MIT
Science, Technology, and
National Security Working Group

# Airborne Patrol to Destroy DPRK ICBMs in Powered Flight

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## Purpose and Motivations for the *Airborne Patrol Against DPRK ICBMs*

### Summary

The DPRK has demonstrated missiles with near-ICBM range and tested underground nuclear or thermonuclear explosives of yield estimated to be 100 or even 250 kilotons—comparable in yield to many of the current U.S. strategic warheads. Although there is not evidence that the DPRK has mastered the technology of a ruggedized warhead and reentry vehicle that would survive the 60 G deceleration and heating of atmospheric reentry at ICBM range, they could do so in time.

It is also not clear that any of the DPRK's nuclear weapons can yet be carried to ICBM range, but that also is only a matter of time.

We sketch here an "*Airborne Patrol System to Destroy DPRK ICBMs in Powered Flight*" incorporating the well established MQ-9 Reaper (Predator B) remotely piloted aircraft (RPA), The Big Wing version of the MQ-9 has a loiter time of some 37 hours at 500 miles from its airbase in South Korea or Japan, carrying two Boost-Phase Intercept missiles assembled of available rocket motors, e.g., from Orbital ATK. A two-stage rocket would provide 4 km/s, with a 75 or 55 kg homing payload providing an additional 2.0 or 1.5 km/s divert velocity, and carrying a 25 kg seeker that would home optically on the booster flame and the ICBM's hard body.

All of the technologies needed to implement the proposed system are proven and no new technologies are needed to realize the system .

The baseline system could technically be deployed in 2020, and would be designed to handle up to 5 simultaneous ICBM launches.

The potential value of this system could be to quickly create an incentive for North Korea to take diplomatic negotiations seriously and to destroy North Korean ICBMs if they are launched at the continental United States.

The proposed *Airborne Patrol System* could be a "first-step system" that can be constantly improved over time. For example, we have analyzed the system assuming that interceptors have a top speed of 4 km/s with a 25 kg seeker. We believe that faster, or lighter and smaller interceptors can be built that would increase the firepower of the system and *possibly* its capability against somewhat shorter range ballistic missiles like the Nodong – which poses a threat to Japan.

Since the *Airborne Patrol System* would be based on the use of drones that would loiter outside of North Korean airspace, the electronic countermeasures needed to defeat distant surface-to-air missile defenses would be easy to implement because of the long-range between the drones and the air-defense radars.

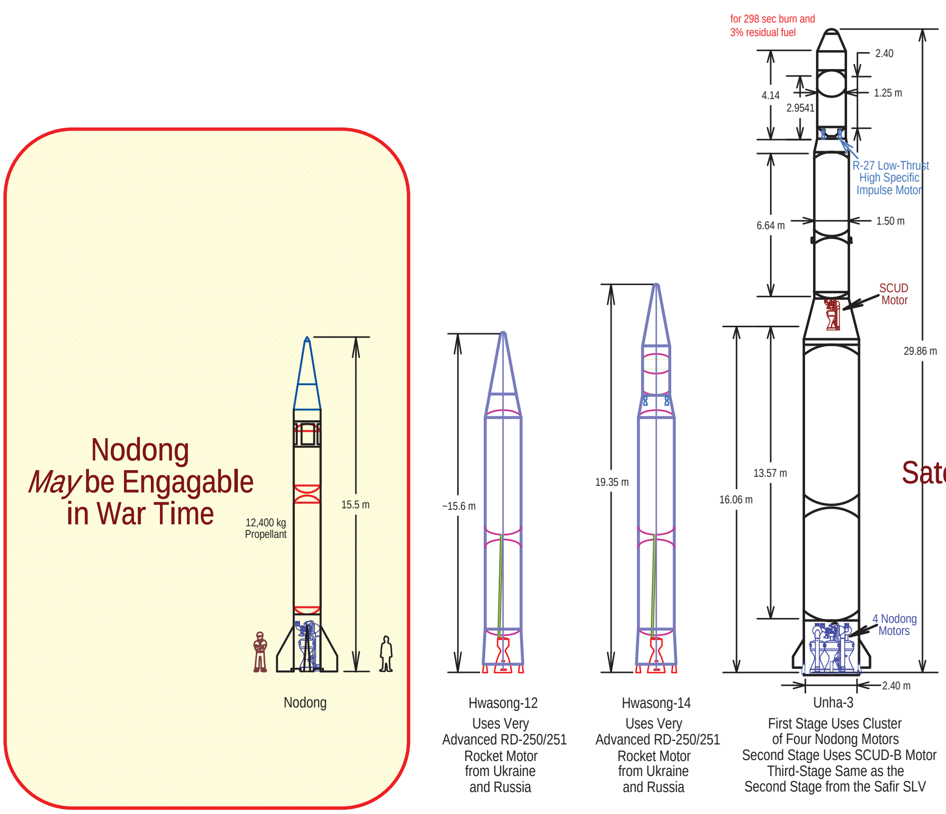
The availability of relatively inexpensive high-payload long-endurance drones will also improve, along with the electronic countermeasures systems to protect them.

# Key Patrol System Elements

- Ballistic Missile Targets to Be Engaged
- Attack Interceptors
- Platforms for Attack Interceptors

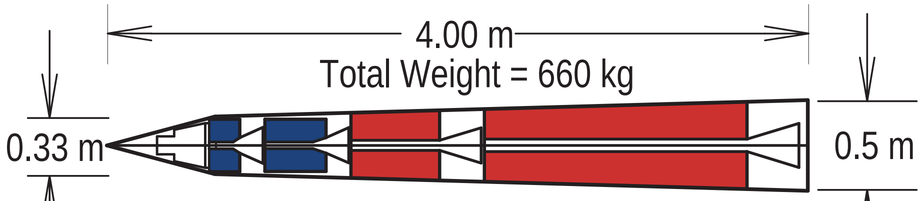


## North Korean Missiles and Satellite Launch Vehicles that Can Be Destroyed After Launch at Will

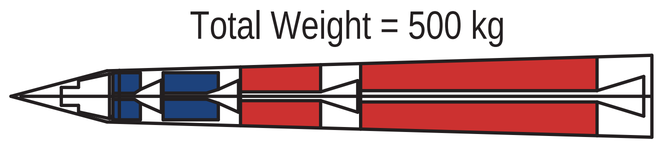



Missiles and Satellite Launch Vehicles that Can Be Destroyed at Will

## Estimated Weight and Propulsion Characteristics of 4+ Km/Sec Airborne Interceptor that Uses Achievable Rocket Motor Technologies




Interceptor with 25 kg Optical and Homing Payload
and Additional **2km/sec** Divert Velocity




Interceptor with 25 kg Optical and Homing Payload
and Additional **1.5km/sec** Divert Velocity

**Attack Interceptor with Kill Vehicle that has ΔV=2 km/sec**

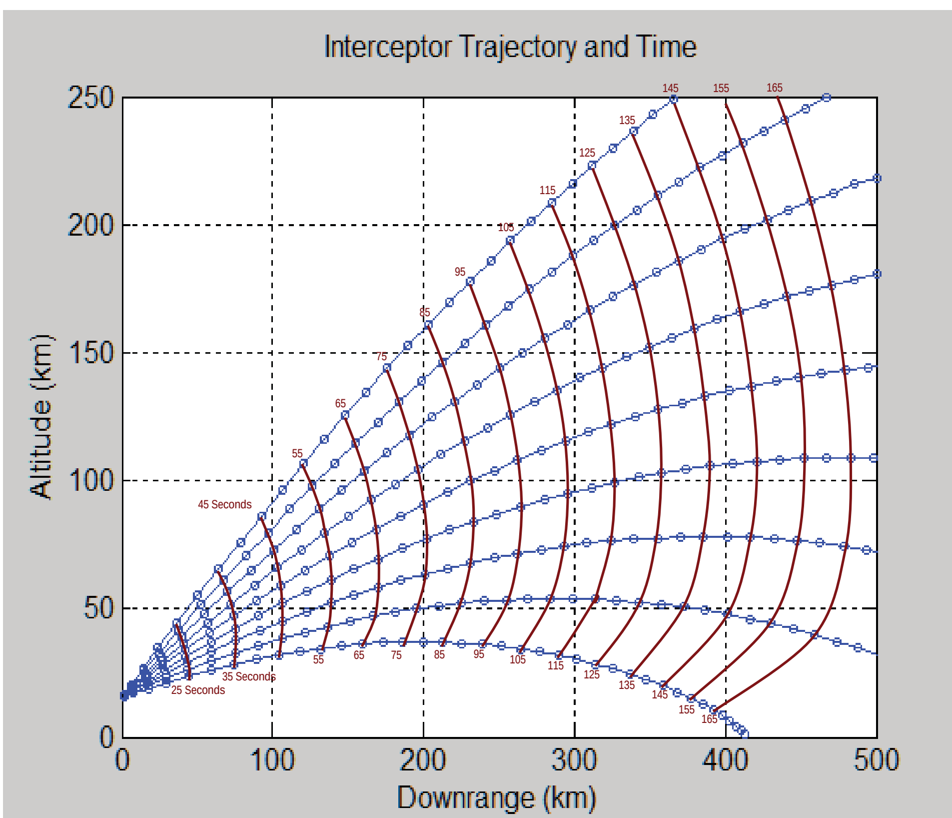
| | |
|---|---|
| Total Weight of Interceptor | 1449.43 lbs (657.34 kg) |
| Payload Weight | 165.38 lbs ( 75.00 kg) |
| Speed at Burnout | 4.00 km/s |
| First Stage Motor Weight | 959.84 lbs (435.30 kg) |
| First Stage Propellant Weight | 767.87 lbs (348.24 kg) |
| First Stage Structural Weight | 191.97 lbs ( 87.06 kg) |
| First Stage Structure Factor | 0.20 |
| First Stage Specific Impulse | 270 sec |
| First Stage Burnout Speed | 2.00 km/s |
| Second Stage Motor Weight | 324.22 lbs (147.04 kg) |
| Second Stage Propellant Weight | 259.37 lbs (117.63 kg) |
| Second Stage Structural Weight | 64.84 lbs ( 29.41 kg) |
| Second Stage Structure Factor | 0.20 |
| Second Stage Specific Impulse | 270 sec |
| Second Stage Burnout Speed | 2.00 km/s |
| Thrust Level of First Stage | 20446.79 lbs (9272.92 kgF) |
| Thrust Burn Time of First Stage | 10.14 seconds |
| Thrust Level of Second Stage | 4604.37 lbs (2088.15 kgF) |
| Thrust Burn Time of Second Stage | 15.21 seconds |

