# *Improving the Accuracy of Precision Guided Munitions with a GPS Ephemeris & Ionospheric Correction Sharing Service (GEISS)*

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# *What is the Problem?*

- Small precision guided munitions need high accuracy GPS for guidance

- Munitions must be initialized prior to launch to allow rapid GPS acquisition

- GPS guided weapons only use satellites for navigation with pre-loaded NAV data

- Denial of GPS service at launch platform also limits PGM navigation performance

# *What is the Solution?*

- GPS Ephemeris and Ionospheric Sharing Service (GEISS)
  - Shares ephemeris data and ionospheric corrections across AFATDS network
  - PGMs are initialized with data from all satellites in view across the network
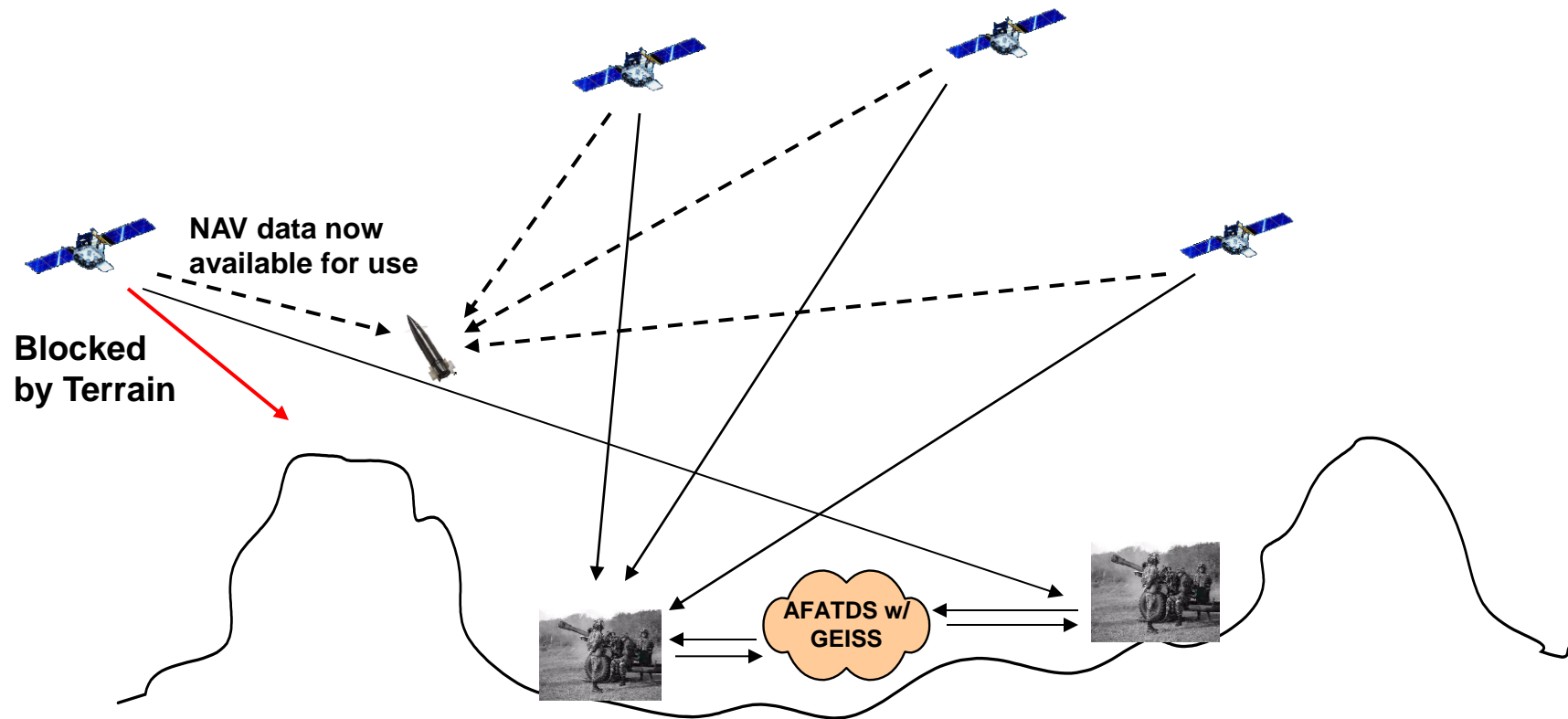  - Allows PGMs to operate with more GPS satellites once they have a better sky view following weapons launch

# *GPS-Guided Munitions that Could Benefit from GEISS*

- Munitions
  - Excalibur
  - M107, M549/A1, M795  (w/ PGK)


- Platforms
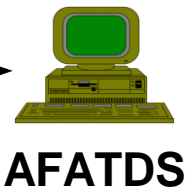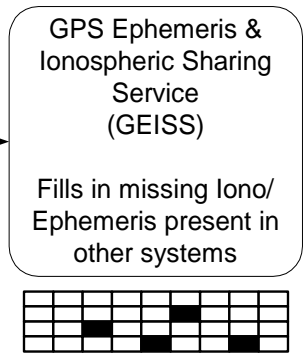  - Paladin, M777A2, Digitized M119

# PGM Performance

- Currently, munitions are initialized with navigation, ephemeris, and Iono data from each weapon platform (WP) GPS receiver, using only satellites visible to that platform

