

## Application of Presently Operating Tactical Aircraft to Destroy Antiship Missile Attacks in the Strait of Hormuz

Existing USAF (US Air Force) and IDF (Israeli Defense Force) tactical aircraft operating in the Gulf region are equipped with AMRAAM missiles. Can they be used to kill Medium Range Ballistic Missiles in their boost (right after launch) phase? The answer is yes.

The attached note (Reference 1) describes the engagement aspects of Fighter-AMRAAM. This particular study (there are some 50 notes) was for an application to the Ukraine War. Beginning in late 2017, presentations were made to Secretary of Defense, Joint Chiefs of Staff, DDRE and USAF Chief of Staff and their offices prompted initially by the North Korean demonstration of nuclear weapons and ICBMS. The detailed dynamics are explored in Reference 2 for that application, where air superiority over the land mass was not at hand.

This operational construct can be used to protect cities and ports (such as in UAE) as well as ships (commercial, Allied, and US ships) at in the Gulf by greatly reducing the ballistic missile threat. It is much easier than in North Korea due to the air superiority achieved by the Allies over the Persian Gulf of Iran.

It should be immediately implemented in theater by US forces and instantly shared with the Israeli forces, as they are intimately familiar with the Iranian threat, fly modern aircraft forces armed with AMRAAMs in the region, and know missile defense.

## Reference 1

### **Fighter-AMRAAM Defense for Ukraine**

Gregory H. Canavan, Robert O. Hunter, Jr., and John C. Browne

10/1/22

Fighter-AMRAAM uses existing fighters and interceptors to negate missile threats in boost phase from areas around Ukraine. They can deter threats from those missiles or intercept them to minimize losses. They could be ready immediately based on assets and command structures currently in theater. Testing and readiness could act as a deterrent to further escalatory measures. The concept was developed with the support of the Pentagon<sup>1</sup> and reviewed in detail.<sup>2</sup>

Missiles are most vulnerable in boost, but that is difficult. Defenses must act w/in minutes of boost. Missiles in Belarus remain in the atmosphere for most of their trajectory, which provides a few hundred seconds more. That can be accomplished by airborne fighters loaded with AMRAAMs ready to act soon after missile launch. Detection using onboard radar minimizes the time to detect, flight time for the interceptor, and maximizes the probability of successful intercept.

Fighter-AMRAAM could deter, reduce the danger of escalation, and intercept nuclear weapons, if necessary. Test and deployment would remove the incentive for missile deployment, threat, or use. It could ensure the survivability and freedom of action of NATO and U.S. forces. It could reach theater-range missiles in boost before they reach midcourse flight. Fighter-AMRAAM could be tested soon to develop confidence.

**Background.** Missiles are most vulnerable in boost where they are slow, move on predictable trajectories, and do not have decoys. In midcourse they move faster, can maneuver, and use decoys. In terminal phase, they can use countermeasures and maneuver strongly. It is best to intercept them in boost, but that is difficult. Defenses must act w/in the ~ 100 s of boost. Iskander

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<sup>1</sup> F-A Report

<sup>2</sup> F-A IDA Review

missiles in Belarus remain in the atmosphere for most of their trajectory, which provides a few hundred seconds more.

Intercept requires prompt warning and alert, which requires prompt detection. Modern fighters could provide that with on-board radars augmented by theater radars and overhead assets. That reduces sensitivity to clouds and weather. Having aircraft in flight ready to act soon after launch minimizes interceptor range and flight time, which assures that they can reach missiles in boost or shortly thereafter. Previous response chains took minutes, which was longer than boost, so defenses never had a chance to kill missiles in boost phase.

**Concept** uses fighters on station armed w/AMRAAM to detect with their onboard radars augmented by external information and command. The primary mode is detection and intercept in the air. That is within the detection and discrimination range of their radars and the range of their interceptors for the distances of Belarus involved. It also avoids concerns about preemption. It could serve as the first of a multi-layer system or preferential defense.

**Engagement.** Radar detection of targets, their interpretation, and transfer of target information to AMRAAM are automated in the fighter. ¶The best information on target detection, environment, aircraft situation, and defenses lie with the pilot. There is adequate time for his decision given a pre-authorized CONOPS for engagement, which is essential for prompt theater defense.¶On release, the radar guides AMRAAM to target or divert, if necessary. Doppler radars are standard on current generation fighters, so they and AMRAAMs are suited for boost phase defense.

**Radars.** Current pulse Doppler radars can detect and track missiles in flight in 10s of seconds after launch. Current AMRAAM interceptors can intercept them within the atmosphere with high probability. Radar detection, clutter and filtering are well understood. Their background is measured and integrated into their radars.

Missile launch signals are predictable and adequate. There is significant experience for intercept at the ~ 150 km ranges involved in theater. They are consistent with AMRAAM's range. Return signals from missiles resemble those

in conventional air to ground and air to air tactical air engagements. Detection by radar occurs seconds after launch, so AMRAAM intercept in the atmosphere reduces technology requirements to that of currently deployed models. ☒

Using on-board radar speeds detection, removes weather limits, and reduces reliance on external warning sensors and communication, which can reduce reaction time. External warning, cueing or oversight can be communicated to the fighter to enhance detection and execution. That allows missile boost timelines to be met with conventional information, pilot training, and tactics.

Conventional radar look- down geometries are adequate. Missiles can be detected at range from altitudes of 5-10 km in < 10s seconds. Radars can also look up to from low altitudes to avoid air defenses and detect a launch in an additional 10 seconds. Either supports the timelines for AMRAAM endo-atmospheric intercept.<sup>3</sup>

**AMRAAM** has demonstrated a kill probability  $P_k > 0.6$  in combat against more difficult targets with higher accelerations and speeds than ballistic missiles in boost. Using four AMRAAMs compounds to a  $P_k$  over 98%. Its range is adequate for the distances to missiles in Belarus. If needed, their range could be extended by adding existing, tested boosters. Fighters and AMRAAMs are available in theater. Allies could participate with their own and U.S. assets.

**Survivability.** The pilot and aircraft are survivable. They can detect and avoid surface to air missiles, avoid air-based defenses, and defend themselves with the assets used to intercept the missiles. The detection and intercept requirements of enemy air defense missiles is known and within the self-defense envelope of our fighter radars and AMRAAMs. Fighters can stand off from enemy air defenses or fly under them to reach missiles in boost. The demonstrated ability to self-defend make it possible to withstand air to air missiles as well.

**Deployment** can be rapid. No development is needed as the fighters,

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<sup>3</sup> GC radar note

AMRAAMs, and radars exist and are deployed in Ukraine and other the theaters at risk. All that is needed is integration and test in representative environments, which could be done in conjunction with current training.

**Conclusion.** Fighter-AMRAAM could deter, reduce the danger of escalation, intercept nuclear weapons. Fighter-AMRAAM could be tested soon to develop confidence in these tactics. Overt tests could remove the incentive for enemy missile deployment, threat, or use. It could ensure the effectiveness, survivability, and freedom of action of NATO and U.S. forces. It could reach theater-range missiles during boost before they can attack. The best defenses are those that never have to be used. The best way to assure that is to have them ready if called upon.



# Fighter-AMRAAM Boost-Phase Defense

Dr. Gregory Canavan, Senior Fellow, Los Alamos National Laboratory

Dr. William Graham, Fmr. Dep. and Acting Admin, NASA; President's Science Advisor, '86-89

Dr. Robert Hunter, Fmr. Assistant Secretary of Energy; Chairman, Innoven Energy

Dr. John Browne, Director, Los Alamos National Laboratory, '97-03

Mr. John Darrah, Fmr. Chief Engineer, NORAD; Chief Scientist Emeritus, USAF Space Command

Dr. Gene McCall, Chairman Emeritus, USAF Science Advisory Board; Fellow, LANL

Dr. Harry Cartland, Fmr. Senior Staff, House Armed Services Committee

Dr. Raymond J. Leopold, IRIDIUM Satcom co-inventor, Fmr Prof MIT, USAF Academy & UNM

An independent, unaffiliated Study funded by Members

## 2. Conclusions up Front

- DPRK progress in nuclear weapons and ICBMs rapid
- Fighters, radars, AMRAAM adequate & deployed
  - Need test of prompt release, clutter & deployment
  - Prompt warning essential, available with aircraft radar
  - Immediate warning & track to pilot in all weather
- Pulse Doppler radars detect, track at  $\approx 100$  km, 10sec
  - Issue: detection by current radar at low Doppler velocity
- Clutter processing at 4<sup>th</sup> gen level adequate
  - Significant role for 4<sup>th</sup> gen and Allies
- Stop DPRK development, provide 2-layer defense, preferential
- CONOPS flexible, survivable
- Gulf & Straits intercept missiles, threats similar DPRK
- Integration & test fast with developed components

