UEI App Note:

Orbital Sciences Corporation uses UEI's PowerDNA Cubes and I/O Modules in 3rd Generation Ground Support System for the Taurus II Rocket Launch System.

by Bob Judd
Director of Marketing
United Electronic Industries, Inc.

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Shaping the Future of Computer-Based I/O™

Orbital Sciences Corporation uses UEI's PowerDNA Cubes and I/O Modules in 3rd Generation Ground Support System for the Taurus II Rocket Launch System.

Orbital Sciences Corporation is an independent publicly-held corporation that specializes in designing/building space launch vehicles for commercial customers and governmental agencies. Orbital has successfully developed more launch vehicles during the last 20 years than any other organization. The Taurus II launch system builds on Orbital's experience with its highly successful Pegasus, Taurus, and Minotaur space launch vehicles as well as launch vehicles developed for the nation's missile defense system.

Since the founding of the company in 1982, Orbital has delivered and launched over 500 launch vehicles and has achieved one of the industry's best mission success records. The company has nearly 200 additional launch vehicles under contract for delivery to customers through 2014.

Orbital has a long history of successful space launch vehicles, sub orbital launch vehicles, target vehicles, and interceptor boost vehicles, as illustrated in Figure 1 below. Orbital's many 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.

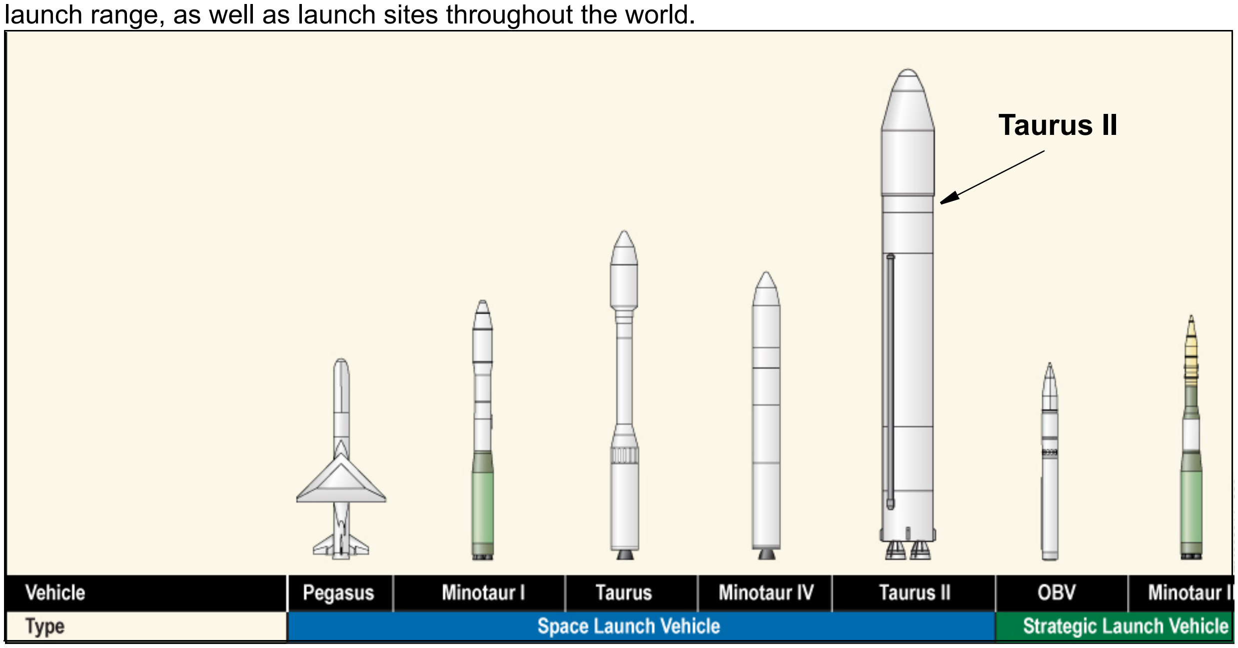


Figure 1. Major Orbital Sciences Vehicles

NOTE: Much of the explanatory text and graphics in this document is from the Orbital Science Taurus II User Guide, published in April 2010. It is reprinted here with the express permission of Orbital Sciences Corporation

The Taurus II launch system us composed of the launch vehicle and its 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 Cape Canaveral, FL, and to launch facilities on the West Coast – either to Vandenberg AFB, CA or Kodiak, AK.

