"Technical and Programmatic Challenges for Dedicated Ride Share Missions"

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ABSTRACT

The Athena RideShare™ launch service, announced by Lockheed Martin and ATK in 2011, is a game-changing approach that lowers launch costs and provides scheduled access to space for small satellites and cubesats.

The Athena RideShare launch service is an extension of a familiar concept, the Post Office's Priority Mail Flat Rate Boxes. If payload fits into the designated volume envelope and mass limit, the customer pays one low flat rate to get to space.

Despite the simplicity of the model, there are significant challenges to execute this idea. Both technical and programmatic challenges have surfaced in the pursuit of setting up this service. Technical challenges include:

- Integrating a variety of mass and volumes in a dynamic launch environment
- Adapting the launch profile to accommodate a wide range of orbital altitudes
- Verification that all payloads will not adversely impact the mission or other payloads

Programmatic challenges have turned out to be the bigger issue, however. Issues include:

- Confirming payloads for the manifest
- Scheduling to ensure all payloads are delivered on time
- Developing appropriate contracts for ride share missions

With a RideShare model, low cost, reliable access to space is indeed possible; however, it is not as easy as it looks. Both technical and programmatic challenges identified can be overcome, and it is easy to see that ride share will become the standard approach for purring small payloads into space in the near-term future.

TECHNICAL AND PROGRAMMATIC CHALLENGES FOR DEDICATED RIDE SHARE MISSIONS

The Athena RideShare™ launch service, announced by Lockheed Martin and ATK in 2011, is a game-changing approach that lowers launch costs and provides scheduled access to space for small satellites and cubesats. The overall concept, while straightforward, offers some significant technical and programmatic challenges in planning and execution.

Buying a dedicated launch vehicle for every satellite is cost prohibitive in today's fiscal environment. With the advent of smaller, more capable satellites, purchasing a rocket for every mission is too expensive. There is a need for a more cost-effective approach to space access.

Instead of trying to radically reduce launch costs through technology breakthroughs, the Lockheed Martin/ATK Athena team examined methods that change the way business is done in order to offer lower launch costs to customers. The LM/ATK Athena team tailored a ride share launch service business approach to better suit customer needs. The result is a cost-effective delivery method for space payloads.

The Athena RideShare launch service is a game-changing approach that lowers the launch costs and provides scheduled services, encouraging innovation. The missions are a bold attempt to change the way space launch services are purchased. RideShare missions change the launch cost paradigm by actually allowing a payload to pay for the portion of the launch vehicle capability that they use, not the whole rocket. By aggregating payloads, Athena can deliver all the payloads to space at a lower cost than what is currently possible.

The Athena RideShare is an extension of a familiar concept—the Post Office's Priority Mail Flat Rate Boxes. If the payload fits into the Athena volume envelope and mass limit, it can get to orbit at one low price on a designated delivery schedule.

The key to the concept is the Athena IIc launch vehicle. Athena IIc, with the most payload capacity of any launch vehicle in the small launch class, is ideally suited for multi-manifest smallsat missions. Most of the hardware is modular to reduce costs and maximize reliability. Powered by ATK solid motors for main propulsion, the launch vehicle is easy to transport and prepare for launch, requiring a small logistics foot print and minimizes facilities infrastructure. Based on earlier Lockheed Martin launch vehicles and missile systems, the Athena IIc has a rich heritage of flight proven design and operations. Athena is a robust, reliable small space launch vehicle.

The Lockheed Martin/ATK Athena RideShare launch service builds on the demonstrated capabilities of the Athena II launch vehicle to affordably deliver multiple payloads to multiple orbits. Athena's multiple payload capability was demonstrated on the Kodiak Star Mission, which delivered three satellites to 800km, and a fourth to 500km. Athena's Orbit Adjust Module, a monopropellant maneuvering stage, makes delivering multiple payloads to multiple orbits a standard Athena service.

Standardized mass and payload volumes for Athena RideShare missions provide a modular approach with significant flexibility. The standard RideShare "slot" for a mission is a satellite mass of 110kg and a satellite envelope of approximately 86 cm x 91cm x 71cm. This modular approach provides significant flexibility in accommodating a variety of payloads. Multiple form factors can be accommodated.