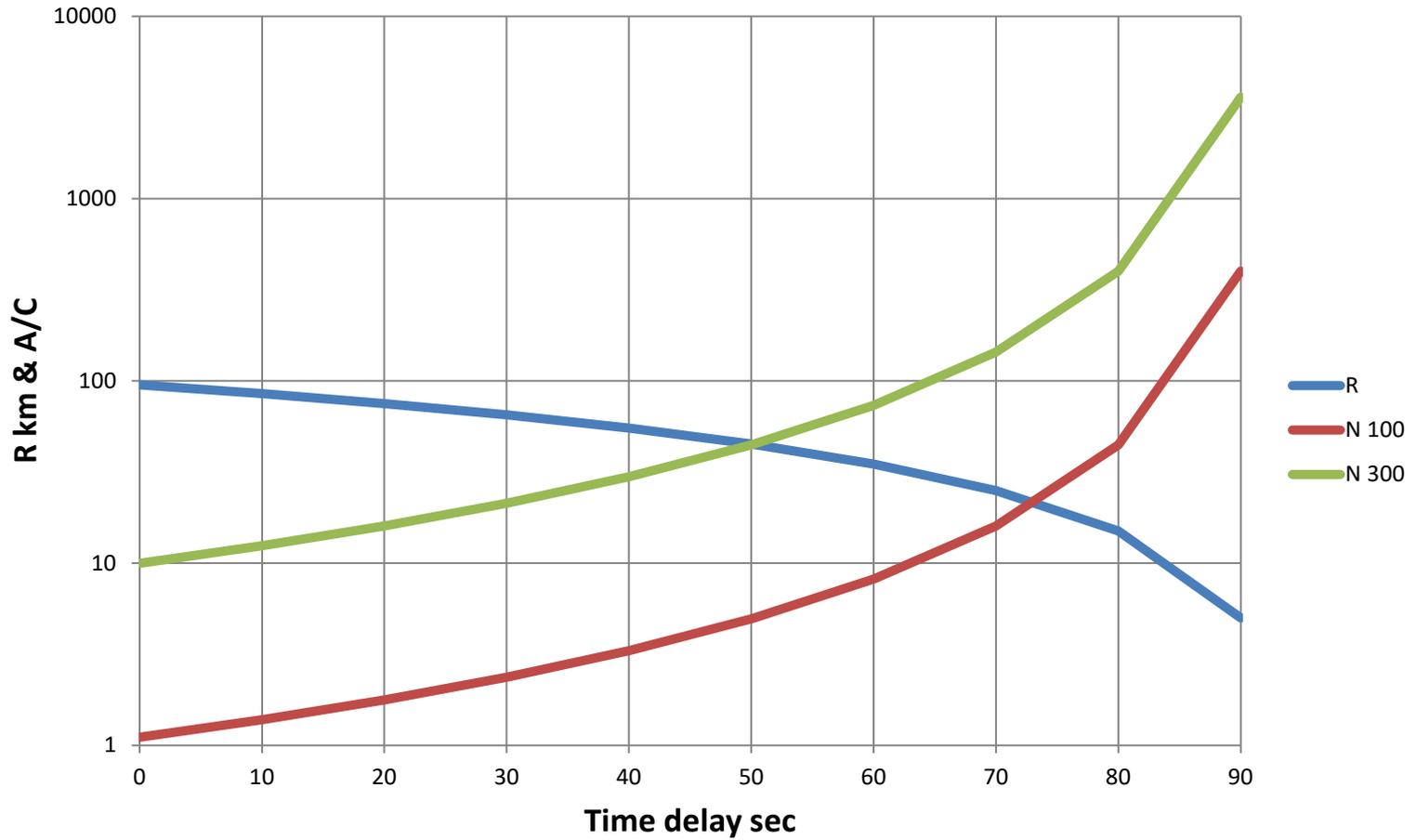
# 3. Fighter-AMRAAM Elements

- Fighters
  - Developed, deployed, available
  - modern array radars
  - 2-way command link supports multiple AMRAAMS, divert
- Radars
  - Long-range, clutter rejection
  - Compatible with most fighters, control AMRAAM
- AMRAAM
  - Range, control, sensor
  - Pk for ICBM intercept
- Existing components can detect & intercept in boost
  - With prompt release

# 4. AMRAAM Boost-Phase Performance

- Pk = 0.65 tested in combat—Compounds to  $\sim 0.98$  (4 AMRAAM)
  - 11/18 combat encounters statistically significant
  - earlier combat targets piloted, evading
  - DPRK Missiles not maneuvering, so higher Pk possible
- Raytheon/MDA NCADE proof of principle for boost phase defense
- AMRAAM 15 kg warhead matched to radar accuracy at 100 Km
  - Removes need for hit-to-kill and IR uncertainties
  - Reduces high frequency corrections in end game of passive IR
- Intercepts to top of atmosphere 30 km
- velocity  $\approx 1.4$  km/s supports  $> 100$  km standoff in 90 sec
  - DPRK ICBM launch areas near coast
  - Survivable standoff for CAP A/C
- Launch from altitudes masked from DPRK radars at 5-10% penalty

# 5. Warning Delay Increases A/C, Cost

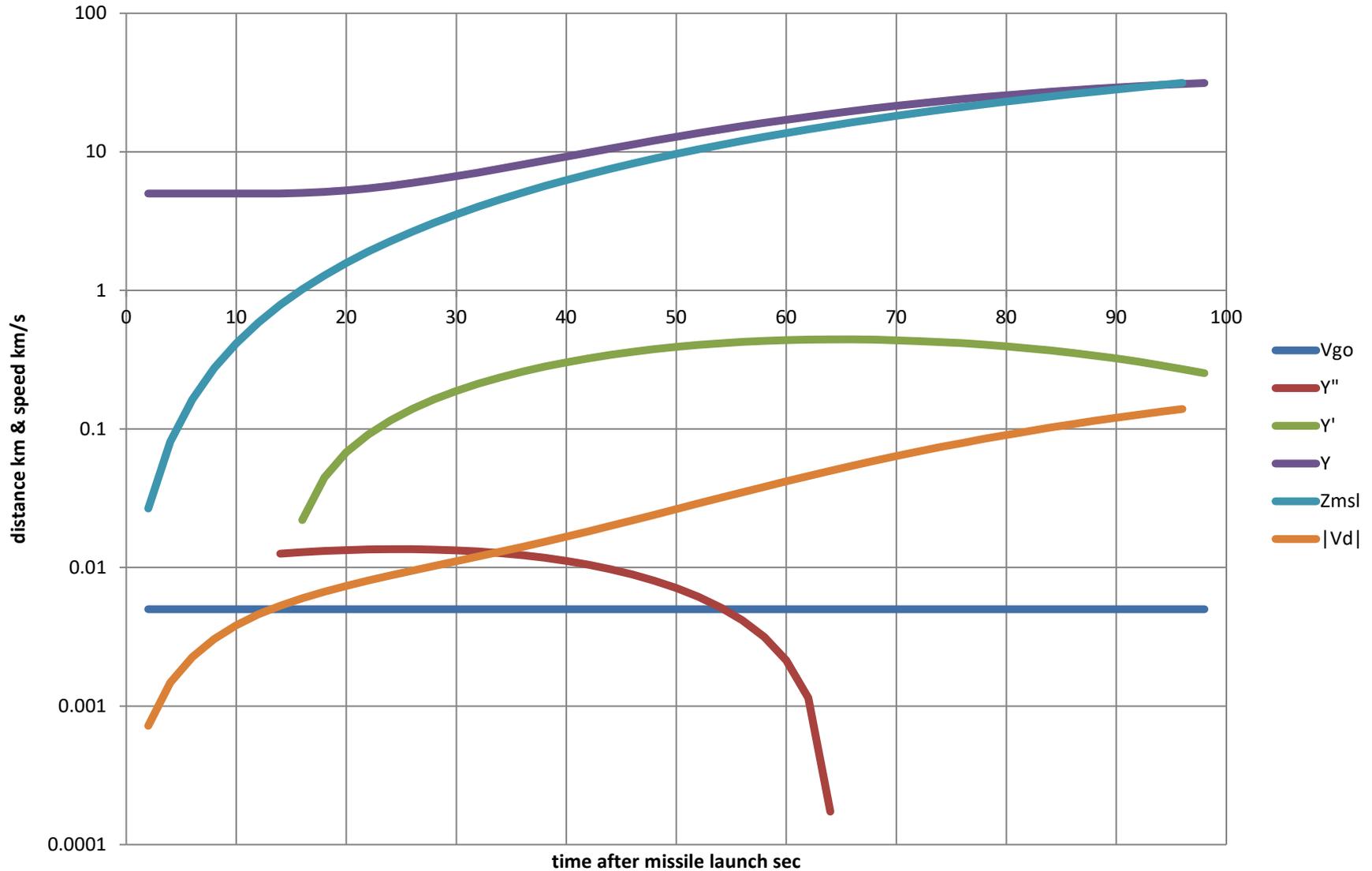


Fighter range falls 3-fold by 60 sec—increases fighters by 10 & cost like amount

# Preferential Defense

- Multilayer preferential defenses can
  - Block further development and deployment of missiles
  - Evolve to high confidence intercept layer
- First layer reduces initial threat to maximum possible—not necessarily perfect
  - Communicates results to 2<sup>nd</sup> layer
  - concentrates assets on those that penetrate 1<sup>st</sup> layer
  - ratio of 1<sup>st</sup> layer survivors to 2<sup>nd</sup> layer interceptors produces exponential reduction in leakage
  - range and engagement time produce uniform low leakage coverage across US, Gulf
- Enhance Aegis, GBI effectiveness
- Fighter-AMRAAM layer attrits threat, obtains early and precise track information
  - Delays adequate for THAAD, PAC3 2<sup>nd</sup> layer defenses distributed in Gulf States
  - Leverage current network for rapid release of interceptors
- Preferential defenses remove incentive for use of theater missiles to
  - threaten or attack
  - US allies and forces in Gulf otherwise vulnerable