The Taurus II provides all the necessary hardware, software, and services to integrate, test, and launch a payload into its prescribed orbit. The Taurus II vehicle is a two-stage, inertially-guided, ground launched vehicle designed to satisfy a wide range of payload requirements.

1.1 Electrical Ground Support Equipment

The Orbital Launch Support Equipment, which includes the Electrical Ground Support Equipment (EGSE), Mechanical Ground Support Equipment (MEGSE) and Concept of Operations (CONOPS) is designed to be adaptable to varying levels of infrastructure at several launch sites on both east and west coasts of the U.S.

1.1.1 Input/Output Connections

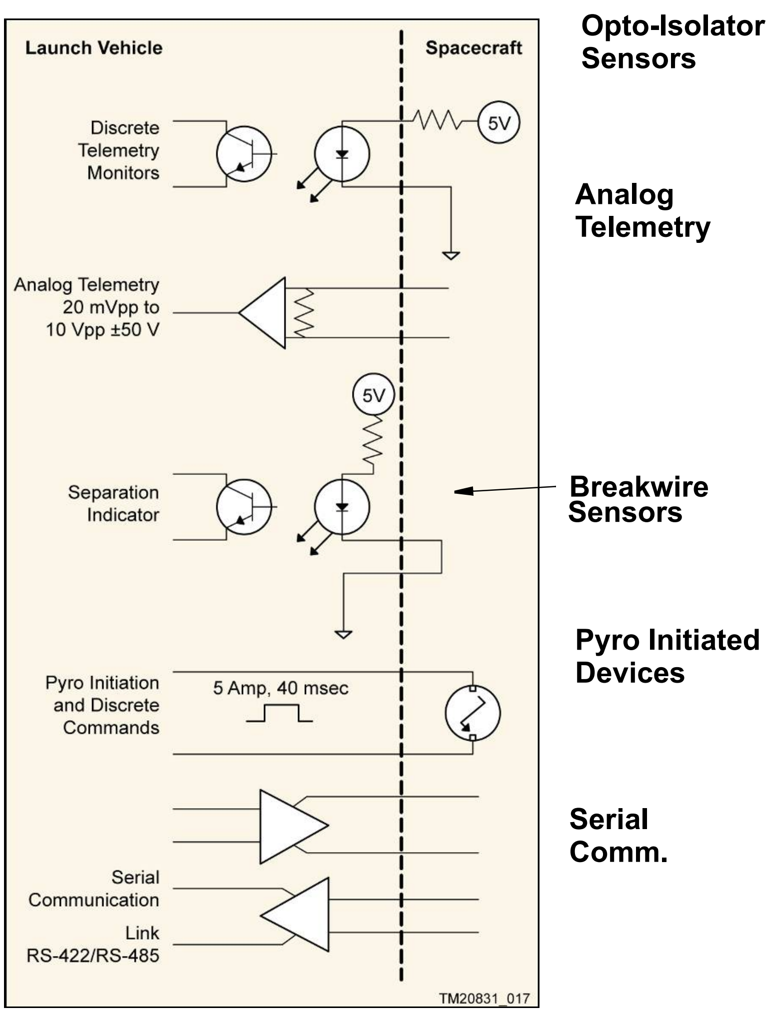


Figure 2. I/O Connections

1.2 GSE Usage Concept

The Orbital GSE is used from the time the components of the flight vehicle are delivered to the test area for pre-integration testing, vehicle integration, and flight simulation, through the launch site build up and launch operations, including the post-launch data gathering and processing. The GSE is then returned to the factory, refurbished and reconfigured to support the launch vehicle throughout its component testing and post flight processing. In general, the life expectancy of a set of GSE hardware is about 10 years.

1.3 GSE History

Orbital's first generation of ground support equipment was based on use of a central server system with distributed I/O. Its original release date was 4th quarter of 1998 and it is still in service today. The second generation of GSE was also based on using a central server, but the I/O system was directly coupled to the server. Its original release date was around the 4th quarter of 2003 and all the systems built at that time are still in service today, more than seven years later.

