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13. ABSTRACT (Maximum 200 words) In 2012, the Navy requested spectrum certification for the shipboard AN/UPX-41(C) Digital Interrogator System, Software Version 5.5 with Mode 5. Current operating conditions for the Navy's AN/UPX-41(C) are the same as restrictions imposed on the AN/UPX-37 digital Identification Friend or Foe (IFF) interrogator. A proposed AN/UPX-41(C) Stage 4 certification was developed to allow the Navy to operate under less restrictive parameters but required that the Navy and FAA validate those proposed restrictions. This report provides the results of the validation effort on the impact to secondary surveillance radars (SSRs). The live testing, which occurred August 18-21, 2014 was conducted in its entirety using four AN/UPX-41(C) digital IFF interrogators at land-based test sites (LBTS).				
14. SUBJECT TERMS AN/UPX-41(C), Identification Friend or Foe, IFF, Aeronautical Surveillance and Collision Avoidance Systems, ASCAS, Secondary Surveillance Radar, SSR, 1030 MHz, 1090 MHz, ADW, DCA, IAD, ORF, NHK, QPL, QVR, Mode S, ATCRBS, ATCBI-5, ATCBI-6, ATCBI-6M, ASR-11			15. NUMBER OF PAGES 883	
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# Background

- ❑ The AN/UPX-41(C)\* Stage-4 operational transmit certification for AEGIS-Class ships was signed by NTIA on June 22, 2012 with geographic and platform number restrictions when operating in proximity to the NAS.<sup>†</sup>
- ❑ Additionally, the Stage-4 certification contained a requirement for a joint FAA-Navy test to validate the operational restrictions.
- ❑ The Volpe Center, in conjunction with the Navy, FAA Spectrum, and FAA aeronautical surveillance and collision avoidance systems (ASCAS) SMEs created a test plan to validate the operational restrictions.
- ❑ From August 18-21, 2014 the FAA and Navy conducted the above-mentioned joint test, under the management of the Volpe Center.
- ❑ Since the test, the Volpe Center has analyzed recorded data to look for instances of harmful interference that would affect ASCAS system performance.

\*AN/UPX-41(C) Digital Interrogator System when operated in conjunction with the OE-120 antenna, the AN/UPX-29(V) Identification Friend or Foe (IFF) system, and the AN/UPX-24 software interface Version 2.1.2, controlled by the Cooperative Engagement Capability (CEC), in Naval surface vessels

<sup>†</sup>See SPS-18778\_1 Navy AN-UPX-41 V5.5 St4

# Test Plan Refresher

## □ Baseline week: August 11<sup>th</sup> – 15<sup>th</sup>

- Baseline recording of data from 5 AM – 5 PM
  - No AN/UPX-41(C) systems Active

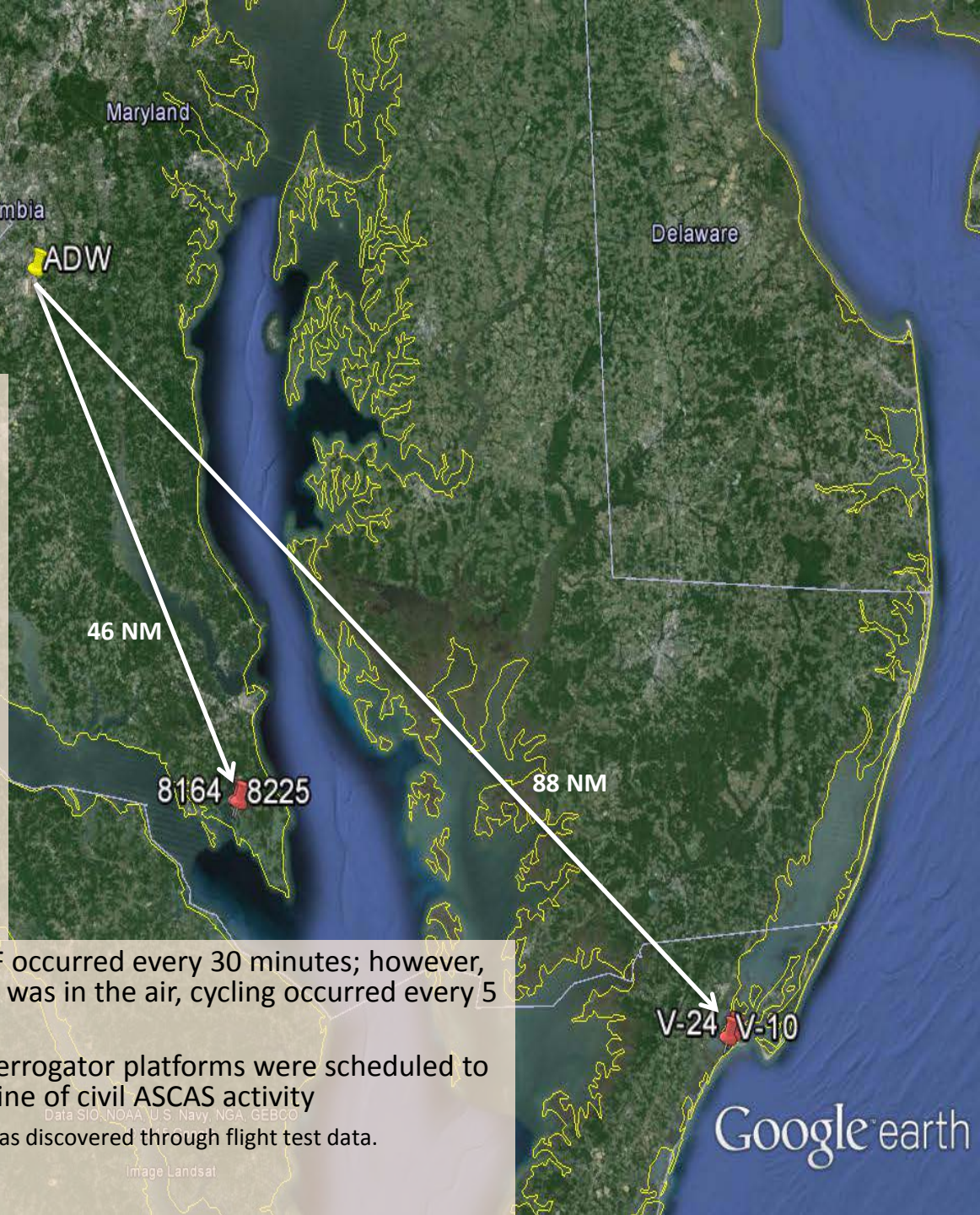
## □ Test week: August 18<sup>th</sup> – 21<sup>st</sup>

- August 18<sup>th</sup> – Baseline recording of data from 5 AM – 5 PM
  - No AN/UPX-41(C) systems Active
- August 19<sup>th</sup> – Record data from 5 AM – 5 PM
  - Cycle 1 and 2 AN/UPX-41(C) systems Active and OFF
- August 20<sup>th</sup> – Record data from 5 AM – 5 PM
  - Cycle 3 and 4 AN/UPX-41(C) systems Active and OFF
- August 21<sup>st</sup> – Record data from 5 AM – 5 PM
  - Cycle 1, 2, 3, and 4 AN/UPX-41(C) systems Active and OFF

- Cycling of AN/UPX-41(C) systems Active/OFF occurred every 30 minutes; however, if N39 (Tech Center signal recording aircraft) was in the air, cycling occurred every 5 minutes

- During the test week, non-essential DoD interrogator platforms were scheduled to be inactive in order to get an accurate baseline of civil ASCAS activity

- This did not occur. Non-test platform radiation was discovered through flight test data.



# Data Recording

- ❑ During the August test, Enroute Common Gateway (ECG) data was recorded at the Tech Center from the ADW site.
- ❑ The Radar Beacon Analysis Tool (RBAT) was used to analyze ECG data to produce statistics for the following list of parameters:
  - Targets per Scan
  - Probability of Detection
  - Identity Reliability
  - Identity Confidence
  - Altitude Reliability
  - Altitude Confidence
  - False Target Percentage
  - 0000 Code Percentage
- ❑ Mode S system version D22020 was used to record data extraction files by Mode S SSR technicians at the SSR Site.
- ❑ Mode S Analysis Tool (MSAT) was used to analyze extraction files to produce statistics for the following list of parameters:
  - FRUIT Rates
  - Interrogation/Reinterrogation Rates
  - ATCRBS Hit count statistics

# Data Analysis

- ❑ Applied time bins that corresponded to the AN/UPX-41(C) Active/OFF periods from test days (August 19<sup>th</sup>-21<sup>st</sup>) to baseline days to produce baseline statistics for all parameters
- ❑ Processed RBAT data through Surveillance Analysis, Scan Summary, and Beacon False Target Summary programs to find parameters of interest for each time bin without geographic or target filters
- ❑ Processed MSAT data through Channel Management Statistics and FRUIT Analysis programs to find parameters of interest for each time bin
  - 1) No geographic or target filters
  - 2) >10 NM filter
- ❑ Produced interrogation, reinterrogation, and hit count statistics for the Tech Center Aircraft (N39) as it flew within the SSRs LOS
  - Focused on possible interference during mainbeam overlap with V10, 8164, and 8225 sites

# Analysis Limitations

- ❑ The theoretical or textbook definition of probability of detection is a function of interrogation/reply round reliability.
- ❑ However, probability of detection in RBAT is the percentage of target updates versus total number of beam dwells over all targets.
- ❑ Therefore, the ability for probability of detection calculated by RBAT to properly represent theoretical probability of detection is minimized as the sample size decreases (either through geographical or time constraints) since it no longer reliably reflects the target population mean.
- ❑ Example: A target population of two where both targets miss one update out of ten scans (approximately 50 seconds) results in a probability of detection of 90%. While this is unacceptable by QARS blip/scan minimums, we have no knowledge of the updates that occurred outside of the given time constraint . If both targets received ten out of ten updates for the previous as well as the next 10 scans, the probability of detection is now 96.7%.

# Mode S Data Extraction Issues

- ❑ Noticed series of messages displayed by MSAT : Interrogation does not match frame table
  - The interrogation type does not match the expected type from the frame table or the time difference is more than 16 USECs
  - 02:34:23.445
  - Frame table not synched with actual periods
  - Try filtering the data starting at a later time or rerun the data
- ❑ After talking with Jim Davis, it was found that these errors occurred when CMS was unable to synchronize the interrogation data with the expected interrogation types from frame table and/or it was not able to maintain synchronization once it was achieved.
  - CMS was unable to synchronize due to interrogation data missing in the beginning of the file. Starting 1-5 seconds later fixed this.
  - CMS was losing sync due to interrogation data missing at a later time in the file.
- ❑ In a single beam dwell, the Mode S sensor records the first 21 interrogations and the rest are thrown away because of data storage space limitations.
- ❑ However, the Mode S sensor does record the number of interrogations past 21 that occurred and stores that amount in a **retry overflow count** field.
- ❑ Originally, MSAT did not count interrogations past 21 because they were not recorded by the Mode S sensor. Now, MSAT has been updated to account for the missing interrogations by considering the retry overflow count as interrogations without replies.
- ❑ Example: if in a beam dwell there are 25 interrogations, the Mode S sensor will record the first 21 and the retry overflow count would be 4.



# Mode S Data Extraction Issues (cont'd)

## All call data for DCA

13:38:17.336	INT	AC	27.58	itime=3cc490	MODE_3A
13:38:17.336	INT	AC	27.64	itime=3d02b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.344	INT	AC	28.19	itime=3ebcf0	MODE_C
13:38:17.344	INT	AC	28.26	itime=3effa0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.352	INT	AC	28.78	itime=409c00	MODE_3A
13:38:17.352	INT	AC	28.85	itime=40dd10	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.359	INT	AC	29.38	itime=427b00	MODE_C
13:38:17.359	INT	AC	29.44	itime=42bb50	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.359	INT	AC	29.99	itime=445890	MODE_3A
13:38:17.367	INT	AC	30.06	itime=4499b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.375	INT	AC	30.59	itime=4639f0	MODE_C
13:38:17.484	INT	AC	39.05	itime=60a300	MODE_C
13:38:17.484	INT	AC	39.11	itime=60e350	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.492	INT	AC	39.62	itime=628090	MODE_3A
13:38:17.492	INT	AC	39.68	itime=62c1b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.500	INT	AC	40.23	itime=6461f0	MODE_C

Data loss through  
about 8.5°

- ❑ Previous accounts of lost interrogation data at the Mode S sites was accounted for using the retry overflow count that was being reported by the Mode S sensor.
- ❑ However, as the analysis progressed, instances were found where the Mode S site was not reporting loss of data, but we can clearly see there is a loss of data (see highlighted above).
- ❑ The site did not report any missing data, but CMS produced a fatal error due to data not being present and having no record of data being lost.
- ❑ This was not discovered previously due to Probability of Detection changing ever so slightly in the absence of 8 degrees of data for a given time period. This fluctuation of probability of detection could be due to many reasons. (low elevation angle, non-compliant transponder, aircraft turning, etc.)

