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Kodiak Star – The Mission, the Challenges, the Success

A look at Lesson's Learned from the first orbital flight from Alaska

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Abstract

The Kodiak Star was a fast paced mission utilizing a number of first flight items including a payload upper deck, a light band separation system, and a method of deploying multiple payloads from the launch vehicle. The total integration time for this mission was 10-months from a novel remote launch complex. The mission configuration consisted of three Air force Payloads (PICOSat, PCSat, Sapphire) and one NASA sponsored payload, Starshine 3. On September 29, 2001, at 6.40p.m. ADT the Kodiak Star mission successfully lifted off from the Kodiak Launch Complex and 2-hours and 40 minutes later, the complete complement of spacecraft successfully separated. The success of this mission is attributed to teamwork amongst multinational groups, early identification and resolution to problems, and focus on a goal of launching the Kodiak Star in a minimum time frame, 10 months.

Introduction

The Kodiak Star mission initial discussions occurred during the 14th AIAA/USU conference on Small Satellites with representatives from National Aeronautics and Space Administration (NASA) and the United States Air Force (USAF). The resulting payload compliment included USAF sponsored small satellites and a NASA sponsored payload, which were other wise without a ride to space. Agreements were developed and feasibility studies performed to establish the mission. Multinational groups were required to achieve the integration of this complement of payloads. This mission required the involvement of two government organizations, one international company, and one domestic company with two teams, two colleges and one private entity. Since the mission itself was designed to require a short integration period, clear communication amongst all parties was essential. Lessons learned from the mission included the ability to form a team environment early in the integration, understanding the flow of communication and information, and implementing this approach through launch. The team environment and interaction were key to the success of the mission of the Kodiak Star.

During the 10-month integration period, Kodiak Star experienced several challenges that could have jeopardized the mission. Issues and concerns were addressed quickly. It was agreed early in the process that any problems must be corrected expeditiously and retest successfully completed within the designed schedule. These components were essential to the successful completion of the mission.

Background of the Mission

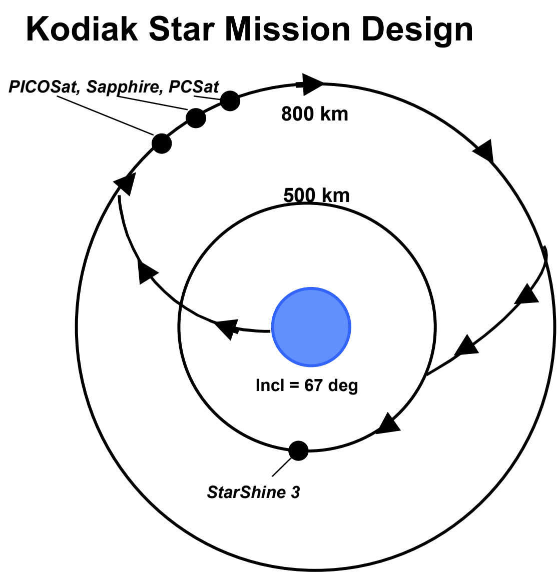
The Kodiak Star mission was a unique mission from the very start, in that the team would be flying the first orbital launch vehicle from a remote site in Alaska with a diverse team. It was formulated at a lunch meeting during the 14th Small Sat Conference, where the USAF and NASA started discussing a possible complement of three Air Force payloads on an Athena I. An Athena launch vehicle became available when the NASA VCL spacecraft experienced technical difficulties and was de-manifested from that vehicle. NASA Headquarters took the lead in searching for a NASA spacecraft that matched the profile of the mission. After the search for a NASA suitable payload for the mission was unsuccessful, NASA worked with the Air Force for a complement of payloads.

During the negotiation with the USAF, the Starshine project approached NASA about the possibility of launching Starshine 3 on the Athena mission. Starshine 3 is the third in a series of spacecraft built with the help of students from around the world. The Starshine 3 mission is to measure upper atmospheric density by measuring the rate of orbital decay of mirrored satellite and correlate variations in atmospheric density with fluctuations in solar extreme ultraviolet radiation. Previous Starshine spacecraft were free flyers released from the Shuttle cargo bay and were restricted to a low earth orbit and inclination. With a ride on the Athena I from Kodiak Alaska, Starshine would be able to achieve a much higher orbit with a greater inclination. This would give Starshine 3 a greater coverage area over the earth for increased sighting around the world.

The Mission

In October 2000, NASA agreed to sponsor Starshine 3 on the Athena vehicle with the Air Force complement of experimental spacecraft. The Kodiak mission would consist of two co-primary payloads (PICOSat for the USAF and the NASA sponsored Starshine 3). The PCSat (US Navel Academy) and Sapphire (Washington University- St Louis) spacecraft would be classified as secondary payloads on the mission. The primary mission requirement was to place PICOSat (built by Surrey Inc. of Great Britain) at 800km with an inclination of 67° and release Starshine3 at an altitude of 500km. The only requirement for the two remaining secondary spacecraft was to be placed in orbit somewhere in space. Since PICOSat had the highest altitude as a requirement, and to reduce risk to the other spacecraft, PICOSat was selected to be the first spacecraft deployed. PCSat and Sapphire were selected to deploy next. PCSat was designed with long “tape measure” antennas that were coiled up under the spacecraft when mated to their separation adapter. At separation, these antennas would deploy and required a large area for clearance as PCSat separated from the Payload Upper Deck. With this in mind, it was determined to separate Sapphire after PICOSat. This would eliminate the risk of the PCSat’s antenna impacting Sapphire as it deployed. Once the Sapphire spacecraft was separated, a delay was built into the software to give some time before PCSat separated. After the PCSat spacecraft separated from the Payload Upper Deck, the Lockheed Martin Astronautics (LMA) Orbital Adjust Module (OAM) performed an orbit change maneuver to lower the orbit from 800km circular to 500km circular (Figure 1) and prepared for the separation of Starshine 3. Upon Starshine 3 separation, the OMA performed a Collision Contamination Avoidance Maneuver (CCAM), to assure that it would not re-contact the spacecraft.

