Loitering Aircraft as a Capability Added for Anti-Ballistic Missile Systems

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In the last few years, there have been a number of successful tests of hypersonic vehicles powered by supersonic-combustion ramjets (scramjets).[1] These have led us to wonder if such vehicles could offer benefits in an anti-ballistic missile (ABM) role. There are two key considerations in such a use of this technology. First, the scramjet works best in a relatively thin layer of the earth's atmosphere at an altitude of approximately 90,000 feet. This is not to say that the projectile will not work below this altitude, but it is at this altitude that the hydrogen-fueled engine interacts with the oxygen resulting in hypersonic speeds up to mach 9.6 or nearly 7,000 mph. The second consideration stems directly from the first — unless released directly into that portion of the atmosphere, the projectile will require some form of boost phase to get it there. These considerations led us to investigate the potential benefit of launching a scramjet missile with a kinetic energy (KE) kill mechanism from a high-altitude aircraft loitering in the same region as the missile launch site. The loitering aircraft could be manned or unmanned, and of any type from fighter jet to dirigible. The concept is similar to that of the Air Force's Airborne Laser, which is designed to destroy missiles with a laser mounted in a loitering converted airliner.[2] We considered how much time is available to intercept an incoming missile and whether we could achieve a low total time to intercept.

To assess the viability and usefulness of this option, we conducted a capability and value-added analysis. Consider a hypothetical scenario involving the launch of a theater ballistic missile (TBM) with multiple independent warheads (MIRVs) against a US target. Before its apogee, the missile will "MIRV," that is, dispense the multiple independently-targetable re-entry vehicles or warheads against various targets. Since an interceptor only has one warhead, it cannot defeat multiple reentry vehicles.

Thus, the mission need in our scenario is to destroy the TBM before it can MIRV or before it reaches its apogee. The following table reflects the trajectory parameters of typical ballistic missiles.[3]

	100 km Class Ballistic Missile	3000 km Class Ballistic Missile
Apogee (km)	36	697
Speed at Apogee (km/s)	0.55	3.32
Time to Apogee (s)	95	510

Table 1. Ballistic Missile Parameters.

As the table reflects, any system designed to intercept an incoming missile before it MIRVs must be able to do so within a few minutes of its launch. Additionally, common sense tells us that, for any ground-launched defense, the acceleration of a KE ABM missile must be greater than that of the target missile unless the projectile is moving towards the missile at an angle (i.e., pure "stern chase" vs. an off-angle intercept).

In exploring the usefulness of using a loitering aircraft as a launch platform, we hypothesized that launching from some point above the ground would yield an increase in the time available to identify, classify, and engage incoming targets, compared to a ground launch. We constructed a spreadsheet model to determine the times and altitudes of potential intercepts between TBM launch and apogee. We then simplified the math involved by using Euclidean geometry and the Solver add-in in MS Excel to compute intercept solutions. To compute our solutions, we assumed rough order-of-magnitude acceleration parameters for the missiles and KE projectiles of 150 ft/sec^2 and 170 ft/sec^2 respectively. Figure 1 shows the model structure.

Our model computes three measures of interest: 1) the time required to intercept the missile (in seconds); 2) the height of the TBM at the time of intercept; and, 3) the

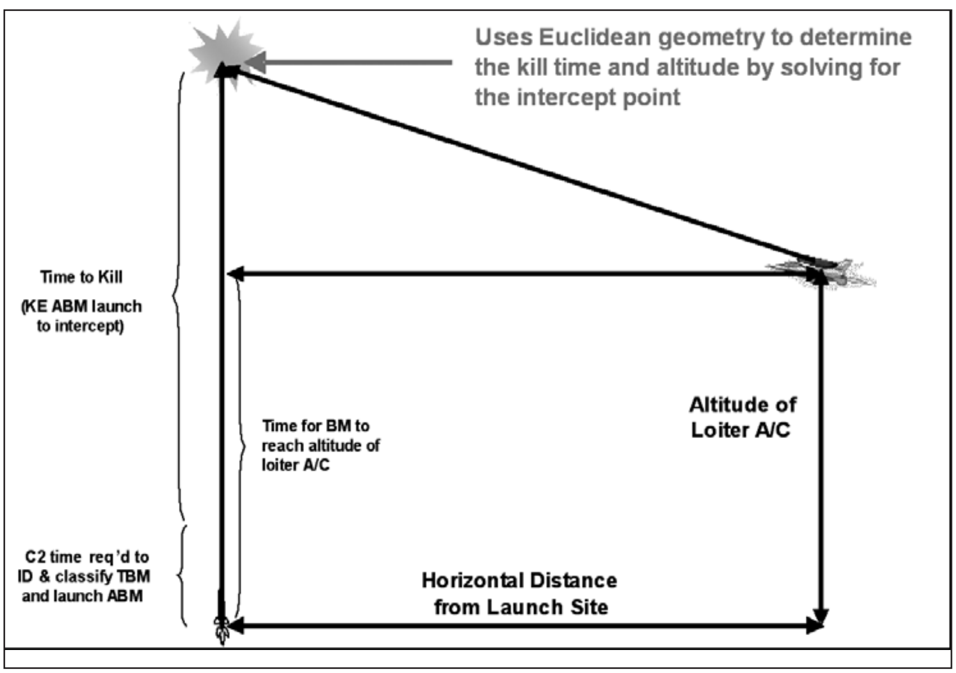

Figure 1. Schematic of how the model works

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elapsed time from TBM launch to intercept. Taking the vertical and horizontal distances into account, the required times for the missile and KE projectile to travel those distances, and the time required to identify and classify the target (command and control or C2 time), the model computes the intercept point using the Pythagorean Theorem. If the interceptor could reach the target before apogee, we considered it a feasible interception geometry. It is worth noting here that the C2 time is a critically important element in this analysis, as it involves virtually all of the variability and error associated with human factors. In general, the more time we have to exercise command and control, the better, as this will usually tend to mitigate identification, classification, and targeting errors.