# Analysis Objective

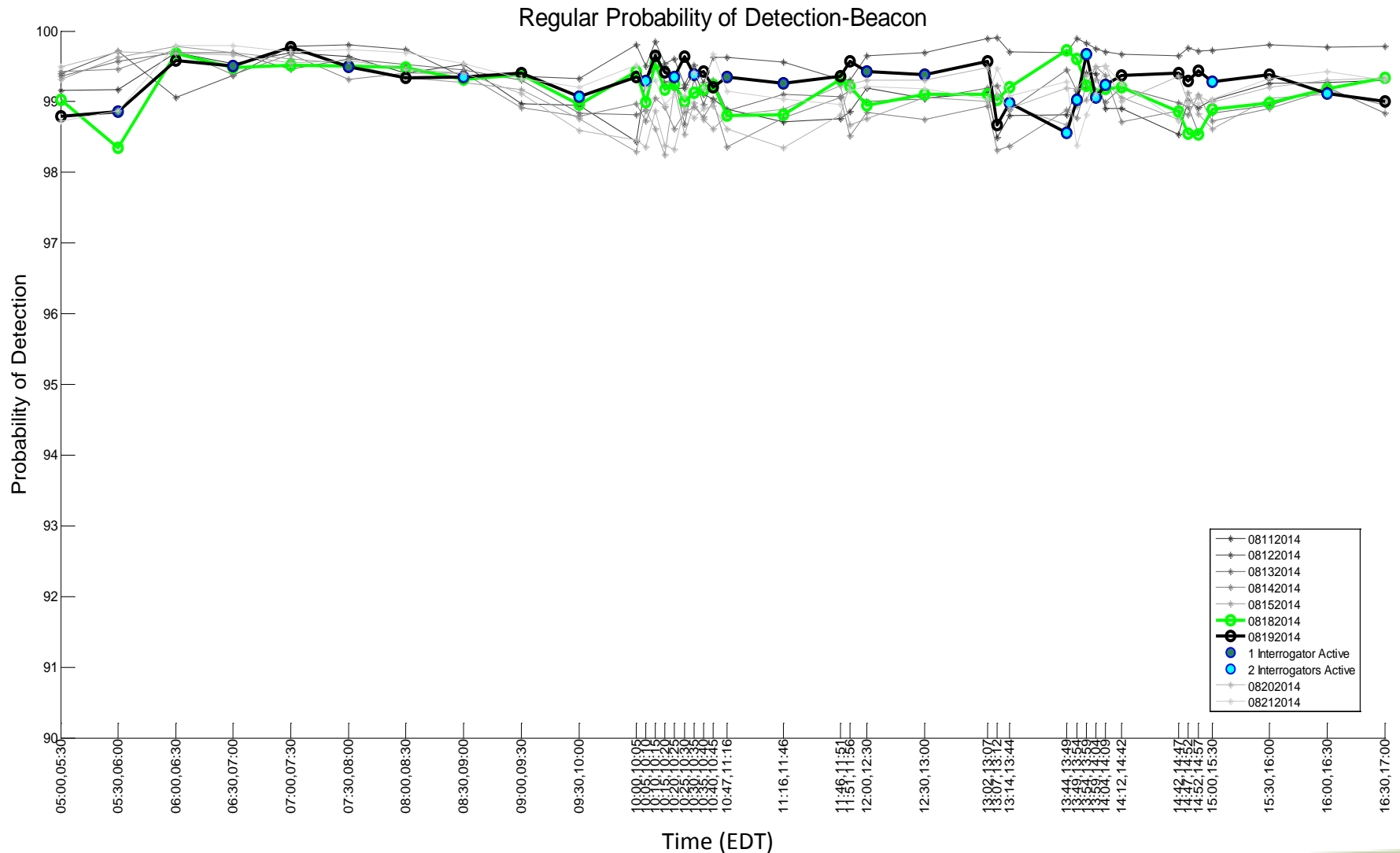
- ❑ We are attempting to observe distinct patterns of change in the metrics of interest between times when the AN/UPX-41(C) systems are OFF and when they are Active.
- ❑ While geographic and time filters reduces target update sample sizes such that a small sample size itself influences the metric of interest, it is more important to focus on the change from Off to Active since both the Off and Active periods have the same constraints applied.

# Plot Guide

- ❑ Plots with multiple days of data utilize the time filters from the Active/Off periods for the date given in the slide's title
- ❑ Plots that use boxplots
  - The edges of the box are the 25<sup>th</sup> and 75<sup>th</sup> percentiles. The maximum whisker length represents approximately 2.7 sigma (99.3%). Points in red are shown as outliers.
    - Exception: Box plots for reinterrogation rate vs time filters have whiskers that reach to the extent of the furthest outlier.
  - For five minute time bins, there are only 65 ADW scans and, if you miss one target update,  $P_d$  will automatically drop to 98.4% (24 out of 25 possible target reports).
  - Horizontal axis 30-min and 5-min time bins are not scaled according to duration.