1.4 Pre-Third Generation GSE

Orbital designed one system — **pre-third** generation — that is based on UEI's rack mounted PowerDNR I/O housing. It uses a complement of DNR I/O modules configured in a 12-slot front-access RACKTangle enclosure, as shown in Figure 1. The RACKtangle contains five DNR-DIO-406 cards, four DNR-AI-205 cards, one DNR-AO-308 card and a DNR-SL-501 card. The DIO-406 cards control and monitor the primary vehicle interface which is a bank of electromechanical relays. The electromechanical relays are used here because of the isolation from the vehicle components when they are turned off or powered down. The electromechanical relays are configured as Power Switches, Battery Chargers and discrete controls for various systems and subsystems on the launch vehicle. The DIO-406 digital I/O cards control and monitor this bank of relays.

The AI-201 analog voltage input cards monitor the batteries during the charge cycle and a variety of analog voltage interfaces with the vehicle. They are also configurable as generic analog interfaces used during the various vehicle test setups. The AO-308 analog voltage output cards are used to simulate analog interfaces, such as pressure transducers, during the test sequences. The SL-501 card is configured as RS-422 for direct communication with the vehicle flight controller from the ground. It is also configured for RS-485 communications when the new Li-Ion batteries are used on the launch vehicle. These batteries have a built-in charger system that is controlled and monitored via a serial comm channel. This type of system also supports a portion of Orbital's Supersonic Sea Skimmer Targets (SSST) program. Orbital is building multiple copies of this system and has delivered 3 or 4 systems to date.

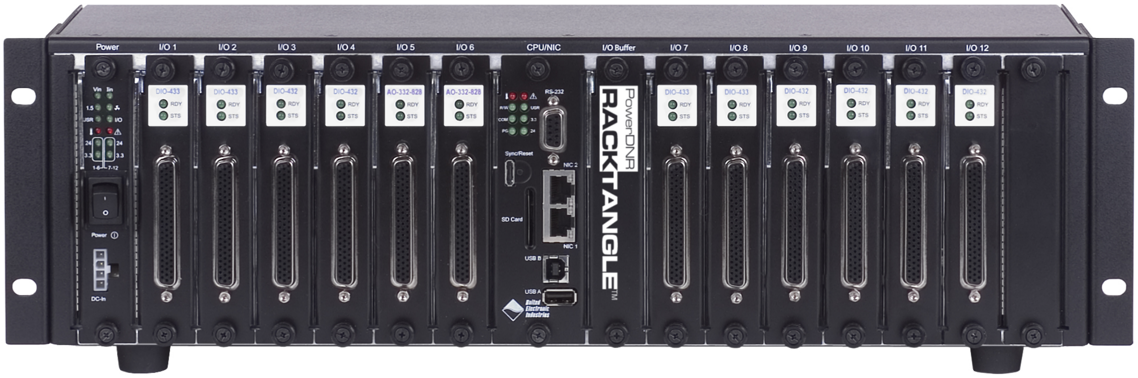


Figure 3. 12-slot UEI RACKtangle

1.5 Third Generation GSE

The third generation of GSE is still in the design phase and is again based on a central server with distributed I/O. The central server is a simple server loaded with the Linux operating system, which controls the GSE via an Ethernet connection. The distributed I/O system uses a variety of UEI PowerDNA layers mounted within multiple Cubes. Orbital's proprietary software provides the user interfaces and also controls and monitors the I/O system and all vehicle interfaces.