- In flight, navigation data is only used from "initialized" satellites, reducing accuracy

**Can't be used – not initialized**

**Blocked by Terrain**

# *PGM Performance w/ GEISS*
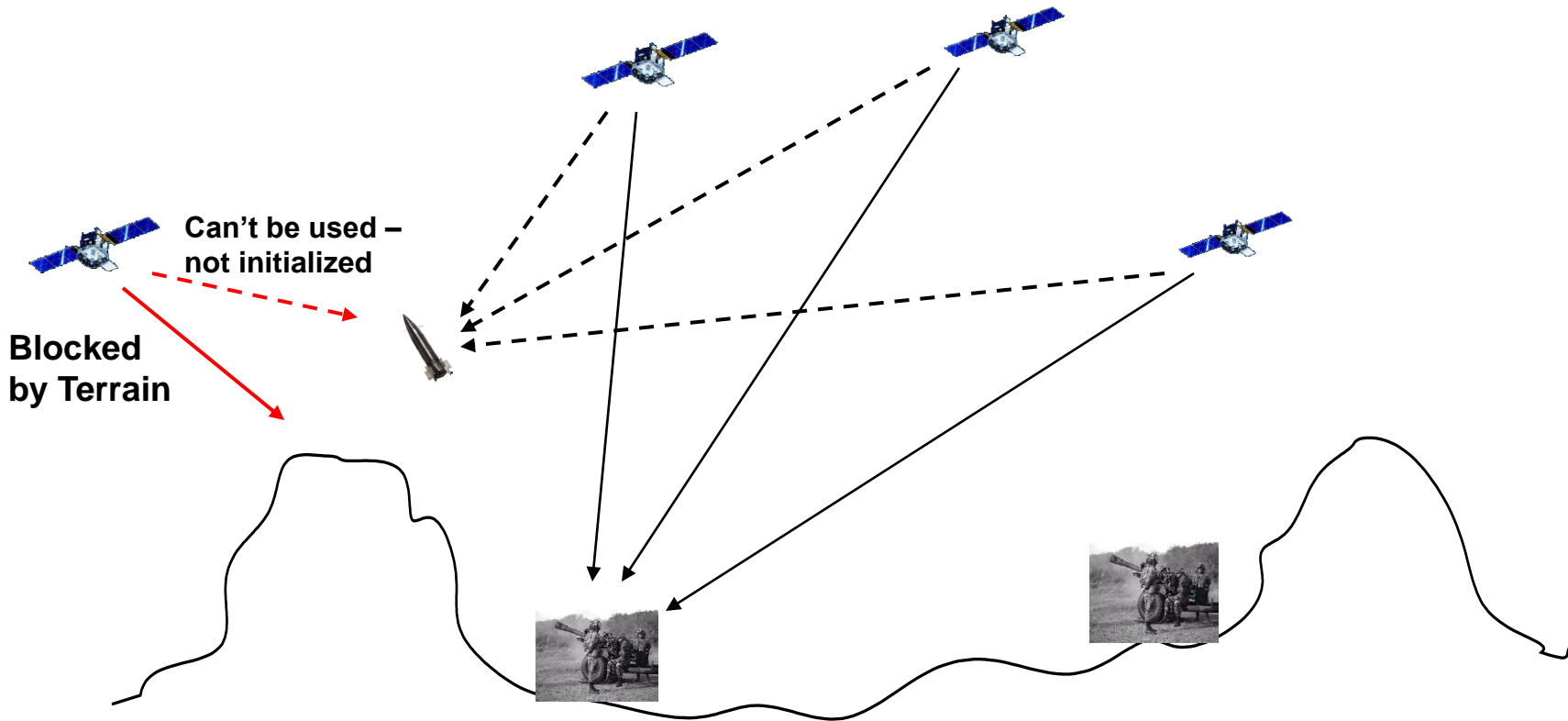
- GEISS "combines" satellite information from each WP GPS receiver and supplies the complete set to each WP through AFATDS for munitions initialization

- This allows even initially blocked satellites to be used in flight when available

**NAV data now available for use**

**Blocked by Terrain**

**AFATDS w/ GEISS**

Option to sync with
PGE data when
SIPRNET connected

GPS Ephemeris &
Ionospheric Sharing
Service
(GEISS)

Fills in missing Iono/
Ephemeris present in
other systems

**AFATDS**

DAGR    PIK

Weapons Platform

PIK

DAGR

Weapons Platform

PIK

DAGR

Weapons Platform

PIK

DAGR

Weapons Platform

Note: TCM-Cannon personnel will make final determination on all
GEISS, AFATDS, and Weapon Platform requirements

