Temasek Defence Systems Institute

A SYSTEMS ANALYSIS ON THE EFFECTIVENESS OF HYPER-VELOCITY GUN SYSTEM (HVPGS) FOR GROUND-BASED AIR AND MISSILE DEFENSE

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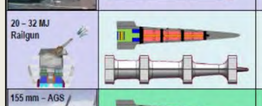
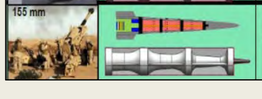
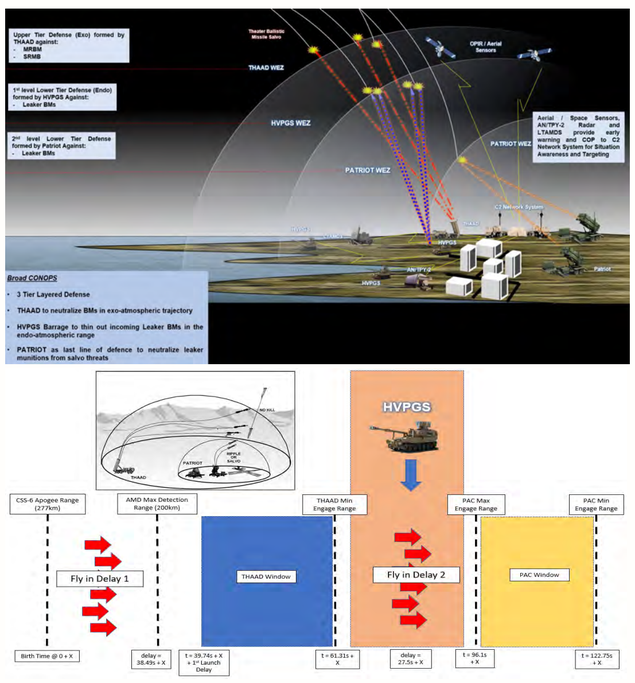
Hyper Velocity Projectiles (HVPs)

HVPs are a new generation of projectiles that has the ability to reach speeds of Mach 5 and above in flight. They offers great potential as a versatile weapon system to Support Naval Surface Fires Support (NSFS), AMD as well as Anti-Surface and Anti-Air Capabilities. Current projections of the projectile sit at approximately $86,000 per round. These are equipped with sensors and basic maneuverability characteristics for counter missile performance. In addition, the HVP's modular design enables it to be configured for a variety of gun systems/platform to meet different mission requirements. This thesis investigates the employment of Hyper Velocity Projectiles (HVPs) as interceptors for the Army's Air and Missile Defense (AMD) enterprise in the 2030–2035 timeline. The research recommends a proposed systems architecture for the incorporation of an HVP Gun System (HVPGS) to an AMD enterprise operating in a contested environment, with emphasis on the operating characteristics of the HVPs and their integration onto the firing platform.

GUN SYSTEM	PROJECTILE (SABOTED & SUB-CALIBER)	MISSION & WARHEAD TYPE	TRANSITION OPPORTUNITES	GAME CHANGING CAPABILITY
5" MK 45 MOD 2/4		NSFS – HE	113 Barrels (PEO IWS)	GUIDED 26 – 41 NM NSFS/ASCM/ASuW
20 – 32 MJ Railgun		NSFS – HE NSFS – KE	FUTURE (PMS405/PEO IWS)	GUIDED 50 - 100 NM NSFS/ASCM/ASuW/ Future Threats
155 mm – AGS		NSFS – HE	6 Barrels (PEO IWS)	GUIDED 40 NM NSFS/ASCM/ASuW
155 mm		Ground Fires – HE	800 ARMY 300 MARINE ASSETS	GUIDED 17 NM Fires/CMD

Proposed Concept of Operations



The proposed CONOPS for the HVPGS is to have the system nested within the larger CONOPS of the AMD enterprise. The first intercept layer of defense would be conducted by the THAAD system against longer range ballistic threats such as IRBMs and MRBMs. The last layer would be defended by the Patriot System holding the line as the final layer of defense against BM leaker threats that are not neutralized.