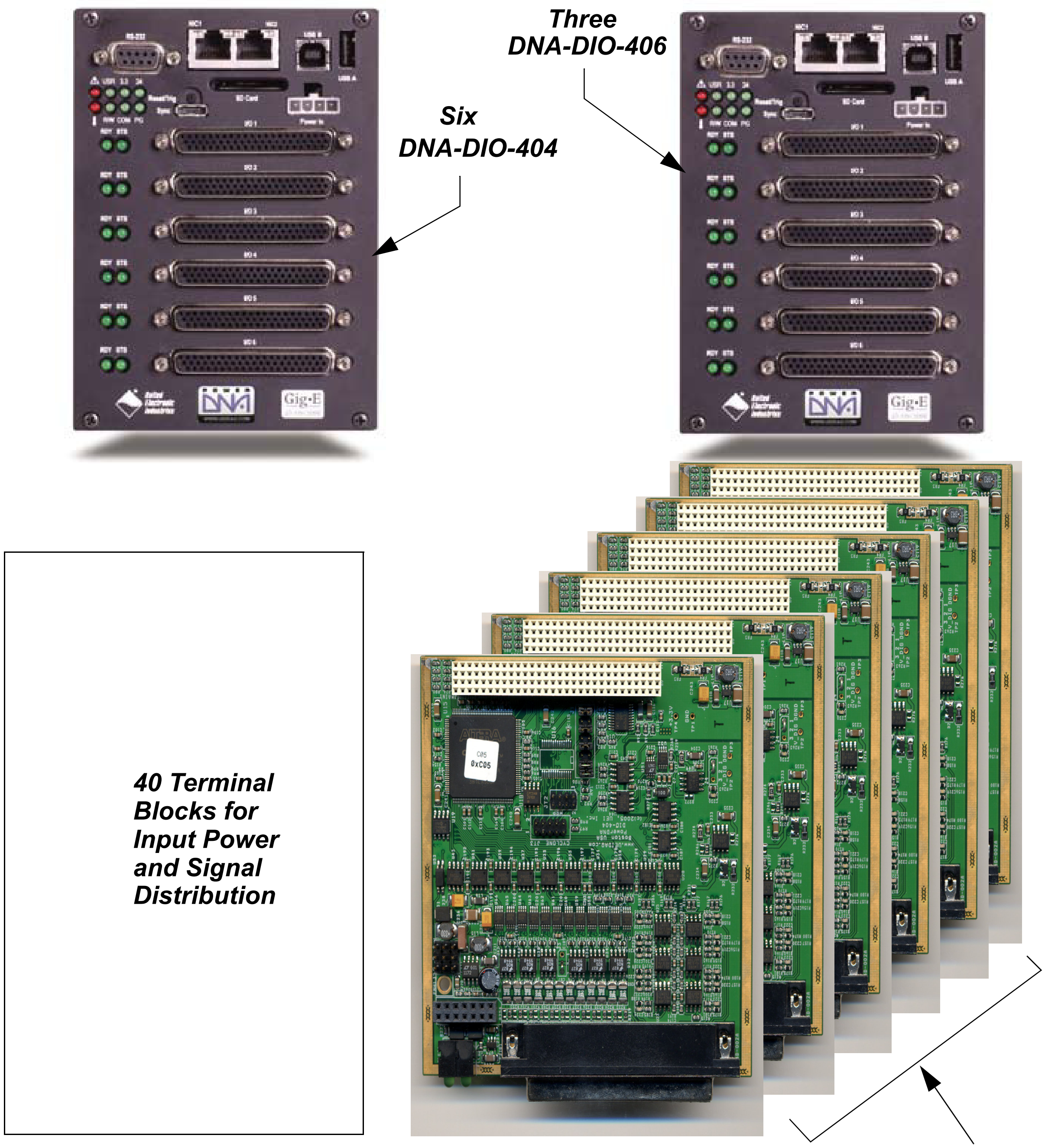
Orbital has released the core building blocks for the GEN 3 GSE -- two shelves of equipment that support all of the interfaces of a launch vehicle. Each of these shelves has a common configuration that will support all of Orbital's launch vehicle programs. In addition, they can be easily reconfigured to support unique requirements or special test scenarios.

The shelf, or package, for each of the two shelves is common. Each allows for mounting of three 6-layer cubes, plus 40 terminal blocks for power and signal distribution, and two stacks of Orbital-designed circuit modules, comprising up to ten total modules. On the input side, the shelf provides capacity for up to 640 wires and three RJ45 ports for Ethernet connections. The output side of the shelf accommodates up to 1024 wires.

The first of the two common shelves is the External Power and Battery Charging Shelf. This unit contains two 6-layer cubes, one with six DNA-DIO-404 cards and one with three DNA-DIO-406 cards. The unit also contains 40 terminal blocks for input power distribution and six Orbital-designed modules. Two of the Orbital-designed modules each contain 12 electromechanical relays configured as external power switches.

