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Paper Session II-A - Lockheed Martin's Next Generation Launch Systems

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Title: Lockheed Martin's Next Generation Launch Systems

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Abstract

The space launch industry is experiencing a tremendous transition from a government dominated customer base to a commercial customer base. According to the Teal Group World Space Briefing, nearly 75 percent of satellites launched from 1997 to 2006 will be civil and commercial satellites (figure 1). Of these, the vast majority are commercial ventures in mobile communications, broadband multi-media services, or direct broadcast television satellites. Nearly three quarters of all proposed payloads are destined for Low Earth Orbit (LEO). Virtually all LEO satellites will belong to multi-satellite systems involving mobile communications or multi-media services. Lockheed Martin is a world leader in the expendable launch vehicle industry. Our heritage which began with the Titan and Atlas launch systems in the late 1950's, has spanned four decades and over 1,000 launches. In the late 1980's, the former General Dynamics Space Systems (GD), recognized the need to develop a launch vehicle that could compete in the international commercial market. In 1987, GDinitiated the first commercial launch vehicle, the Atlas II. TheAtlas vehicle has successfully evolved from II to IIA to IIAS and into today's newest most powerful system yet - the Atlas IIAR which will be operational in late 1998. The driving force behind each system upgrade has been to improve performance while reducing cost and increasing reliability.

Lockheed Martin combined the commercial industry expertise of the Atlas program with the heritage hardware of both the Atlas and Titan programs to develop their next generation launch vehicle the Common Core Booster™ family. The Common Core Booster™ family of launch vehicles will accommodate a wide range of customers, by providing a highly reliable, responsive system with streamlined launch operations. The Common Core Booster™ vehicle allows Lockheed Martin tol effectively compete in international commercial markets, while satisfying the United States government requirements for low cost, reliable access to space.

The purpose of this paper is to describe Lockheed Martin's approach to incorporating the benefits and lessons learned from the Atlas and Titan launch systems into a launch vehicle family that will serve the payload community well into the 21st Century.

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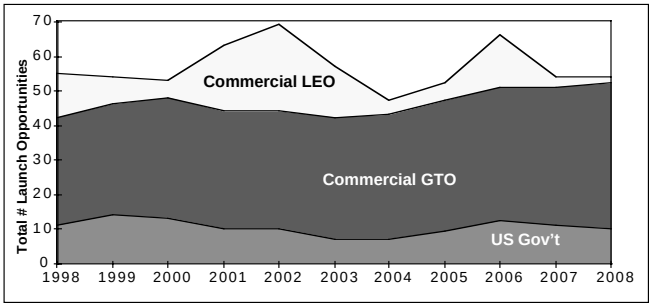

Figure 1 Projected Launch Vehicle Demand

Introduction

Lockheed Martin Astronautics (LMA) has been both responsive and influential to the evolutionary commercialization of space by forming international business relationships and developing launch systems that lower the cost of reliable and dependable access to space. At the 1995 Paris Air Show, Lockheed Martin Corporation and Khrunichev State Research and Production Space Center announced the formation of ILS, International Launch Services, a joint venture stock company to market the Atlas and Proton launch vehicles. In November 1995, Lockheed Martin Astronautics, announced development of a new space launch vehicle, Atlas IIAR, an advanced version of Lockheed Martin's current operational Atlas vehicle. Atlas IIAR is capable of placing 8,900 lbm of payload to geosynchronous transfer orbit (GTO). To date, the Atlas IIAR has completed its Preliminary and Critical Design Reviews, nearly completed the testing of all major components, will complete integrated stage hot fire testing at the NASA Marshall Space Flight Center (MSFC) early in 1998 (Figure 2). Atlas IIAR, marks a major milestone in Lockheed Martin's launch vehicle strategy of reponsive, affordable access to space for our customers. Atlas IIAR demonstratesthesuccessful merger and integration of two former competitors (Martin Marietta and General Dynamics), into a World Class launch services provider.

Figure 2: Atlas IIAR IOC is will be Dec. 1998.

