International Launch Campaign
Pegasus®/MINISAT Launch from Canary Islands

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Abstract. Traditional launch services conduct final launch operations from fixed locations due to a heavy reliance on large amounts of ground support equipment (i.e. launch towers, fuel farms, range tracking, etc.). The Pegasus/MINISAT launch campaign demonstrated a unique ability to locate the launch vehicle nearly anywhere in the world based on each mission's specific requirements and by prepositioning required support equipment where needed.

The logistics to support this type of mobile capability can be complicated and transcend a multitude of disciplines. Issues that had to be solved included vehicle processing facilities, launch control centers, mobile range tracking solutions, international liability and many more. Each of these areas had to be addressed and a solution found. New innovative approaches were necessary to surmount many of the roadblocks encountered.

This mobile capability also requires modifications to regulatory guidance. Our current regulatory guidance developed in support of traditional land based launch systems and does not easily translate to systems that are mobile. Regulatory agencies need to address the unique capabilities of mobile systems, such as Pegasus, Sea-Launch, etc. Because of the ability of these systems to relocate the launch point away from populated areas they are inherently safer to the general public.

Pegasus/MINISAT Overview

The Instituto Nacional de Técnica Aeroespacial (INTA), the Spanish government's space agency, contracted with Orbital Sciences Corporation to conduct the first launch of the Mini-Satellite (MINISAT) class of spacecraft. This launch was the first commercial attempt at transporting an American made launch vehicle to a foreign country to conduct a launch operation campaign. The launch campaign concluded with the successful launch of the MINISAT 01 spacecraft from the Canary Islands on 21 April 1997.

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The launch integration and operations process took place on three continents over a one year period. This process was conducted in five phases: (1) launch vehicle buildup and checkout, (2) transport of the launch vehicle to Spain, (3) integration of launch vehicle and satellite, (4) transport of the launch vehicle/spacecraft to the staging base in the Canary Islands and (5) launch operations.

The first phase involved launch site ground processing operations at Orbital's Vehicle Assembly Building (VAB) at Vandenberg Air Force Base (AFB), California. These operations were conducted utilizing the same Pegasus processing procedures and standards used for processing West Coast Pegasus launches. Normal processing continued through integrated checkout of the launch vehicle prior to spacecraft mate. Since the payload was to be mated in Spain, processing was discontinued at this point and the payload fairing was installed to allow for transport of the vehicle.

The second phase provided for the transport of the launch vehicle to Spain. The Pegasus launch vehicle was transported on the Assembly and Integration Trailer (AIT) to the Orbital Carrier Aircraft (OCA), a highly modified L-1011 TriStar. The AIT was positioned under the L-1011 and then raised to allow for mate of the Pegasus to the aircraft. Final checks of the Pegasus and L-1011 were conducted. The aircraft was then flown from Vandenberg AFB to Torrejon Air Base (AB) in Madrid, Spain with two stops enroute. The first was an overnight stop at Dover AFB for refueling. The second stop was at the Canary Islands to support a Flight Rehearsal of launch day operations.

The third phase commenced with the arrival of the Pegasus launch vehicle at Torrejon AB, offload of the Pegasus vehicle from the L-1011 and transport to INTA's Payload Processing Facility (PPF). Processing activities in support of the integration of the MINISAT satellite with the Pegasus vehicle were conducted at the PPF over the period of about sixty days. During this period the spacecraft was mated to the launch vehicle and a full battery of systems tests performed to verify readiness of the Pegasus/MINISAT vehicle. The vehicle was then transported to the L-1011 and readied for ferry to the staging base.

The fourth phase involved the ferry flight of the Pegasus/MINISAT vehicle to the staging base at Gando AB in the Canary Islands.

The last phase included the final checkout of the vehicle, removal of safe and arm pins, and flight of the OCA to the drop point, approximately 40 nautical miles south of Gran Canaria Island.

**Traditional versus Mobile**

The commercial launch programs developed utilizing existing expendable launch vehicle designs funded by the US government (i.e. Titan, Atlas, Delta, etc.). All of these systems were initially designed to support the US ballistic missile programs of the 1950's and 1960's. These designs were then converted to support the various government space programs. However, many of the basic design features required to support ballistic missile programs remained and still do today.