Figure 1

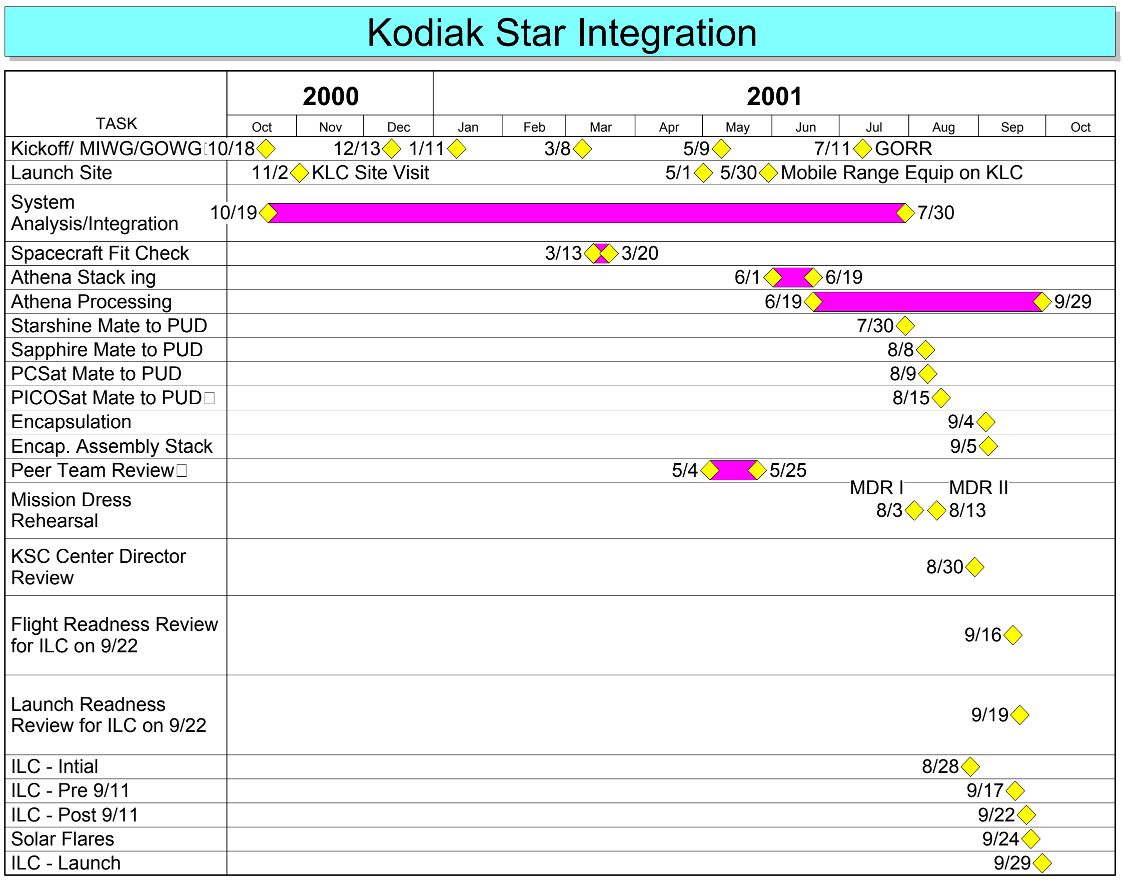


	PICOSat	PCSat	Sapphire	Starshine
Mass (kg)	67	15	22	91
Orbit Alt Range (km)	650 - 1100	200 - 1400	500 - 1100	? - 500
Desired Orbit Alt (km)	800	1100	1100	500
Orbit Inclination (deg)	50 - 70	40 -90	40 - 90	?
Desired Inclination (deg)	55	90	90	polar

Schedule

One of the greatest challenges facing the Kodiak Star team was schedule and timing. This mission had a very aggressive 10-month integration schedule as compared to the normal integration flows for NASA missions of 24 – 30 months. The goal of the team was to streamline the integration flow timeline to reduce schedule by 14-20 months without compromising normal analyses, testing and reviews. The mission was initiated 18 October 2000 with a launch date set for August 31, 2001.