**Attack Interceptor with Kill Vehicle that has ΔV=1.5 km/sec**

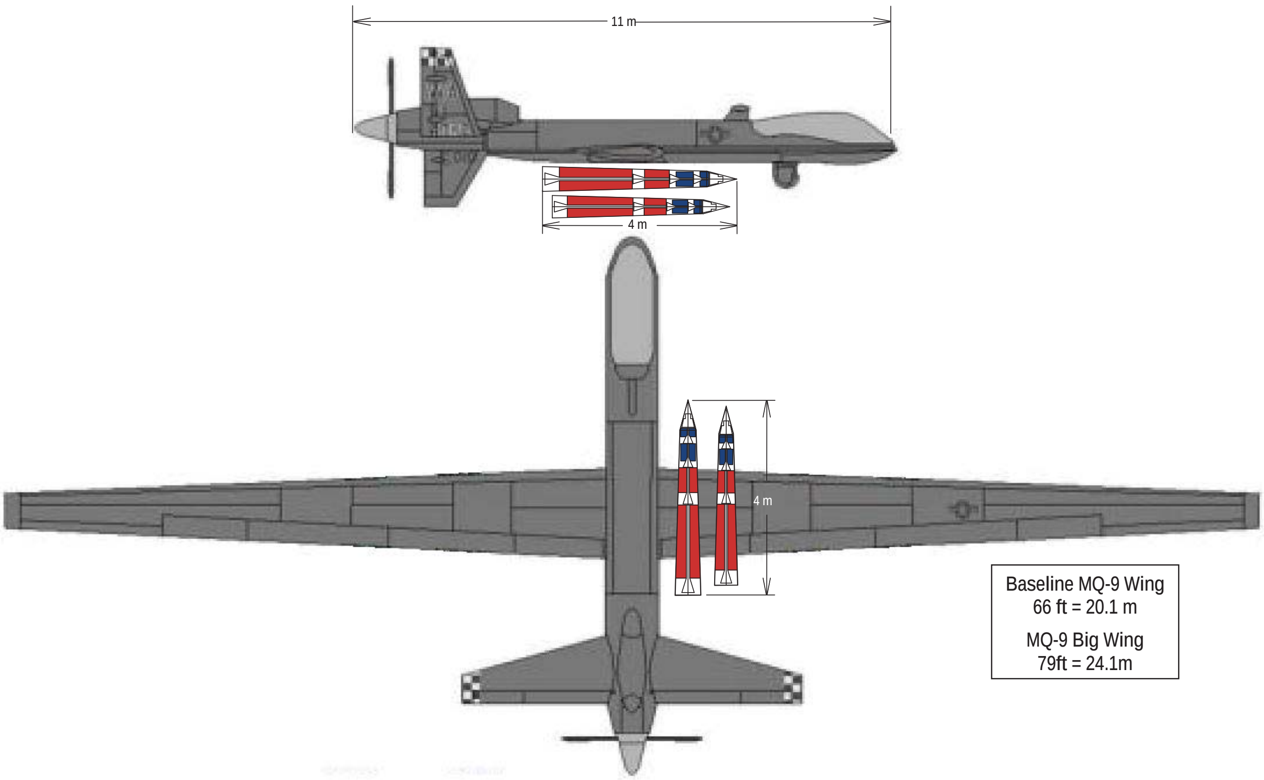
| | |
|---|---|
| Total Weight of Interceptor | 1082.24 lbs (490.81 kg) |
| Payload Weight | 123.48 lbs ( 56.00 kg) |
| Speed at Burnout | 4.00 km/s |
| First Stage Motor Weight | 716.68 lbs (325.03 kg) |
| First Stage Propellant Weight | 573.34 lbs (260.02 kg) |
| First Stage Structural Weight | 143.34 lbs ( 65.01 kg) |
| First Stage Structure Factor | 0.20 |
| First Stage Specific Impulse | 270 sec |
| First Stage Burnout Speed | 2.00 km/s |
| Second Stage Motor Weight | 242.08 lbs (109.79 kg) |
| Second Stage Propellant Weight | 193.67 lbs ( 87.83 kg) |
| Second Stage Structural Weight | 48.42 lbs ( 21.96 kg) |
| Second Stage Structure Factor | 0.20 |
| Second Stage Specific Impulse | 270 sec |
| Second Stage Burnout Speed | 2.00 km/s |
| Thrust Level of First Stage | 15266.93 lbs (6923.78 kgF) |
| Thrust Burn Time of First Stage | 10.14 seconds |
| Thrust Level of Second Stage | 3437.93 lbs (1559.15 kgF) |
| Thrust Burn Time of Second Stage | 15.21 seconds |



## Trajectories that Can be Flown by Interceptor with 25 Second Acceleration Time and 4 km/sec Burnout Speed



## Relatively Inexpensive Drone that Is Already Available and Tested*






## Drone-Based Systems for Post-Launch Precision Tracking to Support Interceptor Homing

### System Precision Tracking on Drones

- Each deployed interceptor carrying drone available for stereo viewing of boosting targets
- Focal plane array operating in the 3-5 micron wavelength band for above cloud tracking
- Focal plane array operating in the 0.5-2.2 microns wavelength band for see-to-the ground detection
- Small field-of-view focal plane array video in the visible wavelengths for tracking and kill assessment

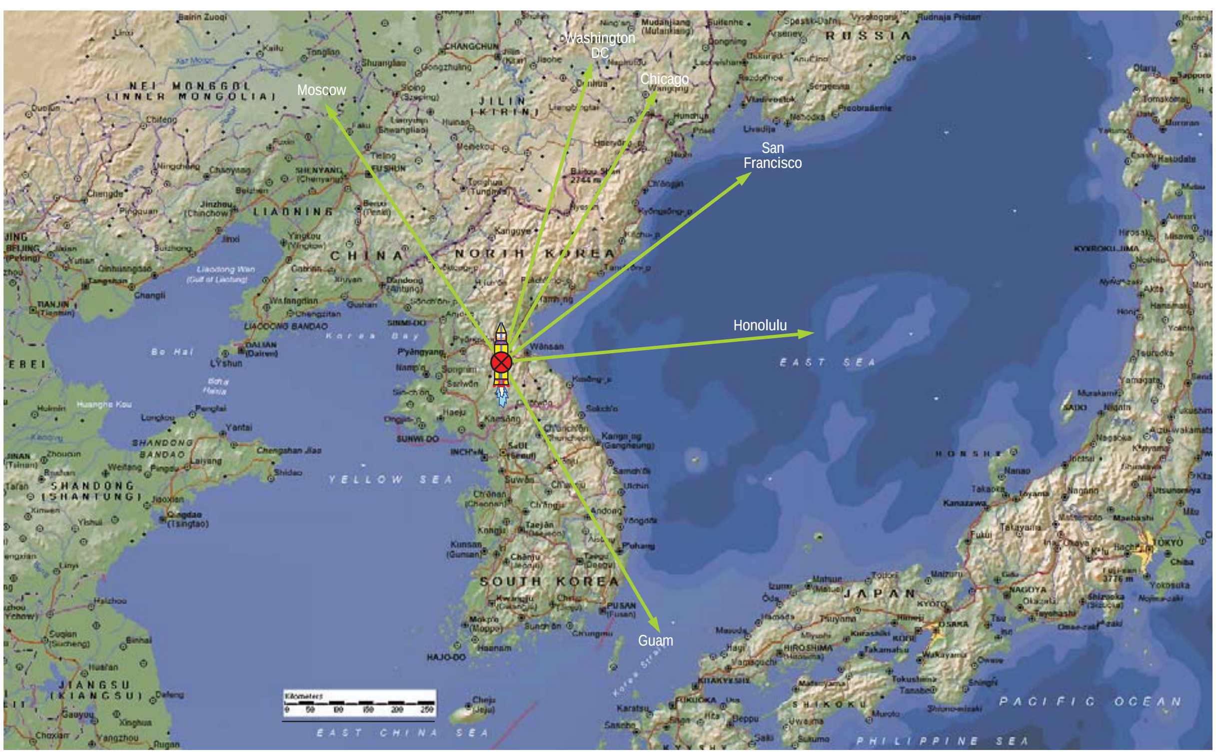
### Homing Sensor on Interceptor

- Focal plane array operating in the 3-5 microns wavelength band for long-range homing
- Megapixel visible or near-infrared focal plane array for accurate long-range images of target body
- Laser illuminator and lidar for endgame target details and range-to-target data

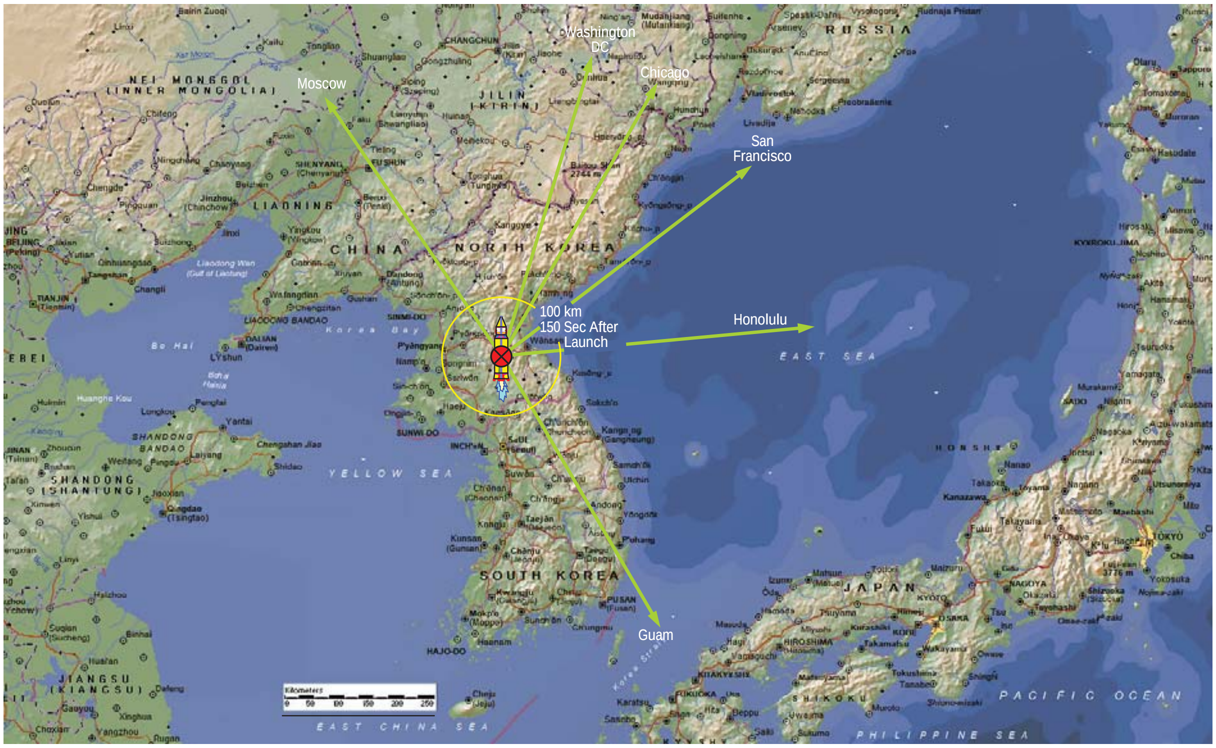
# Geographical and Military Factors Relevant to the Deployment and Operation of the Attack System



## Directions to Different Target Cities or Military Bases for the Hwasong-12 or Hwasong-14 Long-Range Missiles

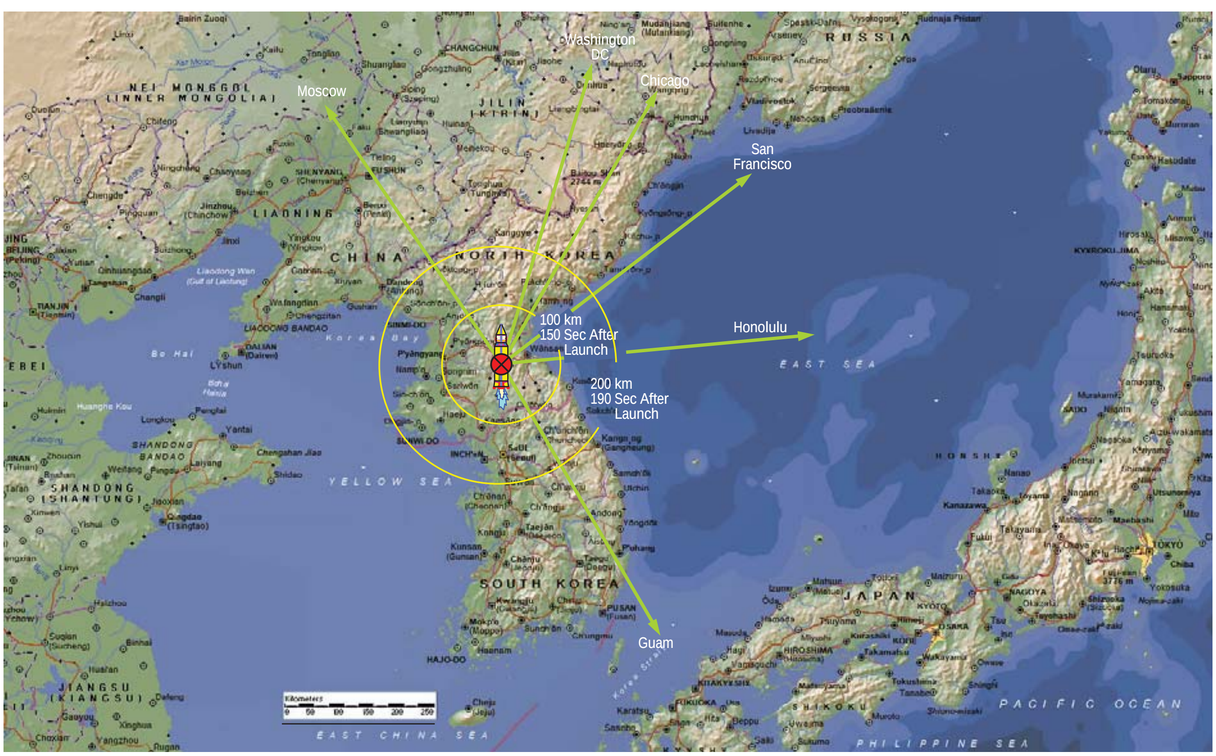


## Distance Travelled by Hwasong-12 and Hwasong-14 During the First 150 Seconds of Powered Flight

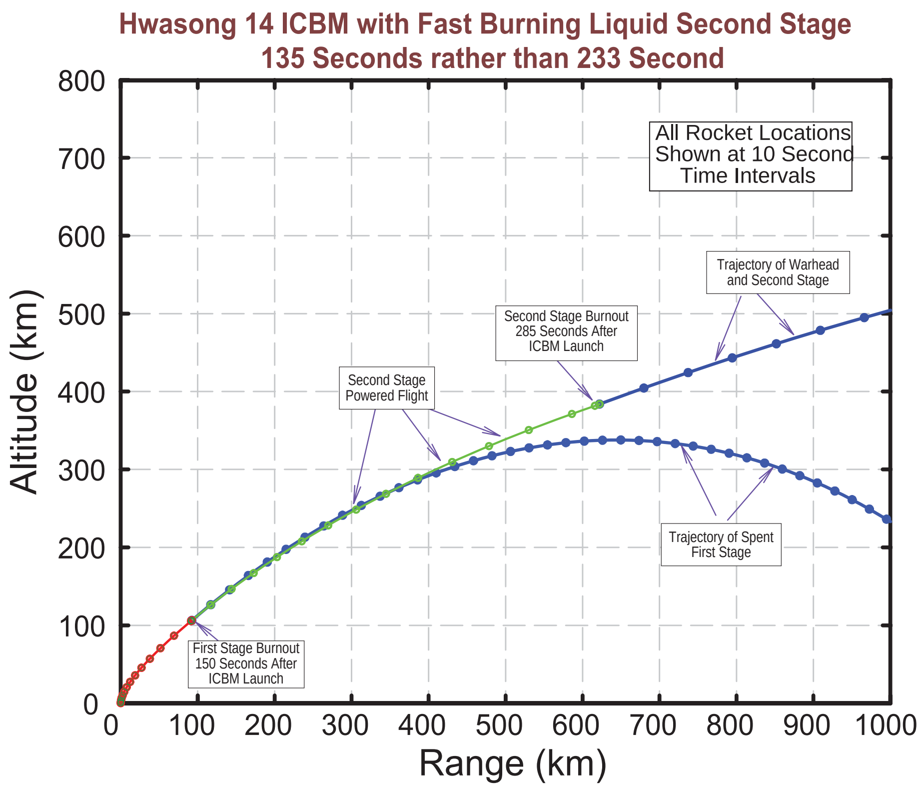





## Distance Travelled by *Upgraded* Hwasong-14 Second Stage During the First 190 Seconds of Powered Flight (40 Seconds After Staging))