The ballistic missile programs had unique requirements that included long storage periods, quick access to fueling, and ready access for maintenance. After conversion to space vehicles, many of these attributes did not change. One of the more cumbersome requirements is a significant reliance on large amounts of ground support equipment (GSE), such as launch towers, fuel farms and fixed range tracking systems. This heavy reliance on large amounts of high cost, fixed location GSE results in systems that are incapable of supporting from more than one or two locations.

Pegasus was developed purely as a commercial launch vehicle. It's design approach was to provide a launch system that would be simple, robust and reliable. As such, it's development was a bottom's up view of an efficient way to process and launch satellites commercially. It was designed with a minimum of ground support equipment. Pegasus vehicle assembly and...
checkout procedures are significantly less complex, safer, and more cost effective than procedures for traditional land based systems.

**International Launch Campaign Requirements**

With the ability to support internationally, the launch provider can take into account several additional requirements that can be satisfied to make its product more attractive to potential payload customers. By being mobile, the launch campaign can be located to improve performance to orbit or be conducted out of the payload customer’s country or be moved further from populated areas to decrease risk to public safety. For the MINISAT launch, the customer requested a launch originating from Spanish soil. With this fundamental need established, we designed a launch campaign to satisfy this requirement.

One of the major obstacles that had to be overcome was the clear definition of support requirements and potential sources to fulfill these needs. The key problem area dealt with the logistical challenges associated with conducting this campaign at an international location.

Issues/questions that had to be solved included the following, as well as many more. Where can vehicle processing be conducted that meets all our production and safety needs? Where and how will launch control be conducted? How would range tracking and flight safety issues be resolved? How would the issue of international liability be addressed? In the early planning phases of this program, a considerable amount of time was spent brainstorming ideas on how to satisfy each of these requirements.

The following paragraphs provide the details of how many of these issues/obstacles were addressed for the MINISAT mission.

**Vehicle Processing Facilities**

When the MINISAT mission was first proposed, one of the first items coordinated dealt with the requirement for facilities that could be utilized for processing the Pegasus Launch Vehicle. This was formally coordinated between Orbital and INTELSAT in the form of the Orbital Facility Requirements Document (FRD) and the INTELSAT response, the Facility Description Document (FDD).

**Dimensions**

A Pegasus XL, the longest of the proposed launch options for MINSAT-01 is 55 feet long, 22 feet wide (at the wing tips), 11 feet tall, and weighs 50,000 lbs (see Figure 1). The AIT, a 20-wheeled trailer used for transport and integration of the launch vehicle is 72 feet long, weighs 50,000 lbs and carries the Pegasus several feet off the ground (see Figure 2). INTELSAT provided, through the Spanish Air Force, a wide-body aircraft tug as a tow vehicle for the AIT.

This laid the basis for facility sizing. Floor loading capability needed to exceed 100 psi to support bringing the loaded AIT into the INTELSAT provided facility for Pegasus and MINISAT processing. The PPF (an acronym informally known as the Pegasus Processing Facility to Orbital and formally known as the Payload Processing Facility to INTELSAT) was an existing building at INTELSAT that had an addition built to support Pegasus processing. Door minimum dimensions for entry into the PPF were established at 14 feet tall by 25 feet wide to allow adequate clearance with a marginally maneuverable AIT.
Pegasus processing equipment is minimal, with three standard 19 inch Electronic Ground Support Equipment (EGSE) racks of electronic equipment and the normal assortment of tool boxes, scales, and workbenches required to support field operations. In addition, a crane with 14 foot hook height and capable of 1000 lb. lifts would be required to remove the fins prior to mating to the L-1011.

Taking this into account, volumetric requirements for the PPF ended up as a minimum width of 30 feet, minimum length of 80 feet, and minimum ceiling height of 16 feet. The completed PPF exceeded these dimensions.