# Target Metrics with No Filter

# Probability of Detection – August 19<sup>th</sup>

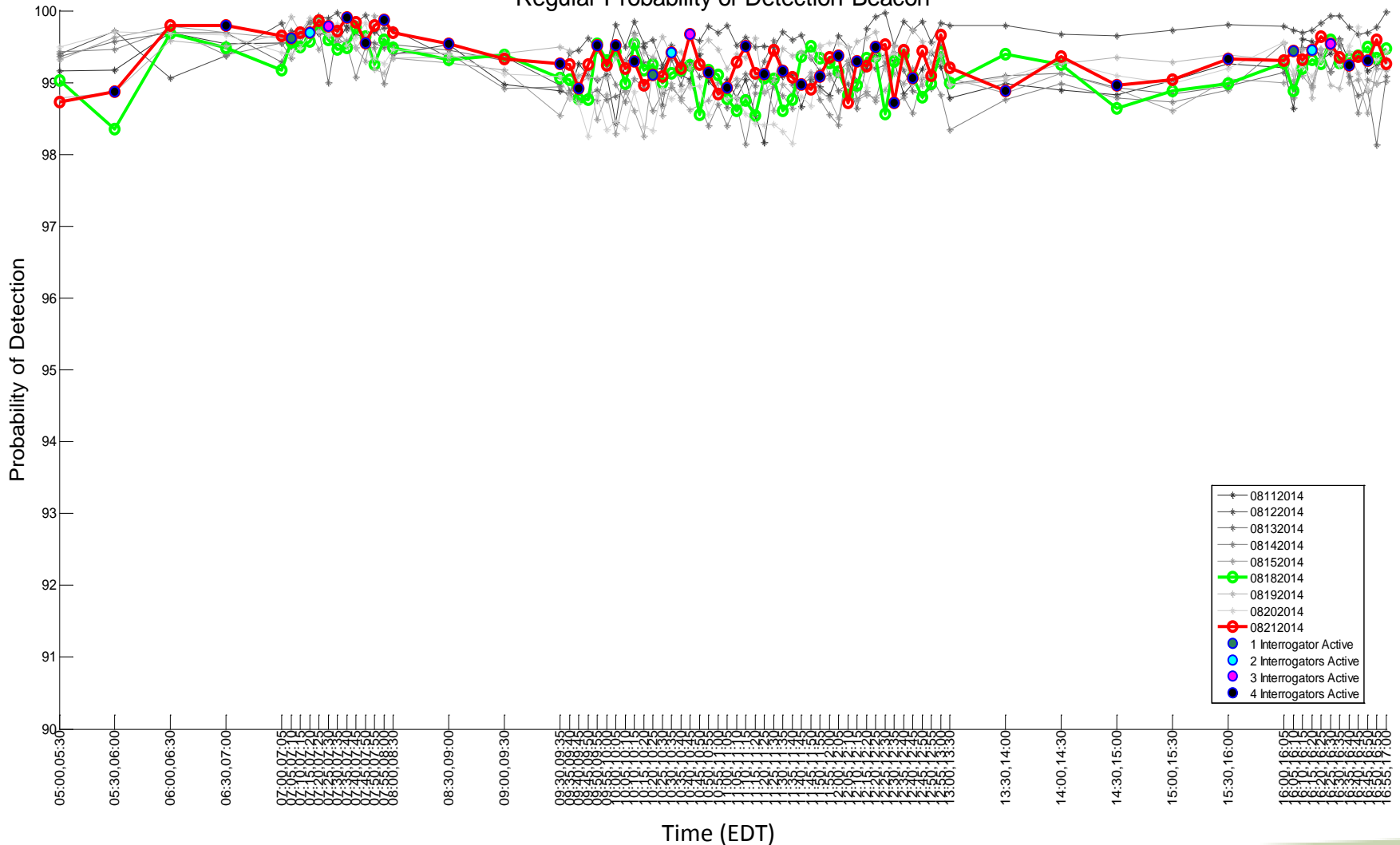


Geographic Filter: None  
Target Filter: None



# Probability of Detection – August 21<sup>st</sup>

Regular Probability of Detection-Beacon

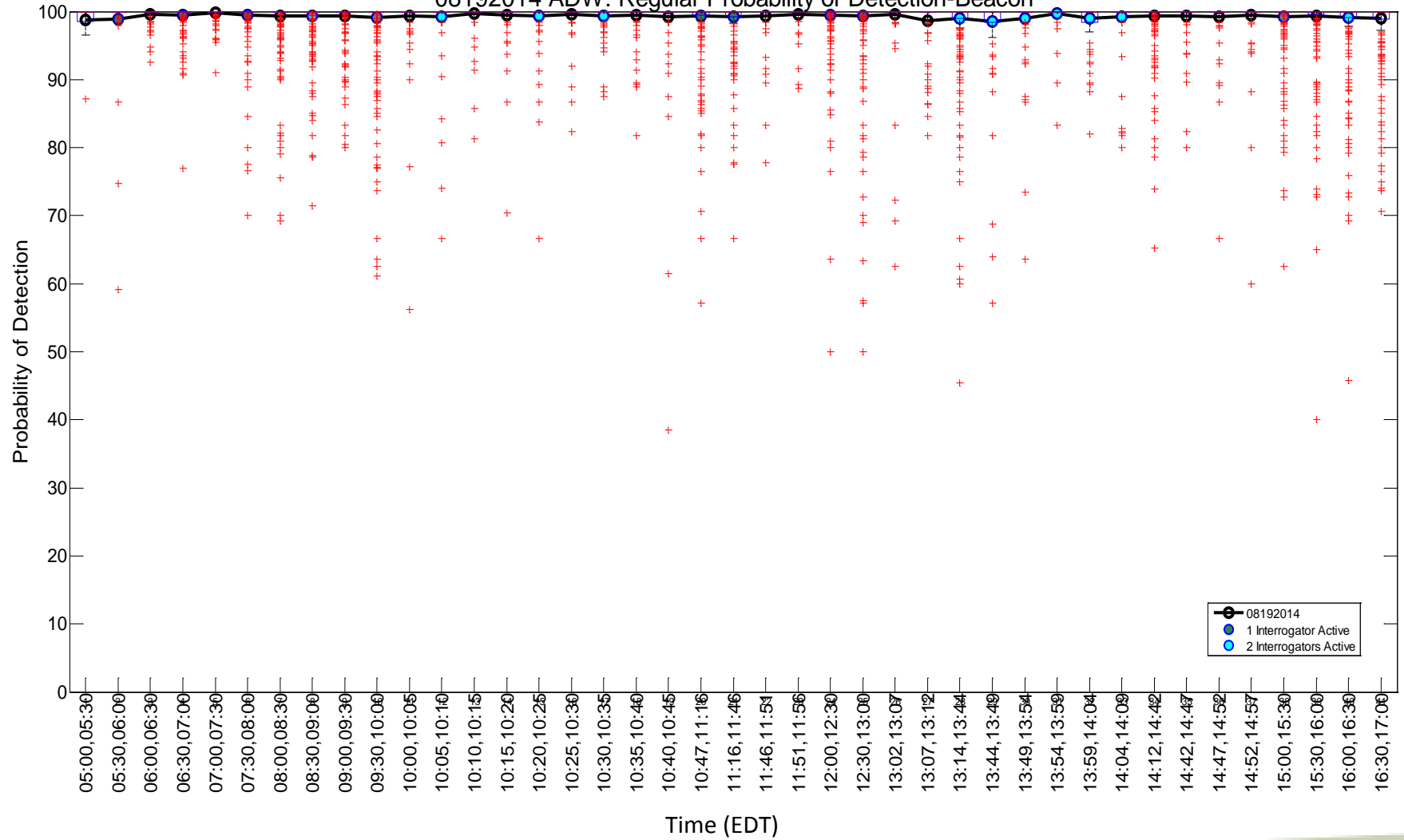


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution

08192014 ADW: Regular Probability of Detection-Beacon

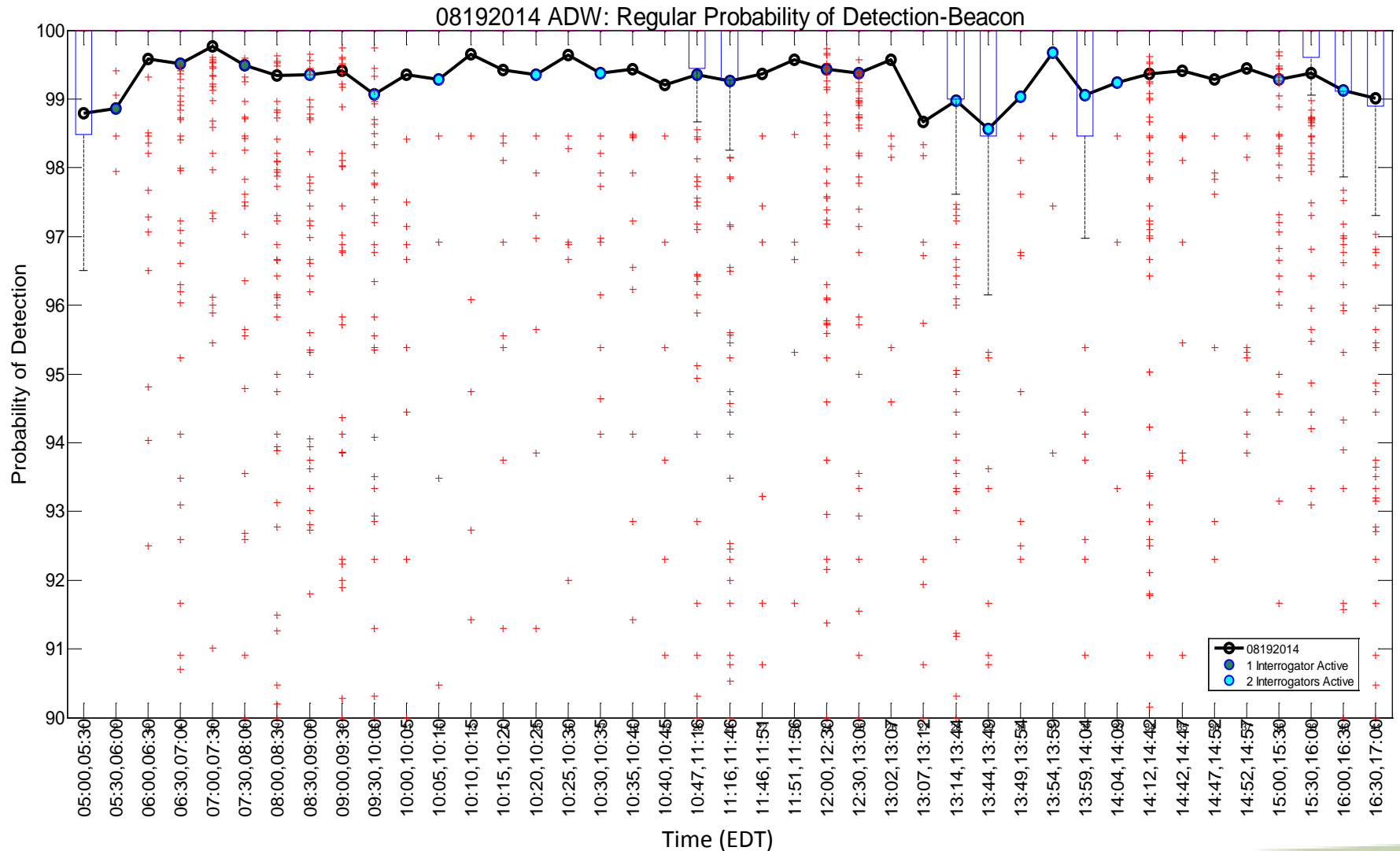


Geographic Filter: None  
 Target Filter: None



# Probability of Detection – August 19<sup>th</sup>

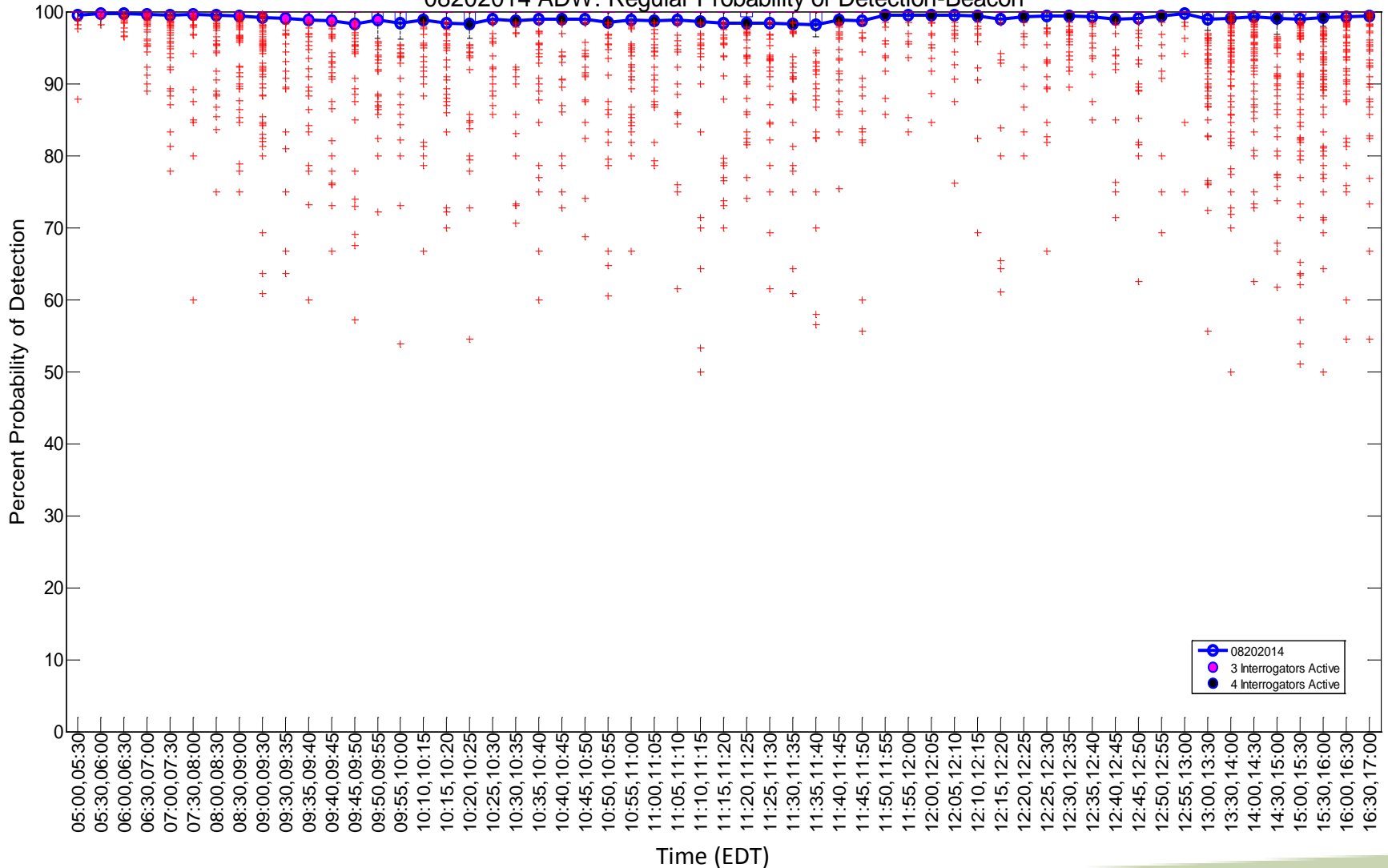
## Individual Aircraft Distribution (zoom-in)



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

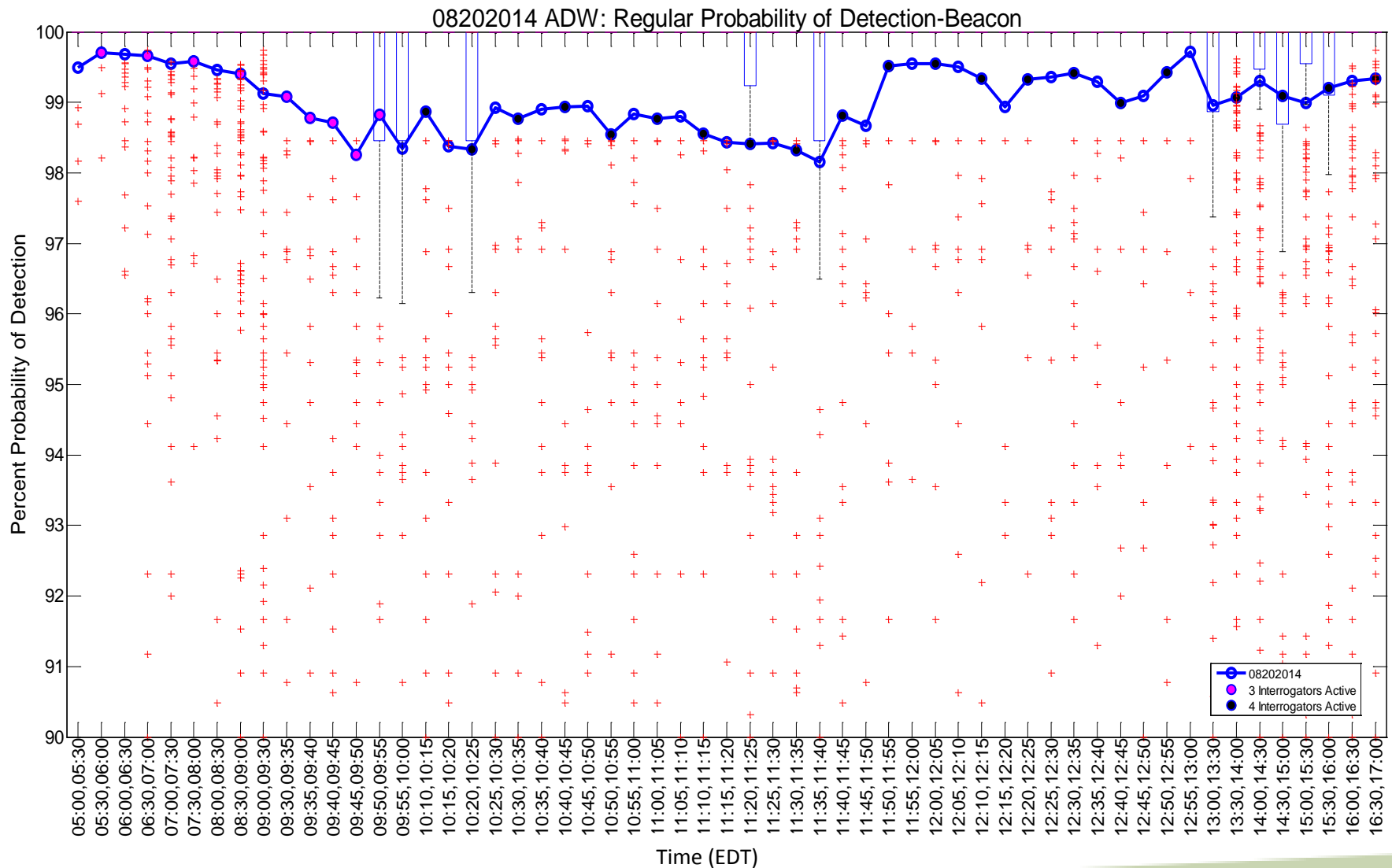
08202014 ADW: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

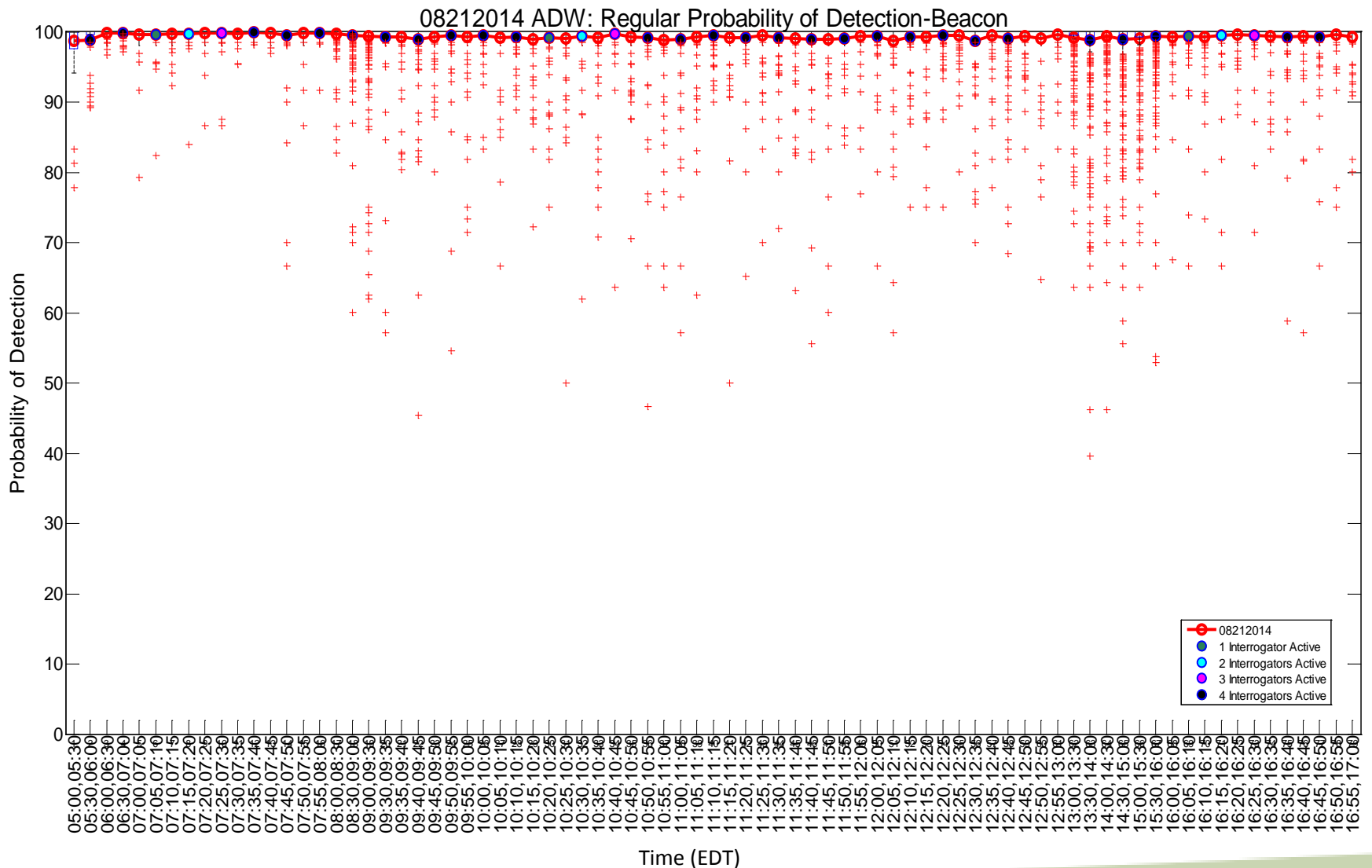
# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