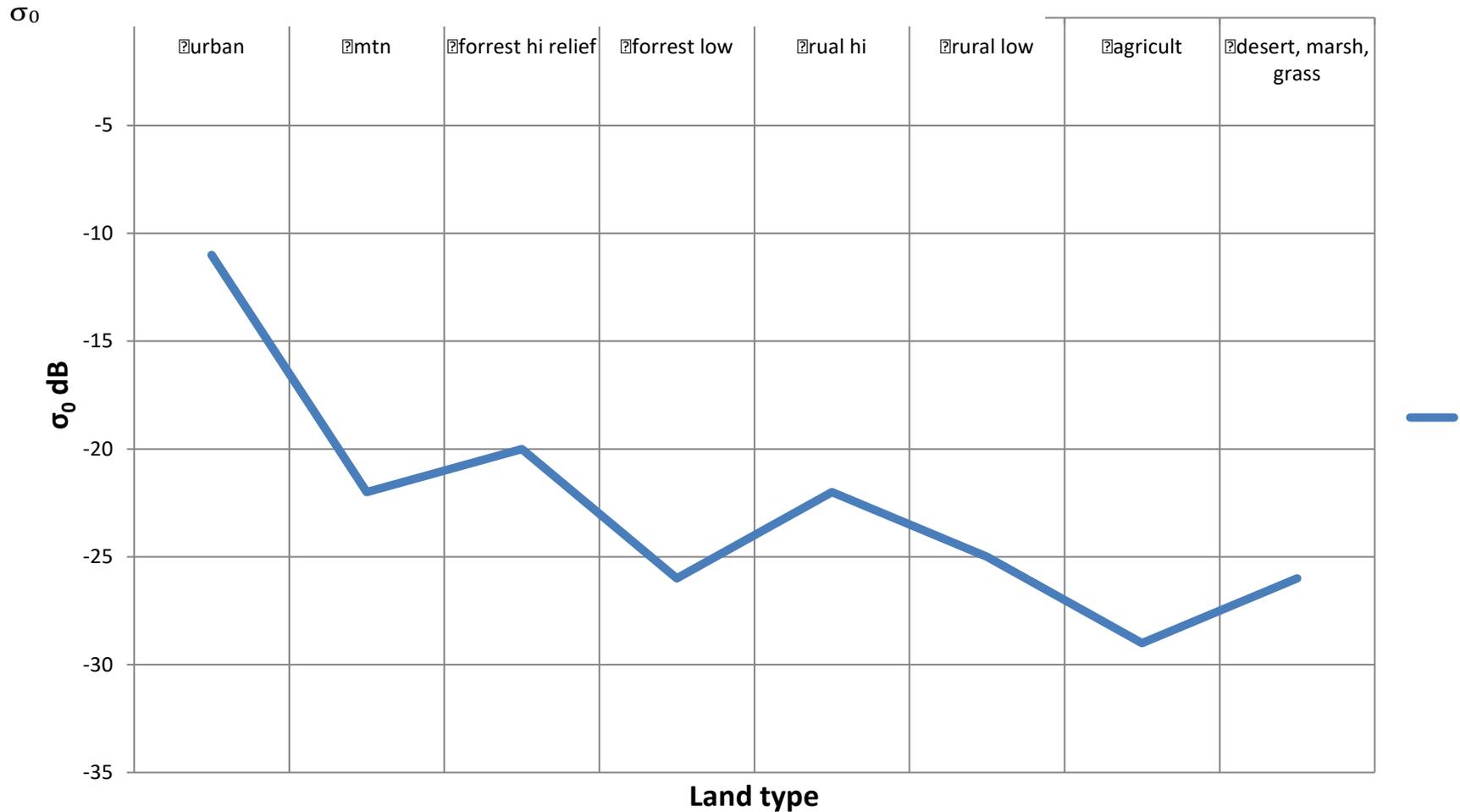
# 7. ICBM intercept 100 s vs time



# 8. Radar Terrain and Clutter

- Terrain types
  - MIT Lincoln Lab (Exponential Decay in Windblown Radar Clutter)
  - Barton, Skolnik, & Toomay field programs and surveys
  - Terrain: grass & agricultural, rural, forest & mountain, urban
  - Successive 10-fold increases in clutter return  $\sigma_o(m^2/m^2)$
- Weather
  - Lincoln Lab data reduces to  $\beta$ , varies  $\approx 2x$  in med-high wind
  - Determines average clutter  $V_o \approx 1/\beta \approx 0.15$  m/s, normalizes estimates
  - Doppler filter  $\approx (V/V_o)^2$  for single delay processing
  - Adequate CPI for boost-phase from 4<sup>th</sup> generation radar
- Range = terrain x weather x clutter suppression
  - Suppression adequate for boost phase all weather, terrain
  - Allows input of current meteorology to predict processing needed