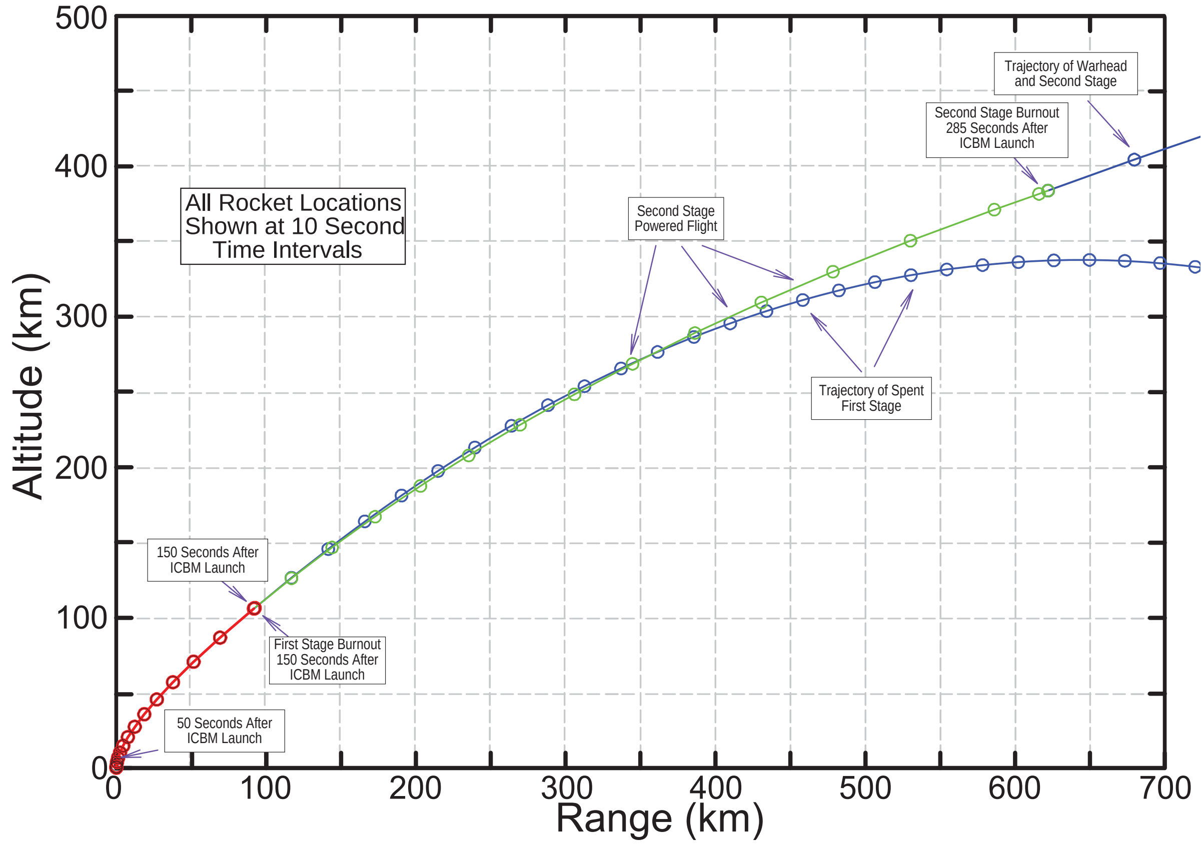
# Powered Flight and Initial Coast Trajectories of the First Stage and Payload of an Upgraded Hwasong-14 North Korean ICBM*



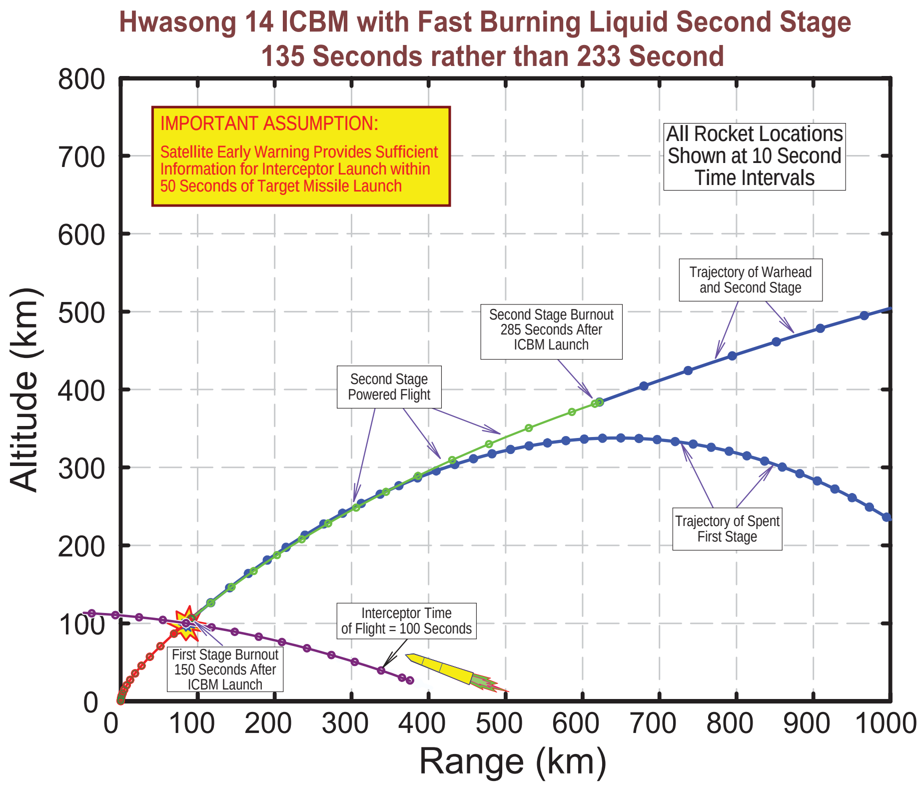

* The upgraded Hwasong-14 assumes a second stage that uses four vernier motors from the R-27 SLBM. The actual Hwasong-14 tested on July 4 and July 28, 2016 has only two vernier engines and has an upper stage powered flight time twice as long as the presumed "upgraded" Hwasong-14 shown here.



# Early Powered Flight and Initial Coast Trajectories of the First Stage and Payload of an Upgraded Hwasong-14 North Korean ICBM*



# Interceptor Lethal Engagement Range against the Hwasong-12 or the First Stage of the Hwasong-14 Is About 320+ Kilometers

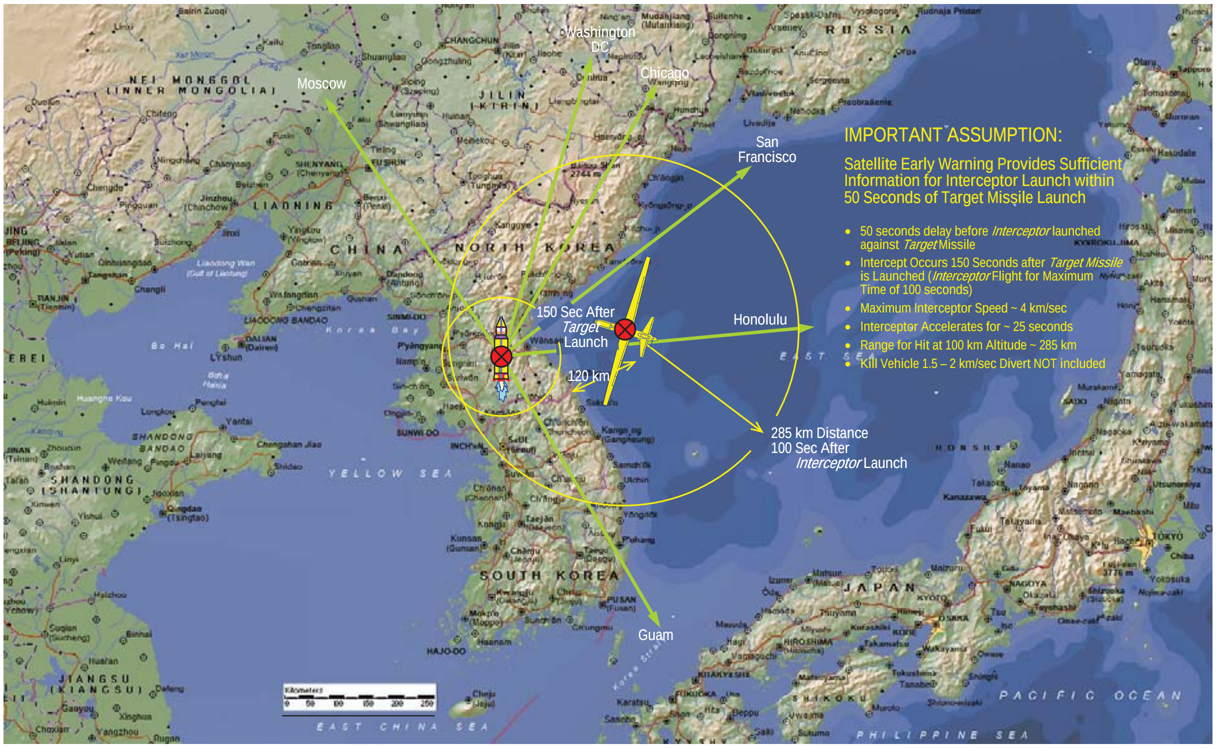



* The upgraded Hwasong-14 assumes a second stage that uses four vernier motors from the R-27 SLBM. The actual Hwasong-14 tested on July 4 and July 28, 2016 has only two vernier engines and has an upper stage powered flight time twice as long as the presumed "upgraded" Hwasong-14 shown here.