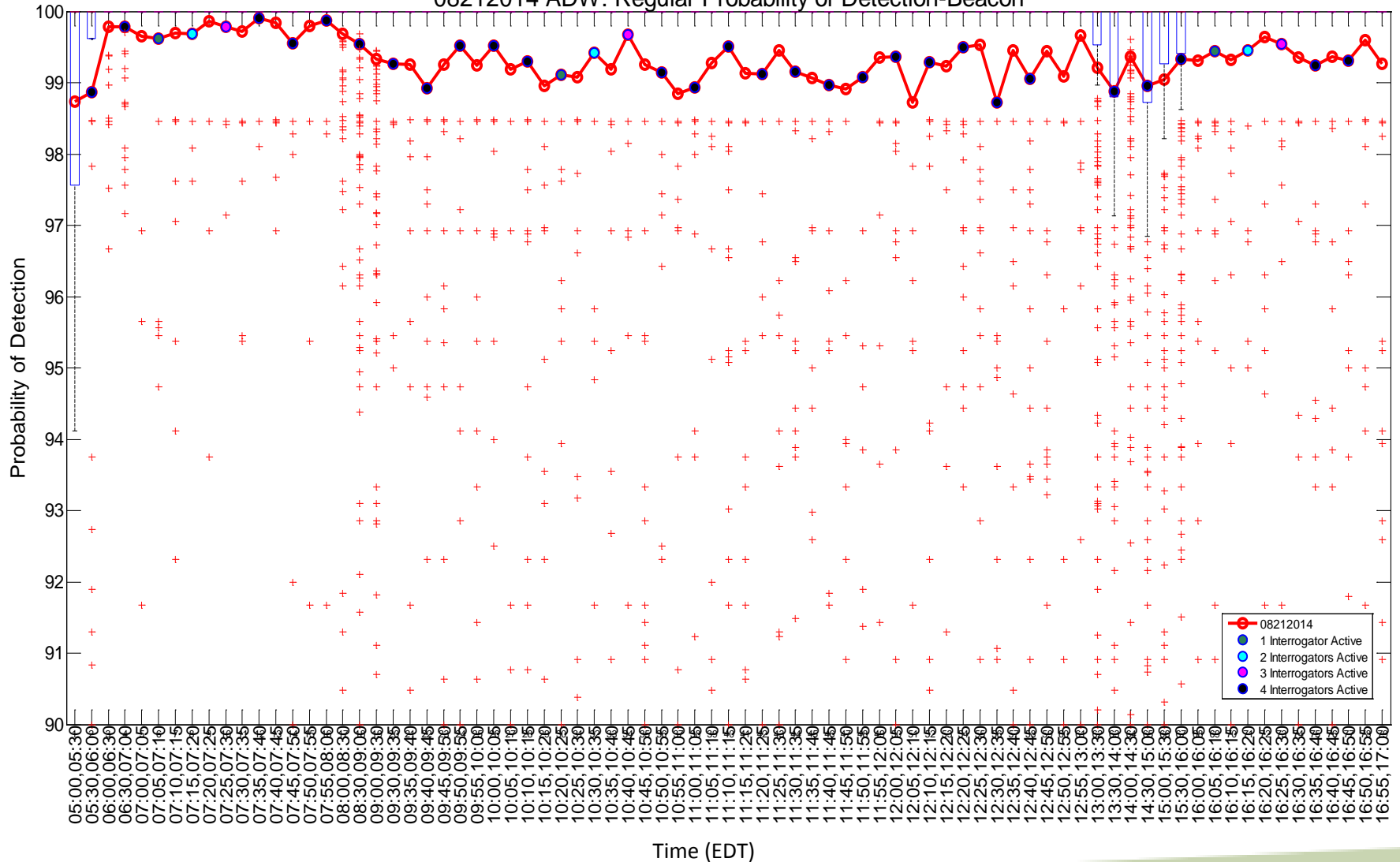


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)

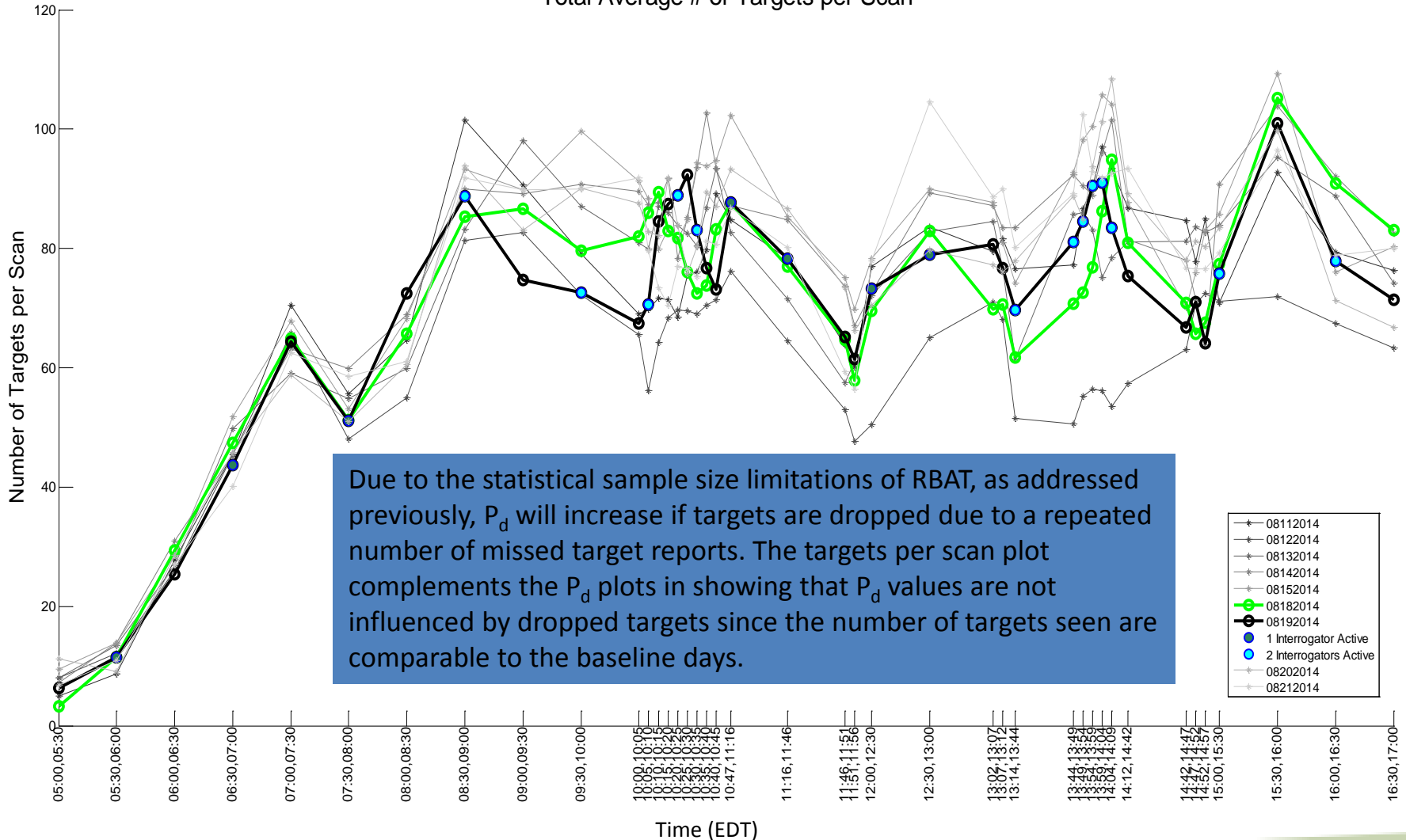
08212014 ADW: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 19<sup>th</sup>

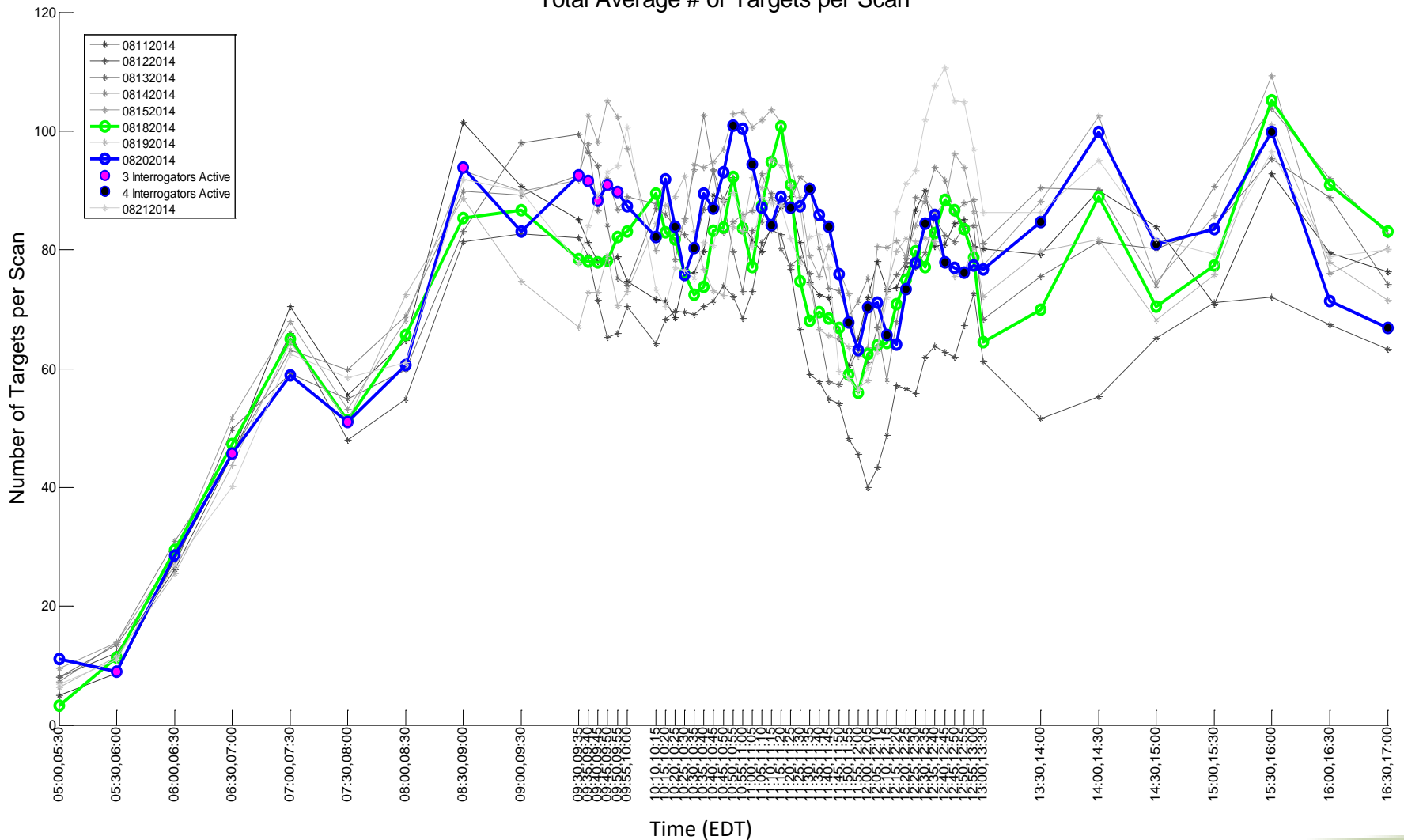
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 20<sup>th</sup>

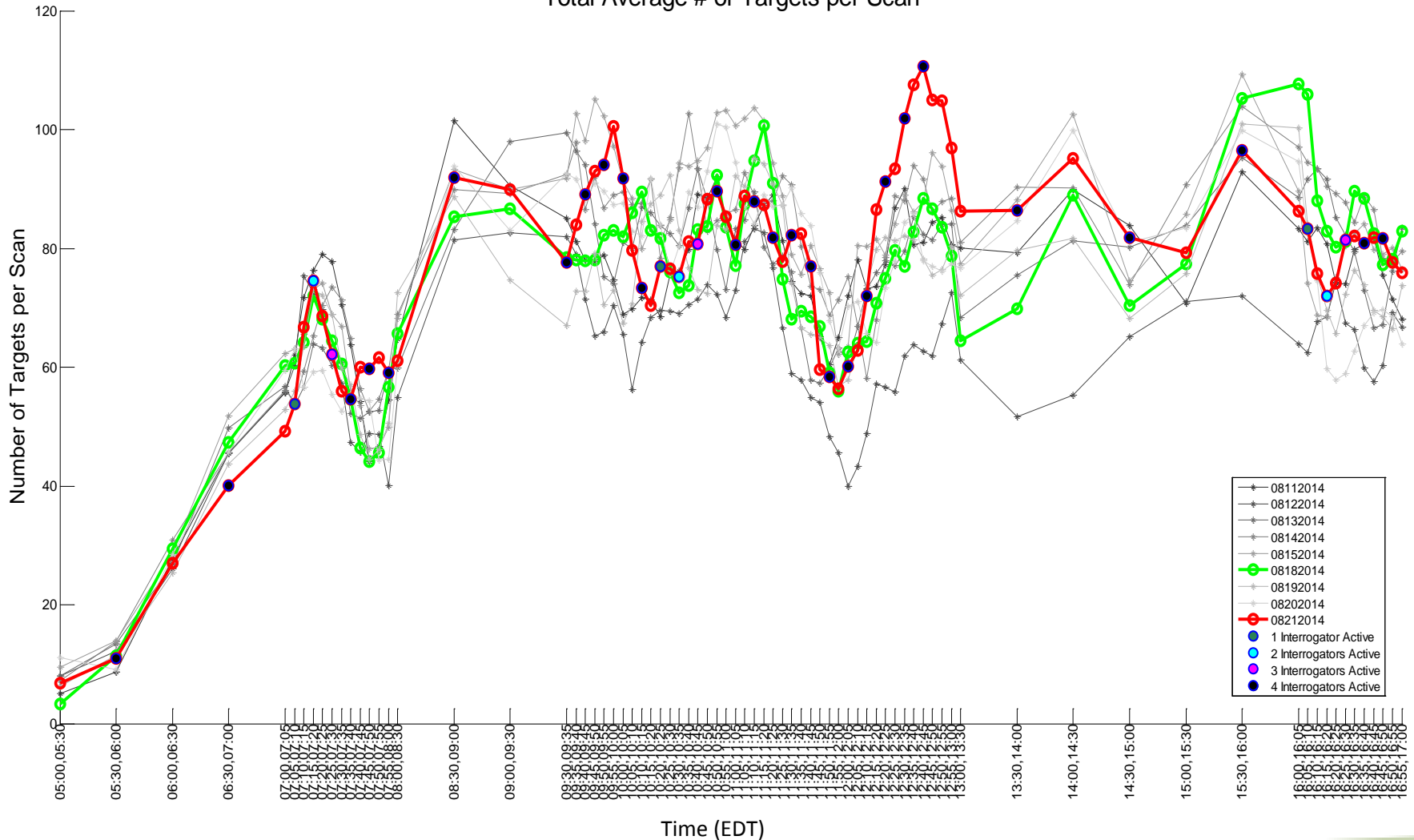
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 21<sup>st</sup>