# 9. Reflectivity $\sigma_0$ (dB) vs terrain

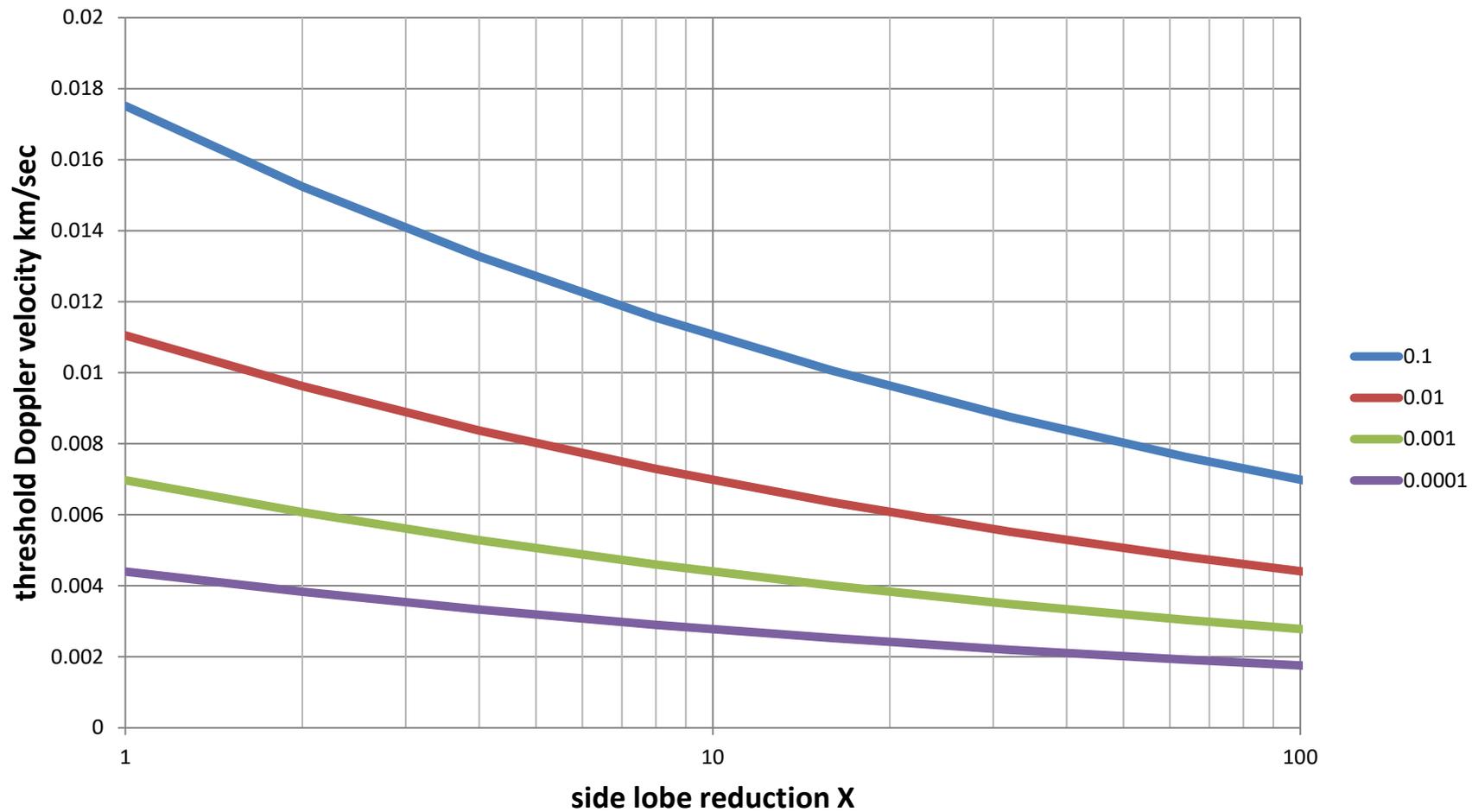


# 10. Boost-Phase Doppler

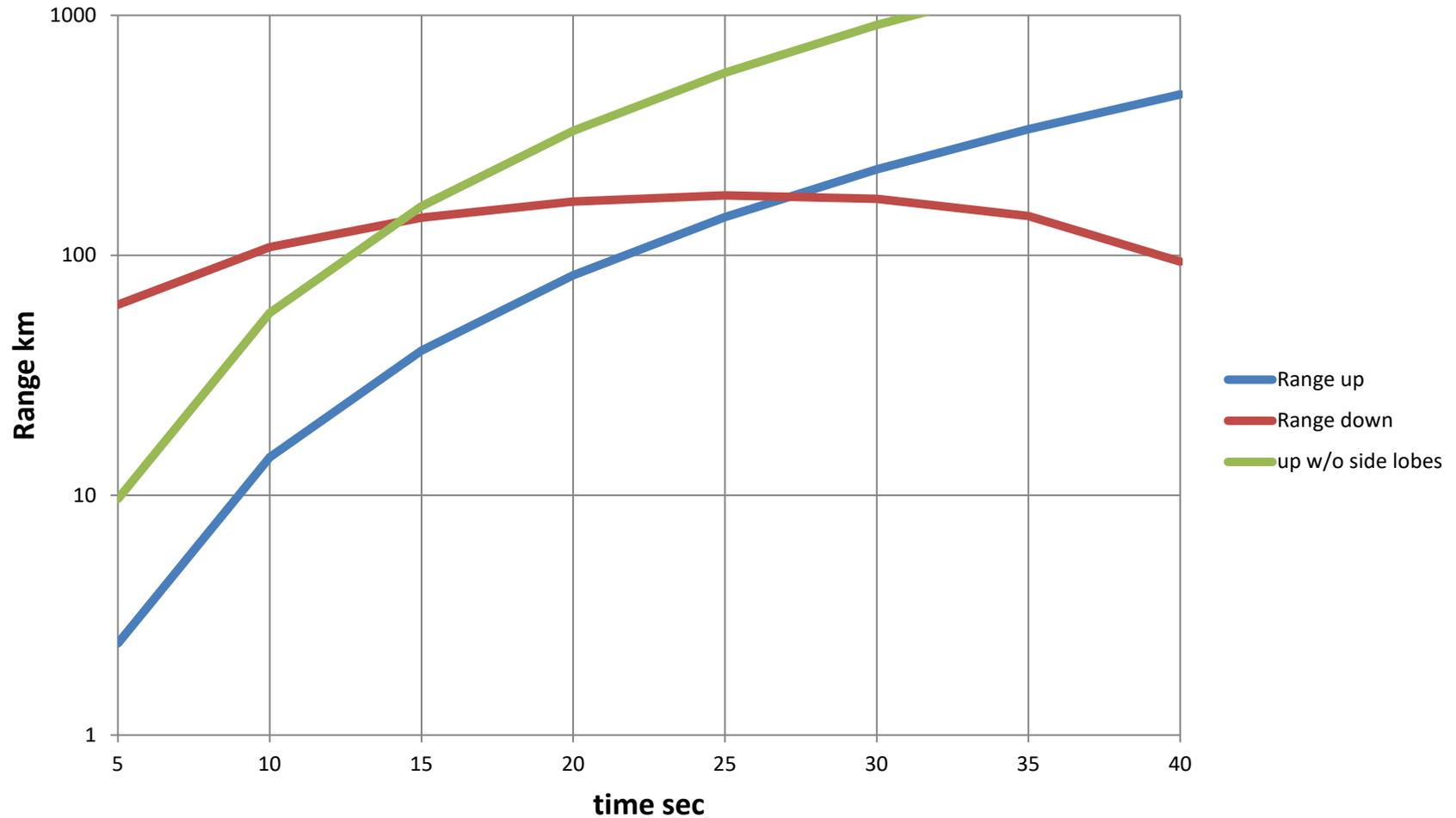
- Spatial S/C =  $\sim (\sigma/(\sigma_0))(N/T_p)$ 
  - $N, T_p$  not independent, vary with  $V_d$
- Doppler velocity  $V_d = \sin\beta V_m \approx \beta V_m \approx \text{altitude/Range } V_m \approx H/R V_m$ 
  - $V_m \approx 5\text{-}20 \text{ m/s}$
  - $V_d \approx 10 - 20 \text{ m/s} \approx 22 \text{ -}44 \text{ mph}$
- Clutter suppression  $\approx (V_d/V_o)^2$ 
  - $V_o \approx 0.15 \text{ m/s}$  (Lincoln Lab rms clutter velocity)
  - Clutter coherence time  $T_c \sim \lambda/V_o \sim 0.1 \text{ s}$
- $F_d = 2V_D/\lambda \approx 40V_D \approx 400 - 1,600 \text{ Hz}$
- Coherent pulses processed  $N \approx F_d \times T_c \approx 40\text{-}160 \quad \sim V_d \text{ (4}^{\text{th}} \text{ generation)}$
- $T_p = 1/(F_d N) = 1/[(N/T_c)N] = T_c/N^2 \quad \sim 1/V_d^2$
- Thus,  $V_d$  determines  $F_d, N, \& T_p$  and all radar scaling
- $V_t = [R\lambda^2/(DX \sigma/\sigma_0)]^{1/5} \sim (\sigma_0/\sigma X)^{1/5}, X \sim 1/\text{side lobe level}$ 
  - $\sigma_0/\sigma$  varies over  $\sim 40\text{dB}$
  - $X$  over  $20 \text{ dB}$ , other scaling weaker

# 11. Threshold Vd vs side lobe suppression X

R = 100 km, x-band, S/C = 10;  $\sigma/\sigma_0$



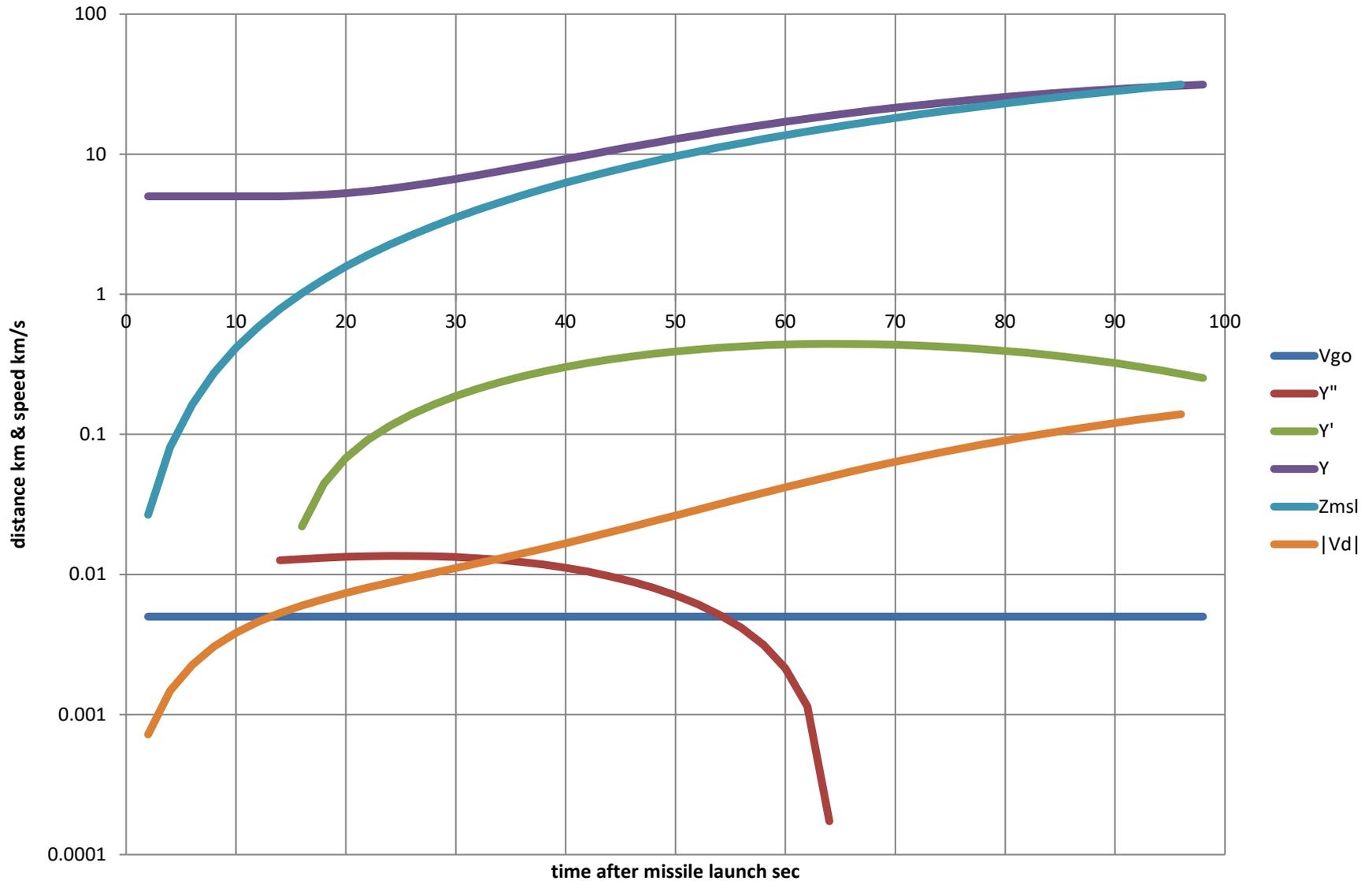
# 12. Detection Range vs Time up & down looking