**Additional Space**

No launch operations could be done without the normal administrative and engineering tasks, so a 800 square foot space adjacent to the PPF was requested for storage, with 400 square feet of secure storage for flight articles. Office space capable of supporting eight people was also requested. In addition, a flammable storage locker was required for non-local storage of volatile fluids used in Pegasus processing.

The storage space requirements were met by a large existing hanger attached to the south side of the PPF. This was more than adequate for storage...
of the Orbital sea container, used for transport of Mechanical Ground Support Equipment (MGSE), as well as other essential supplies. Although this area was not climate controlled, it was a secure site for storage.

**Access to the PPF**

In order to transport the rocket from the aircraft to the PPF construction of an access road was required. Transportation of Pegasus requires that no road could have a centerline turning radius less than 80 feet. Also, the AIT has a ground clearance of six inches when configured for vehicle transport, so maximum crown heights of the road were also specified. In addition, an area to execute a 180 degree turn was also required. Since the trailer is towed from the aircraft, but must be pushed into the PPF, a turnaround area was required near the PPF to enable backing into the high bay. Since existing roads could not support these requirements, INTA proposed and built this additional access to the PPF.

As with many new approaches, some important features are overlooked. It was discovered during transport that even though the road was designed to meet our requirements, certain needs were overlooked. The entrance to the PPF was immediately after exiting a turn. This caused significant problems with centering the vehicle in the bay and required jockeying the AIT back and forth until centering was accomplished. The PPF was designed with anti-static flooring. The continual back and forth movement of the AIT, with it’s large tires, did some damage to the flooring that would not have occurred if a straight run was available outside the building.

Also, for future remote processing sites, the minimum turning radius must be increased because of the addition of a 10 foot wide by 10 foot long trailer attached to the aft end of the AIT to support air conditioning and power generation equipment.

![Figure 2. Pegasus XL Being Backed under Orbital Carrier Aircraft](image)

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To maintain acceptable working conditions, requirements were levied upon INTA for lighting, cleanliness, and environmental control in the PPF. To meet the same conditions that Pegasus is processed at Vandenberg AFB, a minimum lighting level of 46 ft-candles was used for illumination. Temperature control needed to be maintained between 60 and 80 degrees Fahrenheit and humidity between 30 and 80 percent. Cleanliness needed to be maintained at Class 100,000 to ensure that Pegasus commitments for payload cleanliness were met. The entire PPF was engineered and maintained as a clean room and all environmental requirements were exceeded.

Special precautions were taken with Pegasus to ensure that the vehicle would not contaminate its environment, including a complete cleaning and painting of the AIT after arrival and assembly in Spain, and wipe-down of the Pegasus and AIT after arrival in the PPF (See Figure 3).

**Communications**

The mission was meant to be self-sufficient with minimal support required from the United States. With that in mind, communication requirements laid upon the PPF were minimal: three phone lines capable of handling voice and fax communications in the office area. After arrival in Spain, we quickly discovered that this was inadequate, as modem and net communications, extensive fax traffic, and lengthy telecons often
overwhelmed the communications capabilities designed into the PPF office areas. A link to the INTA Internet was also put in, however data communications through the server proved so slow that modem data transfer over international phone lines became the data transfer mechanism of choice.

**Power**

Spanish power is not the 110 VAC, 60 Hz power that is normal in the United States, but is based on a 50 Hz frequency standard. A diesel generator capable of supplying Pegasus power requirements was brought from our Vandenberg launch site to provide the power necessary for our EGSE. This power was run into the PPF processing bay only, and the 208V, 3-phase, 50 Ampere power required by the AIT as well as the 208V, 3-phase, 30 Ampere power required by the EGSE was available only when the generator was running.

All of the personal computers in the engineering office ran off the 220 VAC, 50 Hz local power available. Battery chargers, and other small equipment was put onto one of the two 1000 watt step-down transformers brought to convert power for the high-capacity printer and fax machine. We found it impossible to purchase a high capacity fax machine in the United States that was dual voltage capable, although our combined printer/fax/copier used as backup for the high capacity equipment had no problems with European standard power. In addition, we learned the hard way that some of our personal computers did not have automatic voltage switching for the higher voltage, requiring access to the power supplies to manually switch the voltage from 110 VAC to 220 VAC.