Two more of these same modules are configured as Battery Chargers that support both NiCad batteries and Lithium-Ion batteries. Also, in support of the Lithium-Ion batteries, two Orbital modules are used to power the internal circuitry of the battery chargers and ground control communications during operation. The DIO-406 cards are used as enables for the electromechanical relays. This allows Orbital to disable External Power Switches during battery charging and also to disable Battery Chargers when external power is applied to the system. The DIO-404 cards are responsible for turning the External Power Switches and Battery Chargers on and off and monitoring the states of their outputs. The DIO-404 cards are also responsible for controlling and monitoring each of the Lithium Ion battery ground power circuits. Beyond the common use of this drawer, it can be configured to support any function that requires switching and monitoring of any voltage from 0 to 60 volts at up to 20A. There are a total of 48 such power switches in the common drawer.

Figure 4. External Power and Battery Charging Shelf



Six Orbital-Designed Modules assembled Into a stack. Two modules each contain 12 electromechanical relays configured as external power switches. Two more modules are configured to power the battery chargers and ground control communications when in use. The DIO-404 cards serve as enables for the relays. This permits external power switches and battery chargers to be disabled when external power is applied.

The second drawer (or shelf) does not have a common configuration at this time. However, a version has been designed to support the Taurus II program. It contains two 6-layer cubes, 40 terminal blocks for input power/signal distribution, and seven Orbital-designed modules. One of the cubes contains six AI-205 layers, coupled to its inputs with a 2 x 24 MUX. This configuration allows Orbital to monitor 48 analog channels at up to ±100V. The MUX is controlled by a DIO-403 card installed in the second cube. This capability is used for battery voltage monitors in the Taurus II program. It is also used for connecting various generic voltage monitors during a variety of test configurations. The second cube also contains an SL-501 layer, a DIO-401 layer, two DIO-404 layers and a DIO-406 layer. The serial layer talks to the Lthium Ion batteries to control the built-in charger and to monitor health and status data as well as cell voltages. The DIO-401 layer monitors a variety of 28 volt continuity loops and the second half of the DIO-403 layer monitors a group of 5 volt continuity loops. The two DIO-404 layers and the DIO-406 layer controls and monitors a bank of electromechanical relays plus a bank of solid state relays that are configured as discrete controls and monitors for a variety of systems and sub-systems on the launch vehicle. These discrete items include such items as Safe/Arm devices, Arm/Disarm devices, Ordnance Initiators, camera controls, system enables and disables, lockouts, emergency power off controls, and system aborts as well as temperature and vibration monitors. They also control and monitor the ground interface to the Flight Termination System.