Figure 2



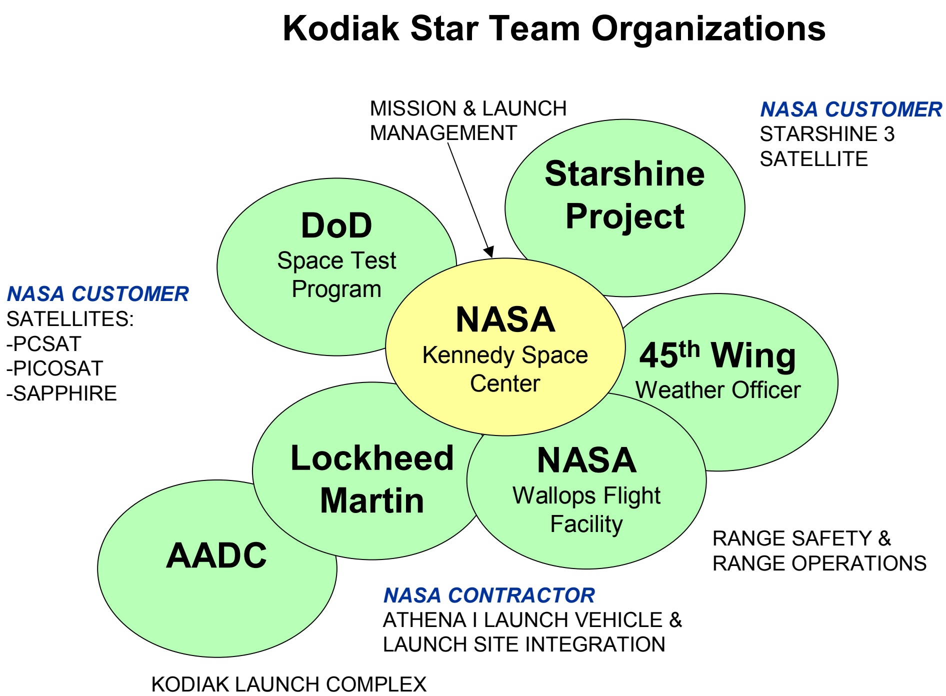
The Challenges

The Team

Even though the Kodiak Star team itself was one of the major reasons for the success of the mission, it was one of the challenges as well. The Kodiak Star team organization was developed with NASA KSC as the nucleus with five different organizations matrixed to NASA (Figure 3). NASA KSC was responsible for the Mission and Launch Management function during the integration flow. Spacecraft customers interface with the NASA team, which consisted of the Space Test Program (STP) from the Department of Defense (DoD), which was responsible for PICOSat, PCSat, and Sapphire. The NASA sponsored spacecraft Starshine 3 was managed by Professor Gil Moore of the Starshine Project. Lockheed Martin was the launch service provider for the Athena I and was contracted to perform launch site activation. The Alaskan Aerospace Development Corporation (AADC) managed the Kodiak Launch Complex. The other organizations on the team were NASA's Wallops Flight

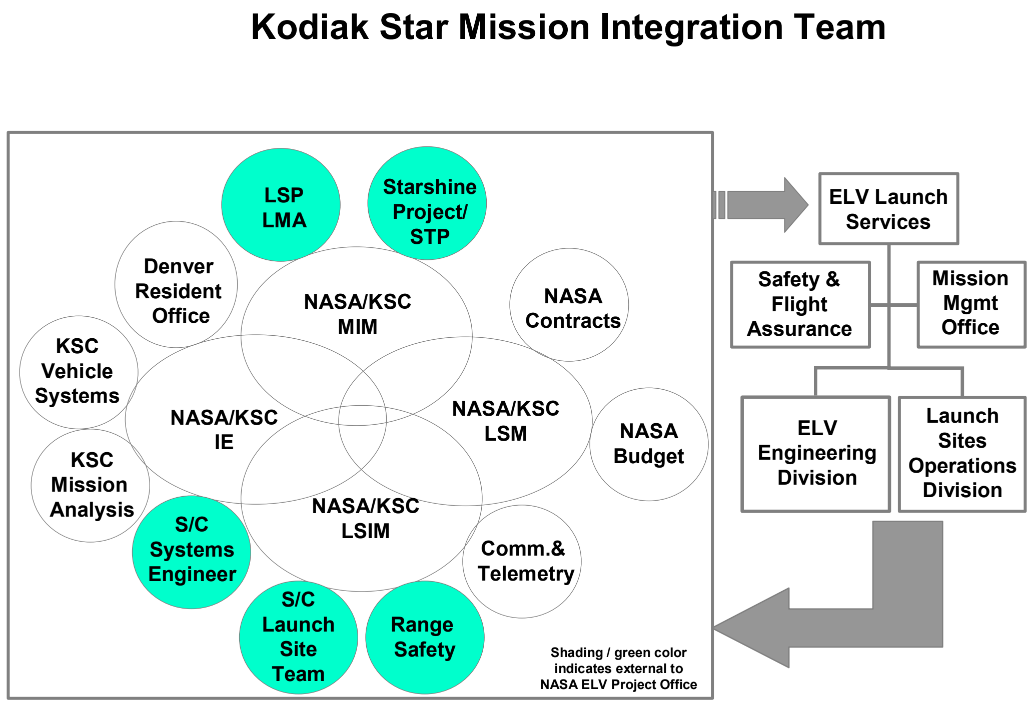
Facility who was responsible for ground and flight safety, and the 45th Space Wing Weather Officer, who was responsible for weather forecasting and prediction during testing and launch countdown.