Compressed air is used for several of the tools used in Pegasus processing as well as local cooling for the avionics section during flight simulations. INTA designed into the PPF high bay the capability to provide the necessary compressed air to support Pegasus processing. Orbital supplied fittings for the high bay of the PPF and provided drawings for compatible interfaces.

**Safety**

OSHA does not exist in Spain, however there are local equivalents. To make sure that our launch vehicle safety standards were met, the Orbital safety document, TD-0018, Pegasus Safety Requirements Document for Ground Operations was levied on INTA for design of the PPF. In addition, fire alarm and protection systems and sensors were specifically spelled out in the FRD. Status safety lights, audible alarms, and warning devices were also specified. The facility had a complex multi-tiered safety system that used a non-halogenated halon substitute in the non-accessible areas and water deluge in the high bay.

Siting for 50,000 lbs of Division 1.3, Class C propellant as well as 350 lbs of Class C initiators and miscellaneous propellants were also specified, to satisfy Spanish range/quantity restrictions for Pegasus.

**Security**

Simple access security to flight hardware was all that Pegasus needed to prevent tampering with the launch vehicle. Orbital was under its own obligation to monitor access to the launch vehicle. As such, Orbital personnel were required to have personnel at the PPF 24 hours per day. The Spanish provided entry control to the facility and the base.

**Launch Control Center**

To implement the MINISAT launch, all range functions needed to be created, essentially from scratch, including radar tracking, telemetry, launch control and range safety. Wallops Flight Facility mobile range resources were utilized to satisfy the radar tracking, telemetry and range safety requirements. These assets were prepositioned at a Canary Island bare-based site, on property owned by INTA. Launch control was contractually agreed to be performed from Madrid. As such, Orbital was contracted to build and deliver a Launch Operations Control Center (LOCC) for this function.
LOCC Requirements

The function of the LOCC is to provide a site for launch control authorities (Mission Directors, Test Conductor, and support engineers) to conduct launch operations. Operational and physical requirements were created by reviewing the minimal needs associated with launches from the Western Range and Wallops. These included access to vehicle data, necessary communications and display equipment, and space requirements. The physical requirement for the LOCC were specified in the FRD\textsuperscript{1} to INTA. Communications requirements for the LOCC were specified in the Range Requirements Document (RRD)\textsuperscript{4}, which also specified other range requirements that normally are handled by the current US federal ranges, but due to the campaign nature of this mission, would be levied on the Spanish. Such requirements included weather forecasting, medical support, area surveillance and air traffic control.

The initial concept of operations was to conduct all flight operations from Torrejon AB in Madrid, flying to the drop point south of the Canary Islands and dropping Pegasus. The concept of operations was later changed to transporting the vehicle to a staging base (Gando AB) and then proceed with the final launch operations from Gando AB.

Facility

After careful review, it was determined that the minimal launch control crew required at the LOCC was 20 personnel. This would include Orbital and INTA management and engineers, essential subcontractor representatives, plus range and US government representatives. To support these 20 launch support positions, 10 consoles were designed and built, as well as three equipment racks to support data and communications routing and recording. One additional console was provided to operate displays set up for public affairs/press areas.

A temperature and humidity controlled facility with at least 2400 square feet of unobstructed space was required. To support console electrical interconnects, raised flooring was used. Security was also specified to prevent unauthorized people from interfering with the launch.

INTA used a fiberglass double-clamshell structure to meet the facility requirements. While environmentally controlled, the structure was uninsulated and located at the edge of the Torrejon flightline, which created interesting situations when the local fighter squadron performed full afterburner takeoffs. This being the first indigenous Spanish satellite launch, a huge VIP and press presence was anticipated and planned for (the LOCC had a glass wall that allowed the hundreds of invited guests and journalists to directly watch the small launch operation team perform).

Utilities

All equipment used in the LOCC was procured to operate on 220 VAC, 50 Hz power. Uninterruptable power in the form of 10 minute battery backup as well as diesel generators were specified for eleven consoles as well as the three equipment racks.