Commercial Atlas IIAR Program Overview

The Atlas IIAR is being developed to meet the needs of commercial users for the next 5 to 10 years. Figure 3 illustrates the evolution path from the existing Atlas vehicles to the Atlas IIAR. Of equal importance, the Atlas IIAR is serving as a risk mitigator in the development of the next generation of Lockheed Martin launch vehicles; the Common Core Booster™ family, which are designed to fulfill the needs of the commercial spacecraft market as well as the needs of the United States government for the next 25 years. Critical systems for Lockheed Martin's Common Core Booster™ family will be flight proven on Atlas IIAR. These include the RD-180 engine propulsion module, helium pressurization system, high energy cryogenic Centaur upper stage, flight avionics and control system, ground communication-command-control system, and payload fairings. By evolving flight proven, heritage hardware, the mission success record of today's current Atlas II family, which is the best in the world, will be passed along to both the Atlas IIAR and common core booster family.

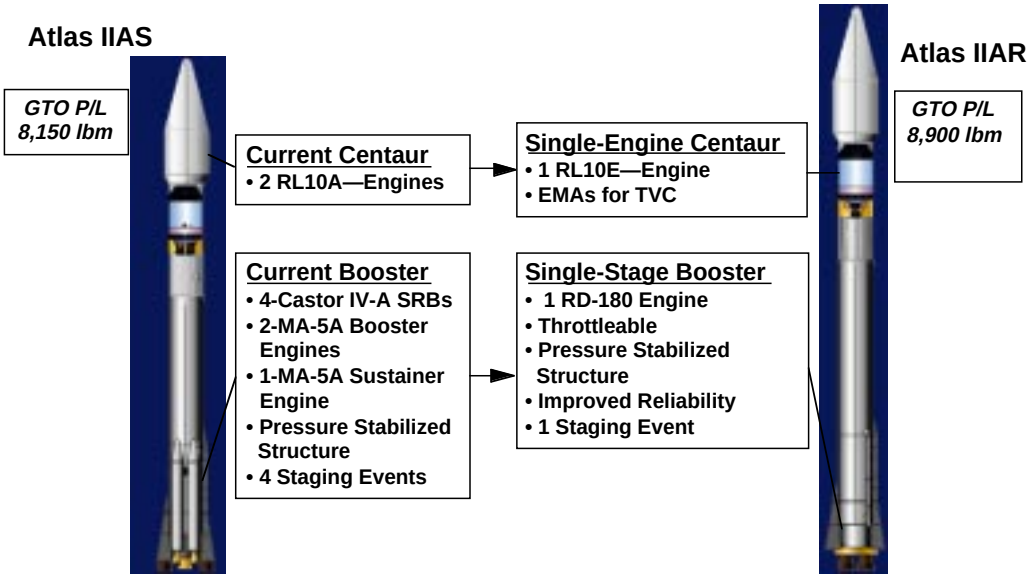

Figure 3 Atlas Evolution

In addition to flight proven hardware, standardized design processes, development methods, and operational practices are crucial to the successful design, development, delivery, and launch of rocket boosters. In response to commercial requirements for performing international business, Lockheed Martin has become ISO 9001 certified (as have many of our subcontractors) to verify our documentation and performance to standardized technical and business practices. As the space industry progresses toward an ever increasing commercial emphasis, with less government oversight, it is important that procedures be documented and maintained. Lockheed Martin is committed to continued ISO certification to demonstrate World Class design, development, manufacturing, delivery, and service capability to the commercial community.

Robust Design for Evolving Future Requirements

Booster Engine

Shortly following the announcement of Atlas IIAR, an extensive study was performed to select a rocket engine for the new booster which would not only need to power the Atlas IIAR but also provide adequate performance margin for the larger common core boosters™ of the future. Every rocket engine in the world, both existing and planned, were included in the selection evaluation. The clear winner was the RD-180 engine built by NPO Energomash of Khimky, Russia (Figure 4). The RD-180 employs staged combustion, and LOX rich turbine drive, delivering high thrust performance (850 Klb sea level thrust and 933 Klb vacuum thrust) in the first throttleable engine to be used on a US expendable launch vehicle. The RD-180 engine is a derivative of the RD-170 engine, the only man-rated, LOx/RP, high pressure, staged combustion engine in production status. The RD-180 shares approximately 70% of its' components with the RD-170 which significantly reduces the development time and cost normally associated with a new engine. The RD-180 has the ability to throttle from 100% to 40% thrust during flight. This provides Lockheed Martin expendable launch systems with the unique capability to tailor the launch accelerations and other environments, to our customers' needs. This feature will allow future satellite designers to take advantage of a "softer ride". It also allows transitional government payloads as well as com-