Figure 3



The NASA Mission Integration Team (MIT) consisted of four interacting elements of which had independent responsibility for the Mission (Figure 4). The Mission Integration Manager (MIM) is responsible for the complete mission integration effort and oversees the other three elements. The Integration Engineer (IE) leads the engineering effort for the integration of the spacecraft to the launch vehicle. The IE also works closely with the Chief and Vehicle engineer to resolve issues during integration. The Launch Service Integration Manager is responsible for launch site activities and ground integration processes for the spacecraft. The last element to the NASA MIT is the Launch Service Manager who manages the contracts and budget between NASA and the Launch Service Provider and other required entities.

Figure 4



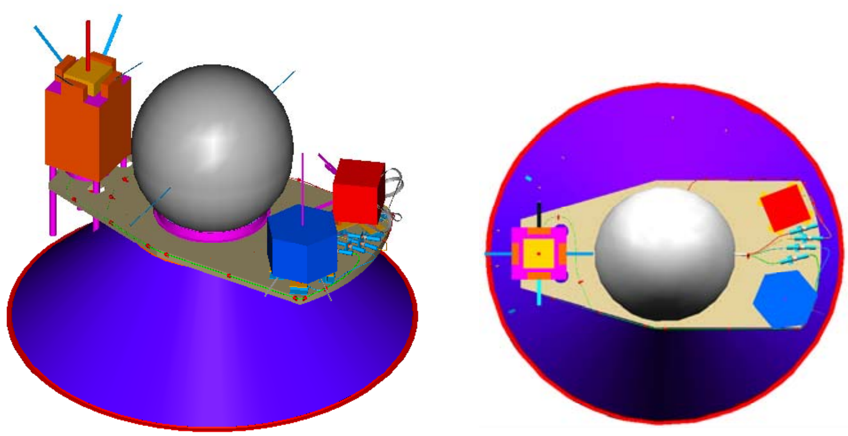
The Payload Upper Deck

The first hurdle to overcome was to determine how to place four spacecraft on top of a rocket that was designed for one. The first requirement was to identify the maximum usable envelope within the payload fairing. After studying the envelopes and separation systems of each of the spacecraft, it was determined that a platform would have to be developed to accommodate the four spacecraft. This platform would then have to be attached to the existing LMA VCL payload adapter. The size and shape of the deck would have to be designed and qualified by analysis to meet the scheduled Initial Launch Capability (ILC). There was to be no environmental testing of the adapter before it was going to be used for flight due to the extremely short schedule. This caused the LMA team to design the deck to factor of safety of 2.0 ultimate, making the deck heavier than necessary, but eliminating the need for a structural qualification testing. Since the individual placement of the spacecraft would also factor into the deck design, a study on the placement of the spacecraft was performed. A ground rule for the study was that none of the spacecraft could encounter any other spacecraft during ascent and separation. In addition, the deployment sequence of each spacecraft would have to be determined.

Kodiak Star was established as to be a co-primary mission, with PICOSat being the primary for the USAF and Starshine 3, primary for NASA. Starshine 3 had the greatest mass requirements for the mission and was larger than the other spacecraft. Starshine 3 was spherical, with a diameter of 36-inch and covered with reflective mirrors. This led the team to place Starshine 3 in the center of the deck on the thrust axis of the Athena. With Starshine in the middle of the deck and the other spacecraft positioned on the outer edges, if Starshine was to be released first there was a major risk of re-contact with the other three spacecraft if the tip-off angle was too great. Therefore, taking all of these factors into consideration, the order of deployment was finalized as PICOSat first, then Sapphire, PCSat and finally Starshine 3. This approach successfully reduced the risk of re-contact with the other spacecraft at separation.

With this information, the NASA/LMA team started the design of what was to be called the Payload Upper Deck (PUD). The PUD took the shape of an ironing board with Starshine in the middle, PICOSat on the small narrow end and Sapphire and PCSat next to each other on the wide end (Figure 5). Since three of the four spacecraft were using tape measures as their antenna systems, the clocking and position of the spacecraft was critical to avoid contacting a fellow spacecraft.

Figure 5 – Spacecraft configuration on the Payload Upper Deck



The design of the PUD was completed in January 2001 and was sent out for manufacturing so it would be ready to support a spacecraft fit check and separation test. Since the integration cycle was short, LMA had to perform Coupled Loads Analysis (CLA), in parallel with the PUD being manufactured. The first run of the CLA revealed a low frequency response in the PUD that was being coupled into the spacecraft, generating unacceptable spacecraft loads. It appeared as though the PUD was inducing a large bending excitation into the spacecraft. To reduce this unacceptable load, the PUD had to be stiffened to eliminate the bending and rotation movement. The PUD was stiffened utilizing four additional struts attached to the corners of the PUD which increased the PUD response, lowering the loads to the spacecrafts.

The Launch Site

One of the unique parts of the Kodiak Star mission was the Launch Site. It is located at the tip of Narrow Cape on the southeast side of Kodiak Island. The Launch site is approximately 42 miles from Kodiak city where the majority of the lodging is available. The 42-miles from Kodiak City to the launch site is predominantly volcanic rock roads with sharp turns and steep grades. With rain, these volcanic rocks would easily puncture vehicle tires causing frequent delays. The commute was accentuated by spectacular vistas (including drops of over 500 feet a few feet from the edge of the road). .