# Shoot-Down Capabilities Against ICBMs and Satellite Launch Vehicles

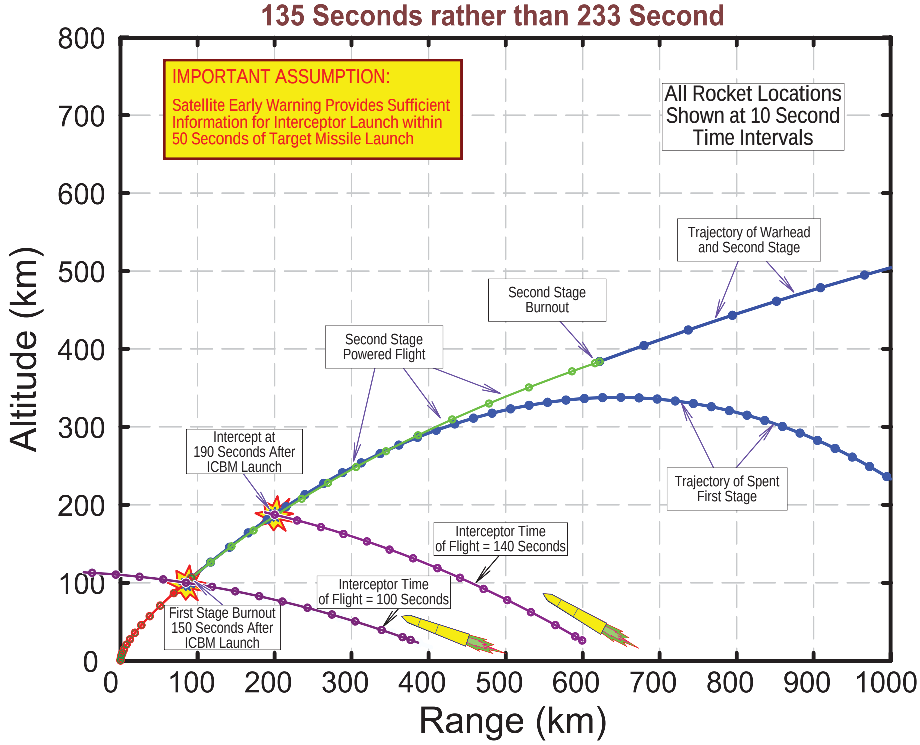
# Interceptor Lethal Engagement Range against the Hwasong-12 or the First Stage of the Hwasong-14 Is About 285+ Kilometers






# Interceptor Lethal Engagement Range against the Hwasong-14 During Early Powered Flight of Its Second Stage Is About 390+ Kilometers

**Hwasong 14 ICBM with Fast Burning Liquid Second Stage**
**135 Seconds rather than 233 Second**

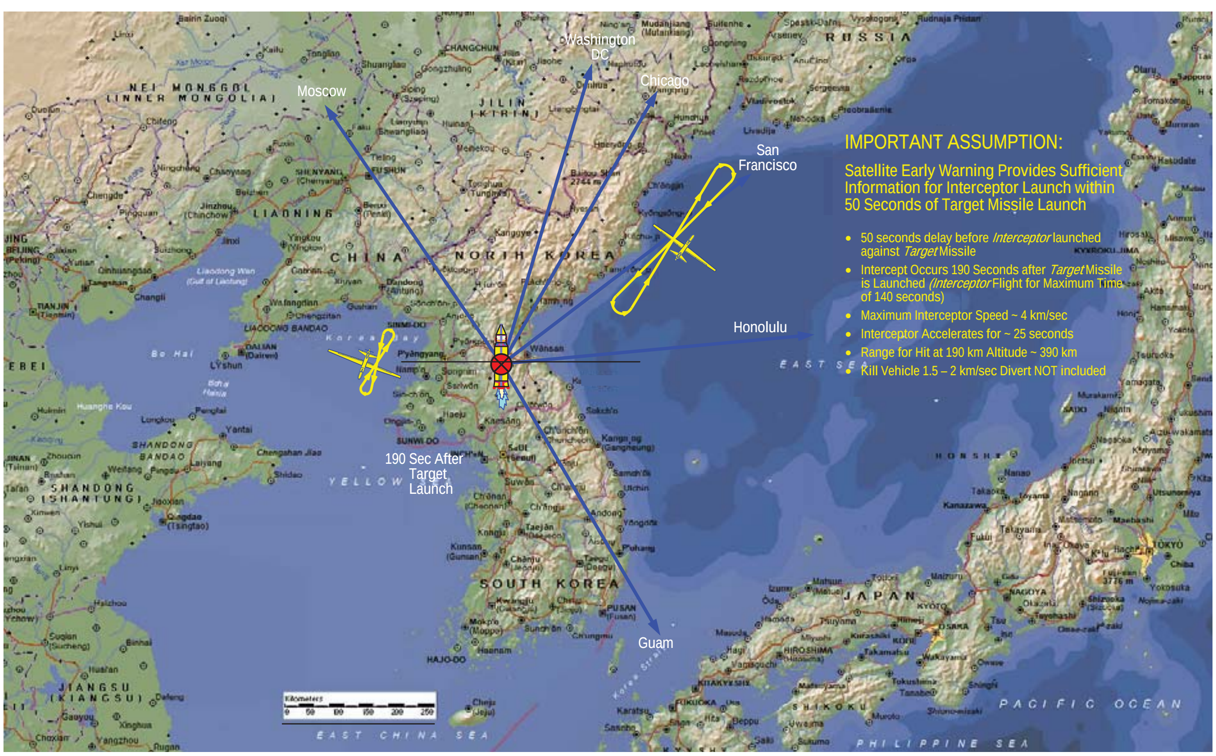



* The upgraded Hwasong-14 assumes a second stage that uses four vernier motors from the R-27 SLBM. The actual Hwasong-14 tested on July 4 and July 28, 2016 has only two vernier engines and has an upper stage powered flight time twice as long as the presumed "upgraded" Hwasong-14 shown here.

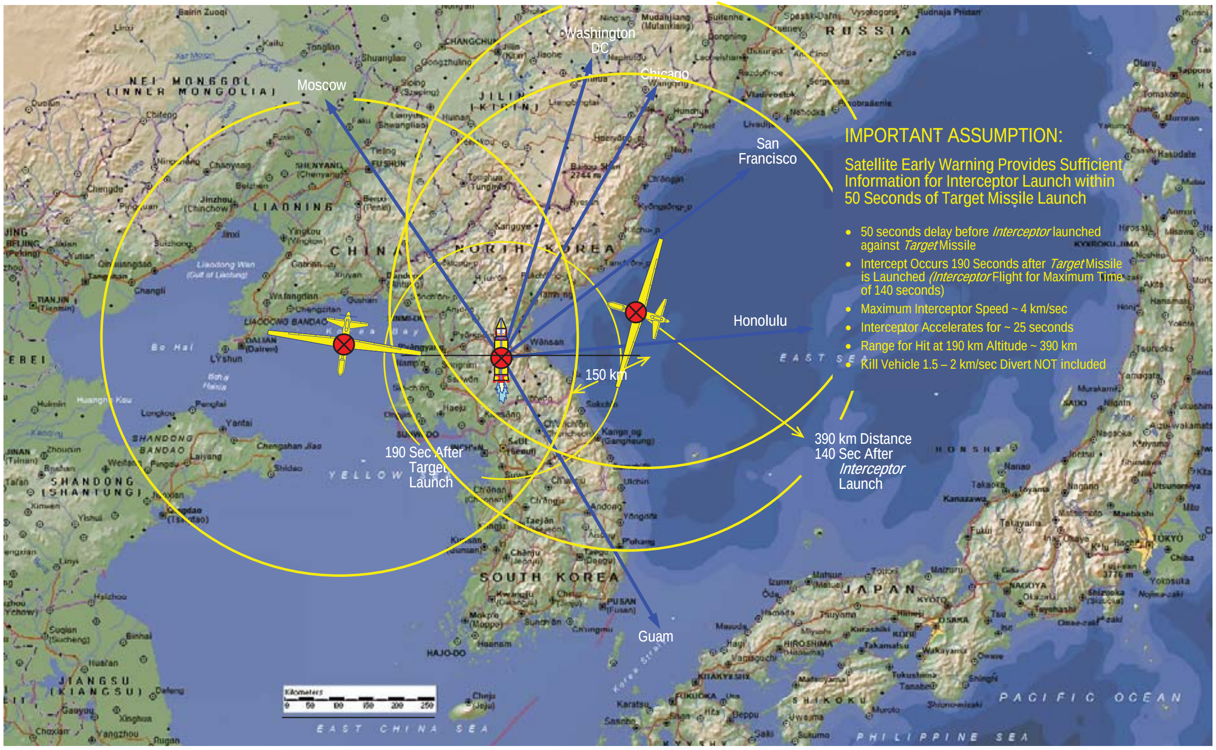
## Interceptor Lethal Engagement Range against the Hwasong-14 During Early Powered Flight of Its Second Stage Is About 390+ Kilometers




## Drone Patrol Patterns against the Hwasong-14 Intercept of Its Second Stage During Early Powered Flight Is About 390+ Kilometers

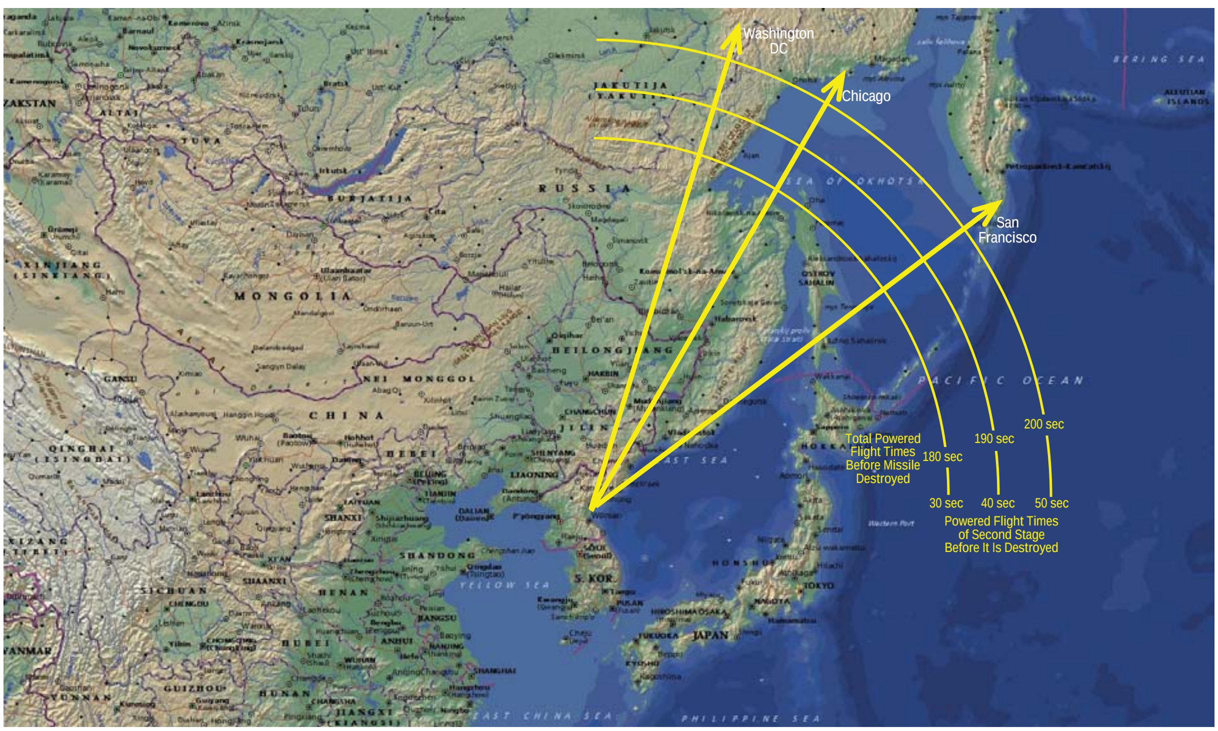


# Drone Patrol Coverage against the Hwasong-14
# Intercept of Its Second Stage During Early Powered Flight Is About 390+ Kilometers

