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ALSET - Air Launch System Enabling Technology R&D program

Takashi Arime, Masanori Sugimine, Seiji Matsuda, Jun Yokote IHI Aerospace Co., Ltd 900, Fujiki Tomioka-shi, Gunma-ken, 370-2398 Japan; 0274-62-7784 t-arime@iac.ihi.co.jp masanori-sugimine@iac.ihi.co.jp jun-yokote@iac.ihi.co.jp matsuda-s@iac.ihi.co.jp

Takayoshi Fuji, Kenji Sasaki Institute for Unmanned Space Experiment Free Flyer 2-12 Kanda Ogawamachi Chiyoda-ku, Tokyo, 101-0052 Japan; 03-3294-4947 fuji@usef.or.jp k.sasaki@usef.or.jp

Dominic DePasquale SpaceWorks Commercial 1701 K St. N.W., Suite750, Washington, D.C., 20006 USA; 1-202-503-1753 dominic.depasquale@sei.aero

Hideki Kanayama, Mitsuteru Kaneoka CSP Japan Inc. 27th floor Fukoku Mutual Life Insurance Building, 2-2-2 Uchisaiwai-cho, Chiyoda-ku, Tokyo 100-0011 Japan; +81-3-3508-8105 kanayama@csp.co.jp kaneoka@csp.co.jp

ABSTRACT

The Air Launch System Enabling Technology (ALSET) small launch vehicle research and development project was initiated in response to the presence of a growing small satellite market and a desire to promote space commercialization generally. An air launch approach to space transportation provides a high degree of reliability, flexibility, and responsiveness to meet the future needs of small satellite operators. ALSET is a Japanese government Ministry of Economy, Trade, and Industry (METI) funded project to examine air launch orbital payload delivery systems and related technologies as a first step toward an operational commercial air launch system. The operational system is envisioned to feature air-launch of a multi-stage solid rocket from an existing large carrier aircraft (C-130 class) for delivery of small payloads on the order of 100 to 200 kilograms to low Earth orbit. This paper will introduce the ALSET project and discuss recent progress.

INTRODUCTION

Air Launch System Enabling Technology (ALSET) is a Japanese government Ministry of Economy, Trade, and Industry (METI) funded project to examine air launch orbital payload delivery systems and related technologies as a first step toward an operational commercial air launch system. The operational system is envisioned to feature air-launch of a multi-stage solid rocket from an existing large carrier aircraft (C-130 class) for delivery of small payloads on the order of 100 to 200 kilograms to low earth orbit. In 2009, a team led by the Institute for Unmanned Space Experiment Free Flyer (USEF), and including IHI Aerospace Co., Ltd.

(IA) and CSP Japan, Inc. (CSP-J), was selected by METI to carry out the ALSET project.

ALSET PROJECT

ALSET consists of six research focus areas: (1) air launch system overall concept study, (2) air launch extraction method selection and technology research, (3) air launch system operations study, (4) GPS ranging and satellite-based telemetry, tracking, and control study and feasibility validation, and (5) low cost and light-weight avionics and (6) legal, regulatory, and safety standards necessary for such a new launch system in Japan. Collaboration with US partners is considered key to success of the project, and the Japanese organizations have teamed with SpaceWorks Commercial to assist with evaluation of alternatives, planning, and program management of US-based activities. A drop test of an instrumented full-scale inert test article is planned for 2013. USEF, IA, and its partners desire to conduct this initial drop test in the US for reasons of carrier aircraft availability, test site accessibility, resident air launch engineering expertise, and an established regulatory environment.

A preliminary technology roadmap, outlining the development to an operational system based upon the ALSET investment is shown in Fig. 1. The ALSET project aims to investigate and determine the necessary basic technologies needed for a commercial air-launch system. Technology demonstration missions in the ALSET project, specifically using sub-orbital tests. could help determine the viability of various flexible and responsive technologies. Air launch technologies, such as launch vehicle loading and deployment, attitude stabilization at ignition in the air, and technologies relevant to the drop sequence need to be verified. The ALSET project is also examining air-launch technologies that would enable launch flexibility, specifically GPS ranging and telemetry via communication satellites. These technologies enable autonomous flight control without secondary radars, command transmitters, destruction command transmitters, etc. which are used in traditional flight control systems. This potentially alleviates the constraint of one single launch site, opening up less restrictive launch ranges.