In the middle layer, the HVPGS would employ HVPs to target and neutralize the incoming leaker ballistic missile salvos. The proposed idea here is to thin out the leaker BM salvo before the second wave of leakers are handed over to the Patriot System as a last line of defense. Here, multiple HVPGS can be dispersed within the WEZ of a Patriot Battery to augment the Lower-Tier Defense with better coverage of the protected region, increasing survivability of the assets by widening the field of engagement and compounding the total rate of fire against incoming threats.

Research Results

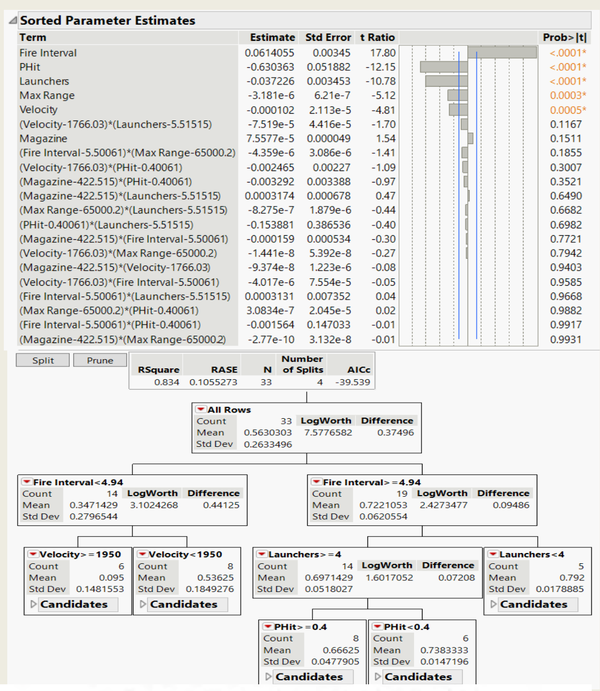
With 33 generated design points (formulated through the **NOLH DOE** approach), this thesis simulated each design point 100 times.

It can be seen that out of the 33 design points, only five are able to meet the 10% or less attrition objective. These are highlighted in green

S/N	NOLH Design						Attrition
	Magazine Depth	Munition Speed	Rate of Fire	Max Range	Prob. Hit	No. of Launchers	
1	750	1167	6.06	49375	0.63	7	0.7033
2	689	2503	8.88	58750	0.38	3	0.8141
3	668	1674	1.84	47813	0.12	6	0.6700
4	463	2319	1	60313	0.66	2	0.0169
5	709	1075	5.78	50938	0.51	7	0.7384
6	730	2411	7.19	54063	0.36	3	0.8080
7	545	1720	1.28	52500	0.1	7	0.5718
8	443	2042	1.56	57188	0.64	3	0.0804
9	525	1398	8.03	66563	0.53	4	0.6676
10	586	1996	7.47	74375	0.23	6	0.7182
11	566	1351	3.25	88438	0.31	2	0.7192
12	607	2088	4.09	86875	0.55	10	0.0002
13	484	1259	8.31	68125	0.46	2	0.7778
14	648	1904	6.63	83750	0.19	6	0.7290
15	504	1305	2.41	85313	0.33	1	0.7151
16	627	1950	4.66	90000	0.59	9	0.0055
17	423	1766	5.5	65000	0.4	6	0.5992
18	95	2365	4.94	80625	0.18	4	0.7641
19	156	1029	2.13	71250	0.42	8	0.2014
20	177	1858	9.16	82188	0.68	5	0.6120
21	382	1213	10	69688	0.14	9	0.7547
22	136	2457	5.22	79063	0.29	4	0.7331
23	115	1121	3.81	75938	0.44	8	0.3543
24	300	1812	9.72	77500	0.7	4	0.6986
25	402	1490	9.44	72813	0.16	8	0.7445
26	320	2135	2.97	63438	0.27	7	0.3949
27	259	1536	3.53	55625	0.57	5	0.4782
28	279	2181	7.75	41563	0.49	9	0.6443
29	238	1444	6.91	43125	0.25	1	0.7718
30	361	2273	2.69	61875	0.34	9	0.0669
31	197	1628	4.38	46250	0.61	5	0.5798
32	341	2227	8.59	44688	0.48	10	0.6678
33	218	1582	6.34	40000	0.21	2	0.7876