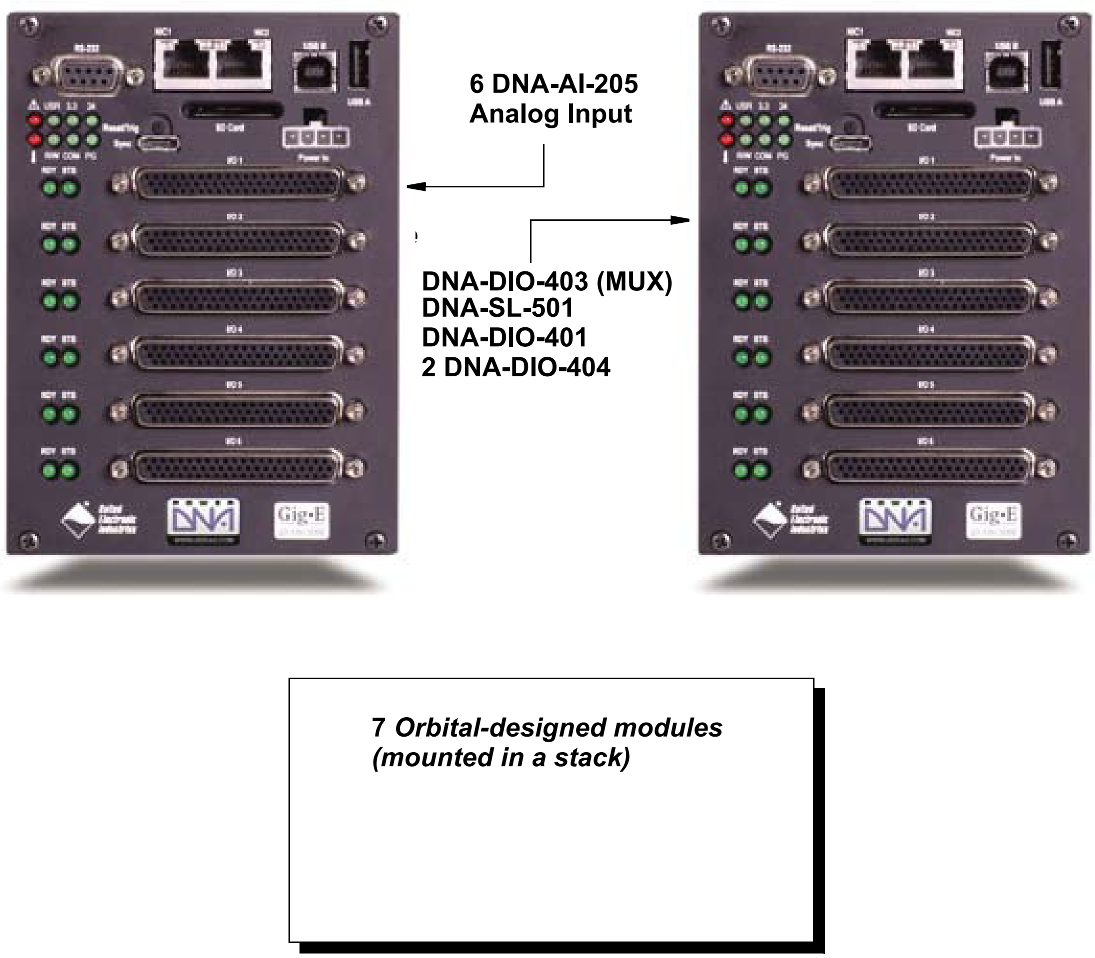


Figure 6. Second Shelf Components

Beyond the four standard cube configurations identified above, five additional configurations have been defined. These additional configurations contain a complement of the standard layers mentioned above along with two more analog input layers, the AI-208 and the AI-211 as well as the DIO-402 digital I/O layer. These additional cube configurations are used for unique launch equipment applications or specific test scenarios within the Taurus II program. In all cases, they control specific vehicle interfaces directly or indirectly through one of the seven Orbital-designed interface modules.

1.6 UEI’s 10-Year Guaranteed Product Availability

As illustrated in this application note, Orbital Sciences’ general product planning philosophy is to design its key products for a lifecycle of at least ten years —reconfiguring and redeploying major system components to meet ever-changing application requirement as customer needs develop over time. UEI’s commitment to provide guaranteed availability of all its products for a minimum of 10 years from date of initial purchase is a major incentive for a large system supplier such as Orbital to “design-in” UEI products. This policy helps the system supplier avoid costly, time-consuming system re-design problems typically caused by key component “end-of-life” product procurement problems.

This guarantee of long-term product availability is an example of UEI’s strong dedication to customer support.