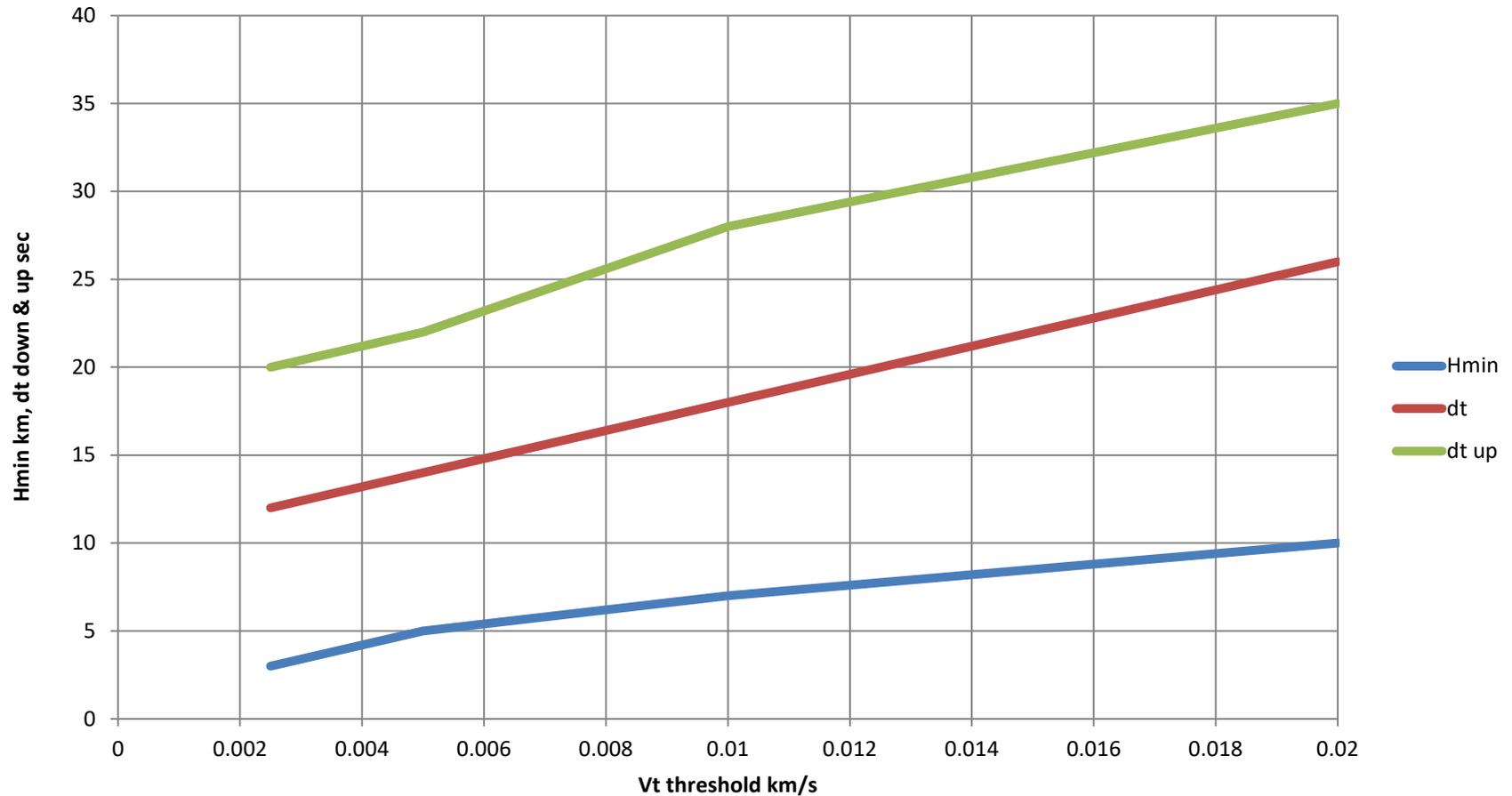
# 13. Look Angles & Side Lobes

- Look down from 5-10 km
  - Detection in 5-10 sec at ~ 100 km
  - Faces maximum clutter
  - Range scales to conventional ~ tactical air
  - vulnerable, ECM
- Look up (above horizon)
  - Detection delayed ~ 10s relative to down
  - Clutter main, side lobes suppressed 20-30 dB
  - Widens main lobe 1.5-2x in search & detection
  - Range increased 2-3-fold ~ air to air
  - Below DPRK radar ECM horizon, out of main beam

