# Temasek Defence Systems Institute

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

MAJ Tay Tian Ren Derek Eugene P. Paulo Paul T. Beery

### 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.







#### **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	NOLE Design								
	3,11	Magazine Depth	Munition Speed	Rate of Fire	Max Range	Prob. Hit	No. of Launchers	Attition		
n	1	750	1167	6.06	49375	0.63	7	0.7033		
	2	689	2503	8.88	58750	0.38	3	0.8141		
la la	3	668	1674	1.84	47813	0.12	6	0.6700		
n	4	463	2319	1	60313	0.66	2	0.0169		
	5	709	1075	5.78	50938	0.51	7	0.7384		
F	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		
S	9	525	1398	8.03	66563	0.53	4	0.6676		
	10	586	1996	7.47	74375	0.23	6	0.7182		
n	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		
٦f	19	156	1029	2.13	71250	0.42	8	0.2014		
	20	177	1858	9.16	82188	0.68	5	0.6120		
<b>\</b> 7	21	382	1213	10	69688	0.14	9	0.7547		
У	22	136	2457	5.22	79063	0.29	4	0.7331		
	23	115	1121	3.81	75938	0.44	8	0.3543		
e	24	300	1812	9.72	77500	0.7	4	0.6986		
Ŭ	25	402	1490	9.44	72813	0.16	8	0.7445		
n	26	320	2135	2.97	63438	0.27	7	0.3949		
11	27	259	1536	3.53	55625	0.57	5	0.4782		
	28	279	2181	7.75	41563	0.49	9	0.6443		
$\mathbf{\Lambda}$	2.0	222		6.04	10105	0.05		0 7740		

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

Sorted Paramete	r Estimates						
Term			Estimate	Std Error	t Ratio		Prob
Fire Interval			0.0614055	0.00345	17.80		<.00
PHit			-0.630363	0.051882	-12.15		<.00
Launchers			-0.037226	0.003453	-10.78		<.00
Max Range			-3.181e-6	6.21e-7	-5.12		0.00
Velocity			-0.000102	2.113e-5	-4.81		0.00
(Velocity-1766.03)*(La	unchers-5.515	515)	-7.519e-5	4.416e-5	-1.70		0.11
Magazine			7.5577e-5	0.000049	1.54		0.15
(Fire Interval-5.50061)	*(Max Range-	65000.2)	-4.359e-6	3.086e-6	-1.41		0.18
(Velocity-1766.03)*(PH	lit-0.40061)		-0.002465	0.00227	-1.09		0.30
(Magazine-422.515)*(	PHit-0.40061)		-0.003292	0.003388	-0.97		0.35
(Magazine-422.515)*(	Launchers-5.5	1515)	0.0003174	0.000678	0.47		0.64
(Max Range-65000.2)	*(Launchers-5	.51515)	-8.275e-7	1.879e-6	-0.44		0.66
(PHit-0.40061)*(Launo	(hers-5.51515)	,	-0.153881	0.386536	-0.40		0.69
(Magazine-422.515)*(	Fire Interval-5	.50061)	-0.000159	0.000534	-0.30		0.77
(Velocity-1766.03)*(M	ax Range-650	00.2)	-1.441e-8	5.392e-8	-0.27		0.79
(Magazine-422.515)*(	Velocity-1766	.03)	-9.374e-8	1.223e-6	-0.08		0.94
(Velocity-1766.03)*(Fig	re Interval-5 5	0061)	-4 017e-6	7 554e-5	-0.05		0.9
(Fire Interval-5 50061)	*(Launchers-5	51515)	0.0003131	0.007352	0.04		0.96
(May Range-65000 2)	*(PHit-0 40061	)	3 0834e-7	2 045e-5	0.02		0.90
(Fire Interval-5 50061)	*(PHit-0.4006)	1)	-0.001564	0 147033	-0.01		0.90
(Magazine-422 515)*(	May Pange-6	5000.2)	-2 770-10	2 1220-9	-0.01		0.9
(Wagazine-422.515) (	Max Range-0.	5000.2)	-2.770-10	5.1526-0	-0.01		0.93
Split Prune	RSquare	RASE	Nu Nof	mber Splits Δ	ICc		
	0.834 0	.1055273	33	4 -39.	539		
	·			1			
	[		ws				
		Count	33	LogWorth	Difference	2	
		Mean Std Dev	0.5630303	7.5776582	0.37496		
	l	Stu Dev	0.2055490				
Fire Interval < 4.94				Fire In	terval>=4.9	94	
Count 14	LogWorth D	ifference	1	Count	19	LogWorth D	Difference
Std Dev 0.2796544	3.1024268	0.44125		Std Dev	0.0620554	2.42/34//	0.09486
510 511 6127 505 11				Staber	0.0020001		
Velocity> = 1950	Velocity	1950	Launc	hers>=4			Launchers < 4
Count 6	Count	8	Count	14	LogWorth	Difference	Count
Std Dev 0.1481553	Std Dev 0.	1849276	Std Dev	0.0518027	1.6017052	0.07208	Std Dev 0.0178
	D Candid	ates	Staber	0.000.002.			D Candidates
P canalates	Candida						candidates
			▼PHit	>=0.4	▼PHit⊲	•0.4	
			Count		Count	6	
			count	0.000	Count	0 7000000	
			Mean	0.6662	5 Mean	0.7383333	



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.

#### Base Model AMD Enterprise (Without HVPGS)

### **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.

									Dase IVI	odel AND Litterprise	(without ny	rusj
S/N			NOLH	Design			Attrition	MOEs	Results	MOPs	C.P.U	Results
1 2 3	750 689 668	1167 2503 1674	67 6.06 49375 0.63 7 0   03 8.88 58750 0.38 3 1   74 1.84 47813 0.12 6 6		0.7033 0.8141 0.6700	Blue		# Blue Force Hits / Red Targets Killed		179.5		
4	463	2319	1 5.78	60313 50938	0.66	2	0.0169	Force	0.0812	# Red Force Hits		5.02
6 7	730	2411	7.19	54063 52500	0.36	3	0.8080	Attrition		# Blue Force Killed / 49 Blue Targets		3.98
9 10	525 586	1596	8.05 7.47	00303 74375	0.33	4	0.0004	Cost #	# PATRIOT Interceptors Launched	\$5.34m	207.27	
11	Salvo	0 Cost o	3.25 F Enga	gement	Agains	st 200 l	l 0.7192	Ratio (CER)	1:16.44	# THAAD Interceptors Launched	\$11.2m	48
		Munitions						Modif	ied AMD Enterprise (	With HVPGS		
1800		-	-					MOEs	Results	MOPs	C.P.U	Results
1600 1400								Cost	<b>1</b> :16.44x	# PATRIOT Interceptors Launched	\$3.4m	207.27
1200 1000					1	1		Ratio (CER)		# THAAD Interceptors Launched	\$11.2m	48
800 600						-1				# PATRIOT Interceptors Launched	\$5.34m	63.62
200			1					Engagement	1:8.96x	# THAAD Interceptors Launched	\$11.2m	48
	Ba	seline (BN	()	Wit	h HVPGS	(BM)		Ratio (CER)		#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.

