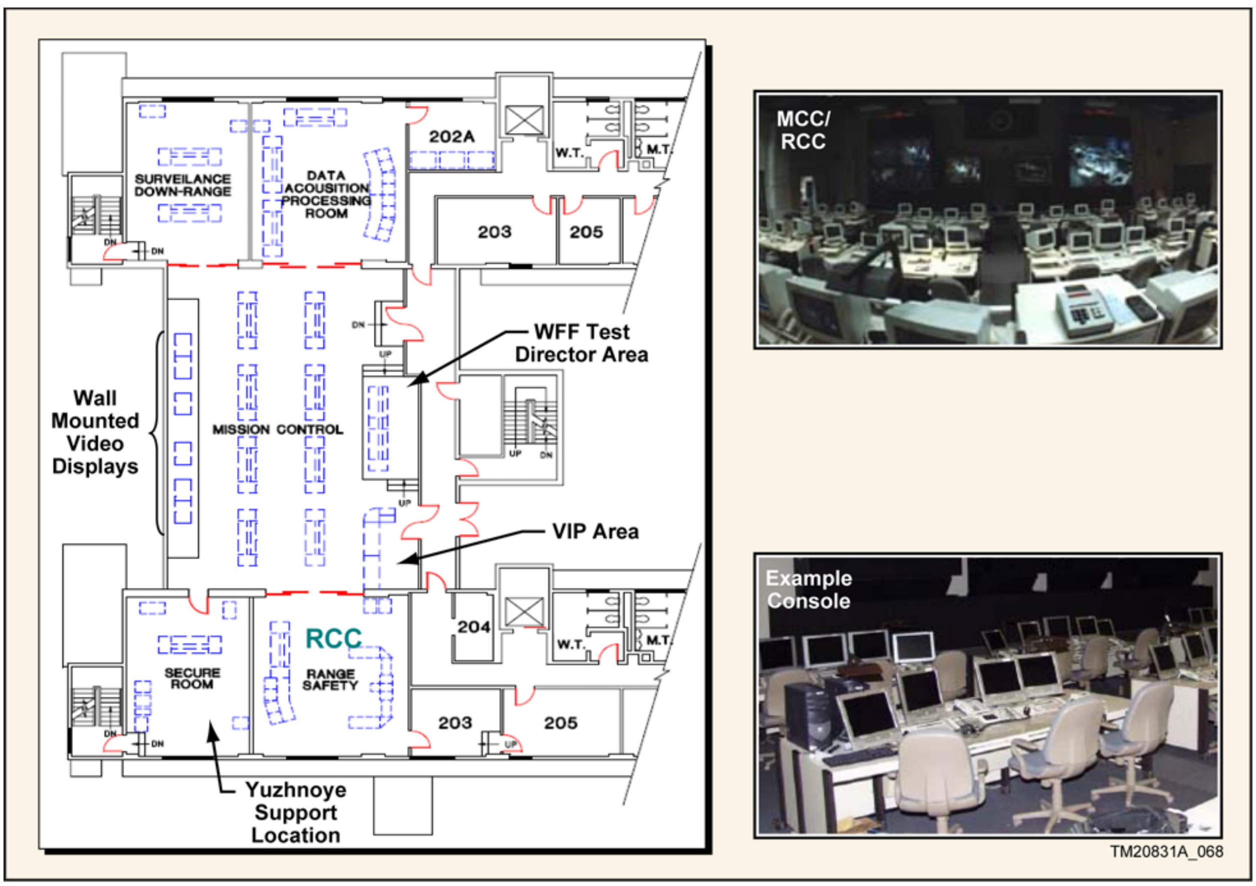


**Figure 7.7.3.3-1. WFF Mission/Range Control Center**

#### 7.7.3.5. Customer Mission Control

In addition to the launch support facilities at WFF, Orbital also provides separate facilities offsite that can be utilized by the Customer Support Team to monitor the payload spacecraft prior to separation, and to perform mission management once the spacecraft has separated from the Taurus II. In support of the COTS/CRS missions, Orbital has developed the MCC-D at Orbital Building #2 in Dulles, VA.

The Customer organization can chose to develop and equip a separate/offsite mission support center, or Orbital can provide this capability as an optional launch service.

## 8. OPTIONAL CAPABILITIES

The Taurus II launch service is structured to provide a baseline vehicle configuration which can then be augmented with optional enhancements to meet the specific needs of individual payloads. The baseline vehicle capabilities are defined in the previous sections and the optional capabilities are defined below. Should any Customer have unique requirements not addressed in this Taurus II Users Guide, please contact the Taurus II Program Office directly for further assistance.