1.7 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, and forms the primary interface between the Taurus launch vehicle and ground systems. The Stage 1 Assembly consists of the Yuzhnoye-(Okrainian)-developed Stage 1 core structure and tanks, the AJ26-62 Main Engine System (Aerojet General MES) (Russian-developed) and Range-required Flight Termination System. The Stage 1 propulsion system uses Liquid Oxygen (LOX) and kerosene Rocket Propellant (RP)
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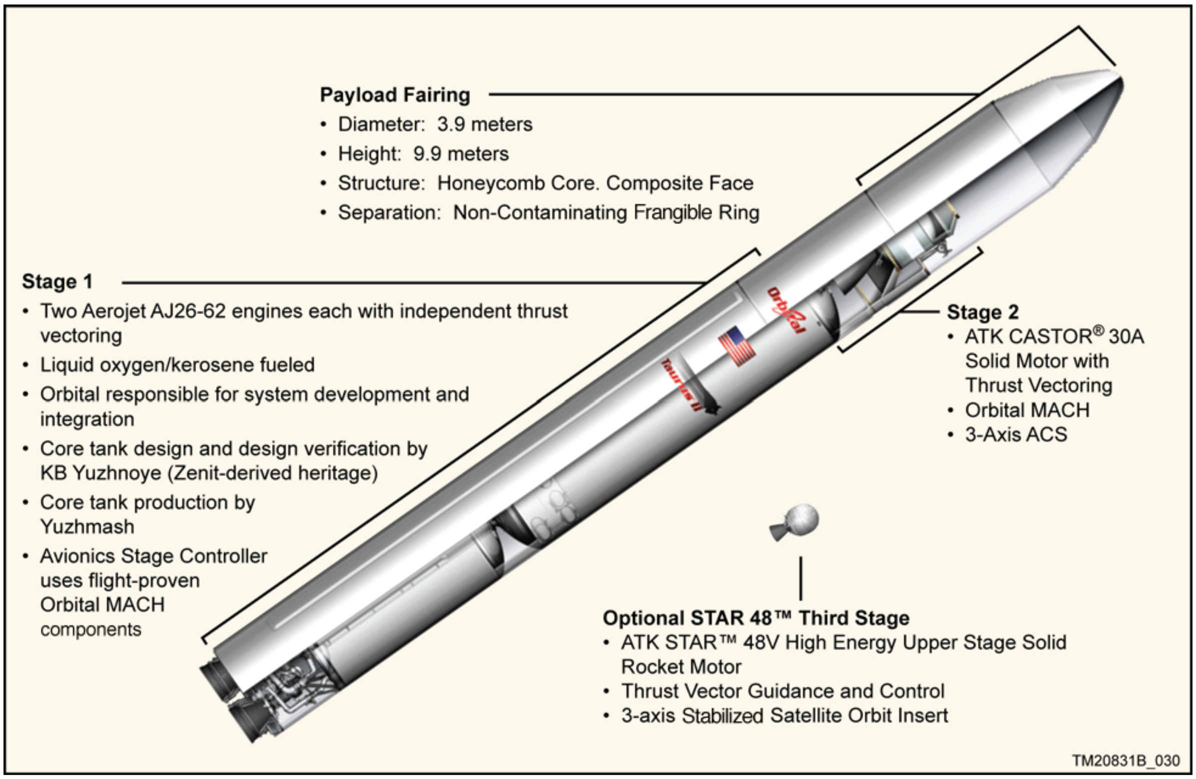

Figure 7.. Taurus II Launch Vehicle

The LOX and RP-1 tank bays consist primarily of the propellant tanks. Both tanks have liquid level sensors that are used during propellant loading and for measuring propellant levels in flight. The 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 pressurization system supplies gas through a manifold of valves that are cycled open/closed to control propellant flow rate. Liquid level sensors in the LOX tank ensure that helium tanks are submerged prior to beginning the helium fill, and emergency valves protect against over-pressurization.

The aft bay contains the Main Engine System (MES), which is the primary interface between the launch vehicle and ground systems. The MES generates thrust for launch vehicle motion and control during Stage 1 ascent.The MES consists of two Aerojet General AJ26-62 LOX/RP-1 rocket engines mounted on a thrust frame with individual Thrust Vector Control (TVC) systems on each engine. 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 flow rates of oxidizer and fuel.

1.8 Stage 2 Assembly

Stage 2 of the Taurus II contains the Stage 2 avionics module, the second stage motor and adaptor cone, the Stage 1/2 interstage, Stage 1/2 separation system, the fairing separation system, and an Attitude Control System. The avionics design uses Orbital's latest Module Avionics Control Hardware (MACH) to provide power transfer, data acquisition, booster interfaces, and ordnance initiation. This advanced system provides communication with vehicle subsystems, Launch Support Equipment, and the payload via standard Ethernet links and UEI discrete I/O hardware. The Taurus II MACH system provides up to 3 Mbps of real-time vehicle data with dedicated bandwidth and channels reserved for payload use.