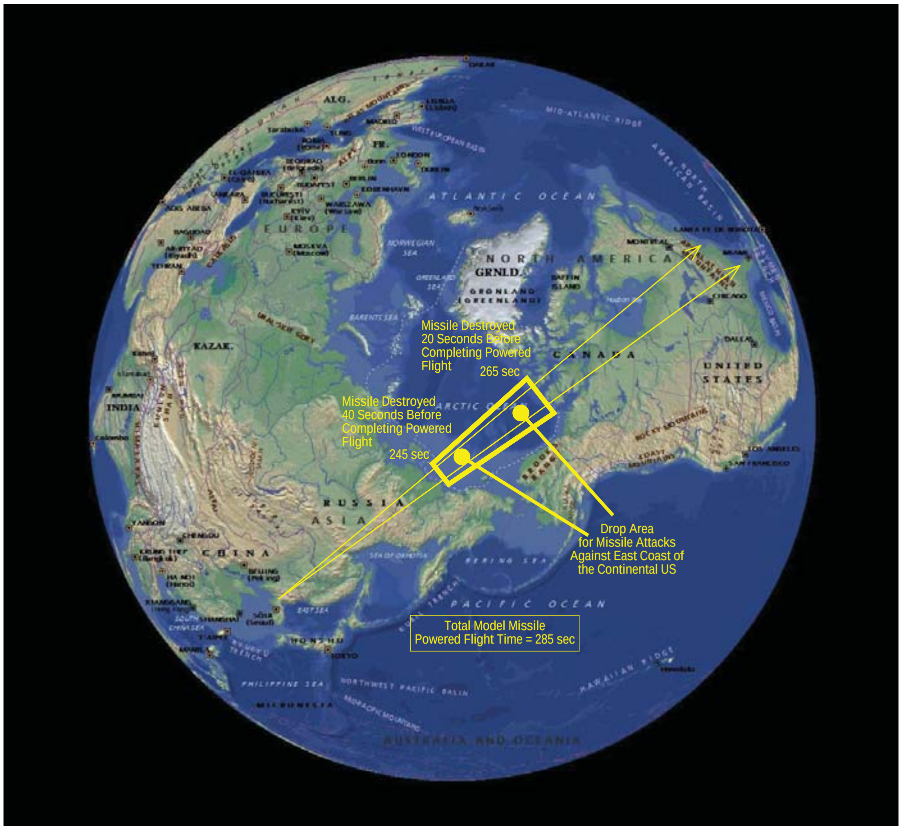





# Impact Areas of the Hwasong-14 Debris after Being Hit
# at Different Times After Launch



## Impact Areas of the Hwasong-14 Debris after Being Hit at Different Times After Launch

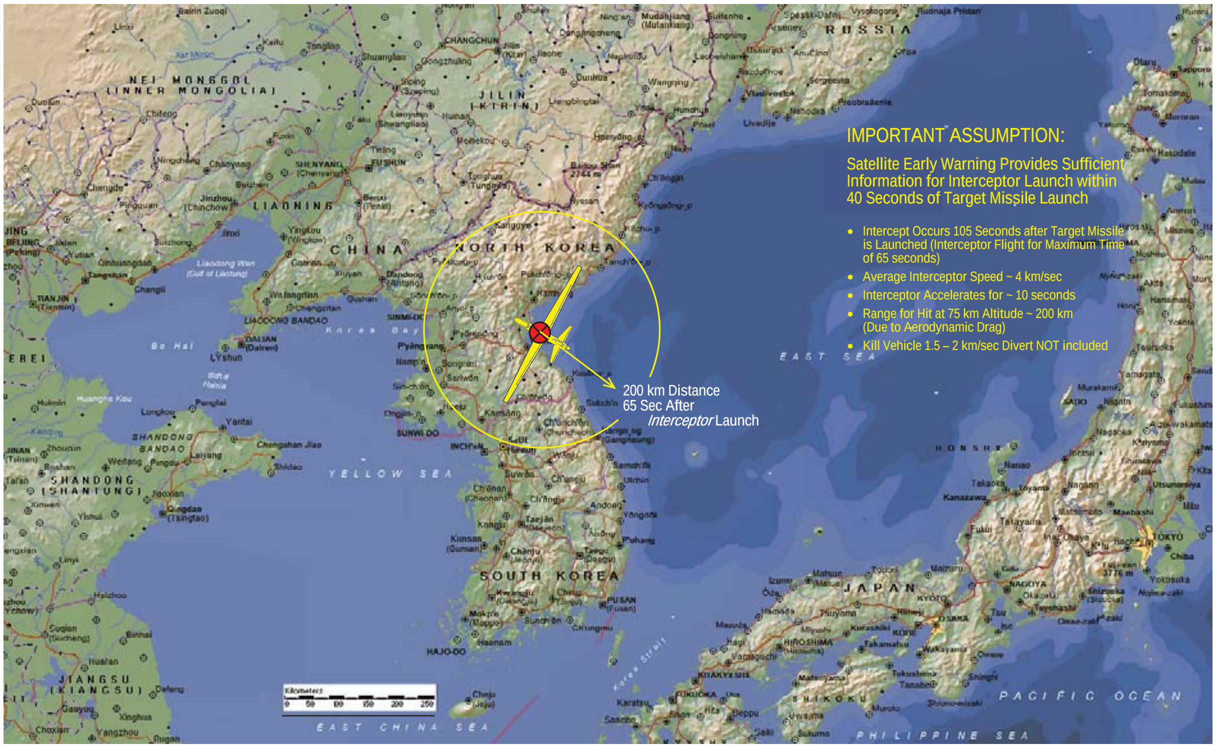





# APPENDIX

## Capabilities in War

## *If War Starts* – GO IN AFTER THE NODONGS!
## Interceptor Lethal Engagement Range against the North Korean Nodong

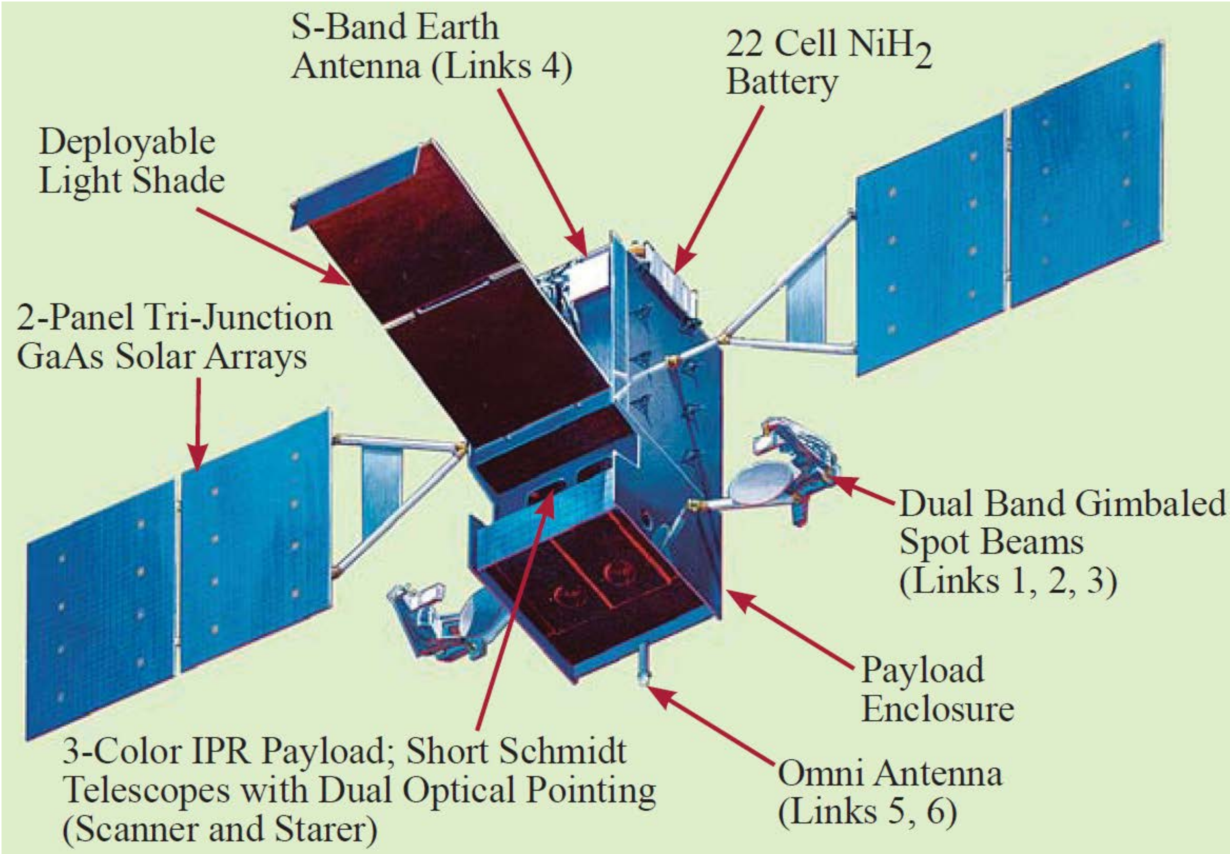





# APPENDIX

# A Key Enabling Technology
## Near Instantaneous Launch Detection and Tracking from Satellites

## The Space-Based Infrared Satellite (SBIRS) Geosynchronous Spacecraft






## Satellite Features

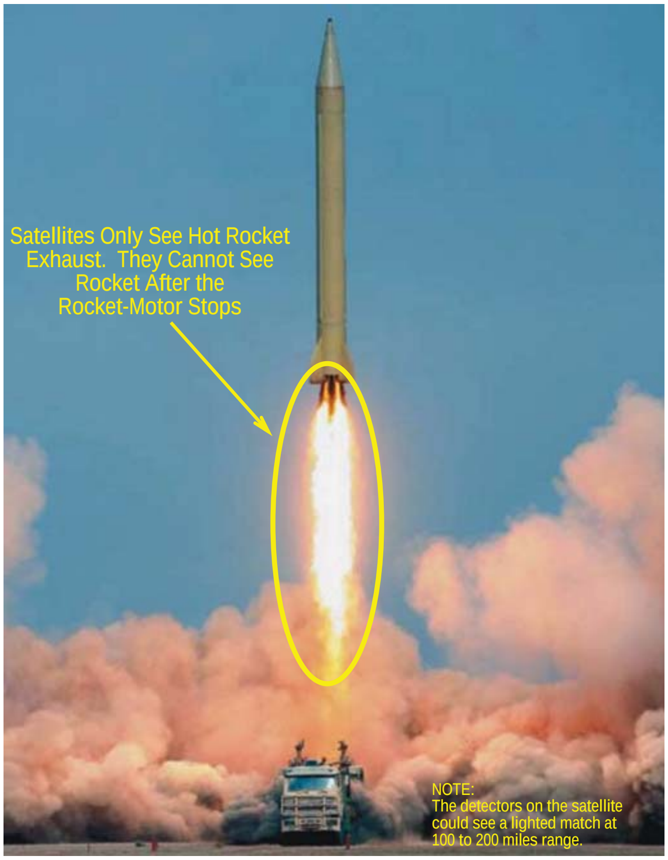
- A2100 derived spacecraft, 12-year design life, 9.8-year MMD
- ~10,000-lb predicted wet weight at launch
- 3-axis stabilized with 0.05 deg pointing accuracy; solar flyer attitude control
- RH-32 rad-hardened single board computers with reloadable flight software
- ~2800 watts generated by GaAs solar arrays
- GPS receiver with Selected Availability Secure Anti-Spoof Module (SAASM)
- ~1000-lb infrared payload: scanning and staring sensors
  - 3 colors: short-wave, mid-wave, and see-to-ground sensor-chip assemblies
  - Short Schmidt telescopes with dual optical pointing
  - Agile precision pointing and control
  - Passive thermal cooling
- Secure communications links for normal, survivable, and endurable operations

100 Mbs data-rate to ground

~500+ lb Infrared Sensor Payload: Scanning and Staring Sensors

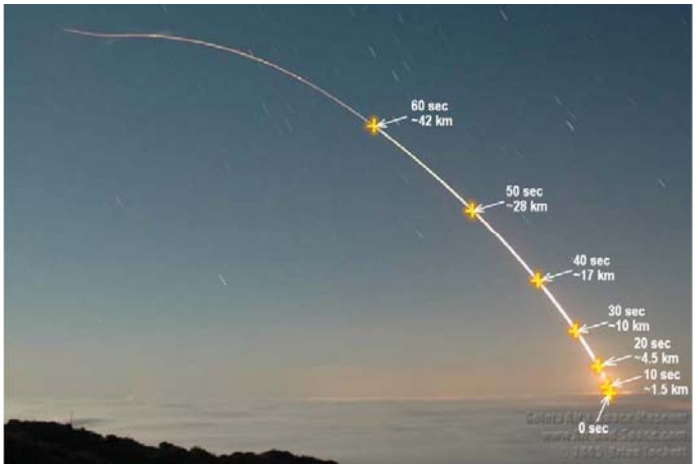
SWIR~2.69-2.95 μm, MWIR~4.3 μm, and 0.5-2.2 μm (see-to-ground)