mercial satellites, designed for other systems, to be flown on the Atlas IIAR with minimumal integration time and expense. By mid-1998, the RD-180 will have completed 20,000 seconds ofhot fire qualification testing,. Utilizing an engine with minimal developmental and operational requirements is key to developing a low cost, highly reliable system, in a cost effective manner.
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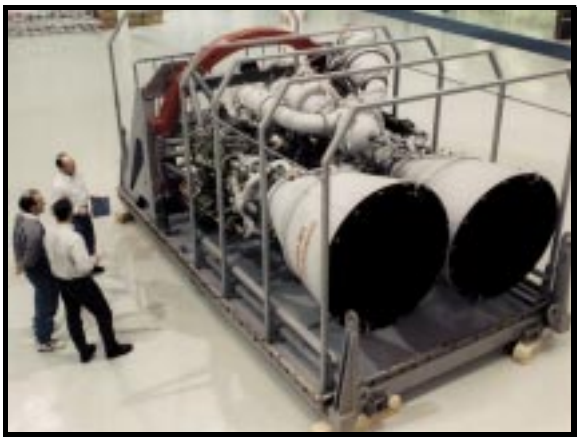

Figure 4a: Integration and assembly pathfinders have been performed with the high fidelity prototype RD-180, shown here in Lockheed Martin's Final Assembly Building (FAB)

Figure 4b: The RD-180 is integrated to the thrust structure and RP-1 fuel tank for propulsion testing at Lockheed Martin Astronautics

Another major improvement associated with Atlas IIAR was, development of the Single Engine Centaur, or SEC (Figure 5). The SEC uses a single Pratt and Whitney RL-10A-4-1 engine in place of the two engines used on the Dual Engine Centaur (DEC) that currently flies on the Atlas IIA and IIAS. The high thrust of the RD-180 allows replacement of the dual engines with a single engine due to additional energy in terms of velocity and loft angle of the vehicle at booster separation. This results in a high altitude trajectory of the upper stage after

jettison from the Atlas IIAR core when compared to the trajectory of the DEC after separation from the Atlas IIA/IIAS core (Figure 6). With this higher lofted, higher altitude Centaur trajectory, Centaur performance is less thrust dependent and more Isp dependent. In addition to a more optimum trajectory, replacing the DEC with the SEC, over 4200 parts were eliminated from the Centaur upper stage, increasing flight reliability of the Centaur by 25 percent. As a result, the DEC is adequately replaced with the more reliable SEC.

Figure 5: High fidelity prototype of the Single Engine Centaur undergoing structural testing in Lockheed Martin's Vertical Test Facility.

Figure 6: The high thrust RD-180 permits higher lofting of the trajectory, producing increased performance to GTO.

The robust thrust and high Isp of the RD-180 enables 7 engines on the Atlas IIAS (4 Castor IV-A SRB's, 2 MA-5A booster engines, and 1 MA-5A sustainer engine) to be replaced by a single RD-180 rocket engine. The number of staging events, prior to the Centaur phase of flight, is correspondingly reduced from 5 events to a single stage event. The reduction in engines and staging events furtherenhances the reliability of the Atlas. Anther feature of the RD-180 that serves to increase reliability is the health monitoring systemUpon ignition, health monitoring of the RD-180 allows propulsion systems to be checked and verified, before the vehicle is committed to launch. During flight, the throttleability of the RD-180 permits the vehicle to suppress the environmental effects of flight during load causing events such as maximum dynamic pressure and booster engine cutoff.

The Atlas IIAR not only responds to the commercial demands for higher reliability, but to increased payload mass to orbit as well. The Atlas IIAR delivers 4037 kg to GTO compared to 3697 kg of Atlas IIAS. With the addition of two Castor IV solid rocket boosters, the Atlas IIAR will deliver 4264 kg to GTO. Further evolution of the Atlas IIAR to the common core booster family will enable Lockheed Martin to address the performance needs of the commercial satellite community for many years to come. The RD-180 has ample thrust and performance to power the larger common core booster and its greater reserve of propellants. At liftoff, the Atlas IIAR only utilizes 71 percent of the thrust capability of the RD-180. As the commercial needs eventually outgrow the Atlas IIAR, the same propulsion elements of the IIAR will serve to propel the Common Core Booster™. With a higher thrust profile and a stretched version of Centaur upper

stage, the common core booster is a low risk evolution of the Atlas IIAR that will serve to meet the needs of the commercial market for the foreseeable future.