### 8.1. Optional Payload Interfaces

For each payload, Orbital works with the Customer to ensure that the payload unique interface requirements are met with the most reliable and cost effective solution possible. The optional payload requirements and services are then specifically documented in the mission ICD.

#### 8.1.1. Mechanical Interface Options

As discussed in Section 5, the Taurus II launch service includes all standard hardware and integration services necessary to mechanically attach the payload to and separate the payload from the Taurus II launch vehicle.

Orbital-provided separation systems include the industry standard RUAG 937, 1194, 1666, and 2624 low shock clamp band mechanisms. One of these separation systems is provided as part of the Taurus II standard launch service.

Customers may choose one of the Orbital-provided separation system that best fits their payload requirements, or provide an alternate solution.

For Customers that provide their own adapter and/or separation system, the top surface of the 1575 mm (62.01 in.) diameter mechanical ring defined in Section 5, is the mechanical interface between the spacecraft provided hardware and the launch vehicle. If a Customer-provided spacecraft adapter and/or separation system is used, interfaces for ground handling, encapsulation and transportation equipment must also be provided, or must conform to existing Taurus II GSE.

Both standard and Customer-provided payload mechanical interfaces and separation systems are defined and controlled in the mission ICD and Mechanical Interface Control Drawing (MICD).

#### 8.1.2. Electrical Interface Options

As discussed in Section 5, the Taurus II launch service includes all standard hardware and integration services necessary to electrically attach the payload to and separate the payload from the Taurus II launch vehicle.

For Customers that provide their own adapter and/or separation system, the top surface of the 1575 mm (62.01 in.) diameter mechanical ring defined in Section 5, is the location of the electrical interface between the spacecraft provided hardware and the Taurus II launch vehicle. Two 61 pin connectors provide payload communication services from the ground to the spacecraft via a dedicated payload umbilical within the vehicle. If a Customer-provided spacecraft adapter and/or separation system is used, interfaces for electrical ground handling equipment must also be provided, or must conform to existing Taurus II EGSE. Both standard and Customer-provided payload electrical interfaces are defined and controlled in the mission ICD and the EICD.

### 8.2. Fairing Enhancements

#### 8.2.1. Additional Fairing Access Doors

In addition to the two standard 609 mm x 609 mm (24 in. x 24 in.) payload fairing access doors, Orbital can provide the Customer with additional, non-standard access doors and fairing access configurations. Small circular access panels and access doors in the lower cylindrical and first conic section of the fairing can also be provided as negotiated mission-specific enhancements.

Typically, one access door is located in each half of the cylindrical section of the fairing, and the doors are positioned according to user requirements within the available zones defined in Section 5. Should the Customer chose to modify the standard access door configuration, Orbital will verify, through analysis, the structural integrity of the fairing with the additional door(s) in the desired location(s). Provided this analysis shows the additional door sizes and locations are feasible, Orbital will then manufacture the additional door(s) and the modified fairing for the mission. This analysis is validated in the acceptance test of the flight fairing structure. In order to ensure Taurus II can meet the non-standard requirements, all positions of all payload fairing access doors must be defined no later than L-8 months.

#### 8.2.2. Increased Payload Volume

To accommodate payloads larger than the user volume provided by the standard Taurus II fairing, a larger fairing design is being considered by Orbital. Additional information on increased payload volume capability can be provided on request.

### 8.3. Optional Performance Enhancements

#### 8.3.1. Enhanced Upper Stage

Insertion accuracy and/or orbital increase can be provided as an enhanced option utilizing the Taurus II Enhanced Upper Stage. The enhanced upper stage currently under development, provides a substantial performance improvement to the Taurus II delivered payload capability. The enhanced second stage is a liquid fueled engine which provides multi-burn capability to achieve much higher orbit position and accuracy capability than the standard CASTOR® 30A configuration. The Taurus II enhanced second stage will support the NASA Commercial Resupply Services (CRS) missions starting in 2013, and is available as an option to meet the higher performance requirements of all payloads. Additional details as well as specific performance capability associated with the enhanced second stage can be provided by contacting the Orbital Taurus II program office.

