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Opportunities for Small Satellites and Space Research Using the K-1 Vehicle

Debra Facktor Lepore, Gary Lai, and Tom Taylor
Kistler Aerospace Corporation
3760 Carillon Point, Kirkland, Washington 98033
(425) 889-2001

Abstract

Kistler Aerospace Corporation will launch the K-1 vehicle into orbit from Spaceport Woomera for its first flight test in 2000 and commence commercial operations shortly thereafter. These events will mark two important milestones in aerospace history. First, the K-1 is the world's first fully reusable aerospace vehicle, designed for 100 flights. Second, the K-1 is the first launch vehicle built entirely by private funds for the commercial launch market.

Expendable vehicle launch costs make up a significant portion of satellite program budgets. These costs can be prohibitive for small satellites and space researchers. The reusable K-1 vehicle provides a low cost alternative for access to low-earth orbit (LEO). While large commercial LEO satellites form the core of the K-1's target market, the K-1 can also deliver small satellites as either secondary or primary payloads. The K-1 can also be considered as a platform for microgravity experiments.

Meeting several integration challenges is the key to realizing the potential of the K-1 to support the small satellite and space research communities. These challenges include minimizing the non-recurring engineering required for integration of structures and electrical systems, matching orbits for two or more spacecraft, resolving mutual environment interactions, and solving contractual and scheduling issues. Kistler is committed to working towards viable approaches to make the K-1's low cost space access capability available to the small satellite and space research communities.

Introduction

Since 1993, Kistler Aerospace Corporation has been designing and building the K-1, the world's first fully reusable aerospace vehicle. In 2000, the first K-1 will lift-off on its maiden flight test from Woomera, Australia, heralding a major revolution in space enterprise for the new millennium. Commercial operations will commence shortly after the test program.

The K-1's reusability will transform the economics of space. Instead of expensive expendable rockets, the K-1's two stages return to the launch site with parachutes and airbags for reuse up to 100 times. A single K-1 can be readied for another launch in as little as 9 days. Capable of lifting up to 4,800 kg into

LEO, the K-1's payload capacity is comparable to a medium-lift expendable launch vehicle (ELV).

The K-1's design effort is led by Chief Executive Officer Dr. George Mueller, the former head of NASA's Apollo Manned Space Program. He leads a team of aerospace experts and contractors, including Lockheed Martin Michoud Space Systems, Northrop Grumman Corporation, GenCorp Aerojet, Draper Laboratory, AlliedSignal Aerospace, Irvin Aerospace, Inc, and Oceaneering Thermal Systems.

The K-1 meets the needs of the growing market for commercial LEO communication and remote sensing satellites. The K-1 can also accommodate a wide range of small satellite missions, either as primary or secondary payloads. This paper briefly

describes the K-1 vehicle and focuses on the opportunities the K-1 offers the small satellite and space research communities.

Vehicle Description

The K-1 is a two-stage vehicle, shown in Figure 1. The first stage, or Launch Assist Platform (LAP), is powered by two Aerojet AJ26-58 and one AJ26-59 LOX/kerosene engines. These engines are modified versions of the NK-33 engine built for the Russian Manned Moon Program. Following separation, the LAP is reoriented and the center engine is restarted to return the LAP back to the launch site. The LAP automatically lands using parachutes and airbags approximately 12 minutes after liftoff.

The second stage, or Orbital Vehicle (OV), uses one AJ26-60 engine. This engine is a modified version of the Russian NK-43 engine. After separation from the LAP, the OV main engine ignites to place the vehicle in an elliptical orbit. Following a coast to apogee, the OV Orbital Maneuvering System (OMS) engine fires to circularize the orbit. The OV attitude is then adjusted, the Payload Module dome is opened, and the payload is deployed.

After waiting sufficient time to preclude any interference with the payload, the OMS engine fires again to place the OV into a phasing orbit with the proper period for return. Following a coast phase of approximately 22 hours, the vehicle reorients itself, performs a de-orbit burn with the OMS engine, reenters the Earth's atmosphere, and lands using parachutes and airbags. The vehicle is serviced, integrated with the payload, and readied for the next flight in as few as nine days.