# *Aim Point Errors*



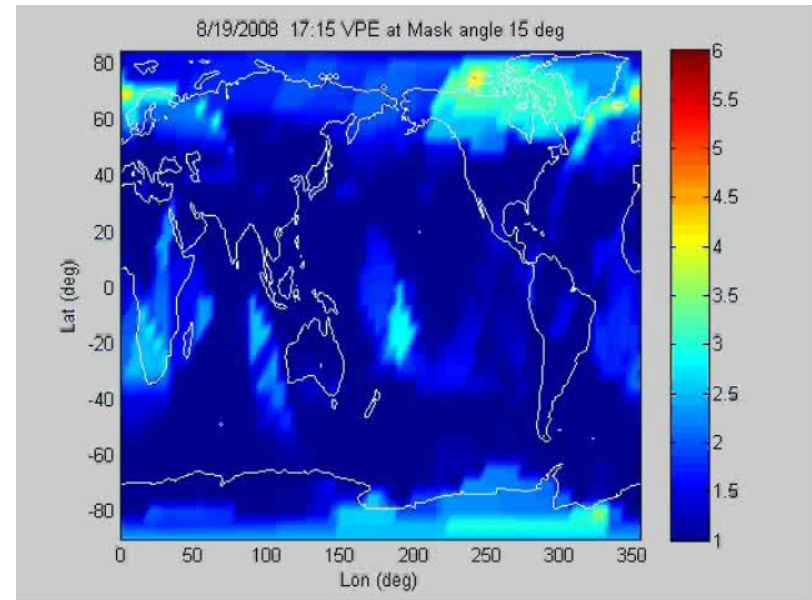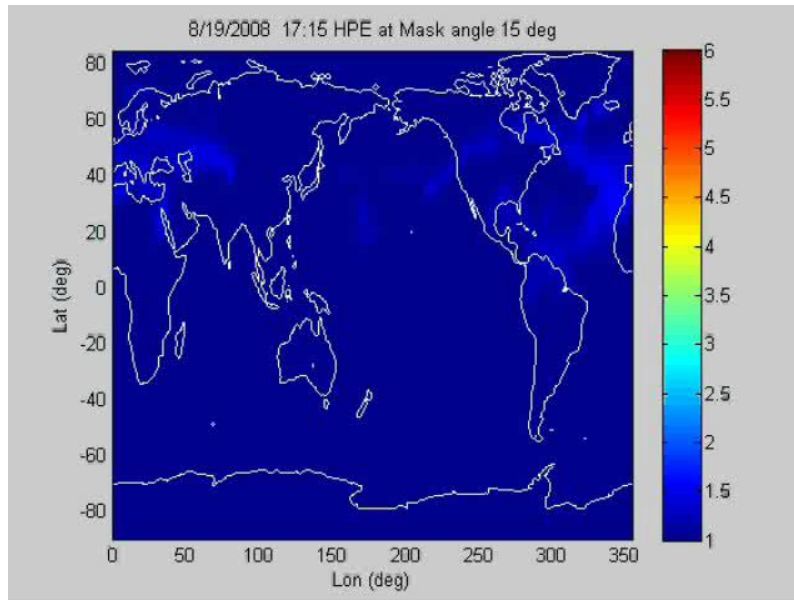Vertical GPS errors map into along track aim point errors
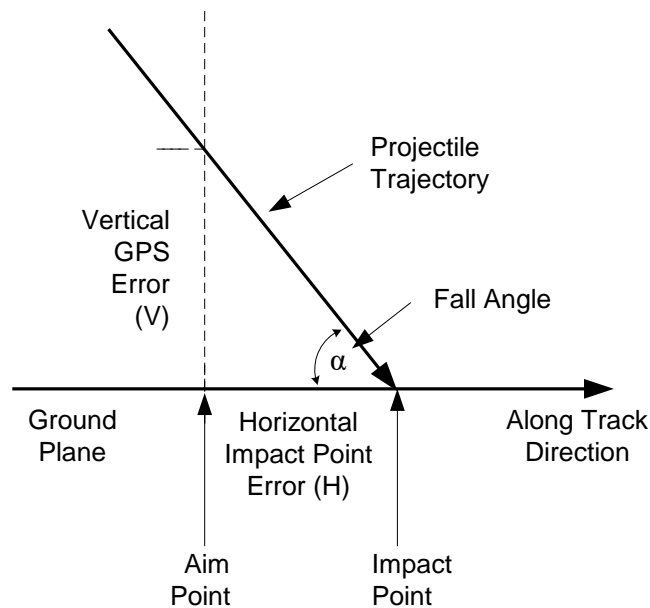
- Horizontal GPS bias errors map into horizontal aim point errors (earth referenced frame)