The communications interface between the LOCC and the NASA Wallops Mobile Range (WMR) was initially specified to support two telemetry data lines, one timing data line, and six voice net channels. In addition, thirteen commercial PBX telephones were required to support the console positions, telemetry support engineers and fax communications. Two phone lines capable of activating a UHF and HF transmitter/receiver were also necessary to provide communications with the Orbital Carrier Aircraft during the flight.

Communications problems encountered in trying to get the Pegasus data from the WMR to the LOCC required extensive revisions to the planned telemetry transmission scheme. For a while, lead times on the specialized communication gear required was the pacing factor for the initial launch capability. Miscommunication and misunderstanding of data specifications and standards, many times caused by the language...
barrier, were often not evident until hardware was attached and tested.

In addition, video support was necessary to handle the data transfer requirements of transmitting the chase video from the Spanish chase aircraft, as well as the OCA on-board video and the Pegasus on-board video into the LOCC for real-time viewing.

Several months before launch INTA added teleconferencing capability between the Canary Islands and the LOCC which greatly aided in video communications between the launch site and the control center. In addition, the readiness reviews conducted prior to launch utilized this teleconferencing capability. It allowed the launch team in Madrid to easily conduct these reviews with the range and launch operations personnel in the Canary Islands.

**Aircraft Support Requirements**

The Pegasus is an air launched rocket. To achieve the necessary launch conditions for the Pegasus, a highly modified L-1011 TriStar is used (known as the Orbital Carrier Aircraft (OCA)). The operational and support requirements for an L-1011 are many and varied. While the OCA is capable of transporting a number of its own logistics and maintenance items (known as a fly away kit) it depends greatly on its staging location for providing necessary ground support equipment and services.

Two staging areas were required to support the L-1011/Pegasus operations. A staging area in Madrid (at Torrejon AB) to support Pegasus processing, and a staging area in Gran Canaria (Gando AB) to support launch operations. Both required basically the same capability; a parking area for the L-1011, ground support equipment, operational resources and services (Air Traffic Control (ATC), weather forecasting, fuel, etc.), as well as administrative and personnel support.

The L-1011 weighs 270,000 lbs (dry weight), is 178' in length, has a wing span of 155', and stands over five stories tall. Due to safety and security requirements the area required to park the L-1011 is roughly 300' in radius at a location capable of handling hazardous cargo. The hazardous operations at Torrejon AB and Gando AB associated with preparing the Pegasus launch vehicle for launch required a parking location (referred to as the Hot Pad) to be a minimum distance from any inhabited offices, work areas, or buildings.

Ground support equipment for the OCA ranged from standard L-1011 support equipment (access stairs, ground power carts, ground air conditioners, maintenance stands, tug, etc.) to unique equipment such as light carts, gaseous nitrogen trucks, air compressors, and electric generators. Most of this equipment was made available through INTA resources, the Spanish Air Force, Iberia Air Lines, as well as the local commercial airport.

As any commercial aircraft requires operational resources and services to facilitate take-off, landing, and flight operations, the OCA relied on the local military and commercial air traffic control centers for these services. Through INTA, services such as flight plan approvals, weather forecasts/updates, and fueling were provided at the military air bases and commercial airports.

The OCA required 15 personnel to operate and maintain it while supporting the MINISAT mission. In addition to hotel and ground transportation, administrative and support facilities were required during the mission. INTA provided office space, telephone, and other administrative equipment to augment the Orbital resources.

**Range Tracking Solutions**

To support the Pegasus/MINISAT launch operations a number of services normally provided by fixed US range resources were needed. Critical flight event data needed to be received, re-transmitted and recorded. The Pegasus launch vehicle needed to be tracked through the planned trajectory. Flight safety command and control capability is required of all
US licensed launches. Additionally, these resources required a communications systems capable of tying the Launch Operations Control Center (LOCC), the range, the Hot Pad, and other support locations together.