Payload Module

The K-1 offers two payload modules to accommodate a range of payload sizes and configurations. Figure 2 illustrates the Standard Payload Module (SPM) and the Extended Payload Module (EPM). Both modules use the same operational philosophy. The EPM has an additional barrel section to accommodate larger payloads. During re-entry, the EPM uses a telescoping mechanism to retract the barrel section for stability and control. For small satellite missions, the SPM would probably be used.

Figure 3 illustrates the basic operating sequence of the SPM. The dome is first opened and moved to the side using a wishbone armature. If required for clearance, three redundant screw jacks then drive an elevator that raises the payload dispenser.

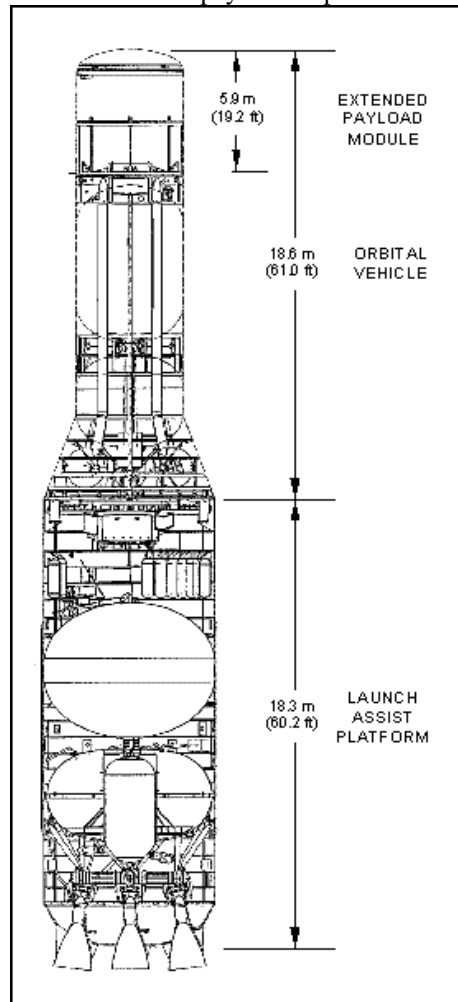


Figure 1. Kistler K-1 Vehicle

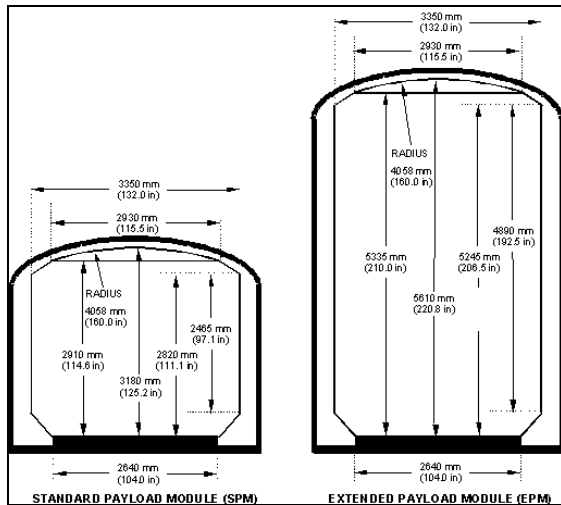


Figure 2. Payload Module Configurations

The payload is then deployed, the screw jacks are run in reverse to lower the elevator, and the dome is closed and sealed for reentry.

Payload Performance

Figure 4 shows the K-1's payload performance capability to circular orbit from Woomera. For initial commercial operations, the K-1 services inclinations between 45 to 60 degrees and 84 to 99 degrees. Expansions of these corridors will be pursued as requirements are defined.

The K-1 is designed primarily to service the LEO commercial communication and remote sensing satellite market. If desired by the customer, the K-1 can deploy payloads with customer-provided upper stages to LEO. Depending on the upper stage used, missions can be considered to geosynchronous orbit, the Moon, or even Mars.