To improve responsiveness, it is preferable to streamline multiple systems involved in the launch architecture, including the launch vehicle itself obviously. In particular, reduction in the size and weight of the avionics subsystem of such small launch vehicles is indispensable because avionics do not scale that much with launch vehicle size. Technologies that the ALSET project will examine for flexibility and responsiveness for air launch systems can also be applied to other ground launch systems.

One of the main initial tests of technical feasibility for the ALSET project will be a drop test from a representative aircraft. This drop test will involve a "dummy" representative stage of the launch vehicle (mass simulator). Potential trade studies have been conducted of candidate aircraft and launch ranges for the test.

							ALSET Project
NO.	Category	Technologies	New Tech	Commercial Technology	Extension of Conventional LV Technology	ALSET scope	Phases Research/Design Development/Testing Operation
1		Vehicle loading & deployment	0			0	
2		Ignition attitude stabilization	0			0	Select air launch □→ Drop test from aircraft □→
3	Air Launch Technology	Launch sequence	0			0	method
4		Safty of solid moter loading			0		
5		INS [*] initialization		0		J	
6	Flexibility	Flight & launch control via com sats		0		0	
7		GPS ranging		0		0	Prototype Technology demonstration
8		Autonomous flight safety		0		0	verification by using Opera-
9		Health monitoring		0		0	test LVS tional
10		Streamlined assembly & integration		0		0	
11	Responsivility	INS in-flight calibration		0)	
12		High precision orbit insertion	0			X	
13		Responsive mission analysis			0		
14	4 5 6 7	Low-cost avionics (COTS component)		0		0	test \Longrightarrow demo by LVS \Longrightarrow
15		Low-shock separation	0				
16		Simplified fairing & inter-stage structure	0				>
17		Standard payload interface			0	J	

Figure 1. Technology Roadmap for ALSET



Figure 2. Air-Launch System Overall Concept

AIR LAUNCH SYSTEM OVERALL CONCEPT STUDY

The ALSET air-launch system concept is shown in Fig. 2. The specific air launch methods described in the following sections is also reflected in this figure. The launch vehicle is loaded onto a cargo aircraft at an airport and ferried to the launch point. During ferry, GPS for ranging is initialized, and satellite communication link for TT&C is established inside the aircraft. The launch vehicle is dropped from the aircraft by an air drop system, decelerated by the parachute, and separates from the parachute. The launch vehicle consists of a three-stage solid rocket motor, and after the third stage burn out, the satellite is placed into a Low Earth Orbit. Until the separation of satellite from the launch vehicle, GPS and satellite communication links are active.

AIR LAUNCH METHOD SELECTION

Three types of air launch methods have been studied during this project: air drop, subsonic horizontal launch, and supersonic zoom launch.

Air drop

This type of air launch system uses existing air drop techniques. The launch vehicle is loaded onto an aircraft's cargo space and dropped by air drop system. Prior examples of this technique include a U.S. Minuteman missile launch from a C-17, target missile launches from a C-130, and dummy launch vehicle drop tests (e.g. AirLaunch LLC's QuickReach). Multiple options exist for platform usage including: utilization of existing platforms, TYPE-V platform, or custom design platforms can be selected.

Advantages of the air drop method including using an existing aircraft with cargo and air drop capability and thus modification to the aircraft is unnecessary, making it possible to adopt it to different cargo aircrafts with the same interface. There is no aerodynamic interference when the aircraft is in flight, because the launch vehicle is inside the cargo space.

Disadvantages of the air drop method include the need for a higher drop altitude than that used for normal ground drop operations, since the preference is for higher altitude to increase launch capability. Additionally, the working environment for the drop crew needs to be considered. Such an air drop will also entail disposal of the parachute and platform.

Subsonic horizontal air launch

Orbital Sciences Corporation (OSC) Pegasus is a representative example of this type of air launch system. The launch vehicle is separated from a horizontally cruising aircraft at subsonic air speed, sustained upward by a pull up maneuver by wing lift. Modified aircraft can carry the launch vehicle under its wing or fuselage is used.