1.9 Stage 2 Motor

The baseline Taurus II uses a CASTOR Model 30A solid fuel rocket for the second stage motor, built by Alliant Tech Systems, Inc. (ATK). it has a composite graphite/epoxy wound case, a mixture of TP-H8299 for its solid fuel, an ignitor and a flex seal at the throat. It generates approximately 80,000 lb of thrust with an Isp of 301 seconds and a burn time of136 seconds. The motor is designed to meet the initial Taurus COTS (Commercial Orbital Transportation Services) for resupply of the International Space Station and NASA CRS (Commercial Resupply Services) mission requirements, with an extended nozzle under development for added performance for future flights.

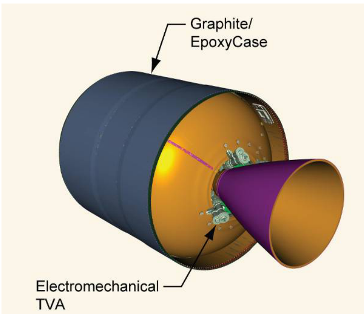

Figure 6. CASTOR 30A Solid Rocket Motor (SRM)

1.10 Attitude Control System (ACS)

The ACS provide three-axis attitude control throughout boosted flight and coast phases and uses the MES to control yaw, pitch, and roll control during Stage 1 powered flight. Stage 2 flight is controlled by the combination of the Stage TVC (thrust vector control) and onboard ACS (attitude control system) system located on the avionics ring. Attitude control is achieved using a 3-axis autopilot with PID control. Stage 1 flies an attitude profile based on trajectory optimization. Stage 2 controls parameters to achieve a target orbit insertion. Coast between Stage 1 and 2 orients the vehicle attitude for Stage 2 ignition and placement into the desired orbit. After the final boost phase, the autopilot orients the vehicle for spacecraft separation, collision and contamination avoidance, and downrange downlink maneuvers. An enhanced second stage liquid fueled engine is under development for use in 2013.

1.11 STAR 48 Third Stage Option

The STAR^{tm} 48 third stage option uses ATK-manufactured solid rocket motors to achieve high energy orbits. These motors have extensive flight history in space applications on Delta and Shuttle rockets.

1.12 Launch Site Infrastructure

Taurus II is designed for lean horizontal processing of the launch vehicle, in a horizontal integration facility in preparation for rollout to the launch pad for erection, fueling, and launch. This facility is used to assemble and test the launch vehicle, mate the payload to the vehicle, checkout the payload, and encapsulate the payload in the fairing. The Launch Control center serves as mission control for Taurus II launches.

1.13 Launch Pad

This facility consists of the minimum equipment needed to support vehicle erection, fueling, and launch such as launch mount with flame duct and lightning towers, ramp to top of the pad, launch equipment vaults to house the vehicle and payload, cable and fueling trenches, water storage, LOX, and RP-1 tanks, nitrogen and helium gas tank skids.

1.14 Mobile GSE (Ground Support Equipment)

The mobile GSE includes the Transporter Erector/Launcher, Environmental Control System, lifting slings, and launch vehicle handling GSE.

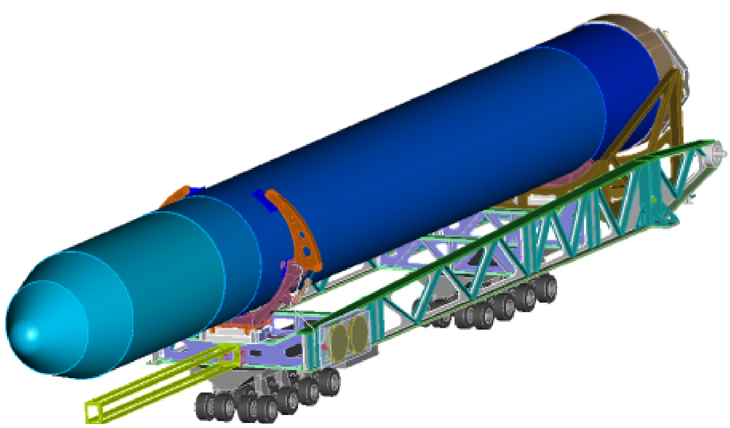

Figure 7. TEL Transporter Erector/Launcher