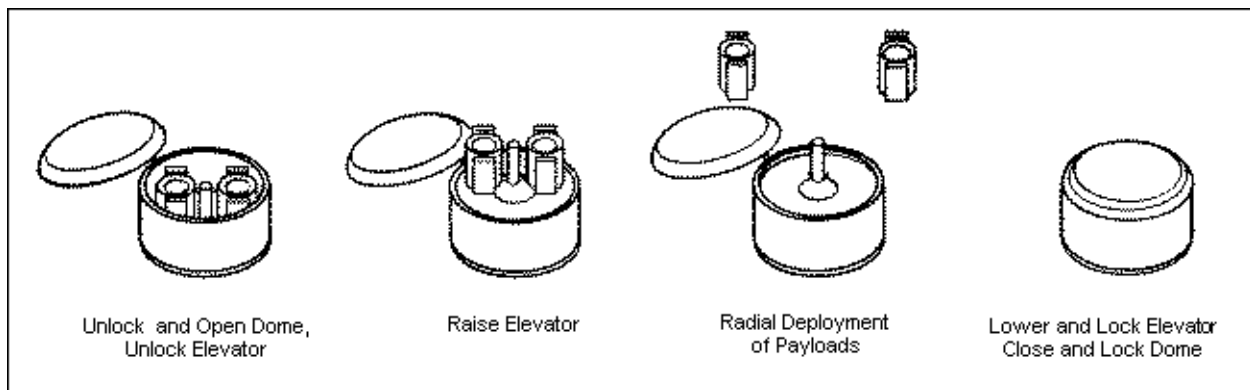


Figure 3: Payload Deployment Sequence

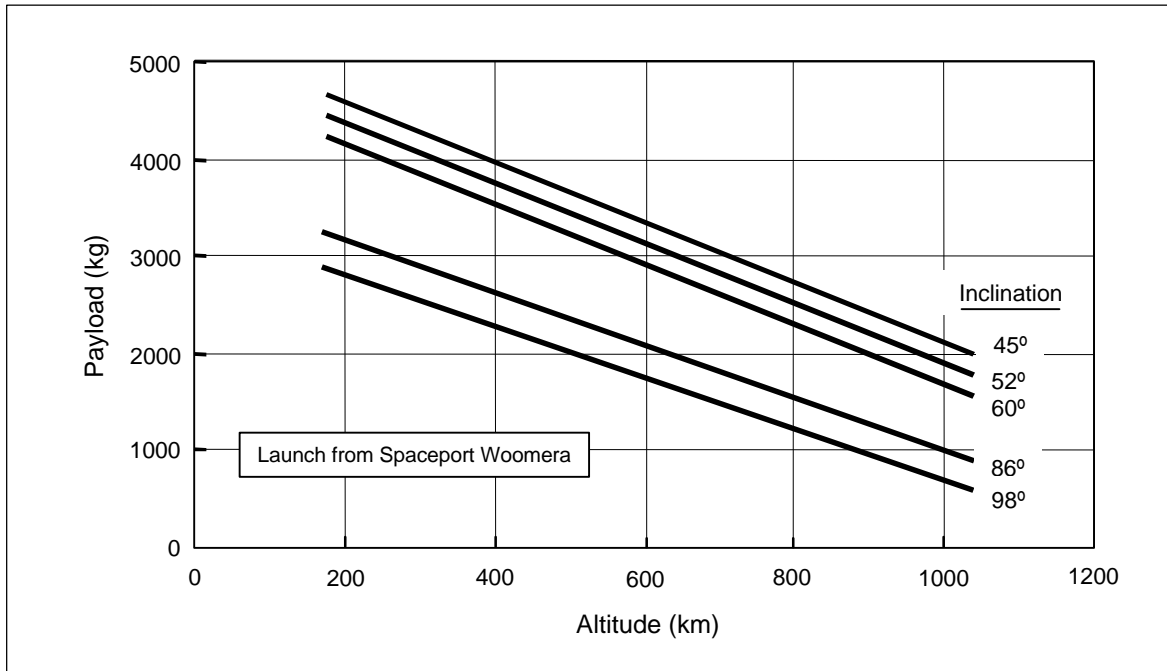


Figure 4: K-1 Circular Orbit Performance with SPM

Small Satellite and Space Research Opportunities on the K-1

The K-1 offers small satellite and space research programs greater access to space. Kistler is considering several approaches to providing this capability. These approaches include carrying small satellites as secondary payloads, scheduling dedicated small satellite missions, and incorporating microgravity experiment packages within the K-1. The following section discuss the opportunities provided by the K-1 and the system integration and programmatic issues that must be considered.