#### 8.3.2. Optional STAR™ 48 Third Stage

The STAR™ 48V (Figure 8.3.2-1) solid rocket motor is the basis for the optional STAR™ 48 third stage on Taurus II. The 3-axis stabilized STAR™ 48 third stage provides a significant performance increase for spacecraft needing to achieve Geo-transfer orbits or requiring Earth-escape trajectories. The STAR™ 48 third stage leverages Orbital's flight proven heritage of the Minotaur family of launch vehicles, as well as the commercial Pegasus and Taurus classic SLVs, to create a low-risk, readily-developed system. The

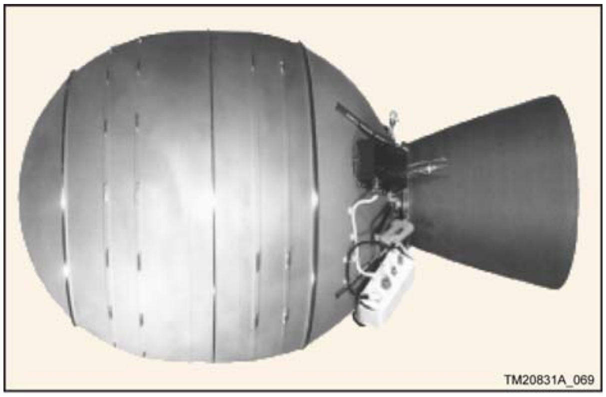


**Figure 8.3.2-1. STAR™ 48**

STAR™ 48V SRM is manufactured by ATK and is derived from the STAR™ 48 motor line that has an extensive flight history in space launch applications stretching back to Delta II and Shuttle. The vectorable nozzle on the STAR™ 48V is being used by the Minotaur IV+ and the Minotaur V as a higher energy alternative with 3-axis stability to the baseline Orion 38 motor, giving Orbital an off-the-shelf stage capability that works well on the Taurus II.

The STAR™ 48V motor has a diameter of 1244.6 mm (49.0 in.) and an overall length of 2032.0 mm (80.0 in.). The motor has two integral flanges, the lower for attachment to the 2nd Stage and the upper for attachment to the payload adaptor. The motor consists of a carbon-phenolic exit cone, 6AL-4V titanium high-strength motor case, silica-filled rubber insulation system, and a propellant system using high-energy TP-H-3340 ammonium perchlorate and aluminum with a Hydroxyl Terminated Polybutadiene (HTPB) binder. The STAR™ 48V motor is also available in propellant off-loaded configurations. The motor is currently qualified for propellant weights ranging from 2010 kg (4430 lb) to 1739 kg (3833 lb) in, which is the maximum off-loaded condition. The amount of off-load is a function of spacecraft weight and the velocity requirements of the mission.

The STAR™ 48 third stage will decrease payload envelope by 2m (79 in) axially from the nominal Taurus II envelope length (either baseline or the 1m (39 in) longer Enhanced envelope).

### 8.4. Contamination Control Options

Orbital understands that payloads have varying requirements for cleanliness, and Taurus II Customers can select any combination of the following contamination control options to meet the unique needs of their payloads.

#### 8.4.1. Integration Environment

With the enhanced contamination control option, Customers are provided with a Class 10,000 (ISO 7) environment during all payload processing activities up to and after fairing encapsulation. The clean room and anteroom(s) can be configured to utilize High Efficiency Particulate Air (HEPA) filter units to filter the air and hydrocarbon content at 15 ppm or less as specified by the customer. Clean room garments are provided for payload staff as well as vehicle staff that need to work inside the clean room.

#### 8.4.2. Fairing Internal Surface Cleanliness

The inner surface of the fairing and payload cone assemblies can be cleaned to cleanliness criteria which ensures no particulate matter visible with normal vision when inspected from 6 to 18 inches when the surface is illuminated using black light, 3200 to 3800 Angstroms (Visibly Clean Plus Ultraviolet), and/or 500 A.

In addition, Orbital can ensure that all materials used within the encapsulated volume have outgassing characteristics of less than 0.1% Total Mass Loss (TML) and less than 0.01% Collected Volatile Condensable Materials (CVCM). Items that don't meet these levels can be masked to ensure they are encapsulated and have no significant effect on the payload.

#### 8.4.3. Nitrogen Purge

As a non-standard service, Orbital can provide gaseous nitrogen purge to the payload and/or payload instrument after fairing encapsulation through lift-off. The Taurus II nitrogen purge option delivers gaseous nitrogen to system distribution lines routed along the inner surface of the fairing for general fairing purge. If the Customer desires purge capability of specific payload instrumentation, Orbital can provide $GN_2$ flow to a pre-defined purge quick disconnect fitting on the payload.