Using our scenario, we sought to test our hypothesis by first computing these three measures based on a ground launch (wherein the altitude of the loiter aircraft = 0 miles), and then re-computing based on a loiter altitude of 14 miles. As Figure 2 depicts, we realized considerable improvements in the measures by increasing the launch altitude of the ABM projectile. In particular, the improvements reflected in the first and second columns reflect the "buffer" that we gain in time, which can translate to extra time for command and control.

These results suggest that increasing the loiter altitude significantly increases time for decision makers. To verify this, we conducted further analyses in which we evaluated increasing loiter altitudes against increasing C2 times at a fixed horizontal distance from the TBM launch site. The results in Table 3 show that by increasing the loiter altitude, we can decrease the time required to intercept within a specified C2 bracket and, consequently, gain additional C2 time (moving to the right and down in the table). "Infeasible" entries indicate failed intercepts whereby a successful intercept requires either a decrease in C2 time, an increase in loiter altitude, or a combination of the two.

Horizontal Distance	Loiter Altitude	Command & Control Times (seconds) 3	6	9	12
50	6	84	102	infeasible	infeasible
	8	80	97	infeasible	infeasible
	10	77	92	infeasible	infeasible
	12	74	87	114	infeasible
	14	71	82	107	infeasible

Table 3. Intercept times resulting from increasing loiter altitude vs. increasing C2 times

Horizontal Distance	Command & Control Times (seconds) 3	6	9	12	15	18	21
15	31	32	37	32	22	16	11
20	37	40	53	32	22	16	11
25	43	48	69	32	22	16	11
30	49	56	80	32	22	16	11
35	55	63	88	32	22	16	11
40	61	70	95	32	22	16	11
45	66	76	101	32	22	16	11
50	71	82	106	32	22	16	11

Table 4. Intercept times resulting from increasing horizontal distance vs. increasing C2 times.

In spite of these enhancements, however, there are some caveats. Most importantly, it is not reasonable to fix the horizontal distance to the TBM launch site, as this creates the impossible notion of altogether perfect intelligence. To assess the impact of the more likely scenario of fluctuating horizontal distances, we evaluated increases in this distance against increasing C2 times at a constant loiter altitude of 14 miles (which we certainly can control). Table 4 shows that, at this constant loiter altitude, the time to intercept increases as the C2 time and horizontal distance increase (right and down in the table). Moreover, we can see that when C2 takes 12 seconds or longer, the ABM projectile cannot catch the TBM in this scenario. Thus, while increasing the loiter altitude yields some gains in time, the uncertainty associated with the horizontal distance between the loiter platform and the TBM launch site makes it imperative to minimize C2 time.

Before we conclude, we need to address the implications of using Euclidean geometry without taking into account the curvature of the Earth. In fact, we explored a spherical-Earth model in conjunction with colleagues at the Army's Aviation and Missile Research, Development, and Engineering Center, which has a high-fidelity simulator that deals with this reality. While Euclidean geometry seems to be an oversimplification of the process, it is actually accurate to a fraction of a second difference for our analysis. One of the primary reasons is that using a loitering aircraft mitigates

	Measures 1	2	3
	Time to Intercept (s) (s)	Altitude of TBM at Time of Intercept (miles)	Elapsed Time from TBM Launch (s)
Ground-based (altitude = 0 miles)	163	429	174
Altitude-based (altitude = 14 miles)	118	235	129

Table 2. Results of ground-based and altitude-based intercept scenarios

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Biography

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the effects of the earth's curvature.

Conclusions

The information presented herein clearly shows that loitering aircraft carrying hypersonic missiles present an advantageous option for defending against ballistic missiles. The employment of such platforms can yield critical increases in the time available for command and control. Furthermore, attacking the ballistic missile during powered ascent precludes it from maneuvering radically to evade. We concluded that our loitering aircraft system offers important benefits and merits further exploration. A likely candidate for a carrier aircraft is a version of the Air Force's Global Hawk, which can loiter at 60,000 feet for 42 to 72 hours (depending on the payload).[4] Even more interesting is ongoing research involving the use of high-altitude airships. A recent Rand technical report describes airships capable of loitering for days (or even up to a year) at altitudes between 100,000 and 140,000 feet with 100-6000 pound payloads.[5] Such efforts clearly indicate that if we provide engineers with a payload, a minimum altitude, and a loitering time, they could develop a strong capability as an ABM platform.

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Biographies

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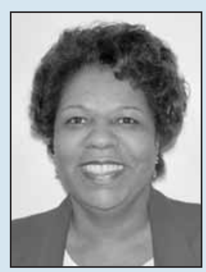

Those of you who have telephoned the MORS Office in the past few months may have noticed a new voice at our end of the line. We'd like to introduce our newest employee, **Colette Burgess**, who has assumed the position of Administrative Assistant. Colette comes to MORS with a wealth of experience in the field of non-profit professional associations—especially in meeting planning. We look forward to her working with us at upcoming workshops and at the 74th MORSS where you'll get to meet her in person. Please welcome Colette to the MORS community!