Secondary Payloads

Opportunities may exist for small satellites to launch from the K-1 as secondary payloads, allowing customers to share the K-1’s low launch cost. Kistler is investigating use of existing, planned, or new small satellite dispensers. One example is a dispenser that would use existing components that have been space qualified. This dispenser could potentially accommodate microsattellites or minisatellites. Figure 5 shows a preliminary

configuration of such a dispenser. A representative primary payload is shown for clarity.

After axial deployment of the primary satellite, up to eight microsattellites, weighing approximately 100 kg or less each, would also deploy axially. The K-1 would be capable of deploying a modest sized primary payload when loaded with eight microsattellites. Primary and secondary payloads would be deployed to the same orbit. A version of this adapter carrying fewer satellites may be used to deploy payloads during the flight test program. Kistler is working with the Universities Space Research Association and other potential customers to offer small satellites launch opportunities on this flight test.

Another example is the Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA) being developed by the Air Force Space Test Program, incorporating proven technologies used on Taurus, Pegasus, and Athena vehicles. The ESPA is shown in Figure 6. Preliminary discussions between the Air Force Space Test Program and Kistler have been held regarding compatibility of the ESPA with the K-1.

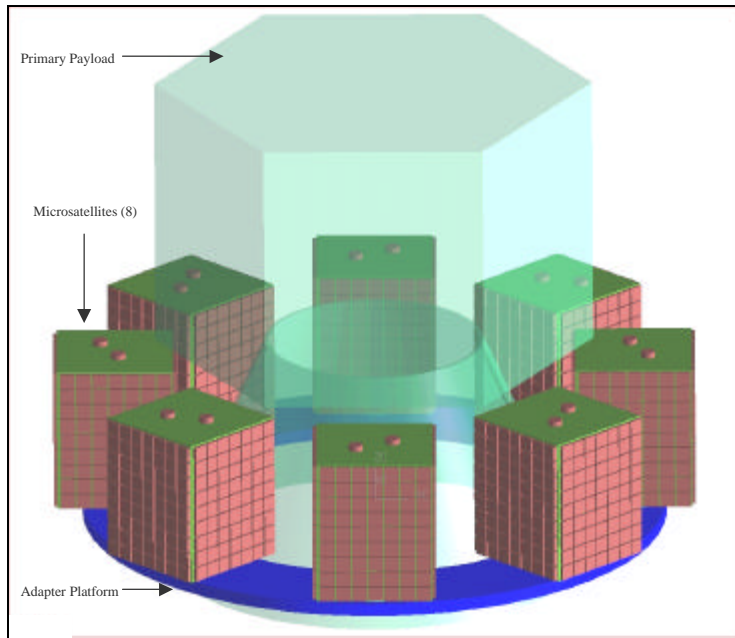


Figure 5: Multiple Microsatellite Adapter Concept for K-1

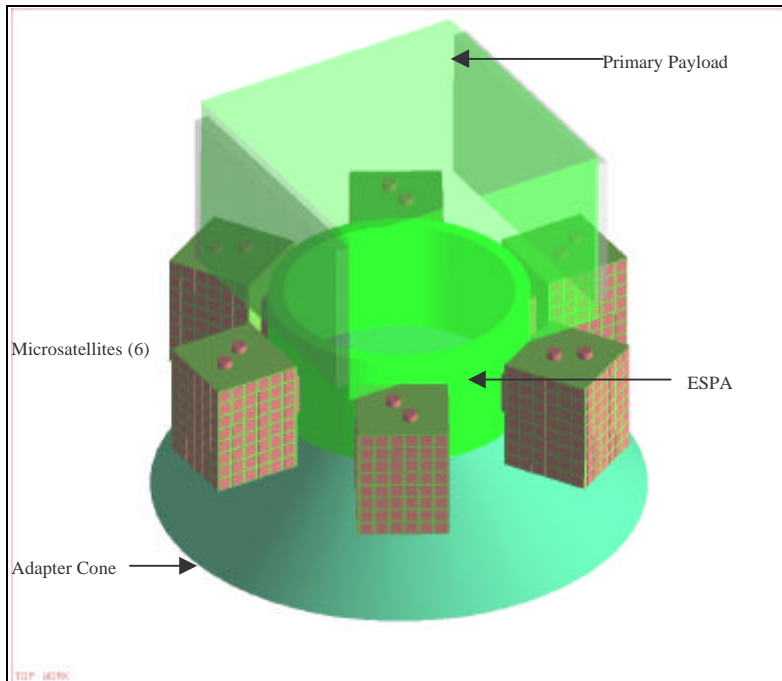


Figure 6: EELV Secondary Payload Adapter

The ESPA radially deploys up to six microsatellites, weighing up to 100 kg each, and axially deploys a

single primary payload. The ESPA is inserted between the main adapter cone and the primary

payload. With an ESPA dispenser carrying six payloads in the microsatellite class, the K-1 could still accommodate a large primary payload. The Air Force Space Test Program expects the ESPA will be ready in 2002.

Dedicated Small Satellite Missions

Depending on the number, mass, and orbit requirements of small satellite customers, the two adapters described previously may even be used to deploy multiple small satellites on a dedicated mission without a primary payload, eliminating the need to find a compatible primary payload customer. In this case, Kistler would require financial commitments from payload customers in advance. Kistler would specify interface and environment requirements each satellite must meet. If this concept proves successful and demand exists, Kistler may schedule additional dedicated small satellite flights on a regular basis.