- Vertical GPS bias errors map into horizontal aim point errors through munition fall angle
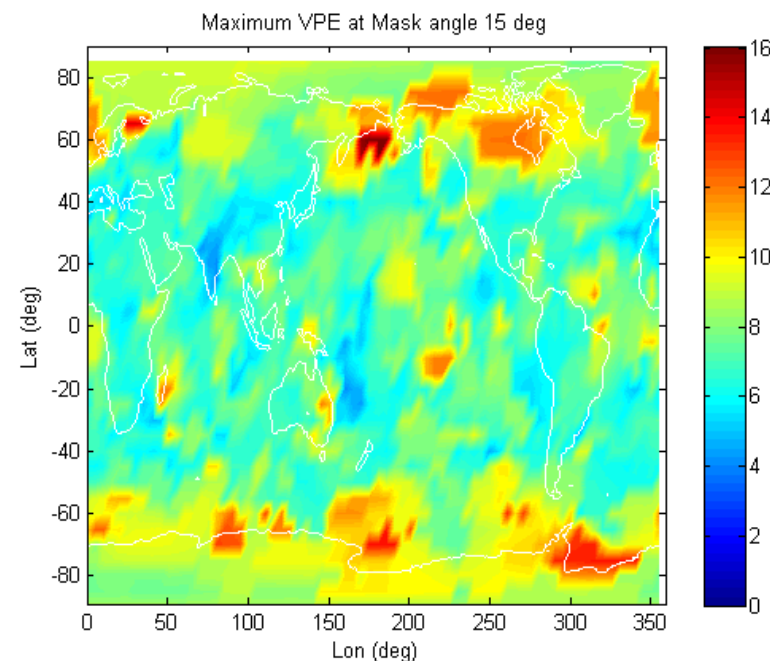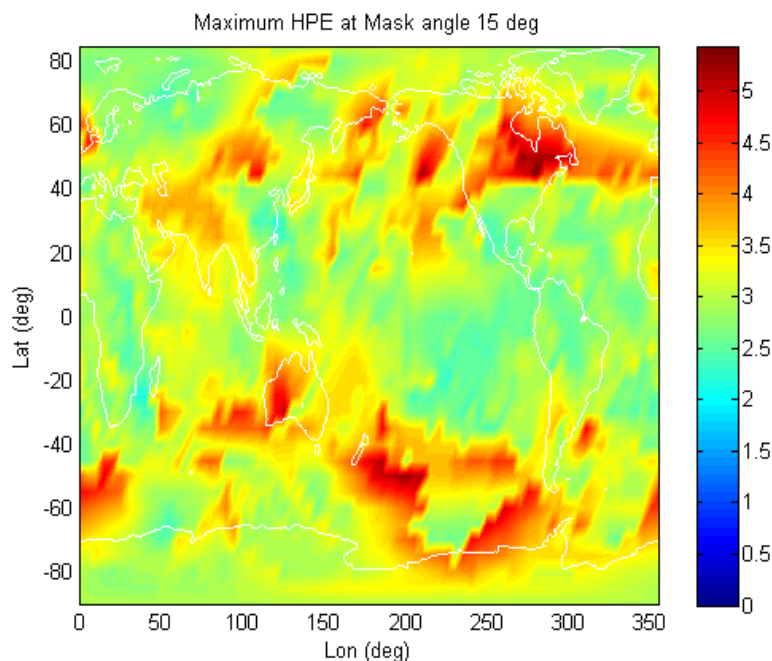  - Result in along track errors
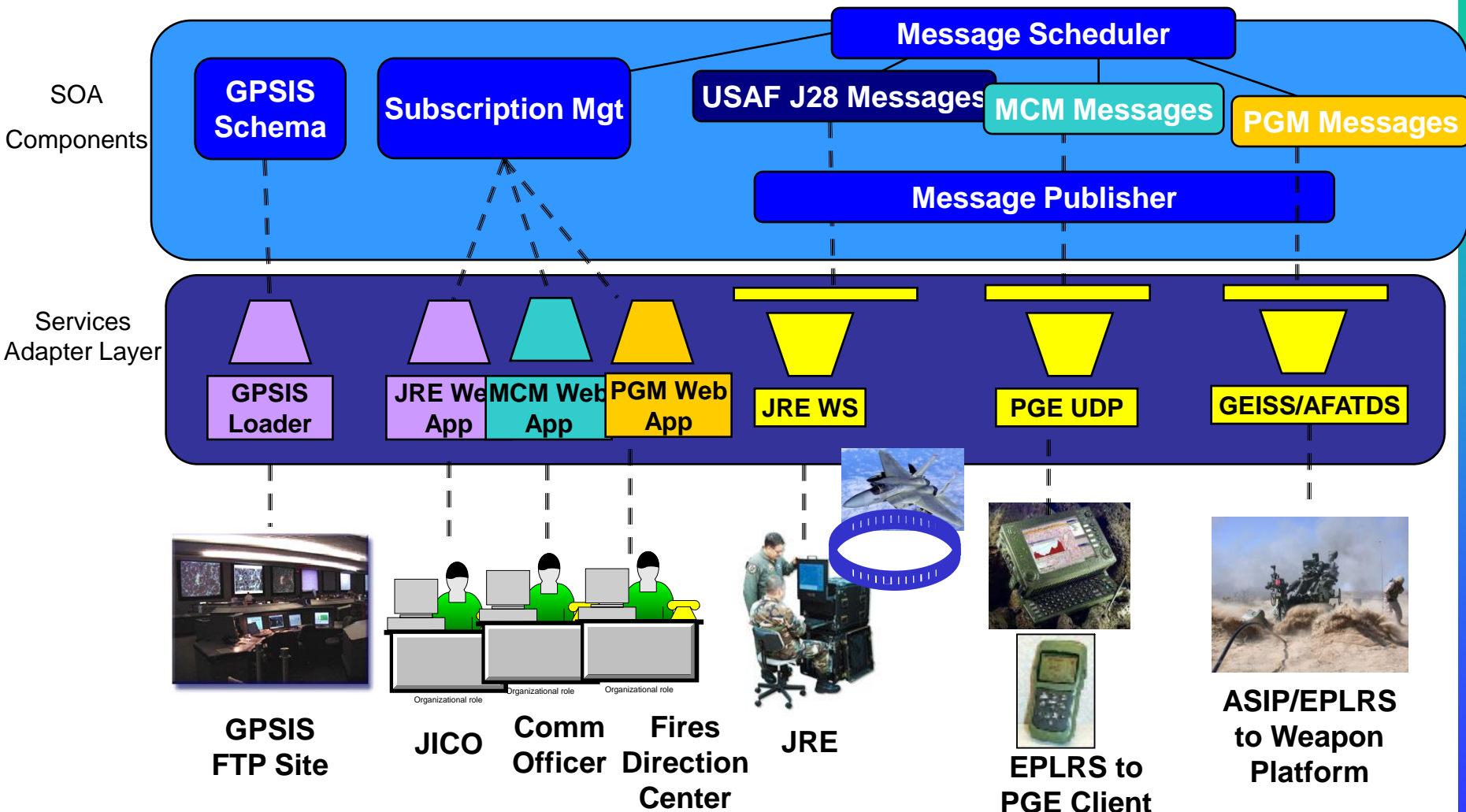
# HPE and VPE
# Antenna 15 Degree Mask Angle