Advantages of this air launch method include the fact that the separation of the launch vehicle from aircraft is conducted by a mechanical interface, thus no disposal issues are caused by launch. Launch capability is increased by the aircraft's high altitude and high horizontal air speed compared from air drop method.

Disadvantages of this air launch methods include the fact that most aircraft are not equipped with mechanical interfaces which can carry such launch vehicles under their wing or fuselage. Thus modification of the aircraft is necessary. Additionally, aerodynamic interference between the launch vehicle and the aircraft needs to be verified for each aircraft type. This narrows the aircraft type selection, and requires certified aircraft.

Supersonic zoom launch

In this air launch method, the aircraft accelerates to supersonic air speed, zooms up and releases the launch vehicle at a certain altitude, velocity and attitude which maximizes the launch capability versus the previous method. Launch capability compared with launch weight is greater in this method than the other two just mentioned.

Advantages of this air launch method include the fact that, similar to the previous methods, no hardware disposal issues are caused by launch. The initial velocity, altitude and attitude is maximized for the air launch method relative to the previous two methods.

Disadvantages include similar ones to the subsonic horizontal launch, namely that modification of the aircraft is necessary. Additionally, launch vehicle initial weight is limited since potentially only a small number of aircraft can fly in supersonic speed.

Trade study

Although the first method list above, air drop, has the most hardware disposed of as part of the air launch method and has an altitude limitation relative to the second and third listed methods, it was selected most suitable. This was due to the reason that the air drop method requires the least modification of the carrier aircraft and aerodynamic interference is minimized.

There are two types of air drop system that essentially can be considered: the Gravity Air Launch system (e.g. AirLaunch LLC's QuickReach) and the TYPE-V Platform Delivery System (PDS). Since many cargo aircraft already use the TYPE-V platform, minimal aircraft modification is necessary and minimal verification tests are necessary with respect to aircraft safety. This enables relative flexibility when it comes to aircraft choice for the commercialization/operational phase, an important parameter of the selection. Thus TYPE-V PDS has been selected for the ALSET project.

AIRCRAFT SELECTION FOR ALSET DROP TEST

Table 1 lists potential candidate aircraft that could be used for the ALSET drop test. The aircraft favorability determination is based on the ability of the aircraft to meet the requirements of the ALSET launch vehicle size, its availability and cost, and its compatibility with potential test ranges.

The maximum payload capability of each aircraft in Table 2 is sourced from publicly available information and is not in itself an indicator of the ability of that airplane to drop a test article of that mass. It is difficult to specify a value for maximum test article mass and dimensions that each aircraft can carry because multiple factors are involved beyond weight. One such factor is clearance of the test article as it exits the aircraft, which is a function of launch vehicle diameter and length, and the dimensions of the aircraft door.

The most promising aircraft for the ALSET drop test are the Lockheed C-130 Hercules and the Boeing C-17 Globemaster III. Both have considerable history with aerial delivery of parachute-extracted heavy loads, and there is aircraft/range comfort in the United States in understanding such an ALSET drop test. Both aircraft are available through U.S. military sources, and the C-130 A-model is additionally available from a commercial provider in the United States. Amongst the aircraft considered, the C-17 and C-130 are the easiest to obtain and present the lowest risk to the ALSET drop test project.

Other aircraft have additional issues. The Lockheed L-100 Hercules is not readily attainable for the ALSET drop test. L-100 production ended in 1994, so it is difficult to use L-100 for ALSET. The Lockheed C-5 Galaxy with cargo capacity near 120 metric tons is certainly capable of dropping launch vehicle, but obtaining this aircraft will be extremely difficult and its size/cost exceed the needs of the ALSET drop test. The Antonov An-124 Ruslan/Condor (C-5 class) and the Ilyushin Il-76 Candid (C-17 class) may be available internationally from foreign (not U.S.) commercial provider, but it will be more difficult to utilize these foreign aircraft in the context of the overall ALSET drop test project.