Total Average # of Targets per Scan

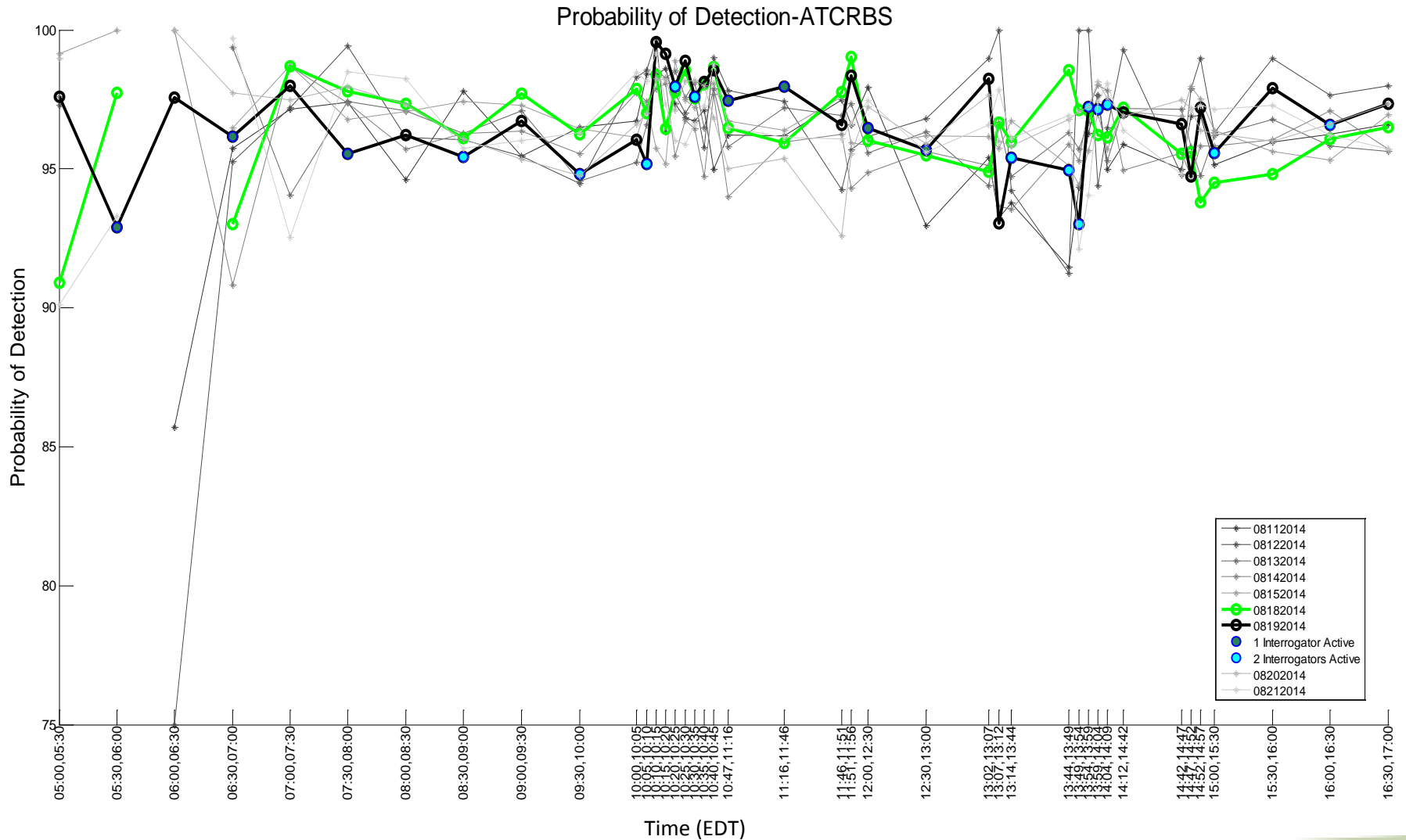


Geographic Filter: None  
Target Filter: None



# Probability of Detection – August 19<sup>th</sup>

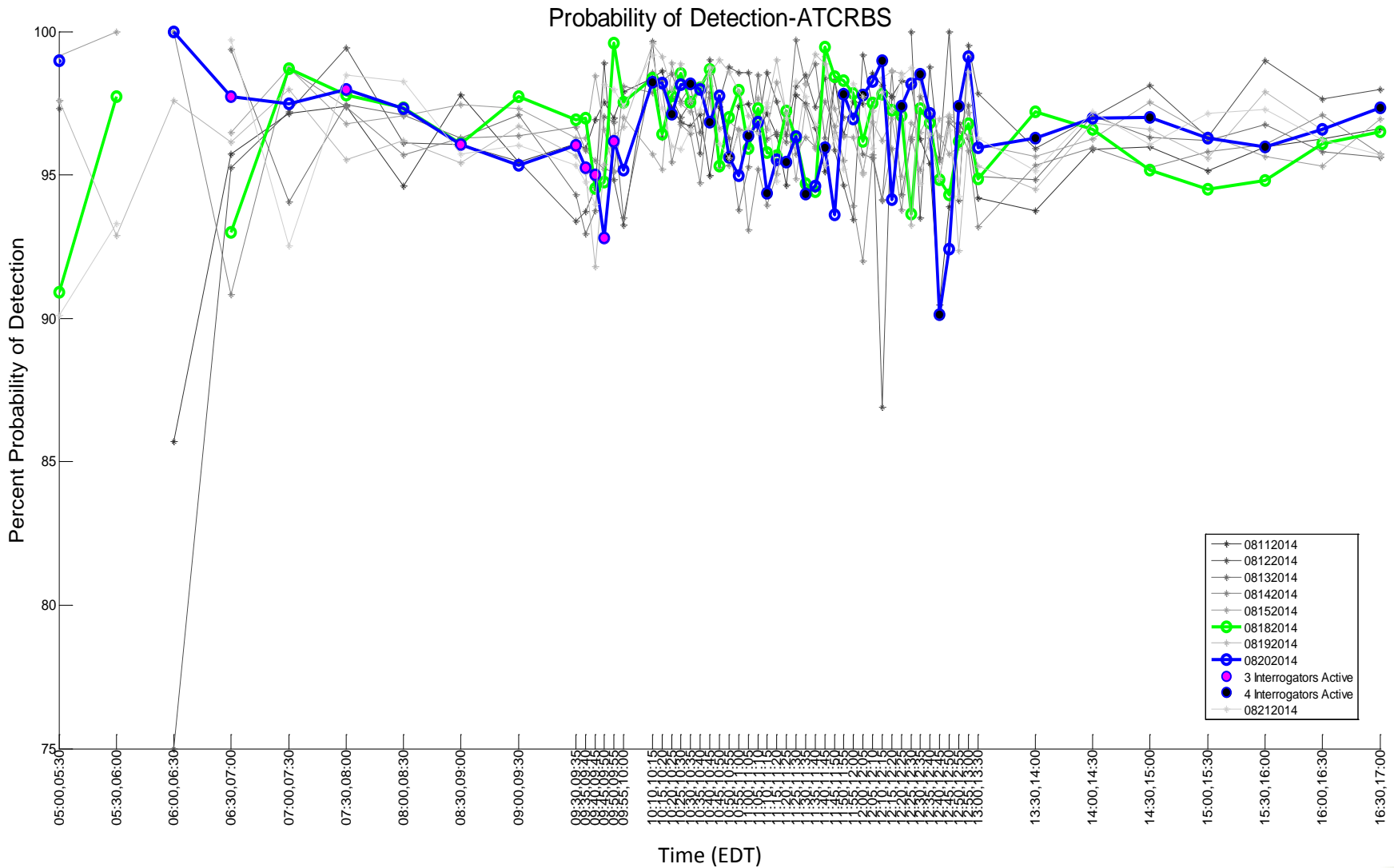
## ATCRBS Targets - Discrete



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

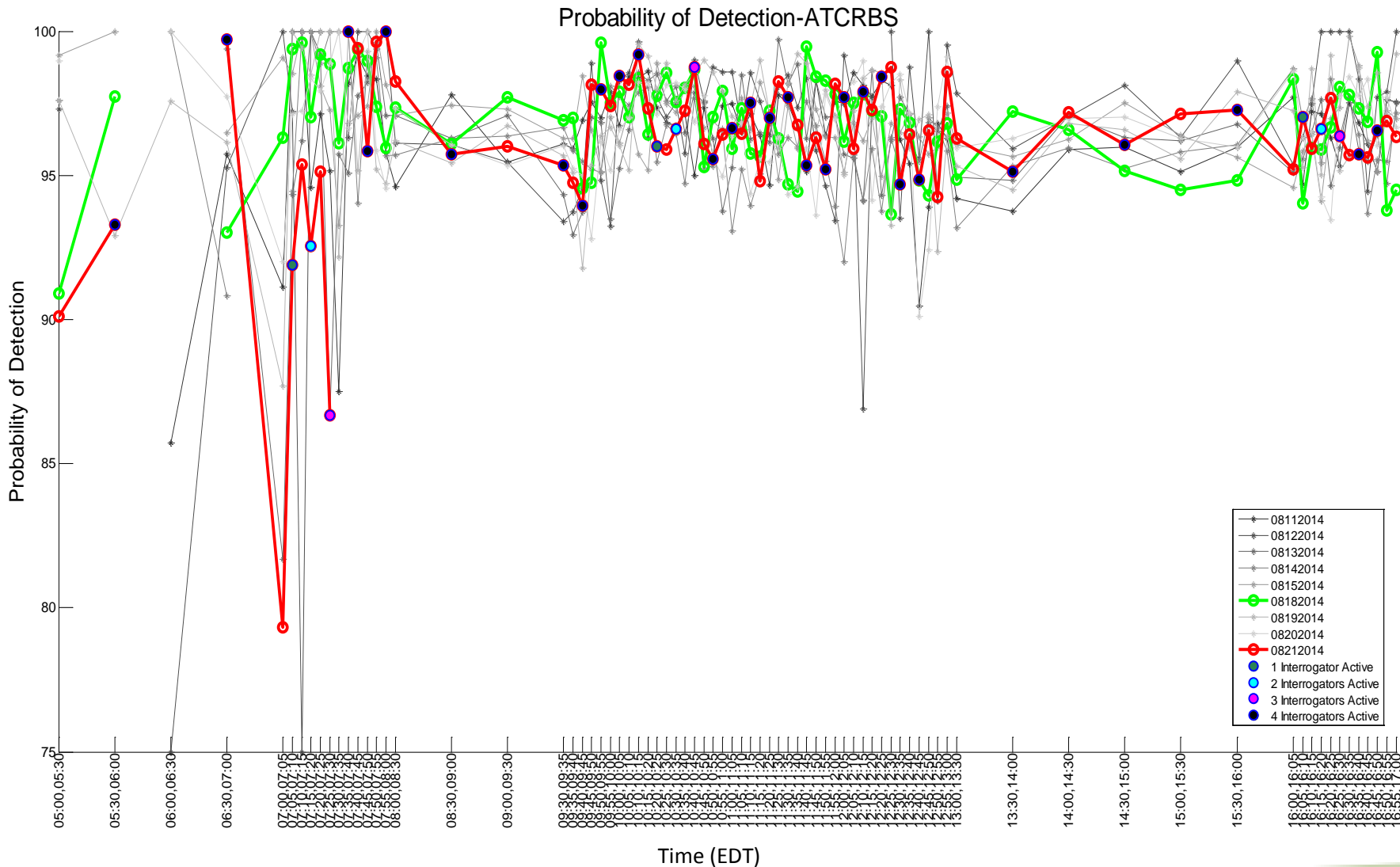
## ATCRBS Targets - Discrete



Geographic Filter: None  
 Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

## ATCRBS Targets - Discrete

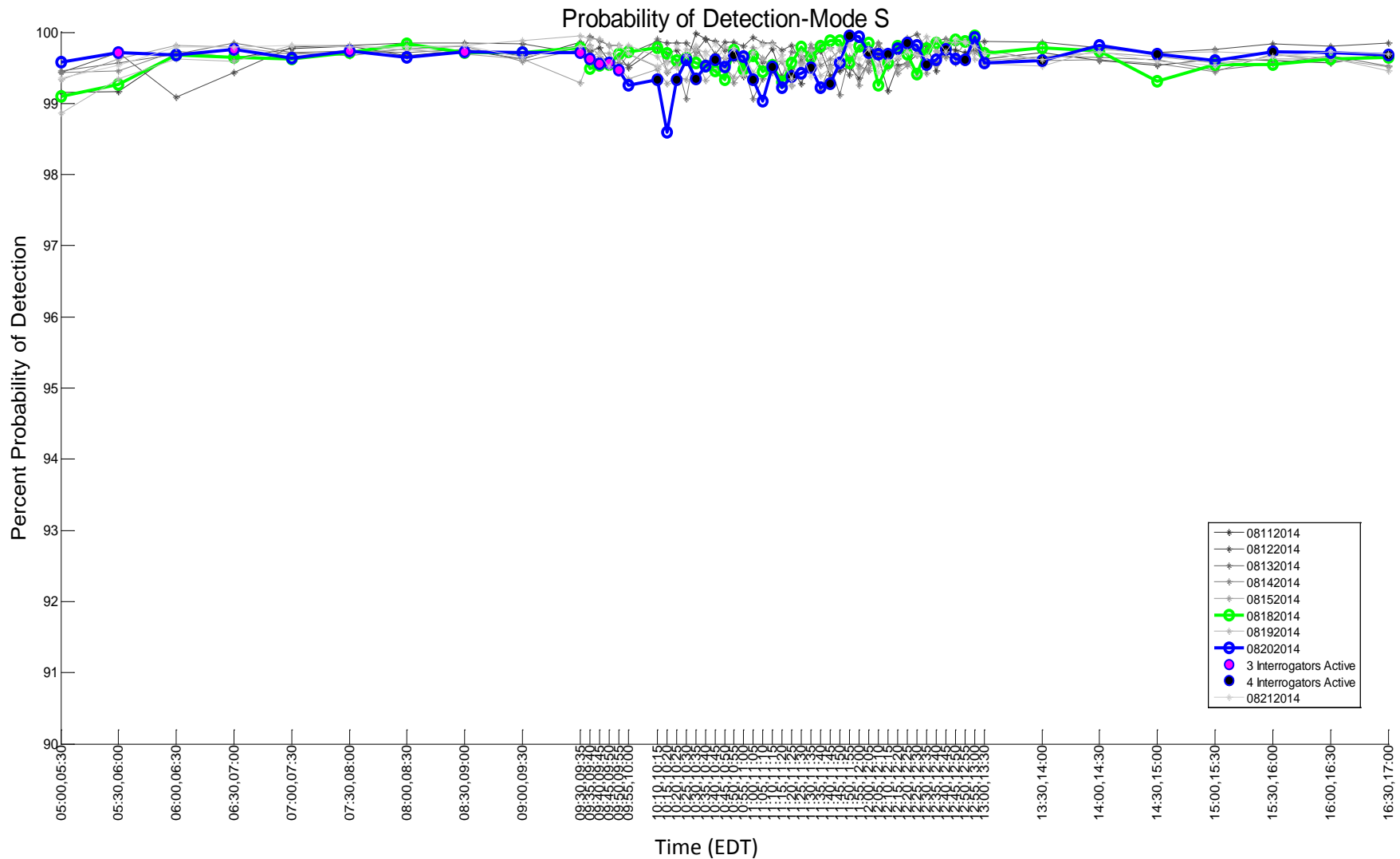


Geographic Filter: None  