The nitrogen supply system is equipped with flow rate metering that can be configured to meet spacecraft requirements for flow rates up to 0.14 scmm (5.0 scfm). The system also includes a particulate filter and pressure switches to continuously monitor and control system operation. The $GN_2$ meets Grade B cleanliness specifications, as defined in MIL-P-27401C. The $GN_2$ is on/off controllable in the launch equipment vault and in the launch control room. The $GN_2$ system's regulators are set to a desired flow rate during prelaunch processing. The $GN_2$ system cannot be adjusted after the launch pad has been cleared of personnel. Payload $GN_2$ purge requirements, including any payload unique purge interfaces, must be defined no later than L-8 months, and documented in the mission ICD.

## 8.5. Enhanced Telemetry Options

Orbital can provide mission-specific instrumentation and telemetry components to support additional payload or experiment data acquisition requirements. Telemetry options include additional payload-dedicated bandwidth and GPS-based precision navigation data.

### 8.5.1. Enhanced Telemetry Bandwidth

A second telemetry data stream capable of up to 2 Mbps data rate can be provided. Maximum data rates depend on the mission coverage required and the launch Range receiver characteristics and configuration.

### 8.5.2. Enhanced Telemetry Instrumentation

To support the higher telemetry data rate capability defined in Section 8.5.1, enhanced telemetry instrumentation can be provided. The instrumentation can include strain gauges, temperature sensors, accelerometers, analog data, and digital data configured to mission-specific requirements.

### 8.5.3. Navigation Data

Precision navigation data using an independent GPS-receiver and telemetry link is available as an enhanced option. This option utilizes the Orbital-developed GPS Position Beacon (GPB) and provides a better than 100 m position accuracy with a nominal 1 Hz data rate.

**APPENDIX A**

PAYLOAD QUESTIONNAIRE

| SPACECRAFT IDENTIFICATION | |
|---|---|
| FULL NAME: | |
| ACRONYM: | |
| OWNER/OPERATOR: | |
| INTEGRATOR(s): | |

| ORBIT INSERTION REQUIREMENTS* | | |
|---|---|---|
| SPHEROID | ❑ Standard<br>❑ Other: | |
| ALTITUDE | Insertion Apse:<br>____ ± ______ ❑ km<br>____ ± ______ ❑ nmi | Opposite Apse:<br>____ ± ______ ❑ km<br>____ ± ______ ❑ nmi |
| *or...* | Semi-Major Axis:<br>____ ± ______ ❑ km<br>____ ± ______ ❑ nmi | Eccentricity:<br>____ ≤ e ≤ __ |
| INCLINATION | ____ ± ______ deg | |
| ORIENTATION | Argument of Perigee:<br>____ ± ______ deg | Longitude of Ascending Node (LAN):<br>____ ± ______ deg |
| | Right Ascension of Ascending Node (RAAN):<br>____ ± ______ deg...for Launch Date: ____ | |

* Note: Mean orbital elements

| LAUNCH WINDOW REQUIREMENTS |
|---|
| NOMINAL LAUNCH DATE: |
| OTHER CONSTRAINTS (if not already implicit from LAN or RAAN requirements, e.g., solar beta angle, eclipse time constraints, early on-orbit ops, etc): |

| GROUND SUPPORT EQUIPMENT | | | |
|---|---|---|---|
| Describe any ground support equipment, mission control facilities (e.g.; LCC, MCC) and Range facilities (e.g., Launch Equipment Vault (LEV) which the Spacecraft intends to use: | | | |
| LSV | Describe (in the table below) Spacecraft EGSE to be located in the LSV. | | |
| | **Equipment Name / Type** | **Approximate Size (LxWxH)** | **Power Requirements** |
| | | | |
| | | | |
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| LEV | Describe (in the table below) Spacecraft EGSE to be located in the LEV. | | |
| | **Equipment Name / Type** | **Approximate Size (LxWxH)** | **Power Requirements** |
| | | | |
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| | Is UPS required for equipment in the LEV? | Yes / No | |

| EARLY ON-ORBIT OPERATIONS |
|---|
| Briefly describe the spacecraft early on-orbit operations, e.g., event triggers (separation sense, sun acquisition, etc), array deployment(s), spin ups/downs, etc: |