K-1 Accommodations for Microgravity Experiments

The K-1 may provide the scientific community access to a short and long duration microgravity environment for experiments. These opportunities are expected to be available during K-1 commercial flights, provided several integration issues can be resolved. During the flight profile of a typical K-1 mission, the LAP experiences approximately 150 seconds of microgravity during its exo-atmospheric descent back towards the launch site. This microgravity duration is equivalent to that obtainable with sounding rockets and longer than the duration provided by drop towers. The OV experiences approximately 22 hours of microgravity before it de-orbits to return to the launch site. This microgravity duration is currently only available with U.S. Space Shuttle missions or recoverable satellites. Both of these opportunities would be available for much less than the prevailing price for sounding rockets and Space Shuttle missions.

Microgravity Experiments on the LAP

The LAP may provide space for small, self-contained, autonomous experiments within its structure. Using this space provides approximately 150 seconds of microgravity flight.

Accelerations during the coast phase are estimated to be less than 10^{-4} g.

During LAP flyback, just prior to the free-fall period, the maximum axial acceleration is 6 g, with lateral accelerations of ± 1 g. As the LAP lands, the resulting lateral loads are 5-8.5 g, depending upon experiment location in the structure. A total mass of approximately 200 kg could be carried. One possible location is the LAP interstage region, shown in Figure 7. Another possible location is the LAP intertank region.

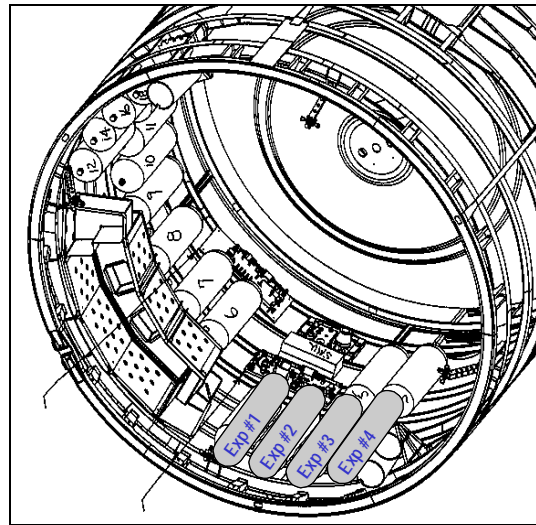


Figure 7: Microgravity Experiment Mounting Location Option in the LAP Interstage Region

Microgravity Experiments on the OV

The OV may be able to support a self-contained experiment rack in the forward compartment, capable of carrying up to approximately 135 kg of experiments. The time available at microgravity levels is roughly 22 hours, subject to OV alignment and re-phasing sequences necessary to accurately determine its position prior to reentry. One location where the experiments may be placed is shown in Figure 8. Overall acceleration levels are expected to be less than 10^{-5} g.