Within the RideShare service offered by Athena, there are no "primary" or "secondary" payloads. This concept provides a vastly different situation from the current ride share experience. Today, most small payloads are at the mercy of a large primary payload. The primary payload can drive additional documentation requests, additional testing, and/or additional costs for the secondary payload— with no assurance that the secondary will be prohibited from flying on launch day. With the Athena RideShare, the Athena team manages all payloads to ensure maximum satisfaction and cost effective use of resources.

Regularly scheduled RideShare launches permit flexibility in the planning of smallsat missions. This is preferable to the usual practice of waiting for opportunities to appear. In addition, should problems arise, the ability to reschedule on a subsequent flight, rather than lose the launch opportunity all together, completely changes how payloads can be built, tested, and flown. For example, if a secondary sensor fails to work properly, the satellite can be slipped to a later launch date, rather than being launched with a diminished capability because no back-up date was available.

Standard Athena ride share services for each payload are intended to provide a complete mission integration experience. Each payload gets a unique ICD and Requirement Verification Matrix. The launch customer also gets a complete set of analyses & reports (consistent with ITAR and security regulations). The standard services attempt to cover most users' needs.

Firm, fixed pricing is based on a percentage of the vehicle's capability. Our current pricing is:

- Smallsats: $12.5M per 110 kg slot
- Cubesats: $300K per 3U

Frequent flyers get a discount on future missions, encouraging regular use. For smallsats, the price is reduced $0.5M for the second time an organization flies a payload and reduced $1M per flight for subsequent launches.

The contract is divided into two phases:

- The first phase is a RideShare Compatibility Assessment Phase. This phase lasts for approximately 30 to 100 days and determines the viability of grouping all the proposed payloads together. Spacecraft aggregation, SV-to-LV and SV-to-SV compatibility assessments are also conducted during Phase 1. A $250K deposit is required for this phase. Should the mission not be viable for a particular mission after the assessment, the $250K deposit will be refunded.
- The second phase is the RideShare Mission Integration Phase. This phase lasts about 21 months and includes:
  - Preliminary Integration Cycle
  - Update Cycle
  - Final Cycle
  - Pre-Launch Preparations
  - Launch
  - Post Launch Operations

Launches are planned with a 60-day launch window.

Despite the simplicity of the business model, there are significant obstacles in the successful execution of the commercial ride share concept. Both technical issues and programmatic challenges have surfaced in the establishment of the service.

Significant technical challenges include:

- Integrating a variety of mass and volumes in a dynamic launch environment
- Adapting the launch profile to accommodate a wide range of orbital altitudes
- Verification that all payloads will not adversely impact the mission or other payloads

Integrating a variety of mass and volumes in a dynamic launch environment is a very complex technical issue. Coupled loads analysis (CLA) of the launch vehicle and satellites is critical in predicting the system responses caused by major dynamic and quasi-static loading events such as liftoff, gust, buffet, and engine startup and shutdown. The CLA helps to minimize risk and maximize the probability of mission success. However, performing a CLA is a time intensive process, often requiring months to complete. It is critical to define the final mass and configuration of the payloads. For a ride share configuration, where multiple payloads are in various states of design maturity, driving all to a frozen design state for the analysis is a major challenge.

One way of addressing the issue is by analyzing each location of the ride share adapter with a standard mass/volume simulator that envelopes the typical mass and volume of the slot can accommodate. If launch environments evaluated with the simulator can be shown to envelope the actual payload environments, the need to perform a final high fidelity CLA can be eliminated.

One large problem to the ride share concept is that there are no "standardized" masses or volumes yet. The Athena ride share is tailored to ESPA standard (although we have turned the overall form factor ninety degrees to fit inside the Athena fairing). Currently, the ride share market is a variety of shapes, sizes, and mass. The modular approach for standardized payloads is a long ways away. Eventually, an evolution to standardized form factor is likely – think of a 36U or a 72U as an example.

Another approach to minimize this issue is to require design finalization early in the launch vehicle analysis cycle. Significant payment milestones early in the launch campaign are intended to incentivize customers to freeze the design of the satellite quickly.