Aircraft	Provider(s)	Payload (Metric Tons)*	Favorable for ALSET?	Summary
C-130A	Commercial Provider (USA)	15.9	Yes	Good candidate aircraft, though older model. Available commercially.
C-130E/H/J	US Air Force (USA)	19.1	Yes	Good candidate aircraft
C-17A	US Air Force (USA)	77.5	Yes	Good candidate aircraft. Likely more difficult to obtain than C-130
L-100 (L-382)	Commercial Provider (USA)	21.8	No	The commercial provider cannot support ALSET drop test
C-5A	US Air Force (USA)	122.5	No	Decertified for air drops by the USAF
IL-76	Commercial Provider (UAE)	46	No	Unfavorable complexity of overseas provider and non-US aircraft
AN-124	Commercial Provider (UAE)	120	No	Unfavorable complexity of overseas provider and non-US aircraft

Table 1. Potential ALSET Drop Test Aircraft Summary

TEST RANGE SELECTION FOR ALSET DROP TEST

The summary results of test range exploration are shown in Table 2 and Fig. 3. The range favorability determination is based on the ability of the range to meet the requirements of the ALSET drop test, its availability and cost, and its compatibility with aircraft. All potential ranges are US government/military ranges. No viable U.S. commercial/civil ranges were identified.

The most suitable test ranges for the ALSET drop test are Yuma Proving Ground (YPG) and Edwards AFB (EAFB). Either site can accommodate the C-130 and the C-17, or other aircraft. Both have considerable history with aerial delivery of parachute-extracted heavy loads, and there is considerable air drop expertise resident at these sites. YPG has hosted multiple USAF air launched target vehicle drop tests and launches. The NASA Ares Jumbo Drop Test Vehicle drop test was conducted at YPG with support from the EAFB AFFTC. Both ranges are accessible for the ALSET drop test through a commercial use agreement (contract).

Eglin Air Force Base is a not well suited for the ALSET drop test. The ALSET drop test is likely not

doable over land at Eglin because the drift of the parachutes might carry the carriage or other hardware outside the available drop area. A drop test over water (Gulf of Mexico) might be possible from Eglin, but greater expense would be required.

China Lake might be a good backup range, but is not as well suited for the ALSET drop test as YPG and EAFB. China Lake and Point Mugu are sister ranges operated by the US Navy. China Lake is a land range, whereas Point Mugu is a sea range. By comparison to YPG, however, China Lake / Point Mugu have less experience with drop tests like the ALSET drop test. It would also likely be more difficult to obtain an aircraft for use at China Lake / Point Mugu.

The Ronald Regan Test Site at Kwajalein Island is not regarded as a good location to conduct the drop because of the range's unfamiliarity with this type of test (versus the other ranges), difficulty/cost of getting an aircraft to the site, and possible complications associated with dropping the test article into the ocean.

Range	Range Test Organization	U.S. Location	Favorable for ALSET	Summary
Yuma Proving Ground	Army Test and Evaluation Center (ATEC)	AZ	Yes	Good candidate test site experienced with ALSET type of drop test.
Edwards Air Force Base	Air Force Flight Test Center (AFFTC)	CA	Yes	Good candidate test site experienced with ALSET type of drop test.
Eglin Air Force Base	Air Force Operational Test and Evaluation Center	FL	No	Drop over land likely not possible. Lack of drop test experience.
China Lake and Point Mugu	Naval Air Warfare Center	CA & Pacific	No	Have capability but not as well suited as YPG or EAFB.
Ronald Reagan Test Site	Kwajalein Range Services, LLC	Pacific	No	Inconvenient for aircraft and complications of ocean drop

Table 2. ALSET Potential United States Test Range Summary



Figure 3. ALSET Potential Air Drop U.S. Test Range Location

CONCLUSION

To respond to increasing demand for small satellite dedicated space launch, an air launch system has been chosen through several trade studies as a preferred pathway for such a system as part of the Japanese ALSET project. After some preliminary trade studies, the air drop method utilizing a PDS was chosen due to aircraft availability and minimal aircraft modification needed. If the ALSET drop test of a "dummy", representative payload is conducted in the United States, the most promising carrier aircraft are determined to be the Lockheed C-130 Hercules and the Boeing C-17 Globemaster III. The most suitable U.S. test ranges are determined to be Yuma Proving Ground (YPG) and Edwards AFB (EAFB). For the ALSET project, a relatively full-scale mass simulator air drop test will be planned to demonstrate utilizing air launch for a future, operational space access system.

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