A number of options for providing these resources and services were initially considered. Orbital first assessed the potential use of existing Spanish resources. While Spain possesses most of the required capabilities (less the flight safety function), they proved to be too diversely located to take full advantage of them. However, a range support location with some existing capability was determined to exist in Gran Canaria. This location, the Maspalomas Space Station, not only contained the necessary infrastructure and property to accommodate these resources, but also possessed a 15 meter S-band antenna that was operational and available. This antenna was used to augment mobile resources brought to Spain in the collection of Pegasus telemetry.

To augment the Maspalomas Space Station capabilities with necessary telemetry and tracking resources three options were considered; 1) develop our own Orbital range capability, 2) solicit other commercial range service providers, and 3) determine what mobile/transportable capabilities existed at the US ranges.

A thorough analysis was undertaken to address Orbital's ability to develop a transportable range capability. While many of us felt that most of the resources required to support this operation could have been developed in time and within existing financial constraints. It was unanimously felt that the flight safety function created an obstacle that could not be surmounted within the time frame necessary. With this approach, Orbital would be required to provide or contract its own flight safety function. Orbital believed that the time required to ensure all the appropriate government licensing requirements had been satisfied was not available to support the planned launch date. For this reason this option was not pursued.

An assessment of other available range providers included both foreign and domestic suppliers. Orbital reviewed the ability of several commercial and governmental sources for providing this capability. The two leading candidates were the NASA's Wallops Mobile Range and a component of the German Space Operations Center, known as DLR.

Both of these organizations had the required equipment necessary to conduct this operation and had supported many sub-orbital launch campaigns around the world. Each possessed all the necessary telemetry, tracking, and communications capability, plus the equipment necessary to perform the flight safety function.

The major difference was that the Wallops Flight Facility is recognized by the FAA's Commercial Space Transportation as a "certified" source for flight safety analysis and support. The decision was made that the process to "certify" non-US government flight safety systems/personnel could not be accomplished in time to support this mission.

The Eastern and Western Ranges each had some level of mobile capability. However, a full (package deal) did not presently exist at either range. NASA's Wallops Flight Facility's (WFF) mobile range assets were selected to provide the necessary telemetry, tracking, communications, and flight safety (command/control) support for this mission. This "package deal" was appealing to both Orbital and INTA. The WFF range resources had already supported sub-orbital campaigns in Alaska, Puerto Rico, Australia, and other locations around the world.

The WFF Mobile Range (WMR) consisted of HF, VHF, UHF, and intercom voice communications, 10' and 18' S-band telemetry antennas, a telemetry van with antenna control and telemetry processing equipment, a 12' C-band radar antenna, a radar van with antenna control, a command and control van that provided the flight safety capability and acted as the hub for all the WMR resources, and various support resources such as power generators and converters. All this equipment was transported from WFF on September 7, 1996 to the Maspalomas Space Station, Gran Canaria, in five 20' shipping containers and four oversize (greater than 40') trailers.

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Prior to the WMR equipment arrival at Gran Canaria a number of site surveys were conducted to determine the optimum location for each piece of equipment, as well as any construction or preparations necessary to accommodate the equipment. Two separate sites (approximately 2500' apart) on the Station were selected; one for the telemetry and command equipment and the other for the radar equipment. At each site the ground was leveled and compacted and ingress/egress roads were excavated. Also at each site a 10' x 10' concrete pad was poured to provide a stable foundation for the radar and telemetry antennas. Other site improvements included running voice and data communication lines between the two sites, as well as to INTA’s Operations Building. In addition power lines were extended from existing station facilities, as well as providing necessary water and sewage services.

On October 9, 1996 all the site preparations were completed and the WMR equipment was delivered. The WMR equipment was setup, checked out and tested to ensure readiness to support the Pegasus launch operations. These services included providing real-time reception, recording and retransmission to the LOCC in Madrid of Pegasus vehicle telemetry, video telemetry from three sources (L-1011 on-board video, INTA provided F-18 chase aircraft video and Pegasus Stage 2 on-board video). Also required was transmission of WMR generated flight safety displays to the LOCC in Madrid. To ensure command and control of the Pegasus during the flight phase, the WMR used its radar to track the C-band transponder on the Pegasus and slaved its two quad-helix UHF command transmitters to follow the Pegasus through Pegasus stage 2/3 separation.