# *Maximum HPE and VPE Antenna 15 Degree Mask Angle*



Note: Different meter error scale on side for HPE vs VPE

# GEISS/PGE Integration Option



**SOA Components**

- Message Scheduler
- GPSIS Schema
- Subscription Mgt
- USAF J28 Messages
- MCM Messages
- PGM Messages
- Message Publisher

**Services Adapter Layer**

- GPSIS Loader
- JRE Web App
- MCM Web App
- PGM Web App
- JRE WS
- PGE UDP
- GEISS/AFATDS

GPSIS FTP Site

JICO

Comm Officer

Fires Direction Center

JRE

EPLRS to PGE Client
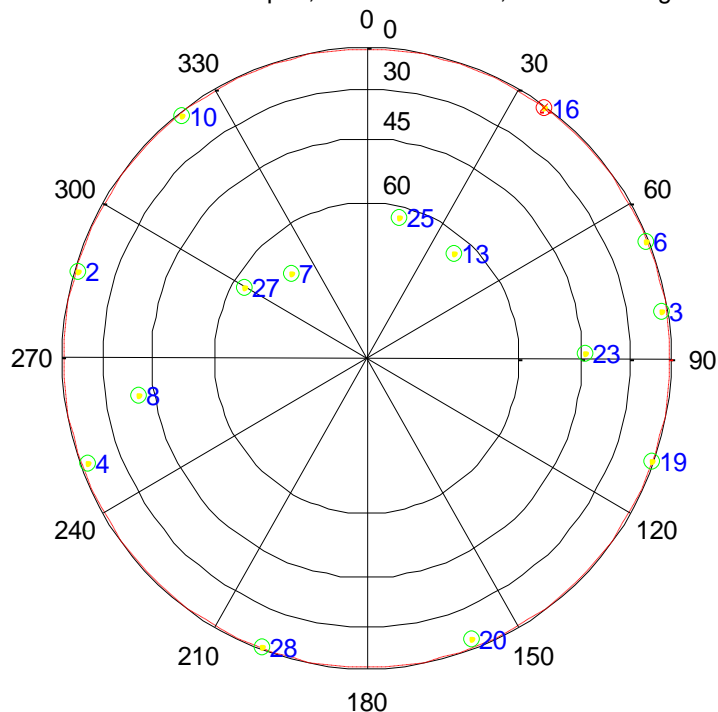
ASIP/EPLRS to Weapon Platform
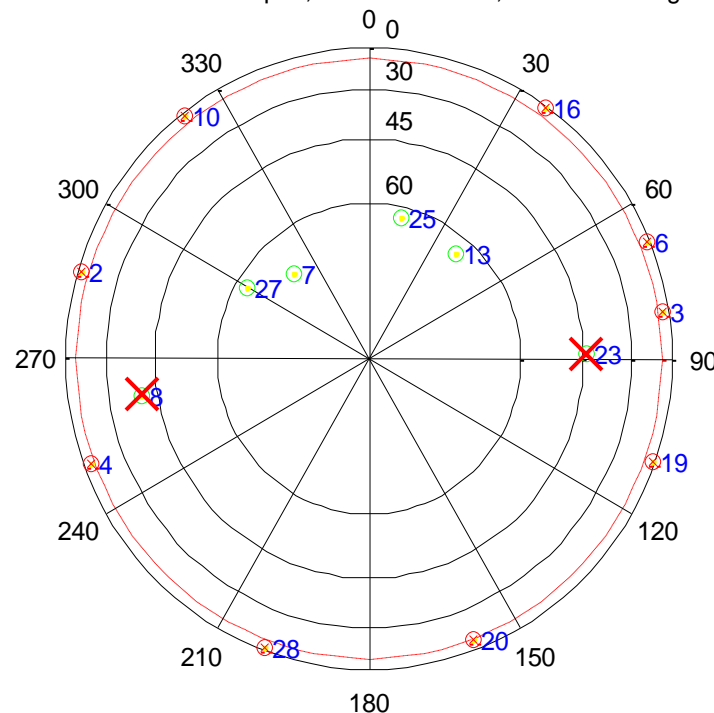
# *Scenarios*