The Launch site was built by AADC and consisted of a Launch complex, enclosed service tower with stand, and umbilical tower. It was capable of to servicing the Athena during integration and check out independent of the weather.

The Spacecraft was processed in the Payload Processing Facility (PPF) about 1 mile from the launch site. This facility was capable of maintaining a class 100,000 clean room environment, which was sufficient to meet the 100,000 class requirement for the Starshine 3. The clean room environment (Class 100,000) was the most stringent requirement for the four spacecraft.

The Launch Control Center (LLC) is located at the entrance to the launch site, where launch countdown activities are performed and office space for the team is provided.

Lightband Qualification

The Starshine Project selected Planetary System Corporation's (PSC) 26-inch Lightband system as the attachment and separation system. This was the first space flight for this system and thus would have to establish that it was designed and tested to proper qualification levels before integration onto the Athena. Prior to integration, NASA, NRL and PSC engineers required a full qualification program to be performed by PSC on the Lightband to include vibration, thermal vacuum, and shock testing.

During thermal vacuum ($1x10^{-6}$Torr) cycling, one of the two Lightband systems failed to separate. This test was performed just four weeks before the scheduled mate of the Lightband and Starshine3 spacecraft onto the Payload Upper Deck. The failure of the Lightband system was traced to the De-tensioner unit, where nickel chromium wires were melting when the separation signal was sent. This potential failure mode and assignable cause was discovered during vacuum chamber testing. NASA KSC sent a Thermal Analyst from the Mission Integration team along with electrical engineers from NRL to help PSC resolve the issue of the melting of the nickel chromium wire. After a complete review of the failure it was concluded that the supply current from the Athena that initiates the Lightband had, to be regulated to 1.86 A +/- 0.0.03A. Because the Athena electrical system could not practically implement a current limiter in the available time, a current limiter was added to the De-tensioner assembly. A custom made current limiter was designed by NRL and PSC engineers. This current limiter was capable of controlling the current levels delivered to the Lightband separation system. The entire separation system was re-qualification tested two weeks prior to the spacecraft to mate in Kodiak. Following addition of the current limiter to the Lightband, two retests of the Flight and spare 26 inch Lightband were conducted in the Thermal vacuum system to verify the design. Another 20 subsystem tests of the current limiter/de-tensioner circuit were separately completed in another thermal vacuum test. Lockheed engineers verified the acceptability of the current limiter circuit at the same time using flight duplicate hardware. The Starshine 3 payload, with the integrated Lightband, was then shipped to Kodiak for integration without delaying the schedule. Following successful separation, telemetry from Starshine-3 verified the Lightband met the spin-up requirement of 5 degrees /second. The novel design of the current limiter resulted in an expedited test and successful completion of the Lightband qualification without a significant impact on the program timing.

NEA Actuator

A high fidelity mockup of each spacecraft and the fight separation system was required to perform a fit check and separation/shock test at Lockheed Martin in Denver. The fit check would be performed on the newly completed Payload Upper Deck that was designed and built by LMA to accommodate the compliment of payloads. The test would install each of the payloads in a reverse order in which they were to be deployed. Each of the Spacecraft was required to bring the flight separation hardware to verify the correct interface between the PUD and the spacecraft. The separation test was designed to simulate a micro gravity condition by using a set of counter weights and pulleys. This would allow the test team to monitor the behavior of each spacecraft at separation in a simulated micro gravity condition.

During the separation test of PCSat the NEA actuator, which held the spacecraft, was unable to release once the signal was sent by the test conductor. After the spacecraft was secured, it was removed from the PUD and an investigation was conducted to understand why the NEA failed to release. After the investigation was performed, the NEA separation bolt was determined to be the source of the failure. Upon investigation, it was found that cold-welding between parts within the NEA device was occurring. The part was removed and a new NEA separation bolt was installed using a modified installation procedure and the test was successfully repeated. Again, a quick identification to a problem and expedited resolution did not impact the program schedule.

Mission Requirements

System requirements for the mission had to be identified at the beginning of the integration flow to verify that each requirement could be met. The requirements for each spacecraft began to be identified at the first Mission Integration Working Group held in October 2000. These requirements would be used to design the mission and any mission unique hardware that would be necessary. Since this was a reduced integration flow, each of the Spacecraft presented their specifications for mass properties, moments of inertia, and product of inertia at the meeting. Once these requirements were recorded, each spacecraft would have to deliver their spacecraft within these specifications. It was agreed that if the weight of the spacecraft were below their required value, they would have to add ballast to get them to their required weight. If any of the spacecraft were over the weight requirement, LMA had a small safety factor, which could be utilized if necessary. From this point forward, no further changes were made in the spacecraft specifications.

Collision Avoidance between Spacecraft

The Kennedy Space Center ELV mission analysis branch identified the potential of collision between the Sapphire and PCSat spacecraft due to characteristics of the original Kodiak Star flight design. The original flight design had the separation events of these two spacecraft spaced by only 10 seconds, effectively pointing in the same attitude, with the PCSat separation speed being greater than Sapphire. Since such a risk assessment was not part of the accelerated Lockheed Martin integration schedule, NASA assumed the responsibility to quantify the risk and derive a mitigation plan.