Voice communication between the WMR, the LOCC, and the Hot Pad (Gando Air Base) was mandatory to support the launch operation. The WMR radio and intercom systems acted as the hub for providing this communication capability to each location as well as to all other support agencies. This included communications with the LOCC in Madrid, the Hot Pad at Gando AB, the OCA, the Spanish AF F-18s, the Spanish military air traffic control and the Spanish Navy surveillance team.

On February 11, 1997, the Pegasus launch vehicle was flown to Gran Canaria from the US aboard the OCA,. As it made its final leg of the trip into the Gando AB it flew by the Station to provide the WMR its first test with the Pegasus launch vehicle. All systems checked out with the exception of the C-band radar. It was later determined the radar’s modulator tube had failed. A replacement tube was ordered from the US and was replaced prior to launch operations. NASA support in expediting this effort was instrumental in maintaining schedule.

An additional test of the remote range was conducted two days later. A Flight Rehearsal was conducted to test all aspects of the mission. The aircraft, with Pegasus underneath, was flown from Gando AB on the same path that would be used on launch day. All launch day activities were rehearsed. This "full up" operation to exercise all systems and support organizations prior to the launch proved to be vital in ensuring readiness for the launch operation. The high fidelity launch simulation verified all systems were ready to support. Upon completion of the rehearsal, the aircraft and Pegasus were then flown to Torrejon AB to continue the Pegasus processing effort. The Canary Island range team, both Orbital, NASA and NASA contractor personnel, then returned to the US.

Two weeks prior to launch the 16 NASA and contractor WMR personnel returned to Gran Canaria to activate and prepare the WMR equipment for Pegasus launch support. Data flow and communications tests between the LOCC and the WMR occurred daily prior to the launch operation. A final Mission Rehearsal was accomplished to exercise the launch operation team protocol. Two days prior to launch, the OCA, with the Pegasus/MINISAT vehicle, arrived at Gando AB from Madrid for final launch preparations.

The Pegasus launch operations began at 0700 GMT (8:00 a.m. local time) on April 21, 1997. All WMR launch support resources were active...
and operational for the Pegasus launch. The Pegasus/MINISAT launch occurred at approximately 1158 GMT (12:58 p.m. local time), all systems functioned nominally during the countdown and flight phases.

Remote Staging Requirements

The MINISAT mission required the capability to process Pegasus at two different locations in Spain. To support the integration of the Pegasus and MINISAT satellite a staging area in Madrid was required. To support the launch operations a staging area in Gran Canaria was required. Both staging locations required the same resources and services to support Pegasus processing. The only exception to this was that no capability existed to demate the Pegasus from the OCA at the Gran Canaria location.

To support Pegasus during its processing, both pre-launch and launch, the staging locations needed; 1) voice communications (both radio and intercom), 2) frequency protection and control (during Pegasus testing), 3) electric power (indirectly through the OCA), 4) ground air conditioning systems (for Pegasus and payload conditioning), 5) fire and security services, and 6) administrative and personnel facilities (capable of establishing computer and telephone systems).

An elaborate intercom communications system was developed and put in place to link the Madrid, Gando Air Base, and WMR operations together. This intercom system allowed outside users (such as the L-1011 and F-18 chase pilots) to be connected to the intercom system via HF and VHF radios.

Prior to the Pegasus departure from Madrid as well as at Gando Air Base a powered on test of the Pegasus was performed (known as the Combined Systems Test). To ensure open loop RF radiation of the Pegasus and command transmitters is not affected by spurious external RF radiation the area must be protected and controlled. These services were provided by INTA and the local military at each staging location. Despite their efforts, an extraneous RF signal was detected during the Combined Systems Test. The signal was determined to be radiating in the command UHF frequency and resulted in unacceptable interference. The test was discontinued and an extensive effort to find the renegade signal was undertaken by INTA, NASA, Orbital, and the local military. The source of the signal was found within eight hours and with the help of local officials was eliminated.