1.  Open Sky (mask angle 5 deg, DAGR default)

    Baghdad 0500Z, 9 Sep 08

    HDOP =  0.71 VDOP= 0.84

2.  Far Field Terrain (mask angle 15 deg)

    Baghdad 0500Z, 9 Sep 08

    HDOP =  5.64 VDOP= 9.61 VAPP

3.  Hide Site (mask angle 40 deg) FOM > 1

    Baghdad 0500Z, 9 Sep 08

    HDOP =  0.71 VDOP= 0.84

# *Scenarios*



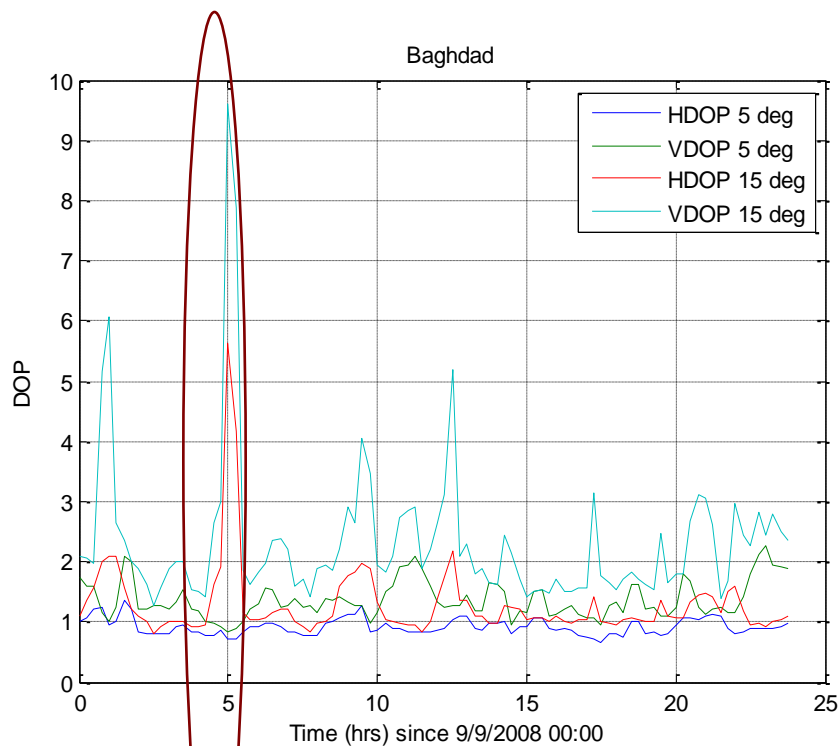Azimuth Elevation plot, view from above, mask = 5 deg



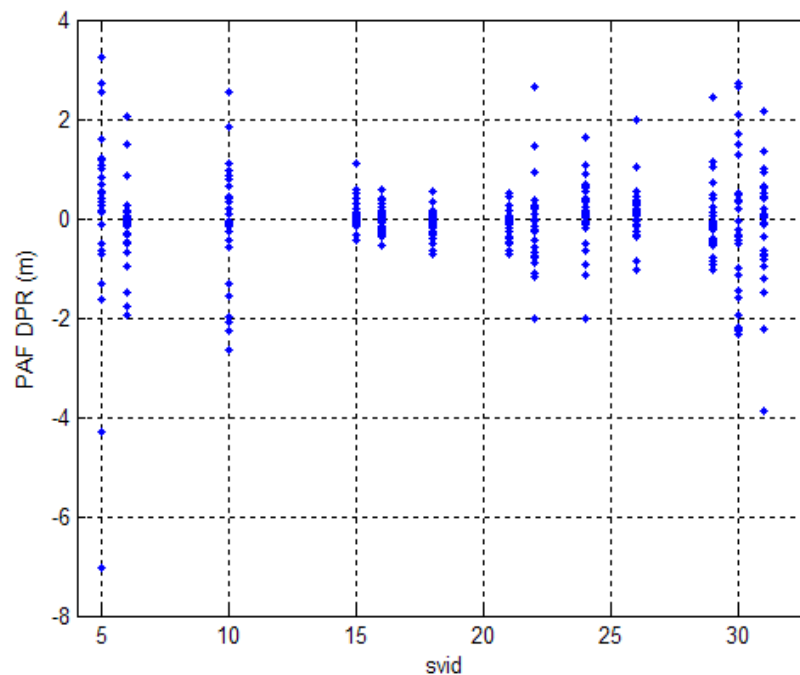Azimuth Elevation plot, view from above, mask = 15 deg

|  | Mask (degree) | | | | |
|---|---|---|---|---|---|
| DOPs | 0 | 5 | 10 | 15 | 20 |
| HDOP | 0.65 | 0.71 | 1.39 | 5.64 | 5.64 |
| VDOP | 0.79 | 0.84 | 1.72 | 9.61 | 9.61 |
| GDOP | 1.11 | 1.20 | 2.48 | 13.11 | 13.11 |