Through **Regression Analysis**, one can see that the HVPGS's Rate of Firing has the greatest effect on the overall Blue Force HVT attrition. This is followed by the Probability of Hit, Number of Launchers, Max Engagement Range and the HVP velocity in order of significance. The outcome is largely expected, as a higher rate of fire allows the HVPGS to launch more HVPs against the incoming salvo attacks.

Using the **Partition Tree Hierarchy** for analysis we can see that a mean attrition value of 56.3% is obtained over 33 design points. If the Rate of Fire is above 4.94 seconds, the mean attrition percentage increases to 72.2% as simulated in 19 of the design points. Next, in the case when a Rate of Fire below 4.94 seconds is achieved, a second level of decomposition shows that the next most significant factor, namely the HVP's velocity is examined. In this level of decomposition, one can see that if the HVP velocity is above or equal to 1950 m/s, it brings the mean attrition percentage down to 9.5% which is within this thesis's stated maximum attrition objective.



Benefits in Cost Engagement Ratio (CER)

In a baseline model simulation, only the number of cheaper Patriot missiles was varied to achieve a Blue Force Attrition percentage of no more than 10%. The investigation revealed that at least five Patriot Launchers (Compared to two launchers originally) with a total of 80 PAC-3 interceptors were needed to bring the Blue Force Attrition percentage down to no more than 10%.

The computed CER is then compared to the CER obtained from the modified AMD Enterprise (With the HVPGS) using design point 8. It can seen that base model AMD Enterprise (Without HVPGS) yields a CER of 1:16.44, while the modified AMD Enterprise (With HVPG) yields a CER of 1:8.96. This represents a 45.4% improvement in the overall CER when the HVPGS is incorporated into the AMD Enterprise, greatly improving the overall cost exchange factor and sustainability for missile defence.

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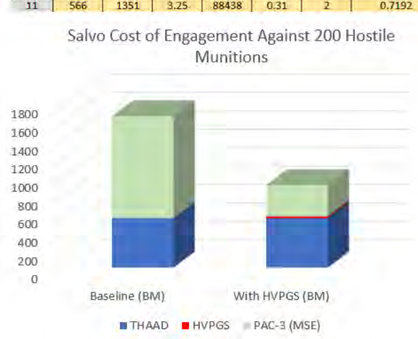

Base Model AMD Enterprise (Without HVPGS)

MOEs	Results	MOPs	C.P.U	Results
Blue Force Attrition	0.0812	# Blue Force Hits / Red Targets Killed		179.5
		# Red Force Hits		5.02
		# Blue Force Killed / 49 Blue Targets		3.98
Cost Engagement Ratio (CER)	1 : 16.44x	# PATRIOT Interceptors Launched	$5.34m	207.27
		# THAAD Interceptors Launched	$11.2m	48

Modified AMD Enterprise (With HVPGS)

MOEs	Results	MOPs	C.P.U	Results
Cost Engagement Ratio (CER)	1 : 16.44x	# PATRIOT Interceptors Launched	$3.4m	207.27
		# THAAD Interceptors Launched	$11.2m	48
Cost Engagement Ratio (CER)	1 : 8.96x	# PATRIOT Interceptors Launched	$5.34m	63.62
		# THAAD Interceptors Launched	$11.2m	48
		#HVPGS Interceptor Launched	$0.085m	222.8

*The CER is computed by dividing the cost of the total number of HVP, THAAD and PATRIOT interceptors used over the estimated cost of the enemy CSS-6 missiles.

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