The processing of launch vehicles is an hazardous activity that requires both a secure area and the immediate availability of emergency services when necessary. For this reason security and fire protection services must be available at all times. A "rocket watch" was conducted 24 hours a day by Orbital personnel and augmented by military patrol to provide physical security and assistance should an unsafe event exist. This military service was coordinated by INTA and provided by the local Spanish Air Force at each location.

Orbital provided most of the computer and administrative resources necessary to support the operations. At each of the staging locations INTA provided (or coordinated) facilities to house the Orbital personnel and the associated equipment. At any one time as many as 50 Orbital personnel were on site to support Pegasus and L-1011 operations.

Regulatory Issues

The conduct of launch operations both domestically and internationally are regulated by certain US and international laws. Most of these laws and regulations were developed during a time period when the only launch vehicles available were traditional land based launch systems. Orbital has had to work with several government agencies to understand how these rules will be applied to vehicles that have a mobile capability.

We believe that several of these regulations and laws need to be changed to address the unique capabilities associated with mobile systems. Because of their ability to be able to locate the launch point significantly away from populated areas they are inherently safer to the general public.

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Launch Licensing

Current US law requires all US launch providers to obtain a launch license from the Federal Aviation Administrations, Office of Commercial Space Transportation. This requirement exists whether the launch will be conducted from the United States or from a foreign country.

As such, Orbital applied and received a launch license to conduct launch operations in Spain. Because of the FAA’s interpretation of the Commercial Space Launch Act (CSLA), there are several areas in which Orbital did not get CSLA protection that is normally provided to launch providers. The FAA currently policy is only to provide CSLA authorized indemnification to launch processing if that processing occurs at the same geographical location as the launch. They also made a determination in our case that the only activity that would be licensed would be the launch operation itself, commencing with aircraft take-off for purposes of launch.

While traditional systems are getting financial protection provided by the CSLA for hazardous activities associated with launch (i.e. receiving and processing launch vehicle motors, mating of vehicle stages, ordnance operations, etc.), this same protection is not being provided to mobile systems for the same activities. These mobile systems actually increase safety to the general public because of their ability to relocate the most hazardous of these activities, the launch itself.

Other questions and regulatory issues that need to be addressed include the following. How are commercial ranges going to be regulated? Is autonomous flight safety (as Boeing’s Sea Launch venture plans) acceptable? How are commercial ranges and flight safety organizations “certified” by the FAA? Will commercial ranges require regulations similar to existing ones for launch providers?

Our government agencies need to continue to be proactive to ensure the growth of the commercial space launch industry. This will benefit both the commercial enterprises conducting these operations and the US government when contracting with these commercial providers. The more the commercial industry grows, the more reliable and cost efficient the launch systems will become.

International Liability

Another issue that presented itself early was how was international liability going to be handled. International law, which includes The Outer Space Treaty as well as several other international agreements, defines who is liable in case of claims resulting from launch operations. It also holds the governments responsible for non-governmental entities conducting launch operations.

It was determined early after consultations with the Office of Commercial Space Transportation and the US State Department that both the US and Spain shared liability under existing international treaties and agreements. The launch effort, since being conducted by Orbital Sciences Corporation, required a launch license as required under current US Federal Regulations, provided by the FAA, in order to ensure compliance with all US and International requirements.

Conclusions

The Pegasus/MINISAT launch campaign was a complete success. Not only is the Spanish MINISAT 01 satellite currently performing its mission in space, but this mission also demonstrated the ability of forward thinking individuals being able to surmount the multitude of problems associated with conducting an international launch campaign.

We believe that the success of this mission will provide additional opportunities for both Orbital and other commercial entities to expand the horizon of launch operations. This expansion will result in future launch campaign operations both domestically and internationally, as well as the development of new approaches to other aspects of the space launch industry. This expansion of ideas is essential for the growth of the overall commercial launch industry.
References


2. INTA MST1/INT/30000/SPE/001, “Facility Description Document for the Mini-Satellite Mission (MINISAT), Sep 95.