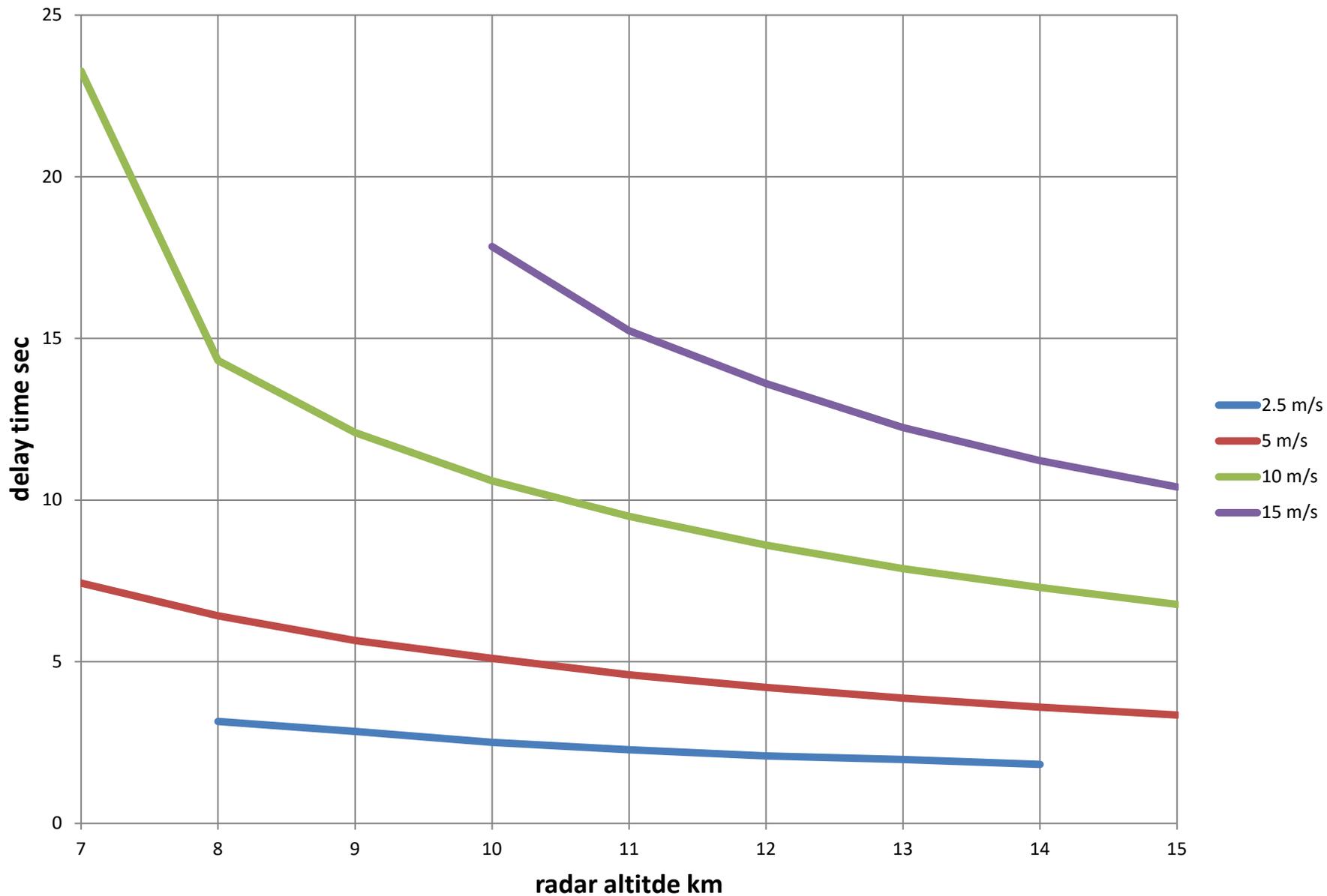
# 14. ICBM intercept at 100 s vs time



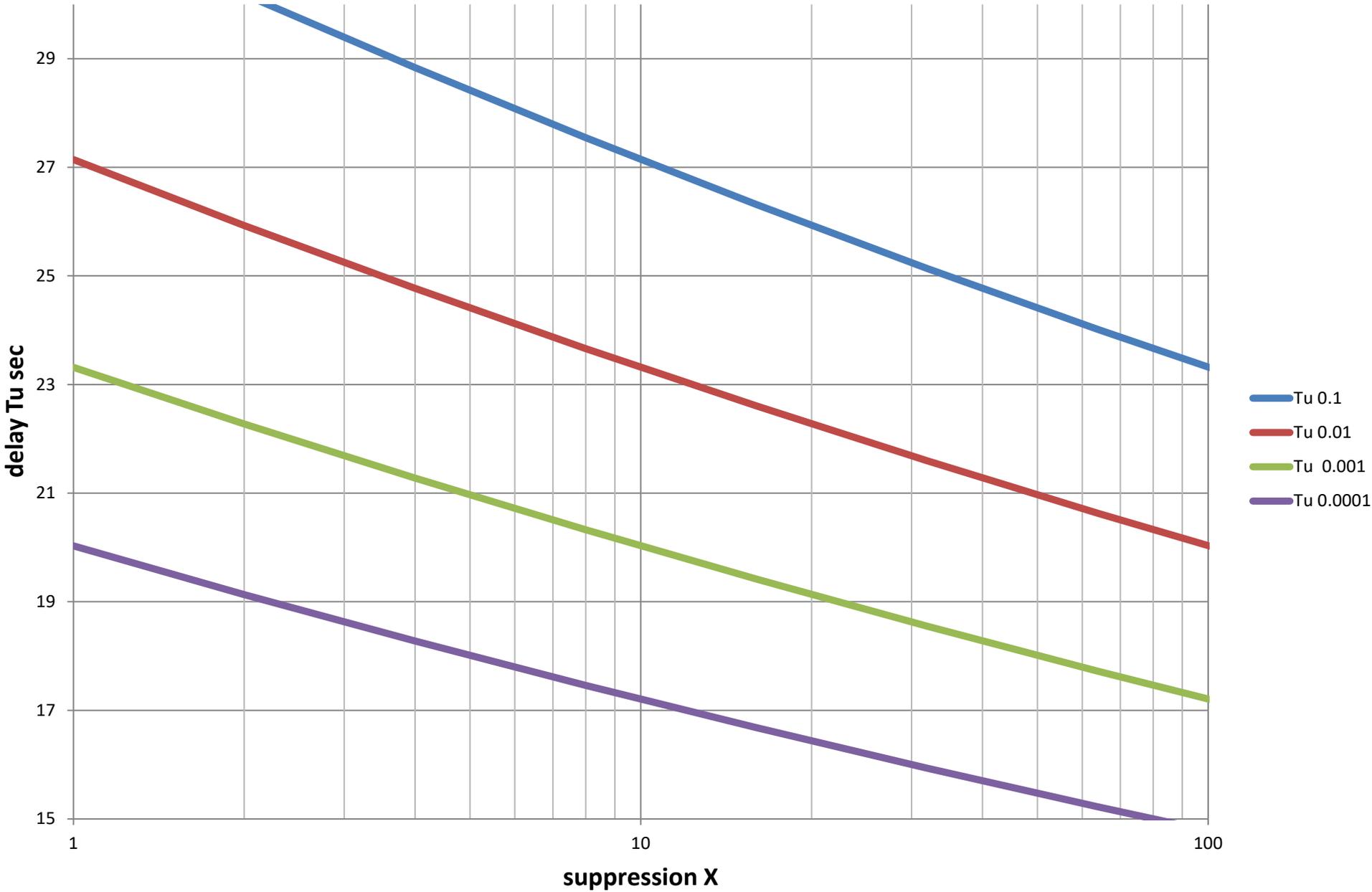
# 15. ICBM intercept delays vs $V_t$



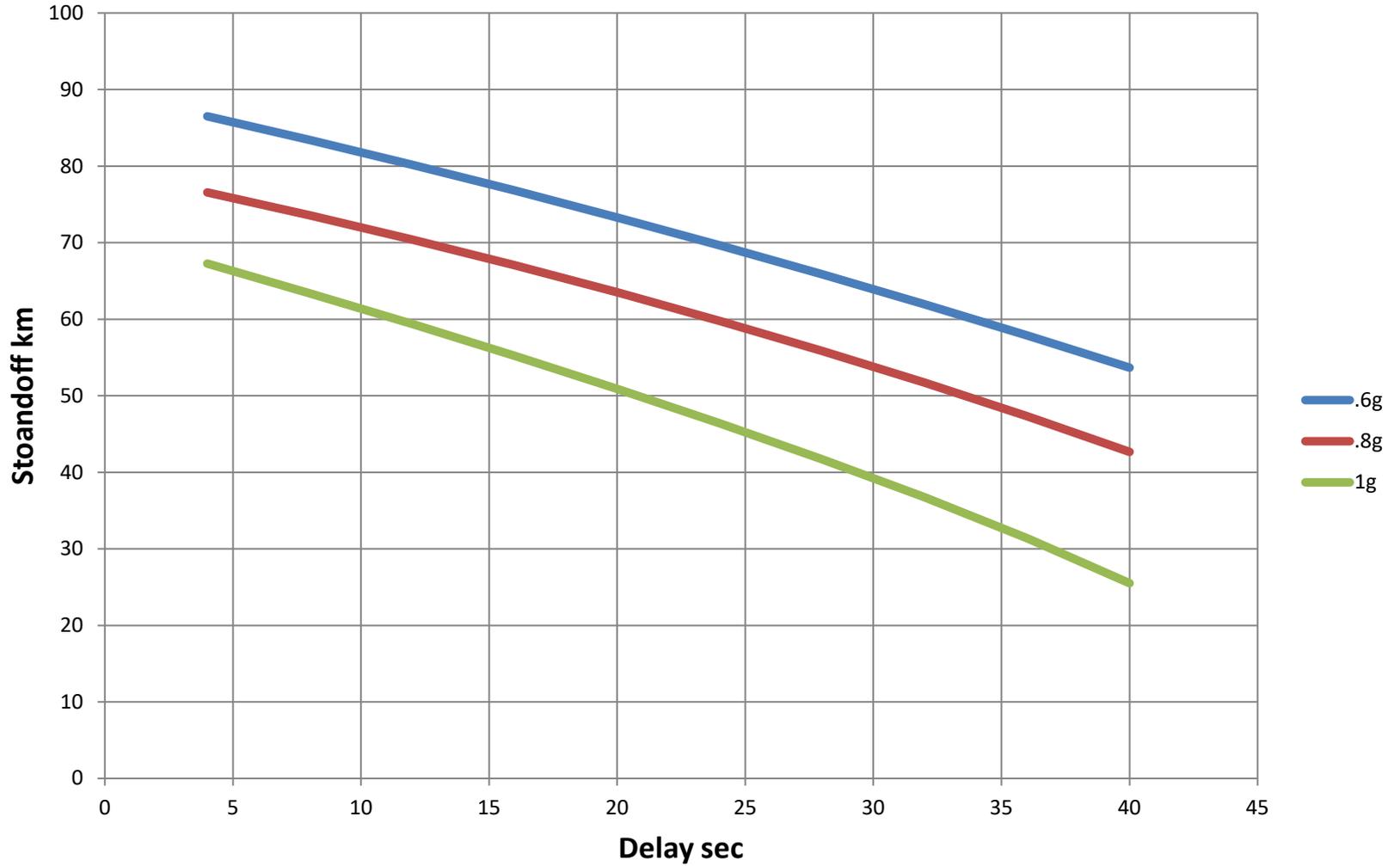
# 16. Tdelay vs H, R=100 km, A=1g ; Vt



# Fig. 17. Tu vs suppression



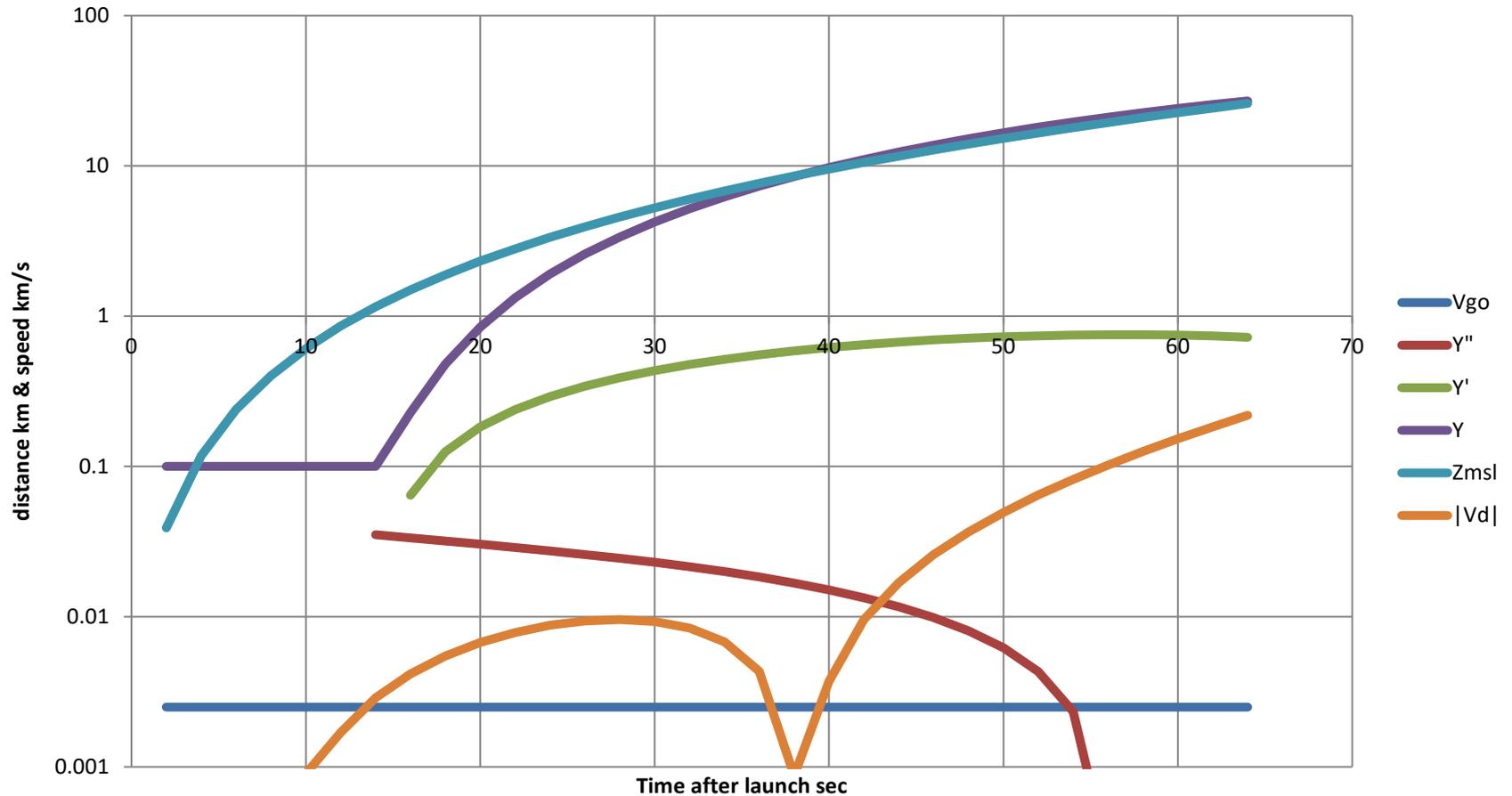
# Fig. 18 . Standoff vs delay; missile Accel



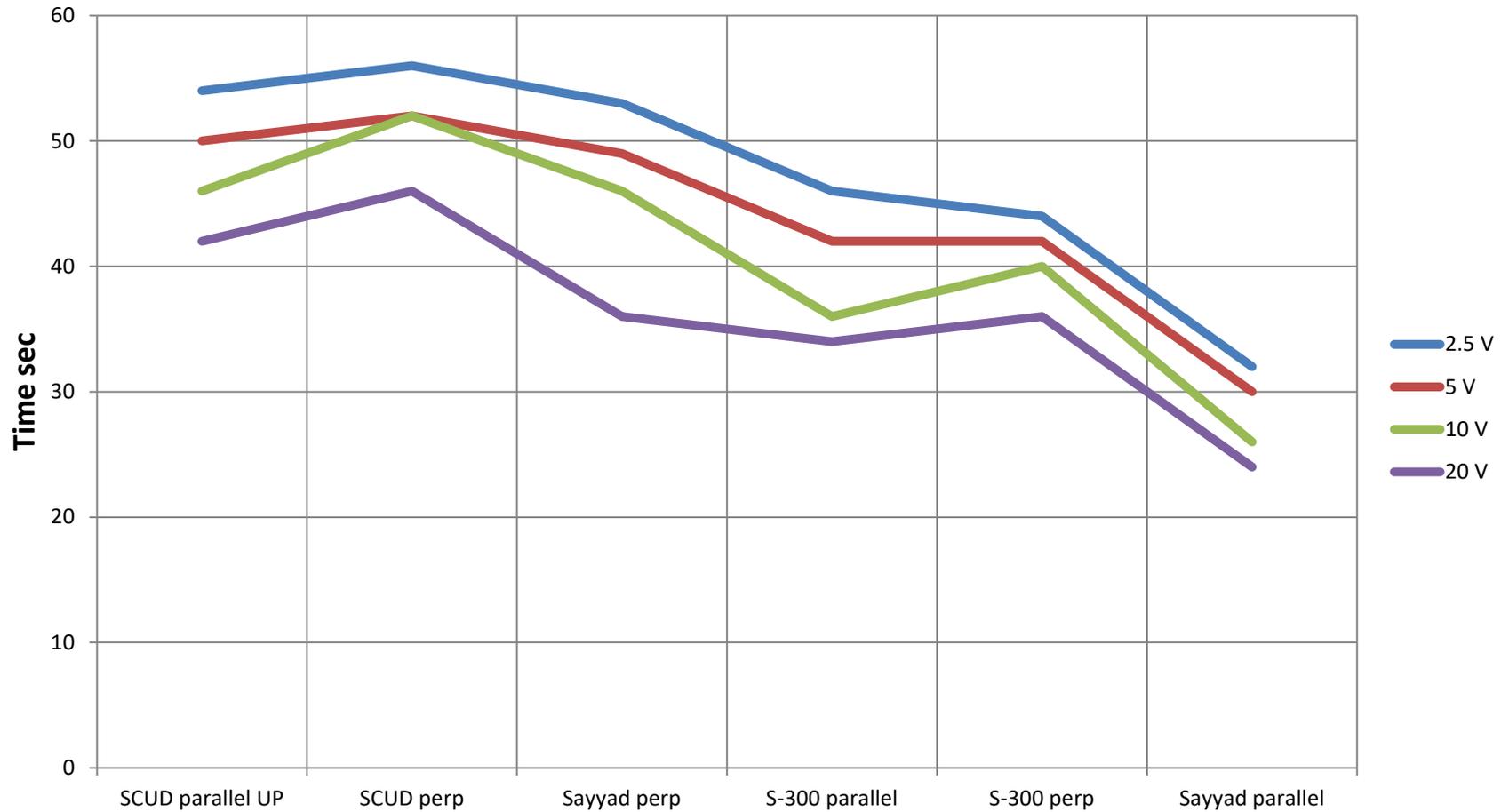
# 19. Summary of ICBM Engagement

- AMRAAM trajectories similar to those derived earlier
  - Feasible, faster, shorter ranges 60-80 km vs 100 km
  - Accelerations and velocities acceptable
  - detection time reduces engagement time and standoff
  - restricts safe altitudes
- Transition down to up at Doppler velocity  $V_t \approx 10$  m/s
  - agrees w/ conventional masking angle  $\approx 6$  degrees,
  - clutter & side lobe suppression can control
  - invertible, to optimize on expected suppression, clutter
  - Esp. for ICBM launchers close to coasts, beaches, & ocean