Target Filter: None



# Probability of Detection – August 20<sup>th</sup>

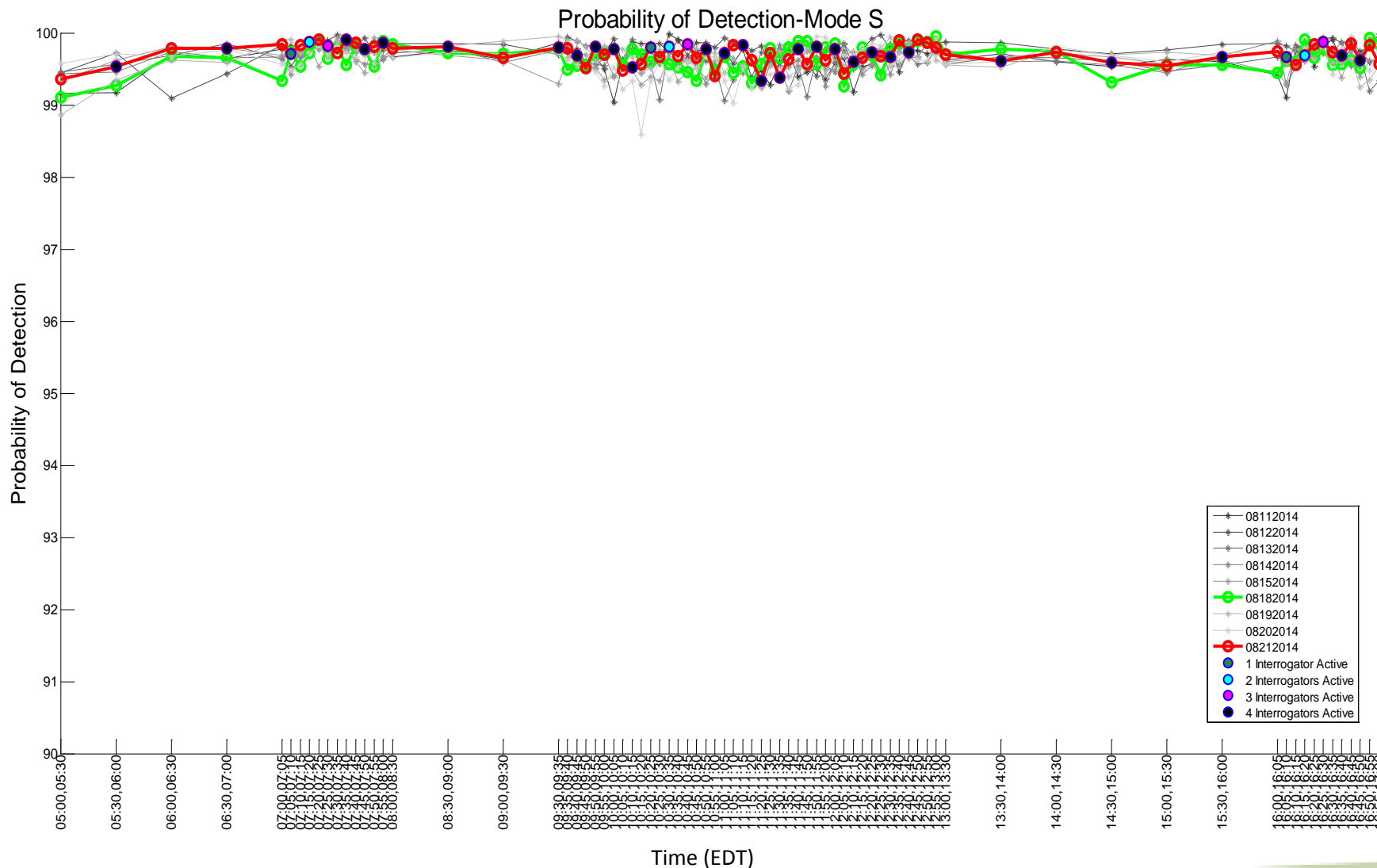
## Mode S Targets



Geographic Filter: None  
Target Filter: None

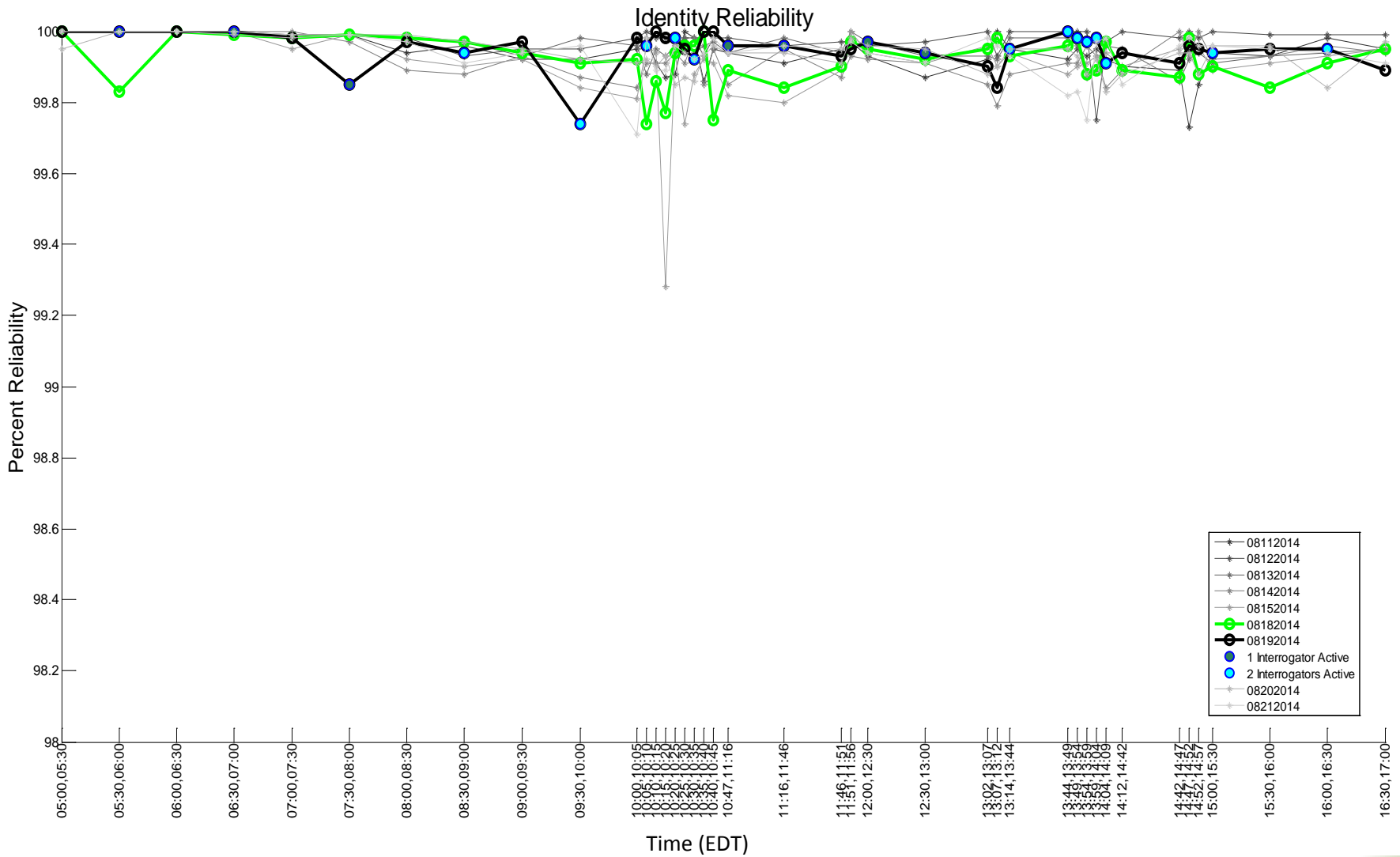
# Probability of Detection – August 21<sup>st</sup>

## Mode S Targets



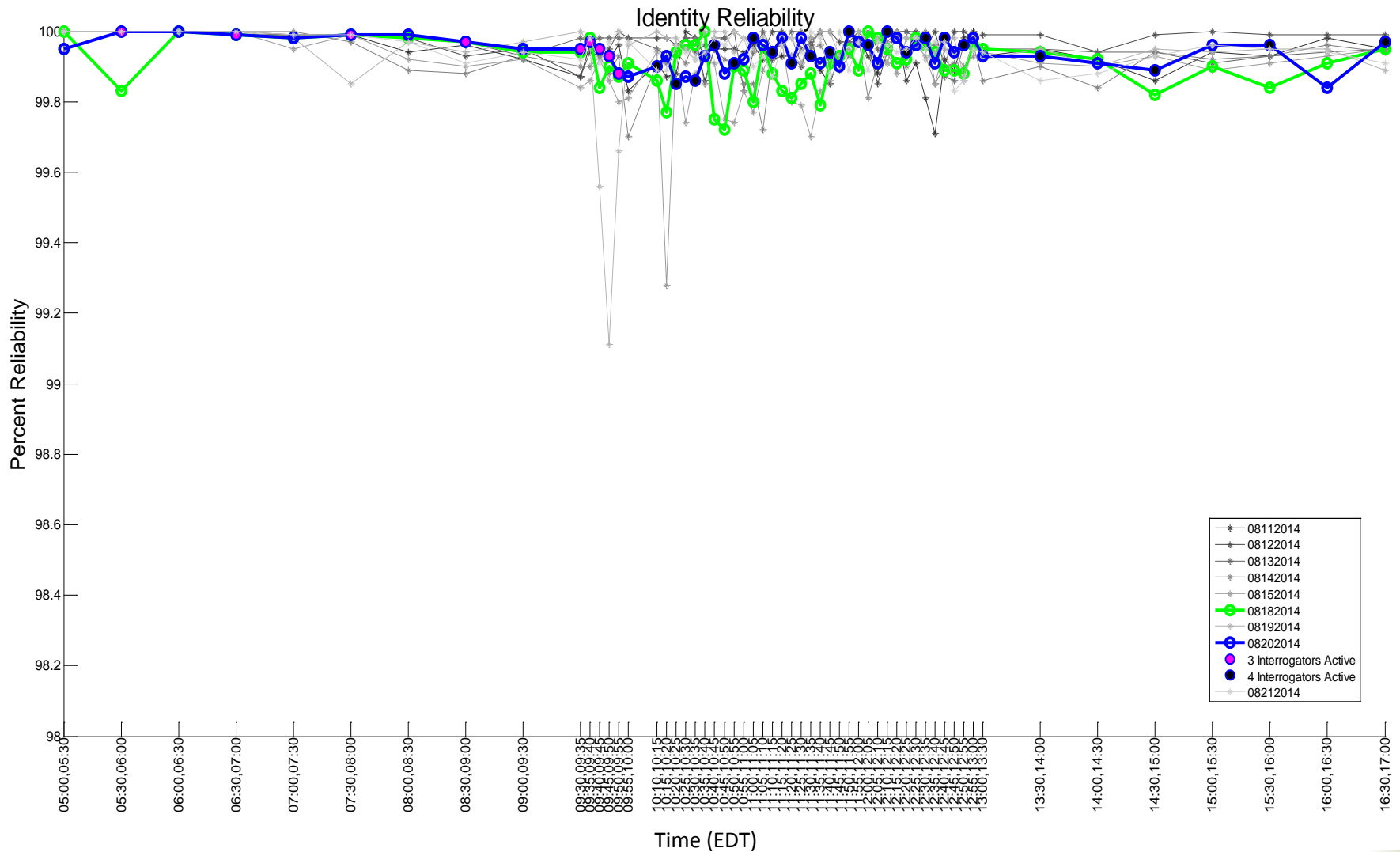
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 19th



Geographic Filter: None  
Target Filter: None

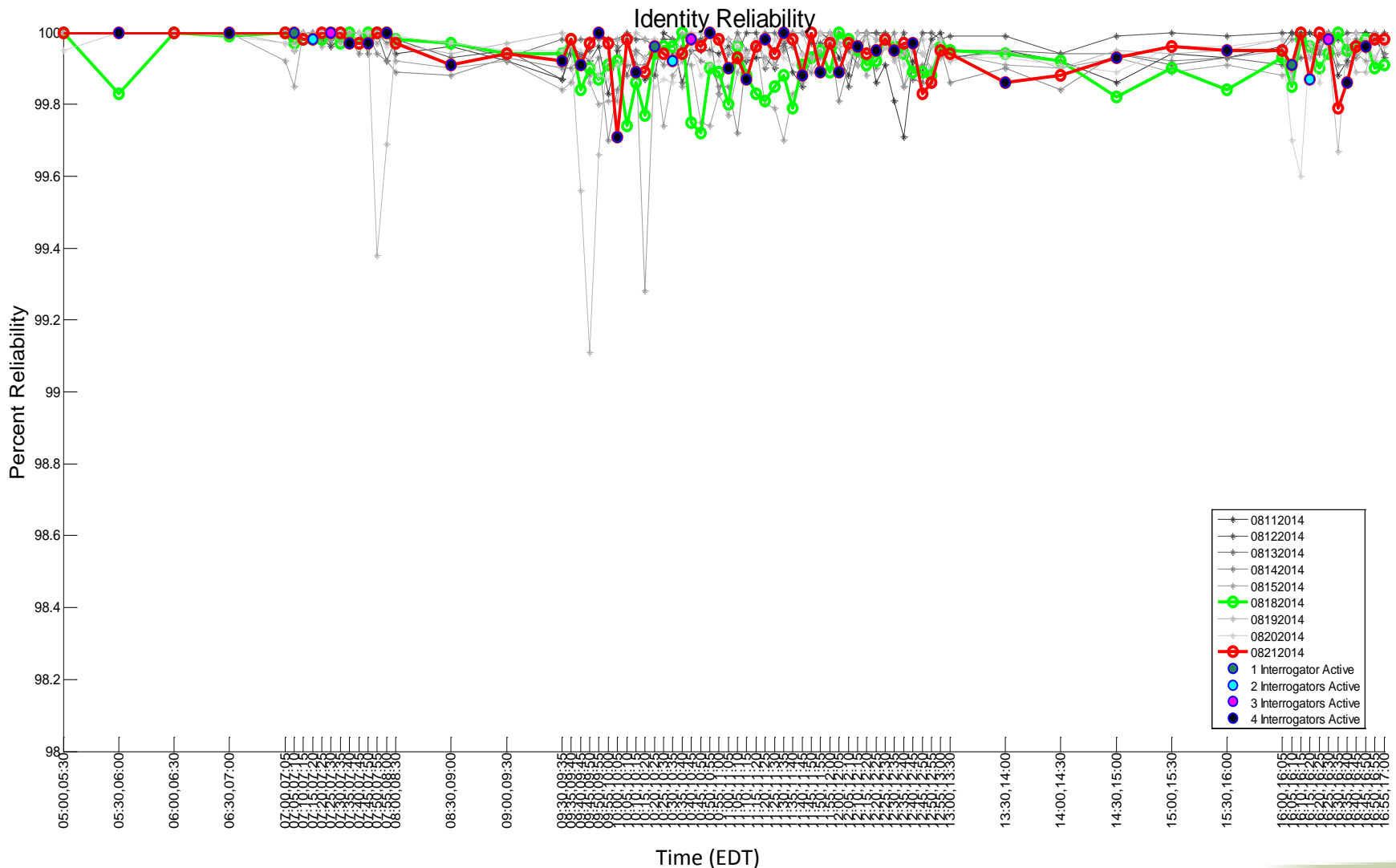
# Identity (3/A) Reliability – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