| SPACECRAFT SEPARATION REQUIREMENTS | |
|---|---|
| ACCELERATION | Longitudinal: = _________ g's Lateral: = _________ g's |
| VELOCITY | Relative Separation Velocity Constraints: |
| ANGULAR RATES (pre-separation) | Longitudinal: _____ ± _____ deg/sec<br>Pitch: ____________ ± ____ deg/sec<br>Yaw: _____________ ± ____ deg/sec |
| ANGULAR RATES (post-separation) | Longitudinal: ___ ± _____ deg/sec<br>Pitch: _____ ± __ deg/sec<br>Yaw: ______ ± __ deg/sec |
| ATTITUDE (at deployment) | Describe Pointing Requirements Including Tolerances: |
| SPIN UP | Longitudinal Spin Rate: ______ ± __________ deg/sec |
| OTHER | Describe Any Other Separation Requirements: |

| SPACECRAFT COORDINATE SYSTEM |
|---|
| Describe the Origin and Orientation of the spacecraft reference coordinate system, including its orientation with respect to the launch vehicle (provide illustration if available): |

| SPACECRAFT PHYSICAL DIMENSIONS | |
|---|---|
| STOWED CONFIGURATION | Length/Height:________ ❑in ❑cm<br>Diameter: ___________ ❑in ❑cm<br><br>Other Pertinent Dimension(s): |
| | Describe any appendages/antennas/etc which extend beyond the basic satellite envelope: |
| ON-ORBIT CONFIGURATION | Describe size and shape: |

***If available, provide electronic files of dimensioned drawings for both stowed and on-orbit configurations.***

| SPACECRAFT MASS PROPERTIES* | | | | | | |
|---|---|---|---|---|---|---|
| PRE-SEPARATION | Inertia units: ❑ $lb_m$-in$^2$ | ❑ kg-m$^2$ | Mass:______________ | ❑ $lb_m$ | ❑ kg |
| | Ixx:__________ | Ixy:__________ | XCG:______________ | ❑ in | ❑ cm |
| | Iyy:__________ | Iyy:__________ | YCG:______________ | ❑ in | ❑ cm |
| | Izz:__________ | Ixz:__________ | ZCG:______________ | ❑ in | ❑ cm |
| POST-SEPARATION (non-separating adapter remaining with launch vehicle) | Inertia units: ❑ $lb_m$-in$^2$ | ❑ kg-m$^2$ | Mass:______________ | ❑ $lb_m$ | ❑ kg |
| | Ixx:__________ | Ixy:__________ | XCG:______________ | ❑ in | ❑ cm |
| | Iyy:__________ | Iyy:__________ | YCG:______________ | ❑ in | ❑ cm |
| | Izz:__________ | Ixz:__________ | ZCG:______________ | ❑ in | ❑ cm |

** Stowed configuration, spacecraft coordinate frame*

| ASCENT TRAJECTORY REQUIREMENTS | |
|---|---|
| Free Molecular Heating at Fairing Separation: | FMH = _______ ❑ W/m² ❑ Btu/ft²/hr |
| Fairing Internal Wall Temperature | T = ________ ❑ deg C ❑ deg F |
| Dynamic Pressure at Fairing Separation: | q = ________ ❑ N/m² ❑ $lb_f/ft^2$ |
| Ambient Pressure at Fairing Separation: | P = ________ ❑ N/m² ❑ $lb_f/in^2$ |
| Maximum Pressure Decay During Ascent: | Δ P = ________ ❑ N/m²/sec ❑ $lb_f/in^2$/sec |
| Thermal Maneuvers During Coast Periods: | |

| SPACECRAFT ENVIRONMENTS | |
|---|---|
| THERMAL DISSIPATION | Spacecraft Thermal Dissipation, Pre-Launch Encapsulated: ___________ Watts<br>Approximate Location of Heat Source: |
| TEMPERATURE | Temperature Limits During Ground/Launch Operations: Max ___________ ❑ deg F ❑ deg C; Min ___________ ❑ deg F ❑ deg C |
| | Component(s) Driving Temperature Constraint:<br>Approximate Location(s): |
| HUMIDITY | Relative Humidity: Max ________ % Min ________ %<br>***or***, Dew Point: Max ___________ ❑ deg F ❑ deg C; Min ___________ ❑ deg F ❑ deg C |
| GAS PURGE | Specify Any Gas Purge Requirements (e.g.; Nitrogen), Including Component Description, Location, and Required Flow Rate:<br>(Nitrogen Purge is a Non-Standard Service) |
| CLEANLINESS | Volumetric Requirements (e.g. Class 100,000): _______<br>Surface Cleanliness (e.g. Visually Clean): _____<br>Other: |
| LOAD LIMITS | Ground Transportation Load Limits:<br>Axial = _______ g's<br>Lateral = _______ g's |