The Future: Common Element System

While the Atlas IIAR is projected to satisfy the needs of customers for several years, a cost effective solution to satisfying a wider range of customers was deemed necessary for Lockheed Martin to maintain itspreeminence as a World class launch services provider. Our common core booster™ launch system, designated the Atlas Common Core™, which will be operational in 2001, (figure 7) is designed to provide the best value to all customers - a responsive system with large payload lift capability margin, a high degree of reliability and operability at a competitive price. We have utilized heritage hardware and design processes from the highly successful Titan and Atlas launch systems. We are developing our system around a 12.5' aluminum structurally stable common core booster™ which will utilize the (by then) flight proven RD-180 engine. We have designed the Atlas Common Core™ system utilizing subsystems developed for Atlas IIAR while maintaining our emphasis on Mission Success. The Atlas Common Core™ system will rely on advanced avionics developed exclusively for Lockheed Martin by Honeywell Space Systems. The avionics suite is a derivative of the existing Atlas guidance system with system health management designed in to provide a highly responsive system at minimum development cost. Due to our extensive intermediate launch vehicle experience, we are designinghardware, such as existing payload fairings (PLF), into our system. We will also rely on the expertise of Contraves to produce a 5m PLF for the heavy lift version of our Atlas Common Core™. All of these PLFs are either flying or require minor modifications to previously flown flight hardware. This, once again, minimizes our design and development cost and risk. The Lockheed Martin Atlas Common Core™ system is designed to accommodate the requirements of all users, both the growing commercial market as well as the United States government needs.

Launch Site Processing and Integration

Another key feature to improving responsiveness and reducing costs, is our streamlined launch operations. A significant amount of effort has been expended by Lockheed Martin to reduce the launch processing time. At present, the Atlas launch systems are nominally processed on 45 day launch centers. We have demonstrated processing times as low as 28 days and are projecting that the Atlas IIAR will be processed in 20 days or less. For the Atlas Common Core™ system, we are projecting even shorter operations timelines. Our analyses have indicated sufficient capability to accommodate the expected launch rates in the future. Our lessons learned from our existing launch operations, our past launch site developments (LC-36, LC-40, LC-41, SLC-3E, SLC-3W, SLC-4, SLC-6.) as well as on-going research and development has led to our moreefficient launch processing design. We are also capitalizing on our unsurpassed expertise in payload processing - national assets, scientific payloads, as well as commercial users - to ensure end users' needs are met. Lockheed Martin is the only launch service provider that has the extensive breadth and depth to ensure that, as we reduce processing timelines and operations costs, that the requirements of the ultimate customer - the payload- are not compromised in any manner. We utilized standard payload interfaces and procedures for all classes of payloads. Payloads willbe processed and integrated with our systems, in a manner very similar to the current Atlas launch vehicles. This synergy with existing systems will minimize time, expense and analyses as we transition to the next generation launch systems.

Responsive To Commercial

The ever increasing demands of commercial satellite manufacturers are driving the requirements of today's space launch industry. While constraints on government budgets are resulting in a downsizing of most government payloads, commercial spacecraft continue to grow larger as the demand for satellite based services increases. The commercial market trends call for increased payload mass and volume, increased reliability and launch availability, lower costs for space access, and reduced time of vehicle order to launch. The next generation of Lockheed Martin launch systems, the Atlas IIAR and the Atlas Common Core™, have the payload lift capability, manufacturing, and launch processing capacity to easily accommodate the growing commercial launch market. In addition to providing the required capability and capacity, Mission Success, invented at Lockheed Martin will remain vitally important. This is because lost time on orbit translates into lost revenue for satellite service suppliers. Satellite users will not trust their assets to a company that can not deliver them to their final orbit. Successful participants in the launch industry must deliver best value to the satellite customer, providing mission success assurance with affordable and timely access to space. Lockheed Martin has successfully demonstrated the ability to meet the needs of end users. In the futureLockheed Martin will continue to be adominant force in assured access to space, and The Best in Space.