A Monte-Carlo orbit propagation technique proposed by KSC Mission Analysis Branch (MAB) was used to examine each part of this analysis task. It was shown that the original flight design produced a 100% probability that Sapphire and PCSat would be within 10 meters of each other shortly after deployment (first 100 seconds). Additional analyses determined that this proximity risk could be greatly reduced by waiting 60 seconds between the Sapphire and PCSat separation events. This added time allowed the Athena upper stage to passively reorient to a different attitude due to the impulse imparted from the Sapphire separation event. Further analyses verified that this new flight sequence resulted in a low proximity risk on subsequent orbit passes. Hence, to ensure mission success, NASA directed LMA to increase the time between the Sapphire and PCSat separation events from 10 to 60 seconds.

For completeness, the proximity risk analysis was expanded to include PICOSat. This examination revealed a significant proximity risk between PICOSat and Sapphire at first orbit passage to violate the 1 meter envelop for each spacecraft. The USAF Space Test Program office was notified of this finding. Since the only mitigation of this risk was to redesign the collision avoidance maneuver, which would result in a launch delay, STP opted to accept this low risk and proceed to launch.

Loads

Because of the Payload Upper Deck, NASA/KSC had to work closely with Lockheed Martin Astronautic to understand the true design loads for the spacecraft. During the Final Design Loads Cycle, the PUD dynamics created loads that exceeded the Interface Control Document using the standard Athena Coupled loads analysis procedure. This resulted in LMA adopting a new methodology for the VLC. During the analysis, LMA discovered that the Spectral Gust forcing function was adversely coupling with the PUD dynamics. This resulted in LMA changing their frequency domain analysis. Upon investigation, KSC considered this approach un-conservative so KSC recommended a return to the frequency domain analysis but with a different gust spectrum.

The Kodiak Star spacecraft fundamental frequencies were higher than usual. Therefore, a special Center of Gravity Load Factor (CGLF) study was performed. This study provided design load data for spacecraft with fundamental frequencies beyond the CLA range. Typically, CGLF are superceded by CLA, but several of the spacecraft primary model frequencies are above the CLA analysis regime. For these cases, LMA generated high frequency center of gravity load factors and which became the governing qualification requirements for primary structure.

ITAR – The International Traffic in Arms Regulation (ITAR) issue was one the biggest programmatic obstacles during the mission. Due to a late start in the ITAR process and short integration time of the mission, it was difficult to get the proper

ITAR paper work in place to conduct meetings with all parties present. Presentations by Lockheed Martin had to be edited to comply with ITAR regulations. Attendance by personal from Surrey, the PICOSat manufacture, was limited during the meetings to prevent their exposure to sensitive material. A key lesson of learned for expediting this procedure in the future is to start the paperwork process as soon as possible and have one point of contact for the process.

Ordnance – The ordnance used for the pyro test and for launch was shipped over from Great Britain for use by PICOSat. The ordnance arrived into the country with few problems, however returning the unused pyro proved more difficult. The paperwork needs to be in place well in advance of the shipment.

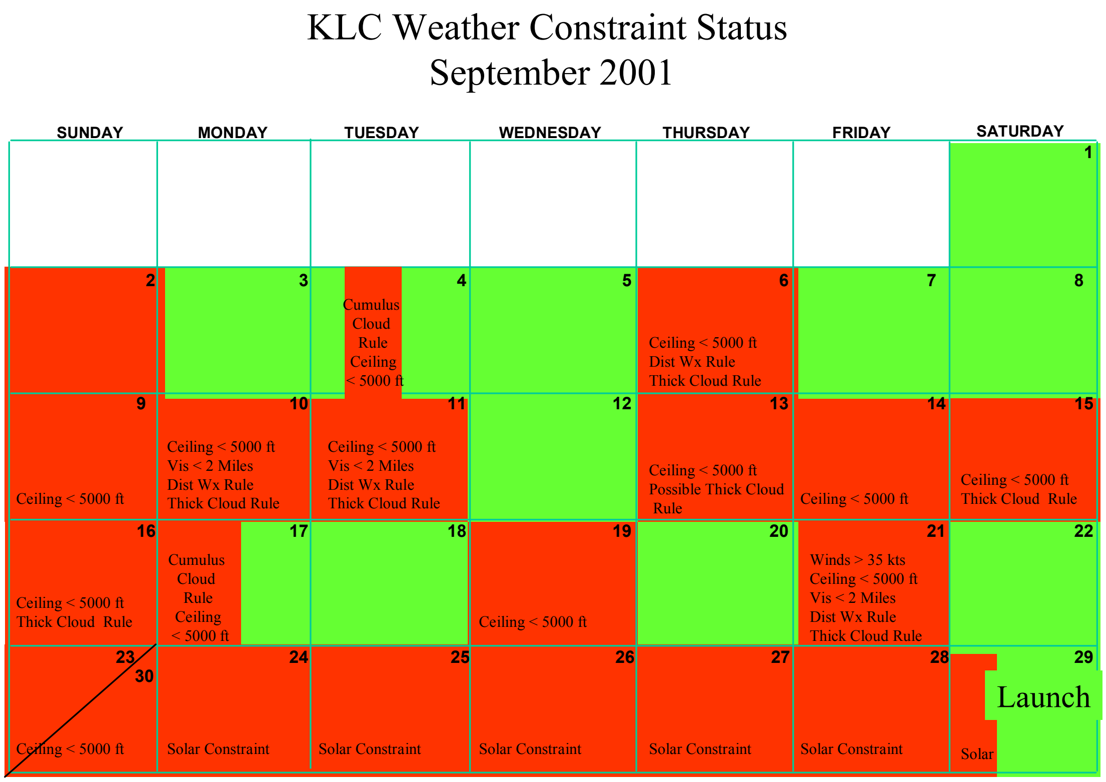
Orbital Debris Reports **-** Orbital Debris Report development is typically the responsibility of the spacecraft organization on the mission, KSC supports in validating launch vehicle inputs. Since KSC was assigned overall mission management responsibility for the Starshine3 spacecraft, KSC was responsible for the orbital debris report for this spacecraft. This report is very labor intensive so KSC contracted Lockheed Martin to perform the report in parallel with the development of the Launch Vehicle report.