| MECHANICAL INTERFACE | |
|---|---|
| DIAMETER | Describe Diameter of Interface (e.g. Bolt Circle, Separation System, etc.) and provide illustration if available: |
| SURFACE FLATNESS | Flatness Requirements for Sep System or Mating Surface of Launch Vehicle: |
| SEPARATION SYSTEM | Will Launch Vehicle Supply the Separation System? Yes / No<br>If Yes, Approximate location of electrical connectors:<br>Special thermal finishes (tape, paint, MLI) needed:<br>If No, Provide a brief description of the proposed system: |
| FAIRING ACCESS | Payload Fairing Access Doors (spacecraft coordinate frame):<br>Longitudinal __________ ❑ in ❑ cm Clocking (deg), Describe:<br>Longitudinal __________ ❑ in ❑ cm Clocking (deg), Describe:<br>Longitudinal __________ ❑ in ❑ cm Clocking (deg), Describe: |
| DYNAMICS | Spacecraft Natural Frequency:<br>Axial ____________ Hz Lateral ____________ Hz<br>Recommended: > TBD Hz > TBD Hz |
| OTHER | Other Mechanical Interface Requirements: |

| ELECTRICAL INTERFACE | | |
|---|---|---|
| Bonding Requirements: | | |
| Are Launch Vehicle Supplied Pyro Commands Required?<br>Yes / No If Yes, magnitude: __________ amps for _________ msec<br>When _________ seconds before separation | | |
| Are Launch Vehicle Supplied Discrete Commands Required?<br>If Yes, describe: | | Yes / No |
| Is Electrical Access to the Satellite Required? | After Encapsulation?<br>At Launch Site? | Yes / No<br>Yes / No |
| Is Spacecraft Battery Charging Required? | After Encapsulation?<br>At Launch Site? | Yes / No<br>Yes / No |
| Is a Telemetry Interface with the Launch Vehicle Flight Computer Required?<br><br>If Yes, describe: | | Yes / No |
| Other Electrical Requirements (e.g.; coax, fiber, etc.): | | |

***Please complete attached sheet of required pass-through signals.***

| RF RADIATION | |
|---|---|
| Time After Separation Until RF Devices Are Activated:<br><br>(Note: Typically, spacecraft radiation is not allowed from encapsulation until after separation.) | |
| Frequency: ________________ MHz | Power: _______________ Watts |
| Location(s) on Spacecraft (spacecraft coordinate frame):<br><br>Longitudinal __________ ❑ in ❑ cm<br><br>Longitudinal __________ ❑ in ❑ cm | <br><br>Clocking (deg), Describe:<br><br>Clocking (deg), Describe: |

**REQUIRED PASS-THROUGH SIGNALS**

| Item No. | Pin | Signal Name | From LEV | To Satellite | Shielding | Max Current (amps) | Total Line Resistance (ohms) |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
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**REQUIRED PASS-THROUGH SIGNALS**

| Item No. | Pin | Signal Name | From LEV | To Satellite | Shielding | Max Current (amps) | Total Line Resistance (ohms) |
|---|---|---|---|---|---|---|---|
| 31 | | | | | | | |
| 32 | | | | | | | |
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| 59 | | | | | | | |
| 60 | --- | Reserved for separation loop | --- | --- | --- | --- | --- |

**REQUIRED PASS-THROUGH SIGNALS**

| Item No. | Pin | Signal Name | From LEV | To Satellite | Shielding | Max Current (amps) | Total Line Resistance (ohms) |
|---|---|---|---|---|---|---|---|
| 61 | --- | Reserved for separation loop | --- | --- | --- | --- | --- |
| 62 | | | | | | | |
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**REQUIRED PASS-THROUGH SIGNALS**

| Item No. | Pin | Signal Name | From LEV | To Satellite | Shielding | Max Current (amps) | Total Line Resistance (ohms) |
|---|---|---|---|---|---|---|---|
| 92 | | | | | | | |
| 93 | | | | | | | |
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| 117 | | | | | | | |
| 118 | | | | | | | |
| 119 | | | | | | | |
| 120 | | | | | | | |
| 121 | --- | Reserved for separation loop | --- | --- | --- | --- | --- |
| 122 | --- | Reserved for separation loop | --- | --- | --- | --- | --- |