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
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 2 km/sec Divert Velocity

Total Weight = 500 kg

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

Total Weight = 660 kg

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

Interceptor Trajectory and Time
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 \textit{Upgraded} Hwasong-14 Second Stage During the First 190 Seconds of Powered Flight (40 Seconds After Staging)
Early 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 had only two vernier engines and has an upper stage powered flight time twice as long as the presumed “upgraded” Hwasong-14 shown here.
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* 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

**IMPORTANT ASSUMPTION:** Satellite Early Warning Provides Sufficient Information for Interceptor Launch within 50 Seconds of Target Missile Launch
- 50 seconds delay before Interceptor launched against Target Missile
- Intercept Occurs 150 Seconds after Target Missile is Launched (Interceptor Flight for Maximum Time of 100 seconds)
- Maximum Interceptor Speed ~ 4 km/sec
- Intercepted Acceleration for ~ 25 seconds
- Range for Hit at 100 km Altitude ~ 285 km
- Kill Vehicle 1.5 – 2 km/sec Divert NOT included

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

**IMPORTANT ASSUMPTION:** Satellite Early Warning Provides Sufficient Information for Interceptor Launch within 50 Seconds of Target Missile Launch
- Intercept at 200 Seconds After ICBM Launch
- Intercept Time of Flight = 140 Seconds
- First Stage Burnout 120 Seconds After ICBM Launch

* 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.
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Satellite Early Warning Provides Sufficient Information for Interceptor Launch within 50 Seconds of Target Missile Launch

- 50 seconds delay before Interceptor launched against Target Missile
- Intercept Occurs 190 Seconds after Target Missile is Launched (Interceptor-Flight for Maximum Time of 140 seconds)
- Maximum Interceptor Speed ~ 4 km/sec
- Interceptor Acceleration for ~ 25 seconds
- Range for Hit at 150 km Altitude ~ 390 km
- Kill Vehicle 1.5 – 2 km/sec Deviation NOT included

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

IMPORTANT ASSUMPTION:
Satellite Early Warning Provides Sufficient Information for Interceptor Launch within 50 Seconds of Target Missile Launch

- 50 seconds delay before Interceptor launched against Target Missile
- Intercept Occurs 190 Seconds after Target Missile is Launched (Interceptor-Flight for Maximum Time of 140 seconds)
- Maximum Interceptor Speed ~ 4 km/sec
- Interceptor Acceleration for ~ 25 seconds
- Range for Hit at 150 km Altitude ~ 390 km
- Kill Vehicle 1.5 – 2 km/sec Deviation NOT included
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

Missile Destroyed 20 Seconds Before Completing Powered Flight: 265 sec
Missile Destroyed 40 Seconds Before Completing Powered Flight: 285 sec
Deep Area for Missile Attack Against East Coast of the Continental US

APPENDIX

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

IMPORTANT ASSUMPTION:
Satellite Early Warning Provides Sufficient Information for Interceptor Launch within 40 Seconds of Target Missile Launch

- Intercept Occurs 105 Seconds after Target Missile is Launched (Interceptor Flight for Maximum Time of 65 seconds)
- Average Interceptor Speed ~ 4 km/sec
- Interceptor Accelerates for ~ 10 seconds
- Range for Hit at 75 km Altitude ~ 200 km (Due to Aerodynamic Drag)
- Kill Vehicle 1.5 – 2 km/s Divert NOT included

APPENDIX

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

Satellites Only See Hot Rocket Exhaust. They Cannot See Rocket After the Rocket-Motor Stops.

NOTE:
The detectors on the satellite could see a lighted match at 100 to 200 miles range.


Transient Infrared Signal When Solid Propellant Minuteman III Rocket is Launched.
When Liquid Propellant Safir Satellite Launch Vehicle Was Being Launched

Photons are Forward Scattered Through Clouds

At each event:
- Forward scattering
- Absorption
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

Effects of increasing optical depth

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

Rayleigh
Vis 50 km (very clear air)
Vis 5 km
MODTRAN 4

Hot Sources at Various Altitudes
Raw Source Radiance

Solid Propellant Source

Spectral Radiance (Arbitrary Units)
Wavelength (μm)
Solid
- 0 km
- 10 km
- 20 km
- 30 km

Liquid Propellant Source

Spectral Radiance (Arbitrary Units)
Wavelength (μm)
Liquid
- 0 km
- 10 km
- 20 km
- 30 km

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.

Signals from SCUD that Would Have Been Observed If There Was NO Atmospheric Absorption of the Short Wave Infrared Emission from the Rocket Plume.

Signals Observed from DSP Satellites in Geosynchronous Orbits.

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

Unclassified

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

Intensity-Time Histories of Russian and US Ballistic Missiles
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:

\[ V_{\text{new}} \approx V_0 \times \left( \frac{W_0}{W_{\text{new}}} \right)^{\frac{1}{3}} \]

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 (\( W_{\text{new}}=12.25 \text{ kg} \)) rather than 25 kg (\( W_0=25 \text{ kg} \))? 

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

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:

\[ \text{Interceptor Weight}_{\text{new}} = \text{Interceptor Weight}_0 \times \left( \frac{W_0}{W_{\text{new}}} \right) \]

where \( \text{Interceptor Weight}_0 = 650 \text{ kg} \) 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 (\( W_{\text{new}}=12.25 \text{ kg} \)) rather than 25 kg (\( W_0=25 \text{ kg} \))? 

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

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

<table>
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<tr>
<th>Aircraft</th>
<th>Origin</th>
<th>Type</th>
<th>Variant</th>
<th>In service</th>
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<td>106</td>
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<tr>
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<td>license built MiG-19</td>
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<tr>
<td>Chengdu J-7</td>
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<td>fighter</td>
<td>F-7</td>
<td>120</td>
<td>license built MiG-21</td>
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North Korean Air Force Fighters that Could Theoretically be a Threat to the Airborne Patrol
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

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<th>Name</th>
<th>Origin</th>
<th>Type</th>
<th>In service</th>
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<td>S-200</td>
<td>Soviet Union</td>
<td>SAM</td>
<td>75 missiles</td>
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<td>S-125 Neva/Pechora</td>
<td>Russia</td>
<td>SAM</td>
<td>300 missiles</td>
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<td>S-75 Dvina</td>
<td>Soviet Union</td>
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<td>SA-7</td>
<td>Russia</td>
<td>MANPADS</td>
<td>4000 units</td>
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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
The Effects of Standoff Jamming on the North Korean S-200 Surface-to-Air Missile System Acquisition and Height-Finding Radars

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