Adapting the launch profile to accommodate a wide range of orbital altitudes is another significant challenge. This, however, is one the mission planners have embraced as an opportunity to excel. Mission constraints include:

- Vehicle performance
- Desired orbit parameters
- Insertion accuracy
- Release sequence
- Battery life
- Communications nodes
- Collision avoidance
- De-orbit of the Athena Orbital Adjust Module (OAM)

One proposed mission involved the deployment of over 40 objects in space, all in discrete orbital locations. Working to achieve an optimum solution within the multiple constraints the ride share problem presents is a demanding problem. The development of automated mission design analysis tools, tailored to the ride share

approach, is expected to minimize overall execution costs.

A major concern of ride share missions has been the impact of one spacecraft on the others. Lockheed Martin plans to perform a compatibility assessment of the spacecraft integrated to the ride share payload adapter to ensure no adverse effects. Requirements have been established to ensure that a spacecraft does not create a hazardous situations (through pressurized containers or electromagnetic interference, for example) that can adversely affect the other rideshare spacecraft, the safety and operation of the launch vehicle and/or the launch site. From the assessment, payload test requirements may be generated in order for the spacecraft to provide an adequate measure of hardware quality and workmanship. The tests are performed to fixed levels which are intended to envelope those that may be expected during a typical mission and allow for some degradation of the hardware during the mission. The levels are tailored by the Lockheed Martin to meet mission specific requirements, such as the enveloping of launch vehicle and/or launch site environments. The test program is intended to uncover workmanship defects as well as design flaws. Successful execution of these tests provides a margin of hardware reliability for both the spacecraft and launch vehicle provider.

Development of these requirements, and the subsequent testing, is a significant challenge, especially with the broad spectrum of payloads that may be integrated on one launch vehicle.

Programmatic challenges have turned out to be the bigger issue, however. Issues include:

- Confirming payloads for the manifest
- Scheduling to ensure all payloads are delivered on time
- Developing appropriate contracts for ride share missions

Confirming payloads to lock down the launch manifest has proven to be the largest challenge to date. To date, customers have been unable to commit to a deposit for a variety of reasons, including:

- Funding gates do not match schedule requirements
- Cash flow projections did not account for launch deposits
- Budget uncertainties and/or program cancellation
- Changes in business plan or scope
- Internal uncertainties as to how to procure a new and unique service

For these reasons, coordinating the final launch manifest has been like herding cats.

Right now, everyone wants to go to space - but on their schedule. That works with a dedicated launch vehicle (or a charter jet) – the old way of doing business. The approach breaks down when you fly a ride share mission (or purchase a commercial airline ticket). Similarly, some customers expect to pay for the LV as close to the launch date as possible. Yet, in a commercial ride share mission, much like a commercial airline, to get the lowest price, the purchase must be made well in advance. No one pays for an airline ticket after they land, but some customers have budgeted their space launches in that very manner. Changing customer expectations in these areas is a long term educational process. As the educational process progresses, it should be easier to confirm multi-mission manifests.

Scheduling the delivery of the payloads to fit into the launch schedule is also a challenge. The design, manufacture and testing of all the spacecraft need to be aligned to execute to an established schedule. It is thought that the smaller sized satellites will not only be less costly, but not as complex, and therefore easier to keep on schedule, but this remains to be proven. The Athena team recognizes that delays are expensive – our goal is to minimize holdups from the day the contract is signed to ensure the launch happens within the required window. The reward is lower costs, both for the launch and the mission support efforts.

What if one spacecraft is not ready to fly at the last minute, despite all the precautions? A launch will not be delayed if one payload has a problem. The option of flying on the next scheduled ride share flight helps reduce the temptation to rush to fix a problem or accept a less than optimal solution to the problem. Under our current concept of operations, a mass simulator for the missing spacecraft is substituted to minimize risk to the overall mission.

Ride share mission contracts need to be tailored for the mission size, cost and complexity. The current approach has been to use a contract similar to the one used to buy a multi-million dollar launch. There is no need to have a contract weighs more than the payload! The Athena ride share is modeled on simplicity – a firm, fixed price approach that is easy to understand and appropriate for the purchase value. This is a new way of doing business. The challenge lies in adjusting expectations accordingly.

In conclusion, the simplicity of the ride share model offers significant improvements in low cost accessibility to space for small spacecraft. Despite the simplicity, there are significant challenges to execute

this concept. Both technical and programmatic challenges identified can be overcome, and it is easy to see that ride share will become the standard approach for purring small payloads into space in the near-term future.