Range Support – At the time the configuration of the Kodiak Launch Site did not have built in Range facilities for the mission flow from the site. Knowing this, NASA KSC would have to acquire mobile range support for the mission. KSC selected the NASA Wallops Flight Facility (WFF) to provide ground and flight safety support for the Kodiak Star mission. Along with this task, the Wallops Flight Facility provided real-time vehicle performance data for the first 440 seconds of the flight and during the first pass over Kodiak. For WFF to perform their task they would have to set up two sites for radars and command vans. The first site would be on Kodiak at the launch site and would have 10-foot, 18-foot telemetry, and radar antennas, which would feed to the control van located, near the Launch Control Center. The second site would be located at Cordova, AK. The Cordova site would house a 7-meter radar antenna with a command mobile van, which was tied to the control van at Kodiak. Due to the weather condition on Cordova, much of the preparation work to support the antenna and installation of the vans had to be completed before the winter months.

Weather

Kodiak Island is located between the Shelikof Strait and the Pacific Ocean with the Gulf of Alaska just to the North. This location and the terrain of the island can develop unique weather patterns not typically seen at either east or west coast launch sites. The common weather pattern at the launch site was three or four days of rain followed by a day or two of clear weather. With this unique weather pattern, the Weather Officer for the Kodiak Star mission kept a calendar to track the weather conditions at potential launch times each day. Shown in Figure 6, the KLC Weather Constraint Status calendar for September indicated only 11 days in the month of September were suitable (shown in green) for launch. The first launch attempt for the mission was on September 22 but due to radar problem at the Cordova site the attempt for the day was scrubbed. September 24 through 29 were red due to one of the largest solar flare activity periods on record. Such high levels of charged particles had a high potential of adversely affecting the Athena avionics. It took four and half days for the eV level to decrease from $1x10^4$ eV/meter to 1eV/meter which is the acceptable level for the next launch attempt.