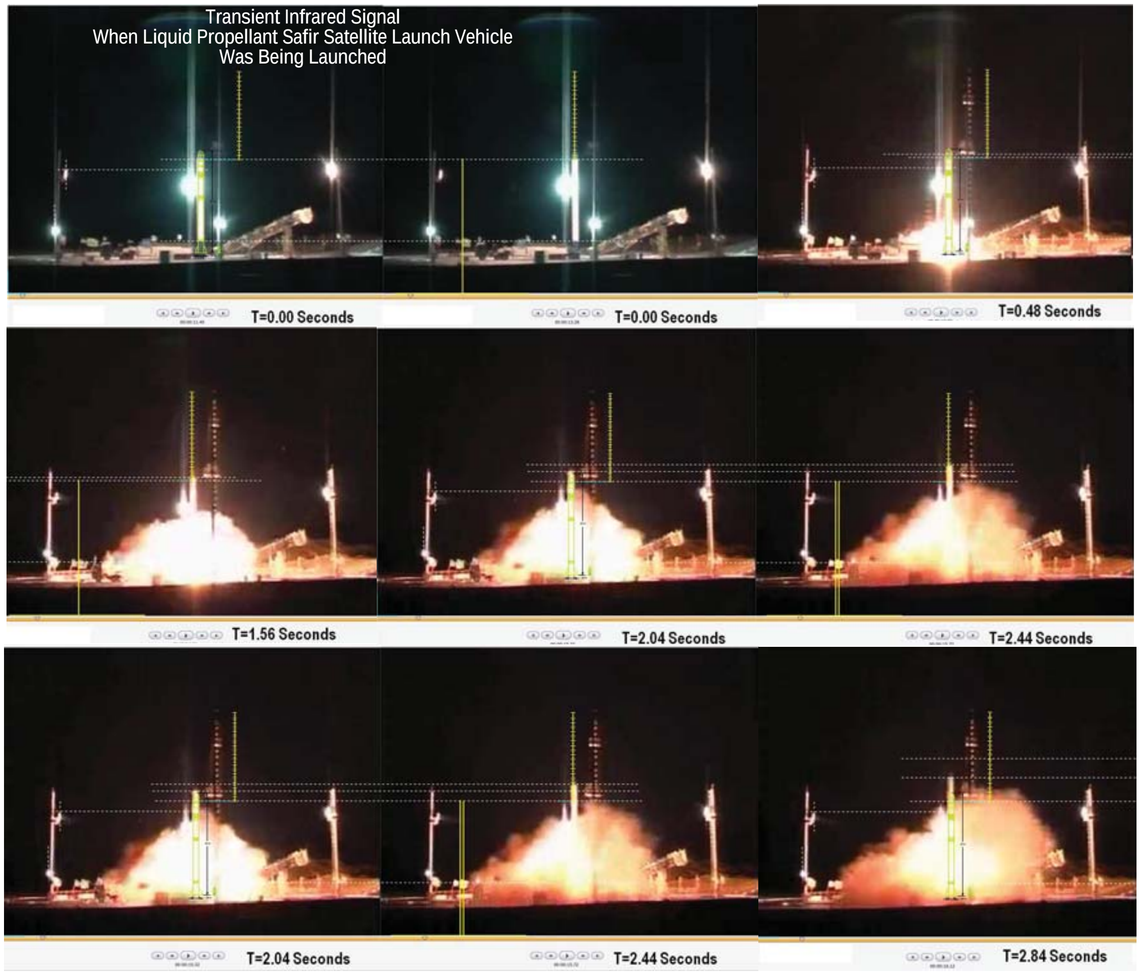
## Nearly Identical to Iranian Shahab 3, Pakistani Ghaury, and North Korean Nodong






http://www.air-and-space.com/20050914%20VAFB%20Minuteman.htm

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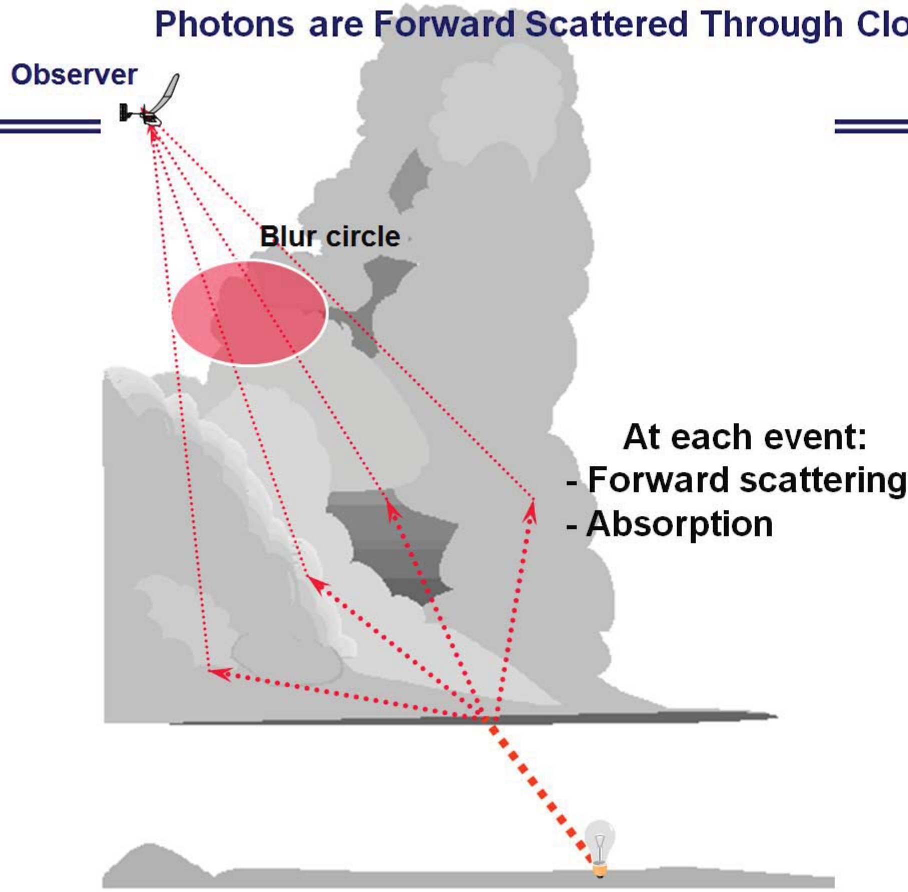
## Photons are Forward Scattered Through Clouds

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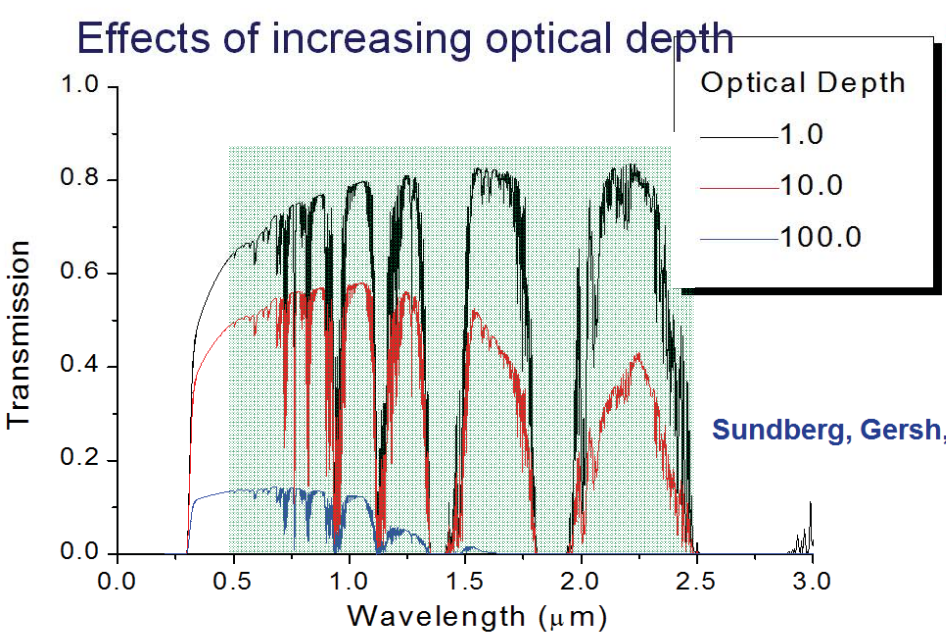
## Optical/Short Wave Infrared Observations of Missiles in Powered Flight Above and Below Heavy Cloud Cover



High Spatial Centroid Determination Achieved by Dithering and/or Pixel-to-Pixel Intensity Interpolation
Achievable Sensitivity Against Sun Backgrounds ~ $10^{-5}$ to $10^{-6}$
Achieved by Frame-to-Frame Subtraction and by Temporal Signal Variations at Ignition and During Powered Flight
Even DSP Could Easily See Aircraft and SCUD Signals Against Backgrounds (~ 20 kW/sr in-band)



## MODTRAN 4 Transmission Calculation
## 2 km Thick Cumulus Cloud
## Zoom in on Previous

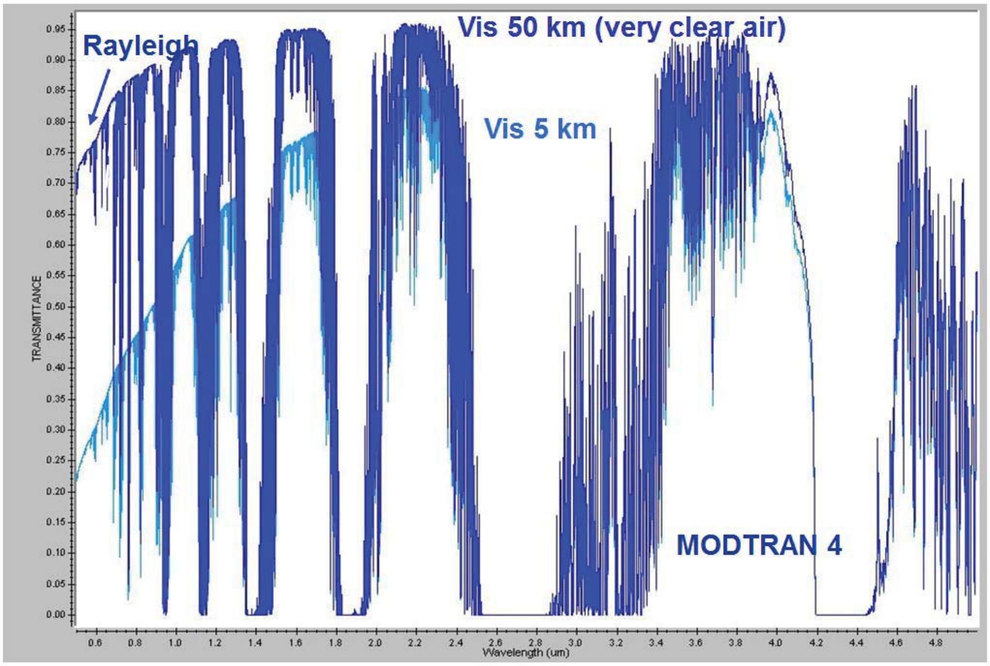



Sundberg, Gersh, & Clark 1999

**Good cloud transmission bands from 0.5-2.2 μm**

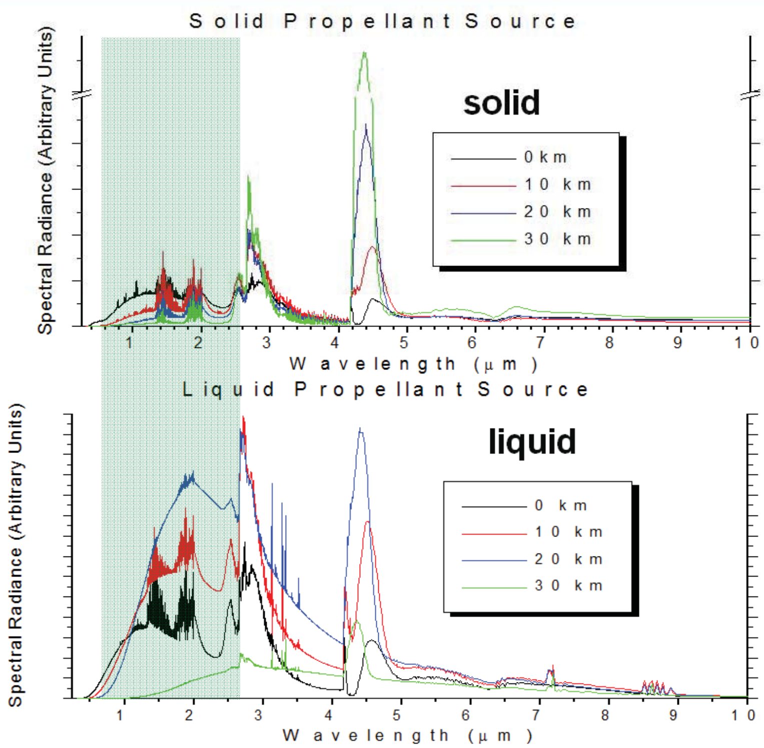
# Effects of Atmospheric Aerosol Load
## (scattering and absorption)
(no clouds)

## Clear Air





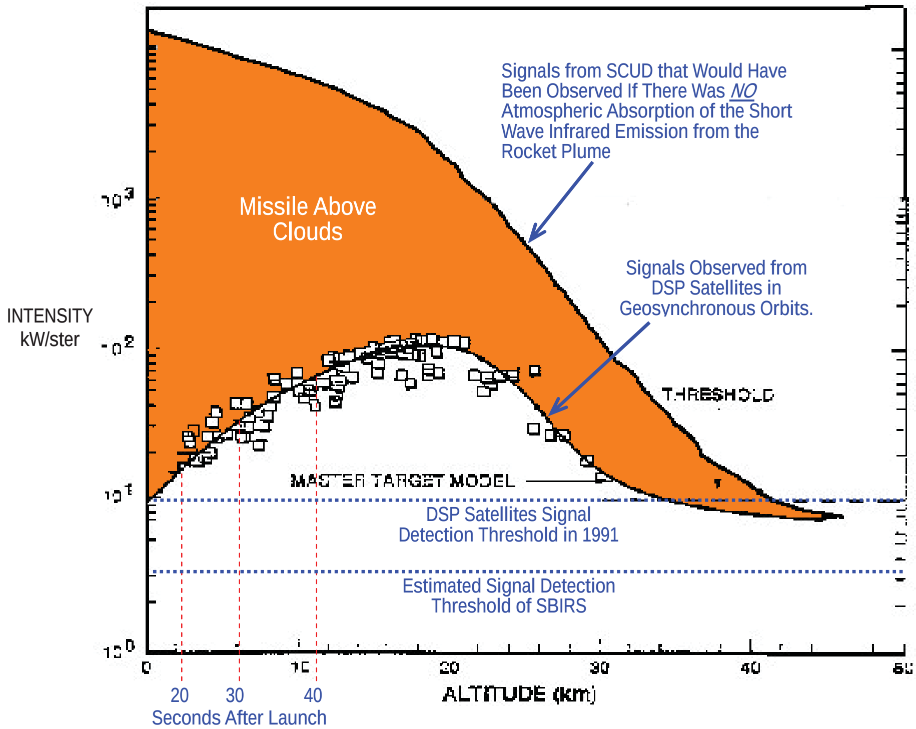

# Hot Sources at Various Altitudes
# Raw Source Radiance




non-specific models

## Short-Wave Infrared Missile Launch Signals (2.7 μm) from the DSP Satellites during the Gulf War of 1991 show that *SCUD Ballistic Missiles Were Detectable within 20 Seconds* of Their Launch