At mask angles >40 deg, FOM exceeds 1, resulting in no shot
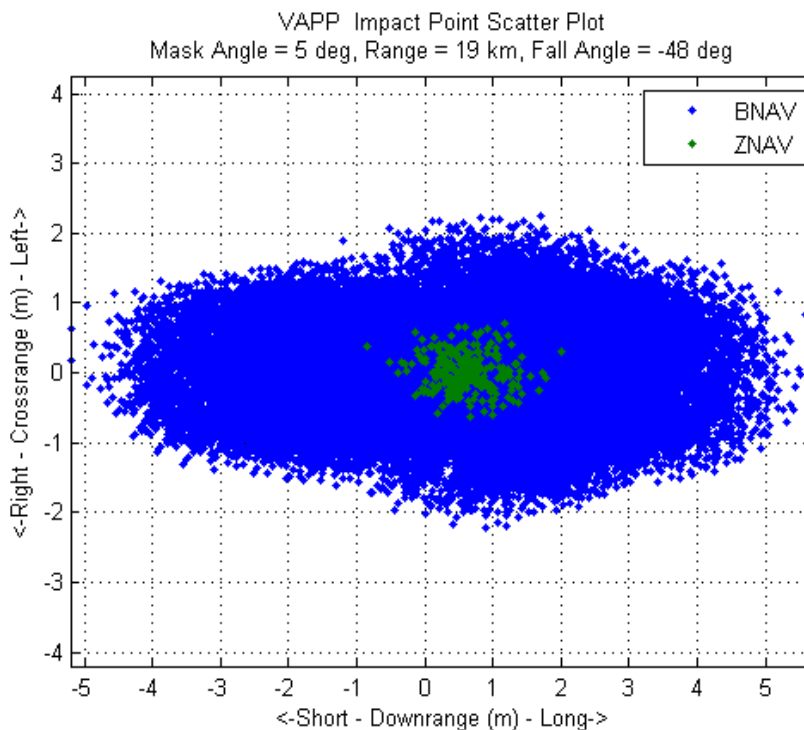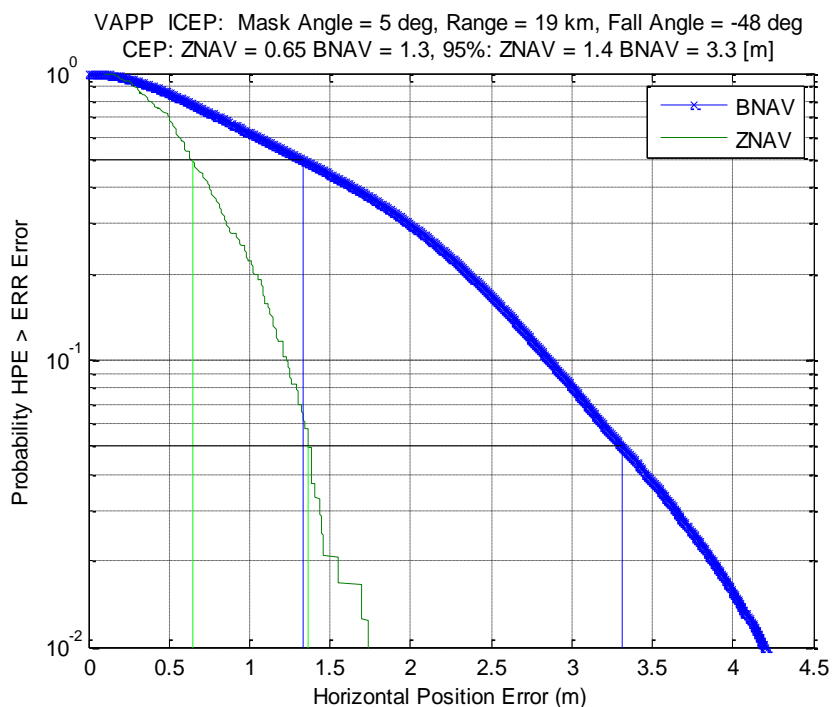
# *Baghdad Performance Analysis*



Time selected

30 Day PAF errors for SVs in view
at selected sidereal time

## *1. Local DAGR Open Sky ICEP & X/Y Plot*
## *5 deg Mask, Baghdad (HDOP=0.71 VDOP=0.84)*
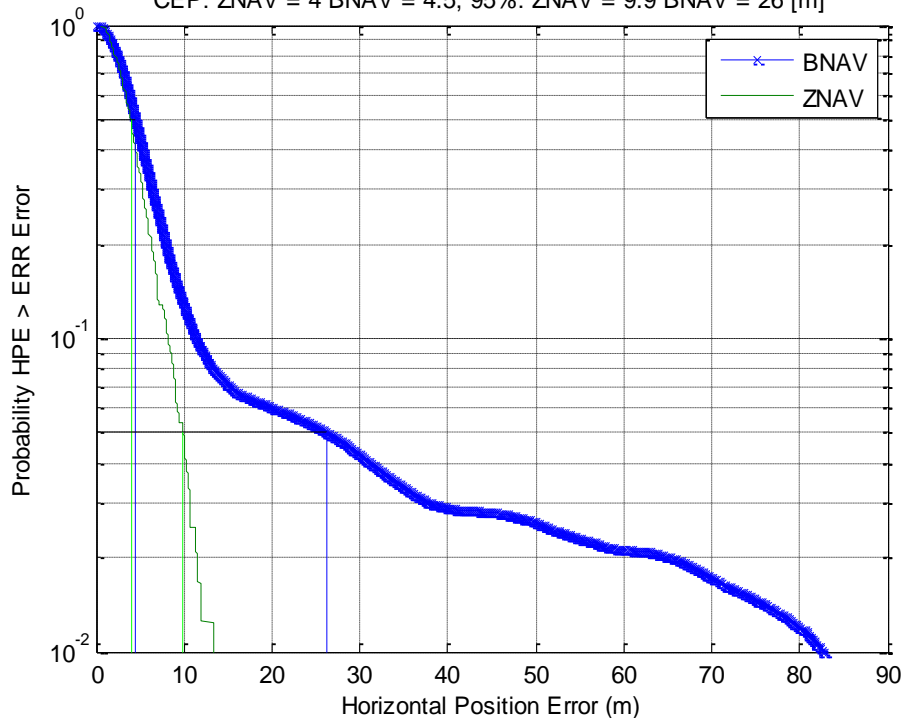## *Range: 19 km, Fall Angle: 48 deg*