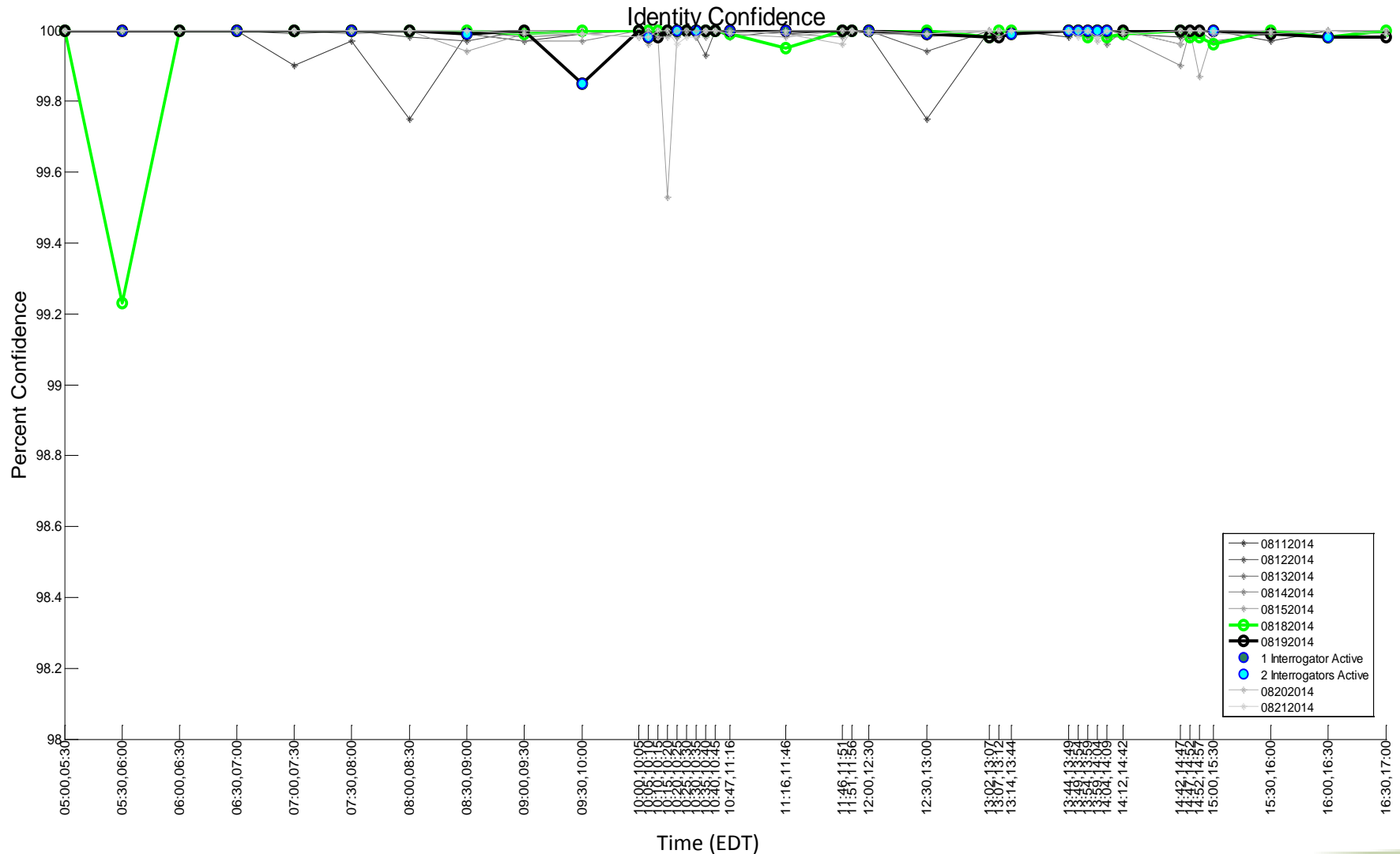


# Identity (3/A) Reliability – August 21<sup>st</sup>



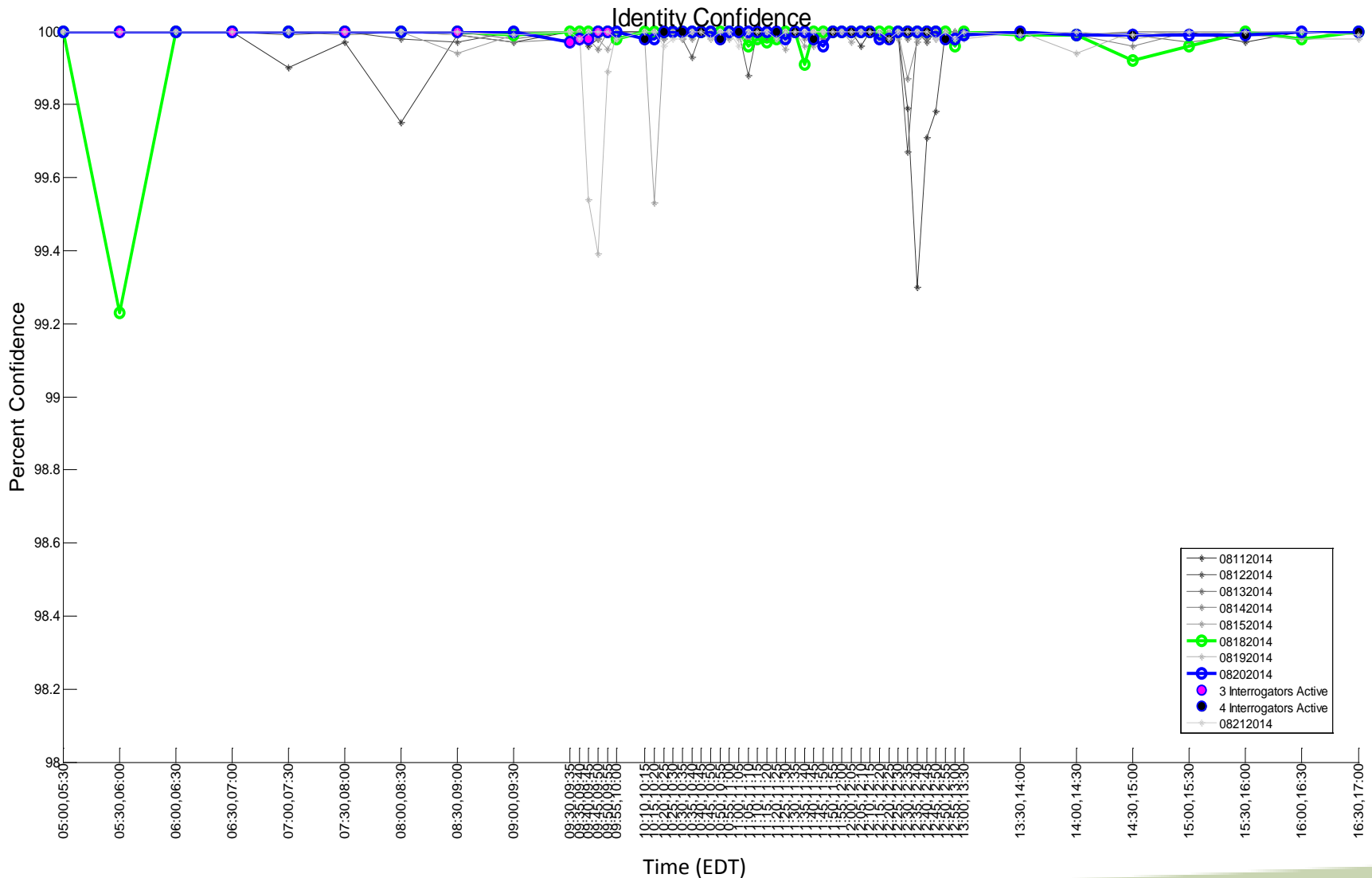
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 19th



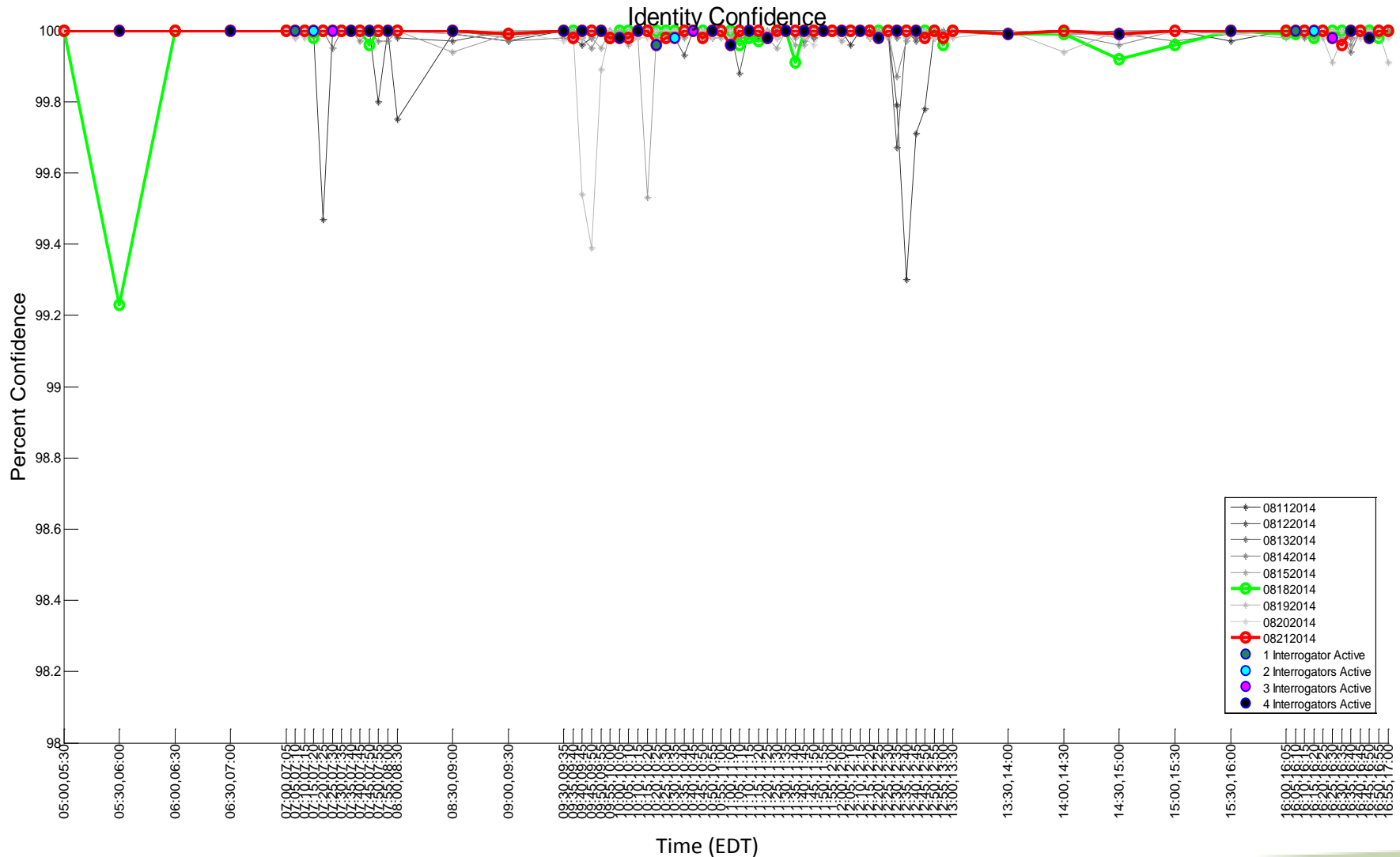
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 20<sup>th</sup>