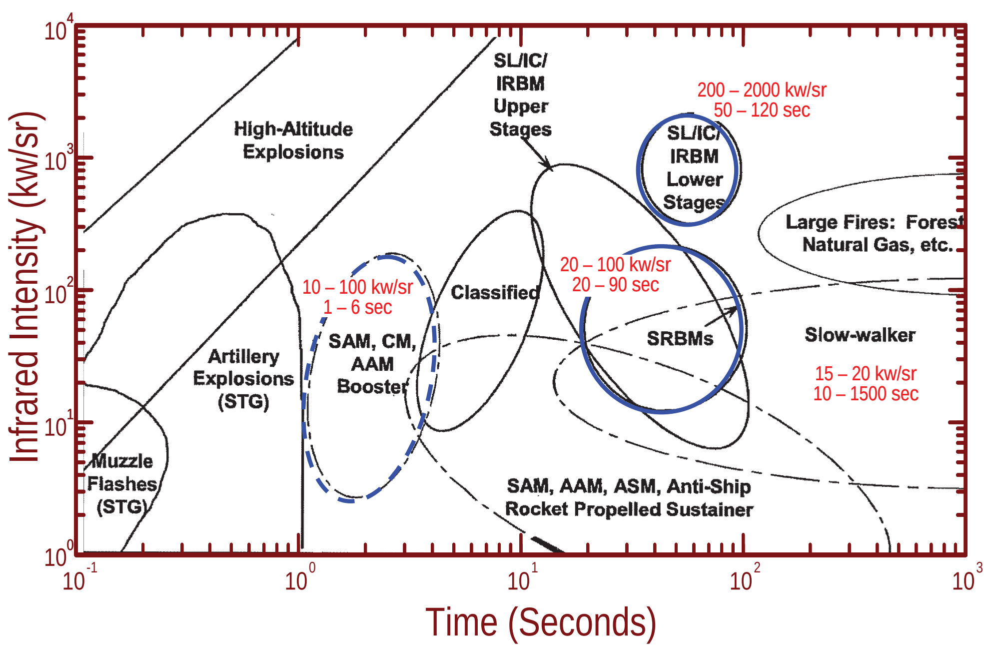
Today's Capabilities with the Space-Based Infrared System (SBIRS)
Allows for Detection of Missile Launches within A Few Tenths of Seconds after Engine Ignition








## Representative SWIR & STG Intensity and Duration of IR Events




SBIRS Transformational Capability
Col. Roger Teague
Commander, Space Group
Space Based Infrared Systems Wing
Space and Missile Systems Center
30 November 2006

Time and Intensity Axise for SBIRS Deduced from Basic Information on the Intensities and Time-Durations of Different Infrared Targets

## US Declassified Data on Peak In-Band Infrared Intensities of the First Stages of Russian and US Ballistic Missiles

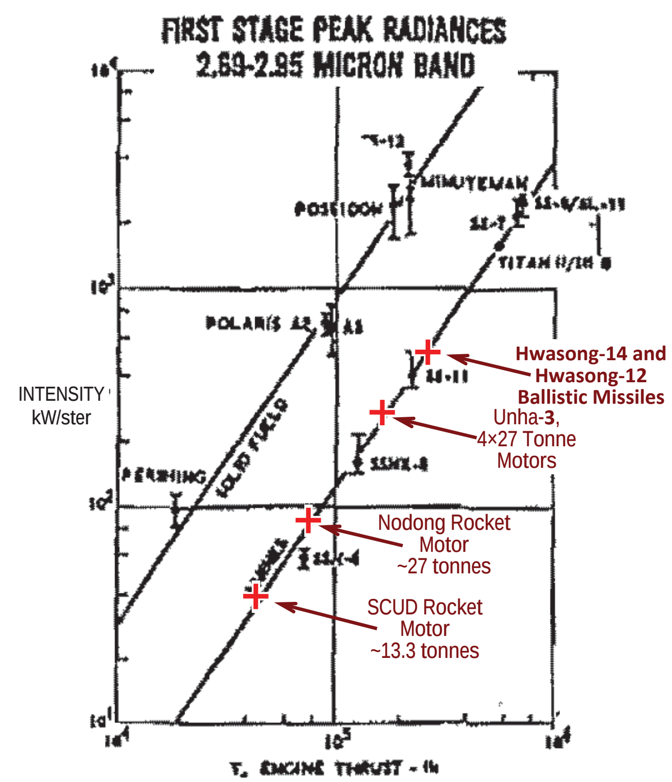
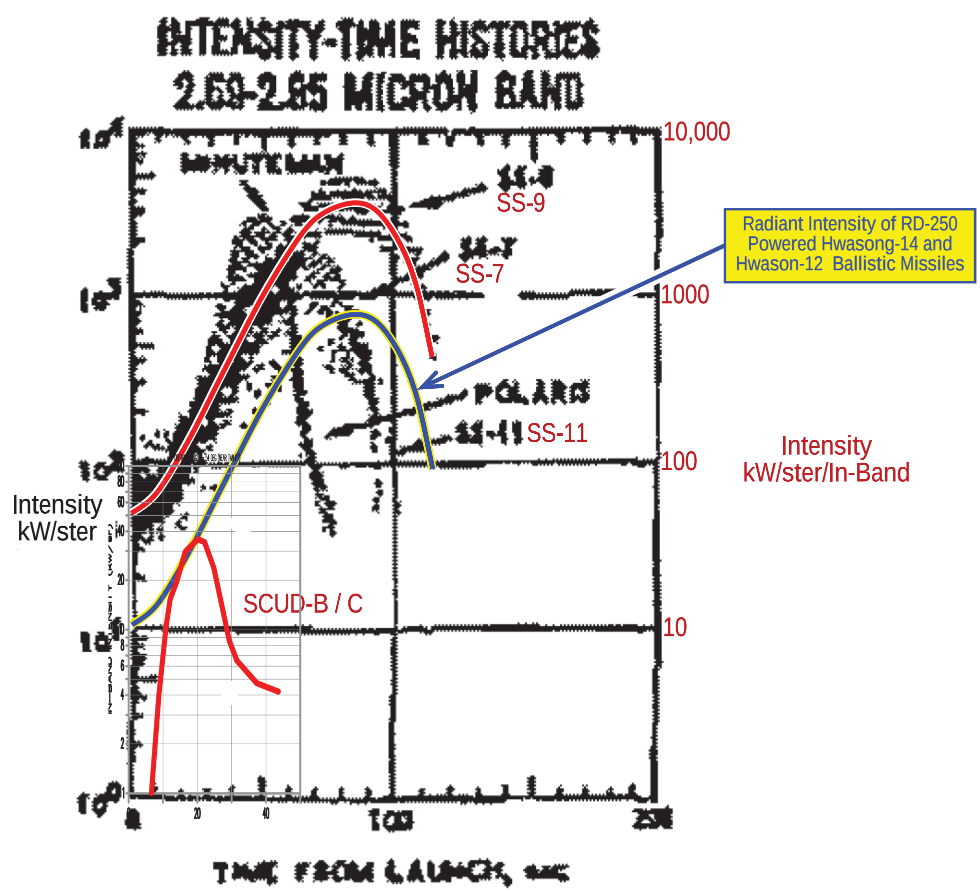



Figure 4. Target intensity. (Figure classified Secret.)



## Intensity-Time Histories of Russian and US Ballistic Missiles

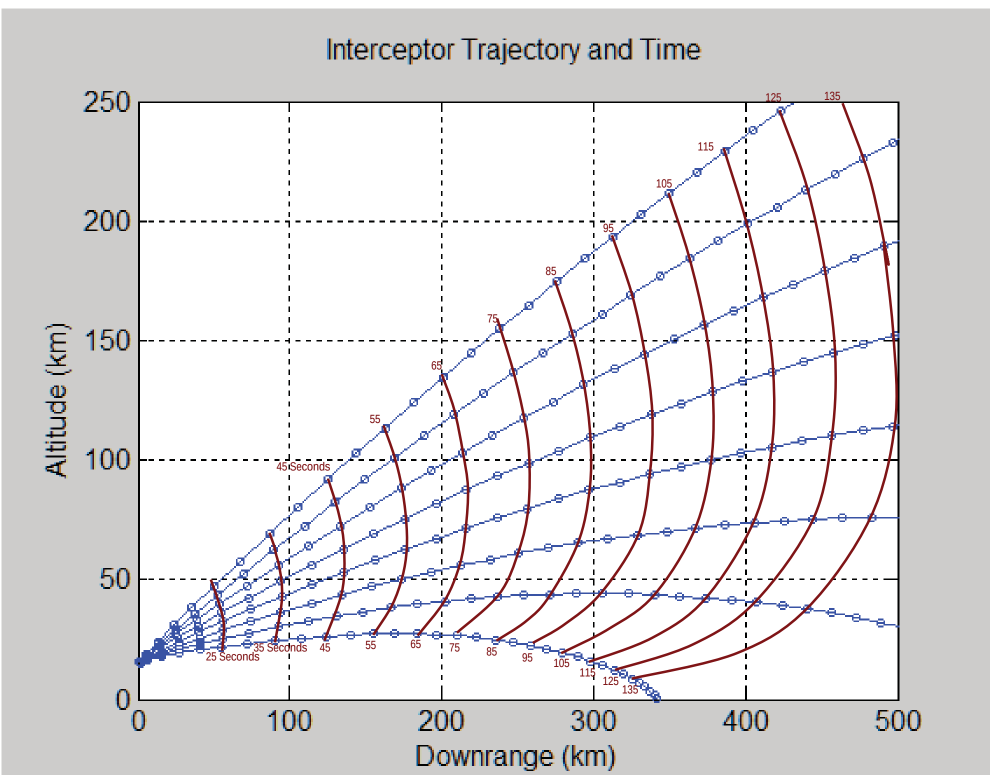


# APPENDIX

# Interceptor Performance Tradeoffs Are Very Flexible for a Fully Optimized System



## Trajectories that Can be Flown by Interceptor with 25 Second Acceleration Time and 5 km/sec Burnout Speed




Total Weight of Interceptor =1316.47 lbs (597.04 kg); EKV Weight=73.78 lbs ( 33.54 kg); Speed at Burnout=5.00 km/s
Advanced Homing and Control System Weight=73.78 lbs ( 15 kg); EKV Divert Velocity=1.5 km/s

## Potential Weights and Burnout Speeds for Interceptors with Kill Vehicle that has a 2 km/sec Divert and 15G Acceleration at Homing Endgame

Baseline Kill Vehicle Assumes Homing and Homing Guidance and Control Section Weighs 25 kg
Potential Increase in Burnout Velocity for a Kill Vehicle of the same weight but lighter Homing Homing Guidance and Control Section scales as follows:

$$V_{New} \approx V_0 \times \left[\frac{W_0}{W_{New}}\right]^{1/3} \text{ where } V_0 = 4\text{km/sec and } W_0 = 25\text{kg}$$

Example1: Baseline Interceptor that propels to 4 km/sec a KV capable of 2km/sec divert and Maximum Endgame Acceleration of 15 G Weighs ~650 kg. What would be the potential burnout speed of an interceptor of roughly the same total weight that had a Homing Guidance and Control Section that weighs 12.5 kg ($W_{New}$=12.25 kg) rather than 25 kg ($W_0$=25 kg)?

$$V_0 \times \left[\frac{W_0}{W_{New}}\right]^{1/3} = 4\text{km/sec} \times \left[\frac{25\text{kg}}{12.25\text{kg}}\right]^{1/3} = 4 \times [2]^{1/3} = 4 \times 1.26 \approx 5\text{km/sec}$$

Baseline Kill Vehicle Assumes Homing and Homing Guidance and Control Section Weighs 25 kg and with a burnout velocity of 4 km/sec
Potential Increase potential total weight of different interceptor with same burnout velocity and Kill Vehicle with same divert velocity and peak endgame acceleration but lighter Homing Guidance and Control Section scales as follows:

$$\text{Interceptor Weight}_{New} = \text{Interceptor Weight}_0 \times \left[\frac{W_{New}}{W_0}\right] \text{ where Interceptor Weight}_0 = 650\text{kg and } W_0 = 25\text{kg}$$

Example2: Baseline Interceptor that propels KV capable of 2km/sec divert and Maximum Endgame Acceleration of 15 G to 4 km/sec a KV Weighs ~650 kg. What could be the total weight of a different interceptor with the same burnout velocity and Kill Vehicle divert and acceleration characteristics with a Homing Homing Guidance and Control Section that weighs 12.5 kg ($W_{New}$=12.25 kg) rather than 25 kg ($W_0$=25 kg)?