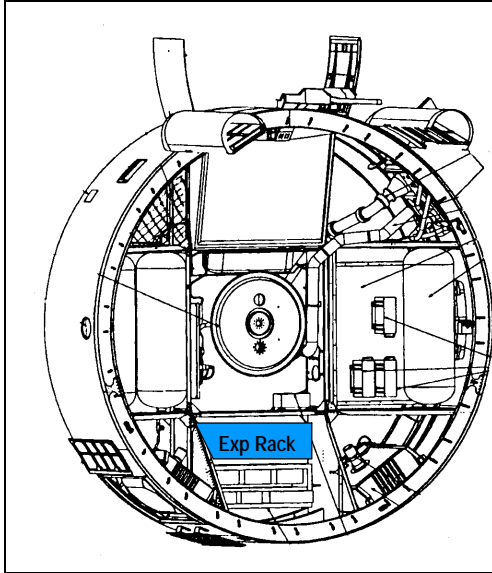


Figure 8: Microgravity Experiment Mounting Location in the OV Forward Compartment

The OV maximum axial acceleration during ascent is 6 g, with lateral accelerations of ± 1 g. OV reentry loads are 8 g axially and ± 2 g laterally. Landing loads for the OV are 10 g laterally at the payload deck.

Integration Challenges

A number of challenges must be overcome to integrate small satellites and microgravity experiments into the K-1.

Mission Planning Issues

The orbital requirements and launch date of secondary payloads or experiments must be matched with an existing primary payload's requirements. The K-1 has only limited ability to make maneuvers in-orbit. Major plane or altitude changes to deploy different payloads to different orbits are not possible.

Once in orbit, a post-deployment collision avoidance plan becomes more complex with multiple satellites. The deployed spacecraft must possess enough propulsion capability to initiate their own collision avoidance maneuvers. These issues are manageable, but require careful planning.

Contractual Issues

Kistler, together with its customers, must also resolve complex contractual issues for a flight carrying payloads from different programs. Each party must resolve its relationship with all other parties. Should one customer decide to cancel their launch, the obligations of all other parties must be clearly defined. Some small satellite programs may discover these issues are beyond the scope of their organization to resolve. The services of a broker to act as an agent for all small satellite programs on a given launch may assist in resolving these issues.

Payload Interaction Issues

With multiple spacecraft, the payload environment becomes more complex. Coupled loads, thermal, vibration, EMI/EMC, contamination, and shock analyses must account for coupling between spacecraft. Potential environmental issues may be resolved through standardization of interfaces and spacecraft requirements.

Non-Recurring Costs

There are significant non-recurring costs associated with the integration of any new payload with a launch vehicle. The payload must be rigorously tested to verify its ability to withstand flight environments. The payload may also require unique interface hardware. Small satellite programs often have only small budgets to resolve these issues. Repeated use of standard small satellite buses and standard interfaces will help minimize non-recurring costs.

Conclusion

The K-1 will commence commercial operations from Woomera, Australia, in 2000, offering new opportunities to the small satellite and space research communities.

The K-1 vehicle can place medium weight primary payloads into low-earth orbit while also carrying additional small secondary payloads. Kistler is investigating several configurations for reusable dispensers that can carry small satellites either as secondary or primary payloads.

The unique reusability of the K-1 may allow Kistler to offer a short and long duration microgravity environment for scientific experiments. These experiments would be self-contained and placed inside either the LAP or the OV. The experiments are recovered after retrieval of the stages.

Resolving the integration issues listed requires close coordination with the small satellite and space research communities. These issues require creative solutions, such as standardization of requirements. Kistler believes these challenges are manageable and is committed to working with customers to provide low-cost space access for small satellites and space researchers.