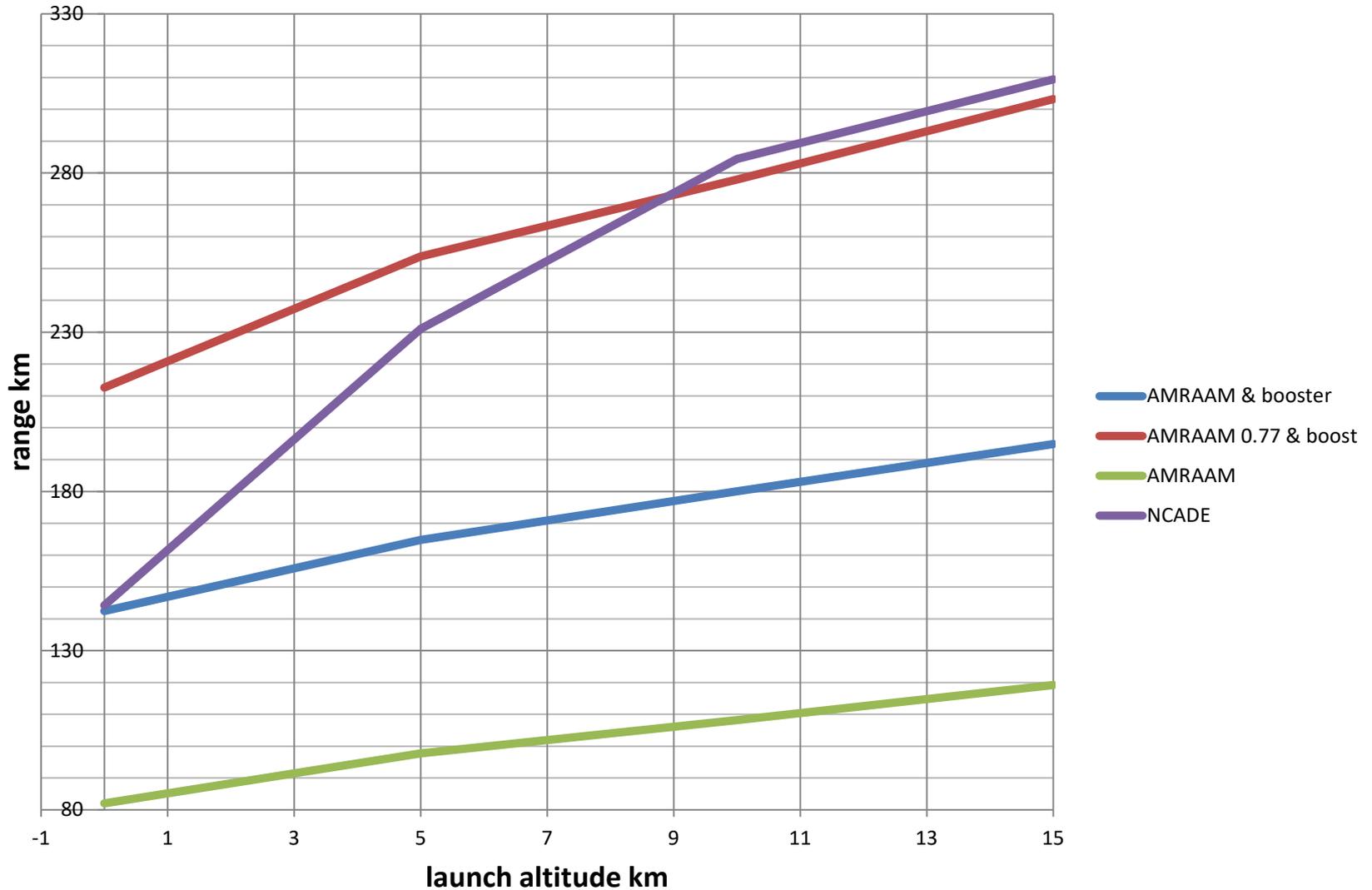
# 20. Theater (400 km SCUD C) intercept



# 21. Theater Engagement times



## 22. Options for intercept at N. Korea range



# 23. Survivability

- VHF radars cannot effectively engage US fighters on CAP.
- Limited number Vietnam-era SAMs are not a threat to stand-off fighters.
- x-band Flap Lid (if available) for fire control, limited search
  - Key elements missing: Big Bird, Clam Shell
  - Cannot penetrate terrain masking, so U.S. assets survivable at low altitudes
- High-altitude radars detected, jammed, attacked by KN-06 (~ S-300?)
  - vulnerable to barrage jammers
  - jammers near launcher block or degrade radar until missile underway
  - LPI and freq hop improve odds, but looking down from above unfavorable ECCM
- Not issue for low altitude looking up
  - Difficult to detect
  - masked by terrain if detected, main lobe above horizon
  - Unfavorable ECM geometry for opponent
- AMRAAM intercept in transit to missile
  - Unsymmetrical engagement where opponent chooses time, knows trajectories
  - Variation of standoff, AMRAAM reduces opponent advantage
  - Opponent interceptor also vulnerable
  - interceptor, sensor, fire control radar susceptible to ECM, attack
  - exhaustion by multiple AMRAAMs fired at each missile

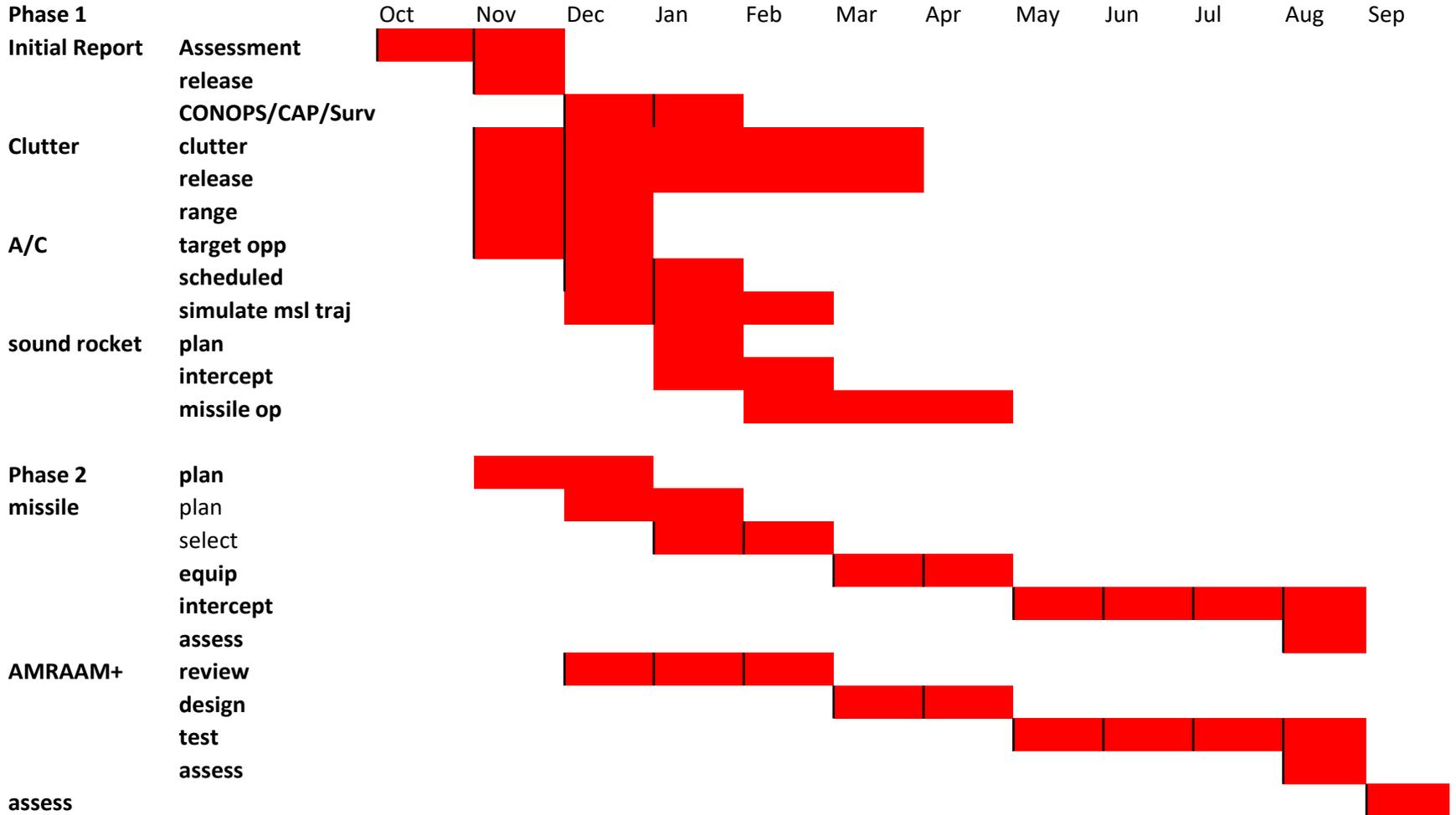
# 24. Concept of Operation

- Radar detects missile, inserts coordinates
  - Check reliability, readiness of sensors & AMRAAM
- Pilot reorient A/C to firing position, if needed
  - launch AMRAAM
- A/C radar track, direct, or divert, if needed
  - No need external sensors or input
  - For established TOR
- Flexible, adaptable Combat Air Patrol
  - min 1 fighter/Launch x no. sites x 3-4 x 2 days on warning
  - At altitude masked by terrain from DPRK radars
  - Launch AMMRAM from there at 5 - 10% penalty
- Permits 4<sup>th</sup> generation & Allied participation

# 25. Senior Operator Issues

- Orbits close to N. Korea
- N. Korea IAD
- 10 km alt vulnerable
- 5<sup>th</sup> gen not available
- AMRAAM intercept up
- Number A/C needed
- Contingency CAP
- RPV w/ sensors to detect
- Satellite constellation
- Fly low, masked
- Limited assets, VHF
- Can fly low, masked
- 4<sup>th</sup> gen adequate, available
- Horizontal at altitude
- $\geq 1$  /site x 2 sites x 3-4
- On warning for ICBM
- Detection not problem
- Delayed

# 26. Integration & Test



# 27. Summary and Conclusions

- DPRK progress in nuclear weapons and ICBMs rapid
- Fighters, radars, AMRAAM adequate & deployed
  - Need test of prompt release, clutter & deployment
  - Prompt warning essential, available with aircraft radar
  - Immediate warning & track to pilot in all weather
- Pulse Doppler radars detect, track at  $\approx 100$  km, 10sec
  - Issue: current radar detection at low Doppler velocity
- Clutter processing at 4<sup>th</sup> gen level adequate
  - Significant role for 4<sup>th</sup> gen and Allies
- Stop DPRK development, provide 2-layer defense, preferential
- CONOPS flexible, survivable
- Intercept Gulf & Straits missiles similar DPRK ICBM
  - Engage interceptors using fast detection, given fuseing, HE warhead
- Integration & test fast with developed components