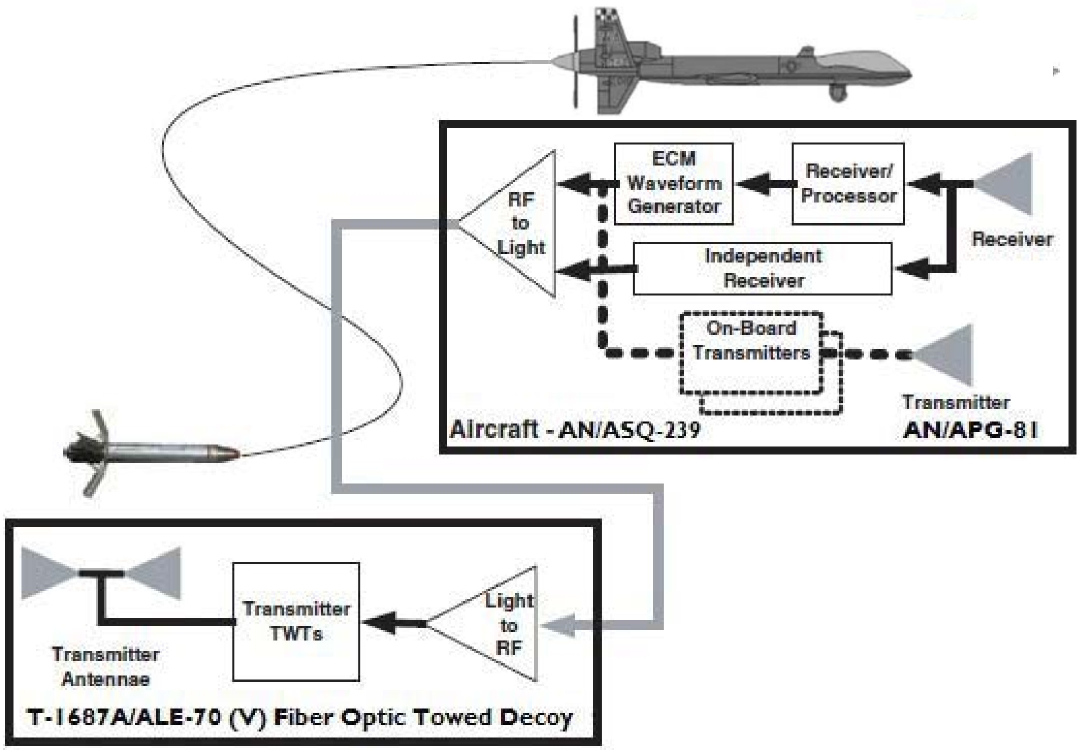
$$\text{Interceptor Weight}_{New} = \text{Interceptor Weight}_0 \times \left[\frac{W_{New}}{W_0}\right] = 650\text{kg} \times \left[\frac{12.5\text{kg}}{25\text{kg}}\right] = 325\text{kg}$$



# APPENDIX

# Survival of Drones Against Long-Range Surface-to-Air Missile Attack is Assured by Fully Tested Electronic Countermeasure Technologies

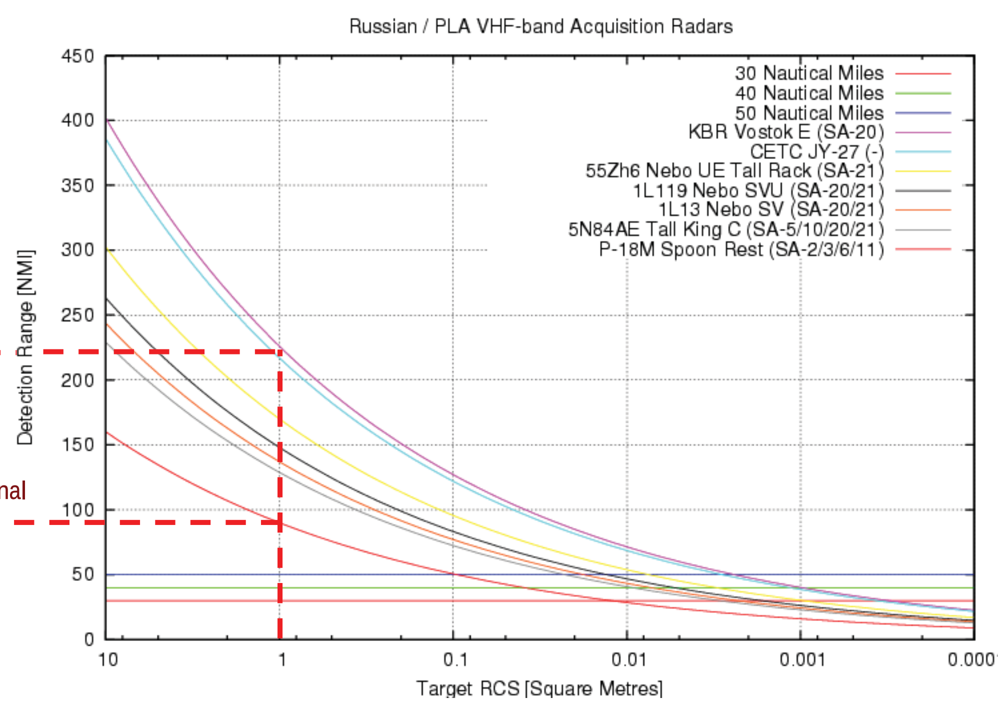
## Drones Protected by Towed Electronic Decoys
## Proven Technology: Uses Digital Radio Frequency Memories to Retransmit Homing Missile Signal Causing Interceptors to Home on Decoy






## Relatively Inexpensive ECM Countermeasures Can Be Used in Standoff Patrols to Protect Drones from Surface-to-Air Missile Attack

Potential VHF Radar Detection Ranges Without Jamming Against a Drone Carrying Missiles on External Pylons




Data from Russian / PLA Low Band Surveillance Radars: http://www.ausairpower.net/APA-Rus-Low-Band-Radars.html

# North Korean Air Force Fighters that Could Theoretically be a Threat to the Airborne Patrol

## North Korean Combat Aircraft

| Aircraft | Origin | Type | Variant | In service | Notes |
|---|---|---|---|---|---|
| MiG-29 | Russia | multirole | | 35 | |
| MiG-21 | Soviet Union | fighter | | 26 | |
| MiG-23 | Soviet Union | fighter-bomber | | 56 | |
| Sukhoi Su-7 | Soviet Union | fighter-bomber | | 18 | |
| Sukhoi Su-25 | Russia | attack | | 34 | |
| Shenyang F-5 | People's Republic of China | fighter | | 106 | derivative of the MiG-17 |
| Shenyang J-6 | People's Republic of China | fighter | F-6 | 97 | license built MiG-19 |
| Chengdu J-7 | People's Republic of China | fighter | F-7 | 120 | license built MiG-21 |



# North Korean Air Force Fighters that Could Theoretically be a Threat to the Airborne Patrol

## North Korea's Combat Aircraft

MiG-29S, (Introduced in 1982)

MiG-23 (Introduced in 1970)

MiG-21 (Introduced in 1959)

Chengdu J-7 (≈MiG-21; Introduced in 1959)

SU-7 (Introduced in 1959)

SU-25 (Introduced in 1981)

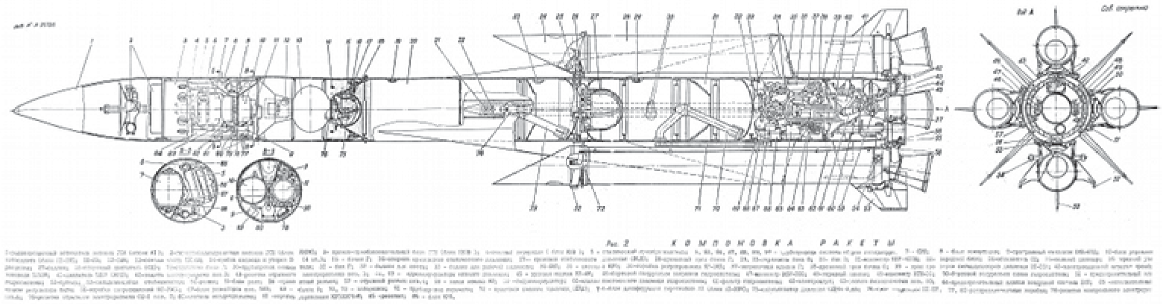
Shenyang J-6 (≈MiG-19; Introduced in 1955)

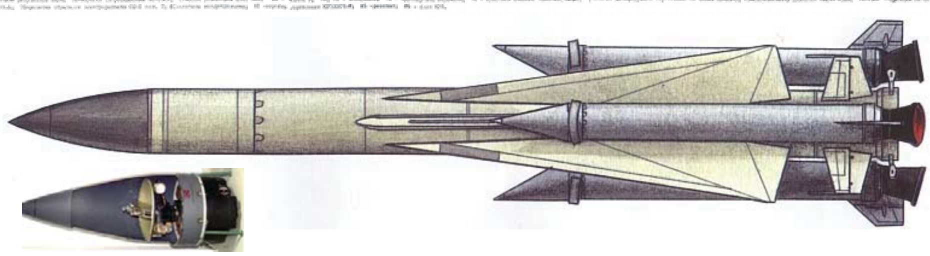
Shenyang F-5 (≈MiG-17; Introduced in 1952)

# North Korean Surface-to-Air Missile Able to Engage the Airborne Patrol

The SA-5 Gammon is the Only North Korean Air-Defense Interceptor that Could Reach Airborne Patrol Drones

| Name | Origin | Type | In service |
|---|---|---|---|
| | | SAM | |
| S-200 | Soviet Union | SAM system | 75 missiles |
| S-125 Neva/Pechora | Russia | SAM system | 300 missiles |
| S-75 Dvina | Soviet Union | SAM system | 1950 missiles |
| SA-7 | Russia | MANPADS | 4000 units |







# The North Korean S-200 Surface-to-Air Missile System Acquisition, Height Finding and Engagement Radars are All Mechanical Scanning and Vulnerable to Standoff Jamming

NITEL 5N84AE Oborona-14 / Tall King C Acquisition Radar

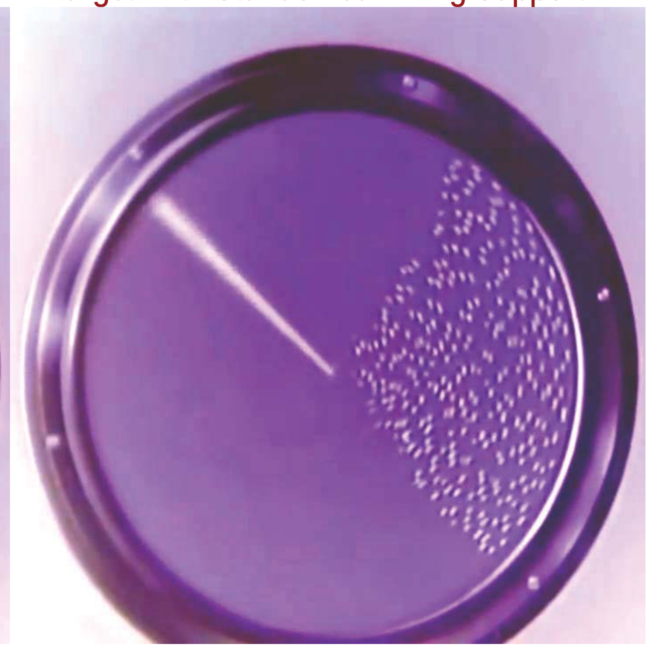
PRV-17 Odd Pair Heightfinding Radar

Almaz K-1V/M / 5N62 Square Pair FMCW Engagement Radar

## The Effects of Standoff Jamming on the North Korean S-200 Surface-to-Air Missile System Acquisition and Height-Finding Radars

Target Without Standoff Jamming Support

Target With Standoff Jamming Support





## Implementation of Standoff Jamming Against the North Korean S-200 Surface-to-Air Missile System Acquisition and Height-Finding Radars