Figure 6

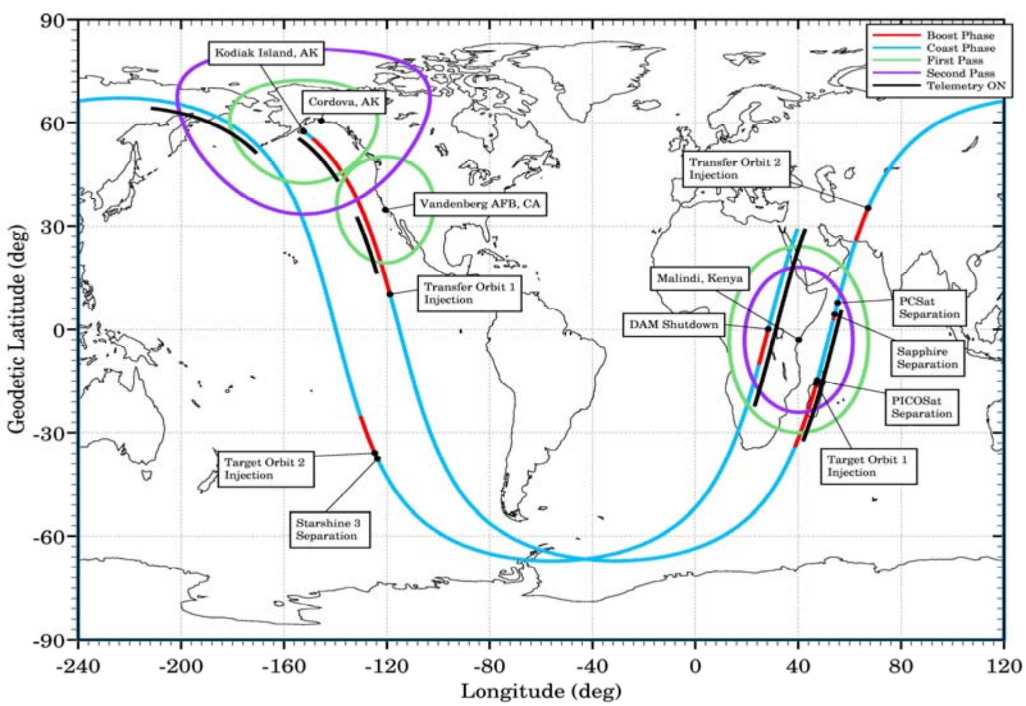


The Success

Mission Performance – The LMA Athena I performed flawlessly in placing the four Kodiak Star spacecraft in their desired orbits. PICOSat and Sapphire separation telemetry was received real time during the pass over Malindi, Kenya (Figure 7). PCSat separation occurred immediately after the spacecraft was out of range of the Malindi tracking station but the OAM avionics of the Athena has the capability to store the separation events and re-transmit once the vehicle crosses over a tracking station. This was the case for both PCSat and Starshine. On the first pass over Kodiak, the PCSat separation was confirmed. The mission plan had Starshine separating over the South Pacific and then retransmitting data during the second pass over Malindi (approximately 2 hours and 43 minutes into the flight). However, the Starshine3 spacecraft confirmation came a little earlier then the Malindi pass. This was made possible by the worldwide

Starshine network. While in Kodiak, the Starshine Project Manager Gil Moore was talking on the phone with a person in Antarctica who was using a hand held receiver. At separation, the Starshine 3 spacecraft started sending data packets, which were received by ham radio operators around the world. Once Starshine 3 passed within sight of Antarctica, spacecraft signal was received by the hand held receiver and confirmation was relayed back to Gil Moore at the Kodiak launch site by telephone. The final confirmation came when the Athena OAM passed over the Malindi tracking station and the stored data for the Starshine 3 separation was received and confirmed.

Figure 7. Flight Profile of the Kodiak Star Mission



Public Relations – The Kodiak team did more than place four spacecraft in orbit while visiting Kodiak, Alaska. One other important job that needed to be performed was outreach to the people of Kodiak, to inform and generate interest on what was going on at the launch site. NASA participated in the Kodiak Town Borough meeting to answer questions about the Kodiak Star launch and inform people about what to expect during the mission processing. Several members of the Kodiak Star team conducted classes in the Kodiak school systems and many of the Kodiak students polished mirrors for the NASA sponsored Starshine 3 spacecraft. Any chance the team had to talk about the mission with local residents was well received.

Team Environment – Being able to develop and maintain the team environment on Kodiak Star mission was the key to its success. Having four different spacecraft, each with their own support teams with identified requirements and ways to maintain them throughout the mission was incredible. Each member of team had a job to perform and they performed it at the best of there ability. Everyone on the team had the "Can Do" attitude that no matter what issue arose, it was addressed and corrected before the issue became a major problem and could result in a delay in the mission schedule and timing. The Kodiak Star Mission team was truly an example of total team integration.

The Lessons Learned

Spacecraft Maturity – During the initial phase of information gathering, it quickly became clear that expectations of team members were varied. This variance led to misunderstandings as to what constitutes completion. If the spacecraft is built, it is important to clearly define the current state of qualification of pre-existing launch hardware. Early requirements definition, validation and base lining would minimize requirement change as the mission maturity Verification/validation of the spacecraft requirements will have to be performed before being selected for a short turn-on, L-12 month or secondary mission

Communication – The communication on this mission was excellent and was reflected in the achievement of the goal. Communication was facilitated by a central focal point, in this casa KSC. Because of the size of the Kodiak team, central coordination was essential to keep organizations tied together.

ITAR – Any mission that will interface with an international party will have to start the ITAR processes as quickly as possible to avoid any loss of communication or delay.

Ordnance – When sending and receiving ordnance from an international party, coordination of the shipping and Customs needs must be identified and addressed in advance to reduce risk of delay.

New Separation System –A flight proven separation system would have minimized the risk to the mission and reduce the amount of review performed, especially for a mission with a tight timeline and already facing significant integration challenges.

Launch Site – Being the first orbital user of the launch site resulted in many logistical challenges for the team. Shipment would have to be delivered to Kodiak by air and then trucked out to the site. It is prudent to think ahead to what you will need during processing and bring it with you. Normal FedEx over night took 2 days to arrive on the island.

Performing Analysis and Manufacturing Hardware in Parallel – Before hardware is designed for a mission, make sure good spacecraft models are in place. Reduction in risk can be achieved by designing in stiffness and additional design margin up front.

Range Support **-** A mobile range can be located in a remote area to support a launch, as long adequate planning, coordination, and early team involvement are implemented. This will reduce risk of a launch date move due to the range not being ready.

Summary

The Kodiak Star Mission was very challenging and offers significant lesson for future missions. A multinational fully integrated team had the opportunity to perform a truly first of a kind mission from a new launch complex with a unique manifest of experimental spacecraft. The integration goal of 10-months was met utilizing quick identification of the issues, and determining innovative ways to solve the problems. The design of the Payload Upper Deck to accommodate the 4-spacecraft was truly unique. Perform a 2-orbit separation of the spacecraft at two different orbits had never been performed by Athena I. The remoteness of the launch site resulted in a high emphasis on planning of shipments and deliveries so that the timetable would not be affected. Finally, the ability of the Kodiak team to utilize a remote range to provide ground and flight safety support for the launch was a difficult task. Additional innovative analyses performed on collision avoidance and coupled loads performed by the team reduced the risk of failure to the mission The single must key element to the success of Kodiak Star was the ability to communicate with a team well over 600 strong and still have it all come together in a very short time.

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