VAPP ICEP: Mask Angle = 5 deg, Range = 19 km, Fall Angle = -48 deg
CEP: ZNAV = 0.65 BNAV = 1.3, 95%: ZNAV = 1.4 BNAV = 3.3 [m]



VAPP Impact Point Scatter Plot
Mask Angle = 5 deg, Range = 19 km, Fall Angle = -48 deg

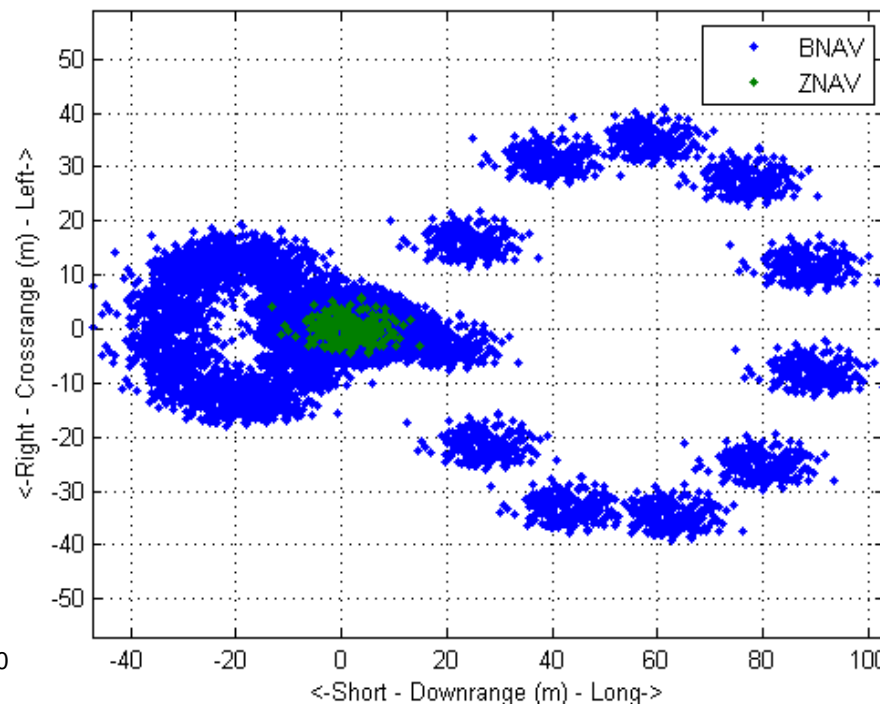| | | | |
|---|---|---|---|
| **ZNAV CEP =** | **0.65m** | **ZNAV 95% =** | **1.4m** |
| **BNAV CEP =** | **1.30m** | **BNAV 95% =** | **3.3m** |

## *2. Local DAGR Open Sky ICEP & X/Y Plot*
## *15 deg Mask, Baghdad (HDOP=5.6  VDOP=9.6)*
## *Range: 19 km, Fall Angle:  48 deg*



VAPP  ICEP:  Mask Angle = 15 deg, Range = 19 km, Fall Angle = -49 deg
CEP: ZNAV = 4 BNAV = 4.5, 95%: ZNAV = 9.9 BNAV = 26 [m]

VAPP  Impact Point Scatter Plot
Mask Angle = 15 deg, Range = 19 km, Fall Angle = -49 deg

| | | | |
|---|---|---|---|
| **ZNAV CEP =** | **4.0 m** | **ZNAV 95% =** | **9.9 m** |
| **BNAV CEP =** | **4.5 m** | **BNAV 95% =** | **26 m** |

# *3.  Mask Angle >40 Deg*

- Without GEISS augmentation, FOM >1, no shot

- With GEISS aiding, effective mask angle reduced, allowing precision shot

# GEISS Scenarios Summary

| Scenario<br>Mask angle | 1. Open-Sky 5 deg | 2. Far Field Terrain 15 deg | 3. Hide Site 40 deg |
|---|---|---|---|
| Local DAGR | OK | Degraded | FOM > 1<br>No shot |
| PGE | High Precision | Degraded | FOM > 1<br>No shot |
| Iono & Ephemeris N/W Sharing | OK | OK | OK |
| PGE + Iono Sharing | High Precision | High Precision | High Precision |

# *Conclusion*

- GEISS network sharing can enhance number of satellites available for use by GPS-guided projectiles
- USA CECOM sponsoring GEISS research and demos for current and future platforms
- CERDEC/ARDEC providing technical oversight and guidance
- Integration with AFATDS will allow deployment to follow-on Excalibur and PGK projectiles with SW upgrades only