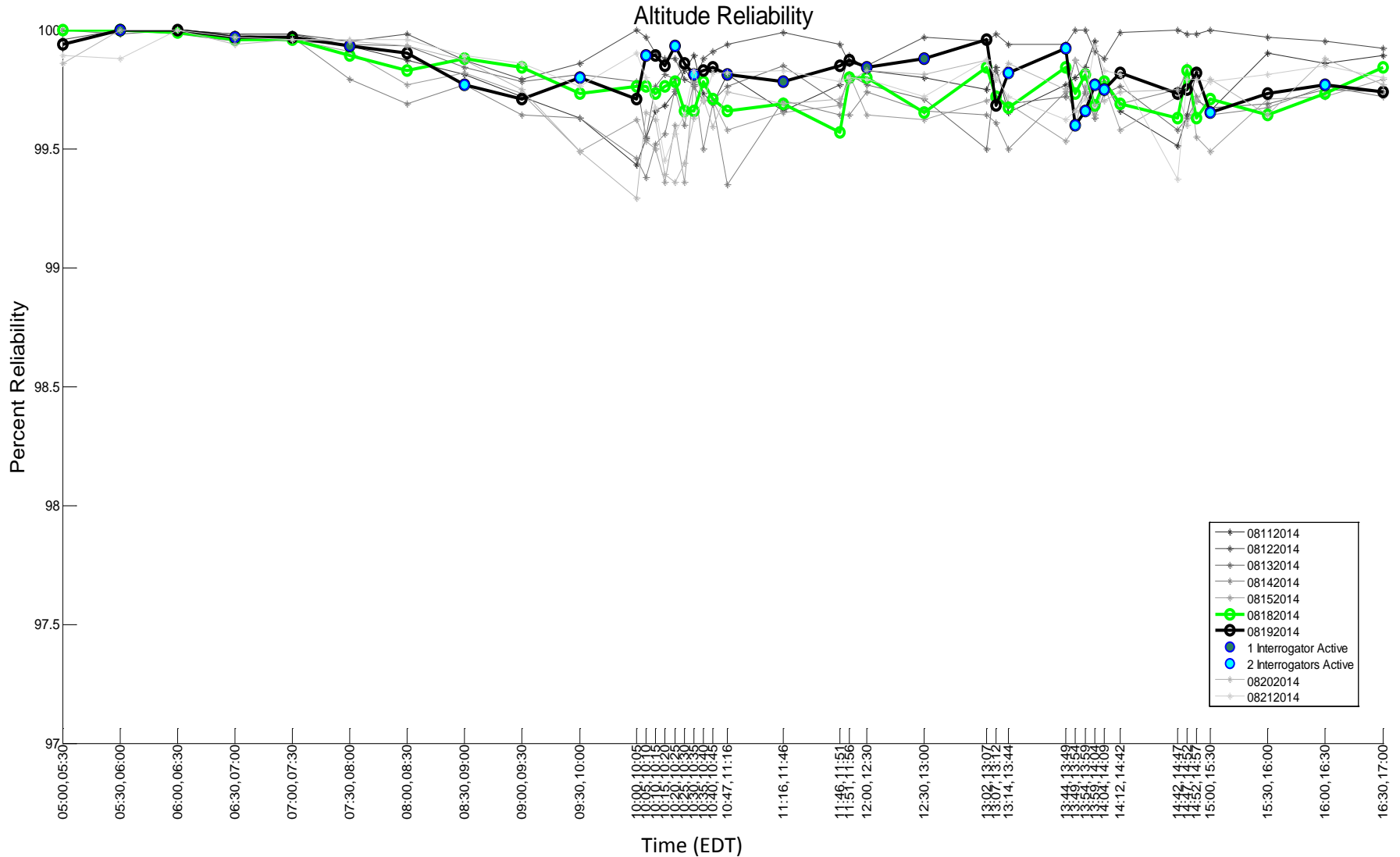
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 21<sup>st</sup>



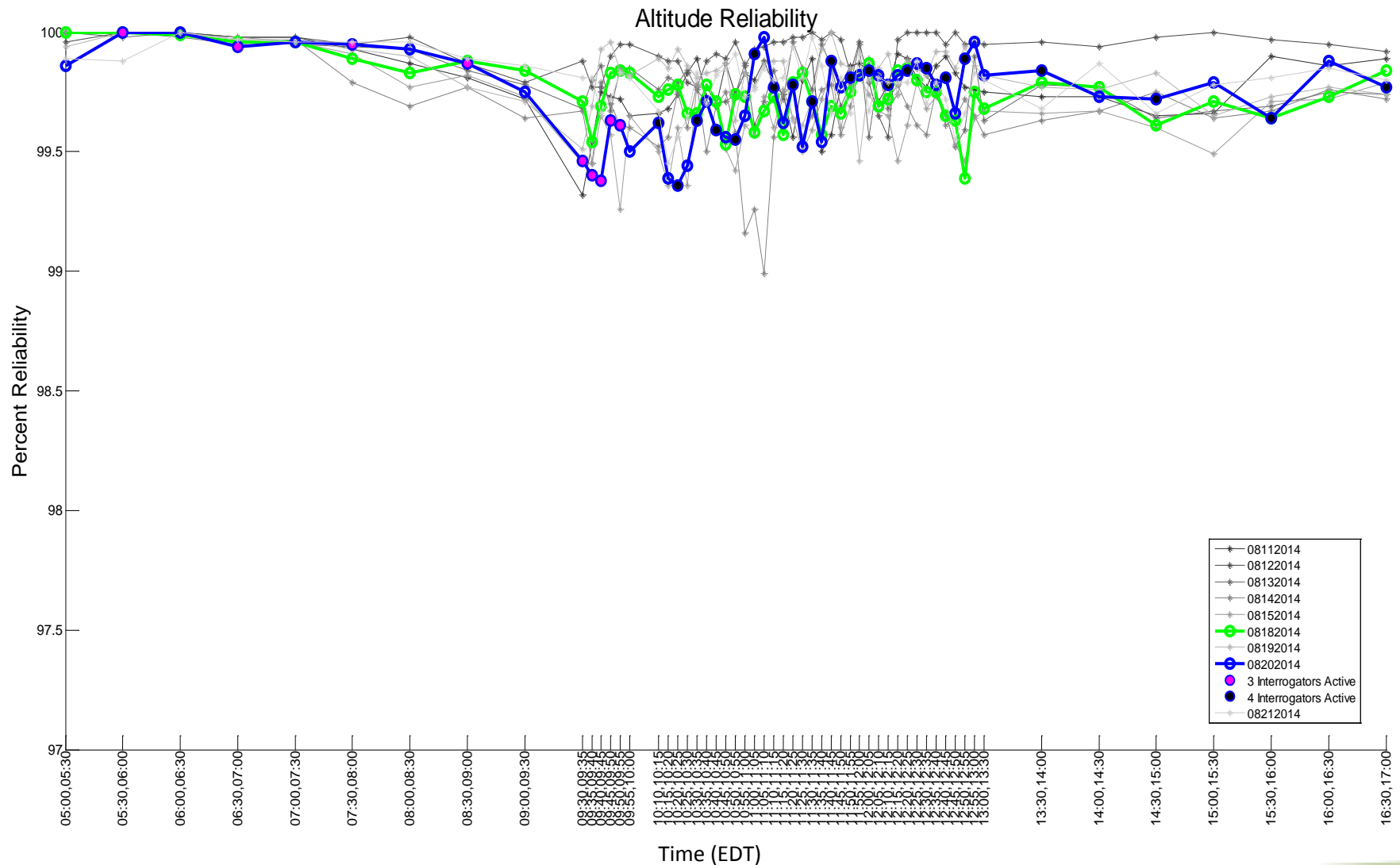
Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 19th



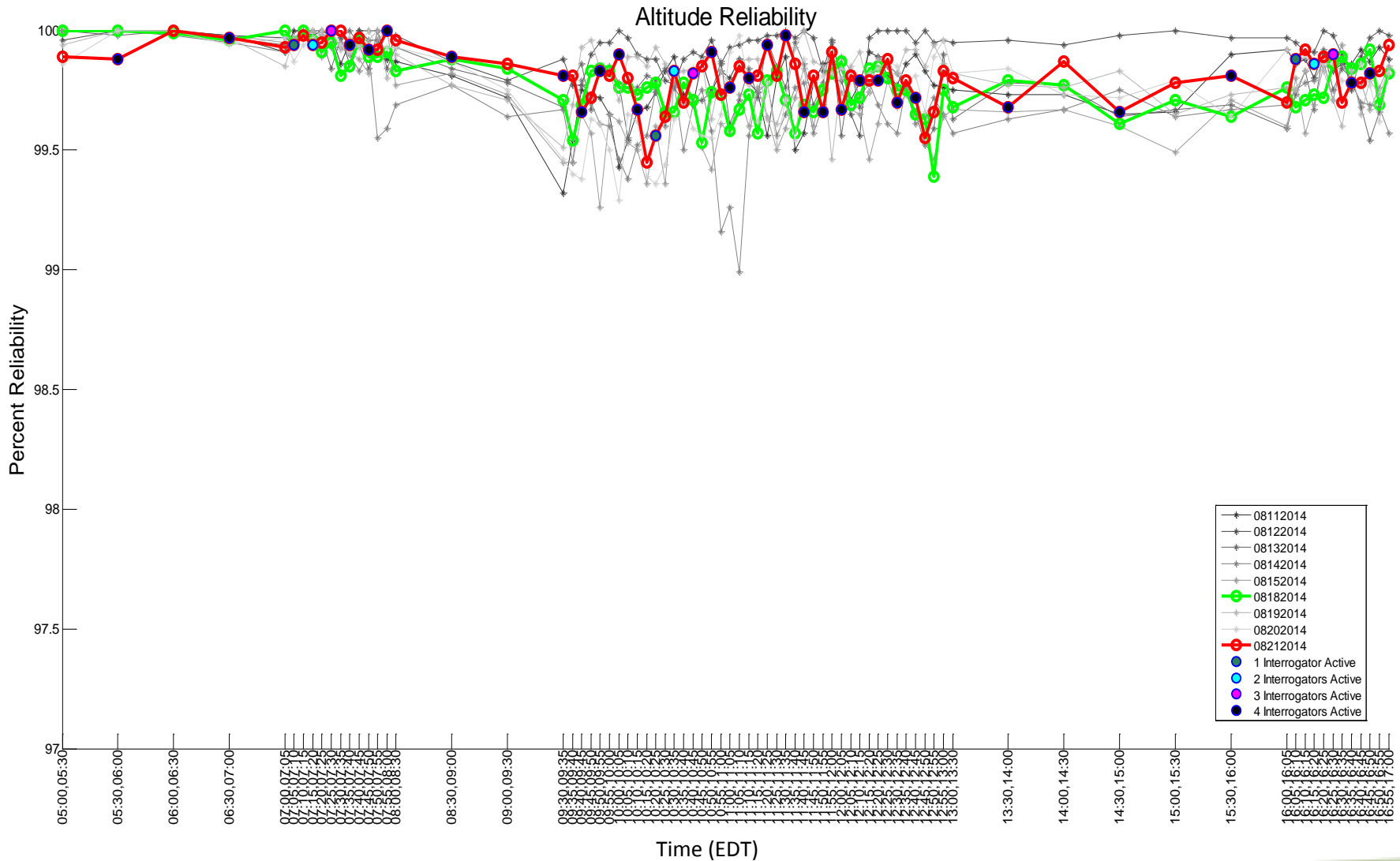
Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 20<sup>th</sup>



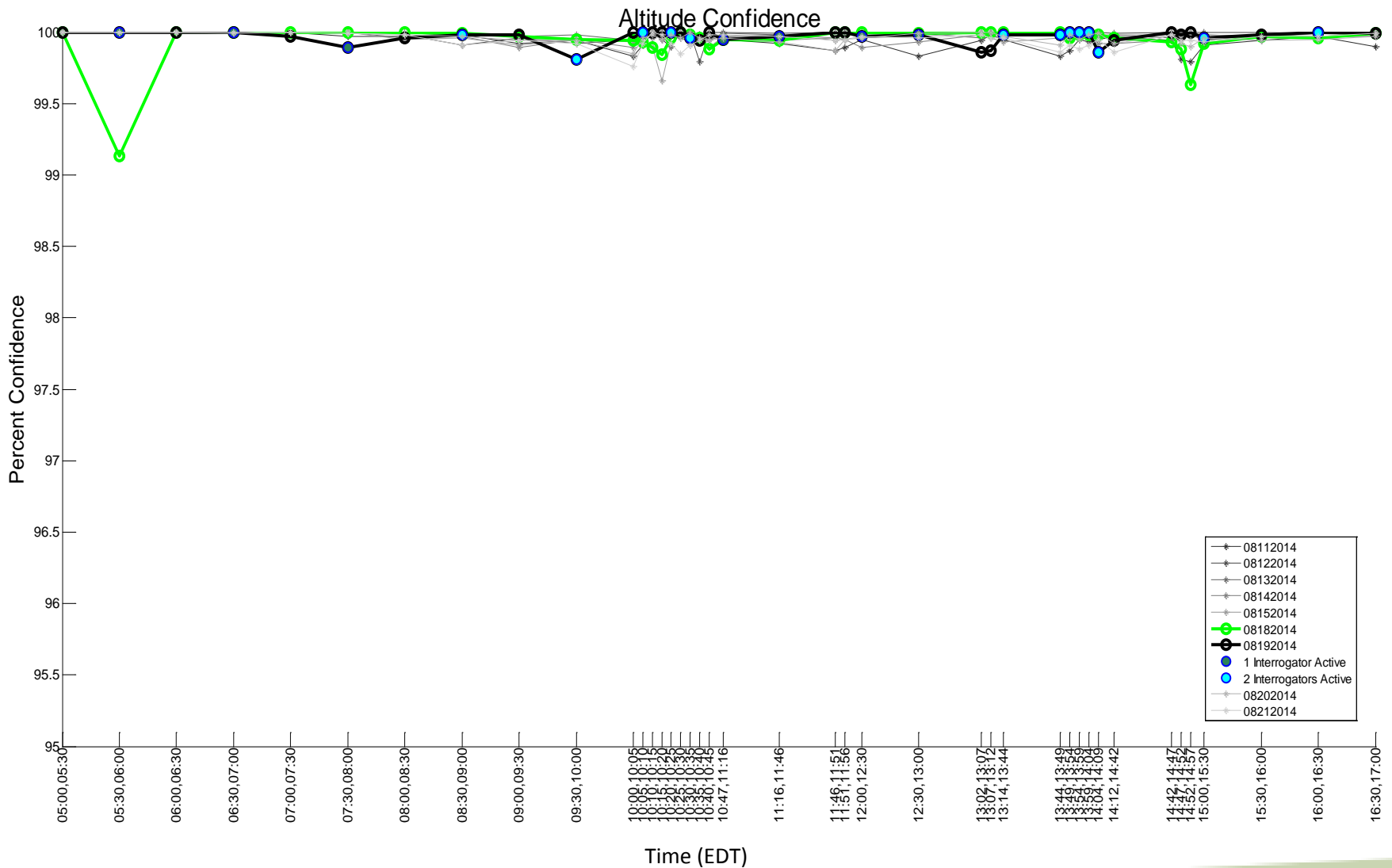
Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

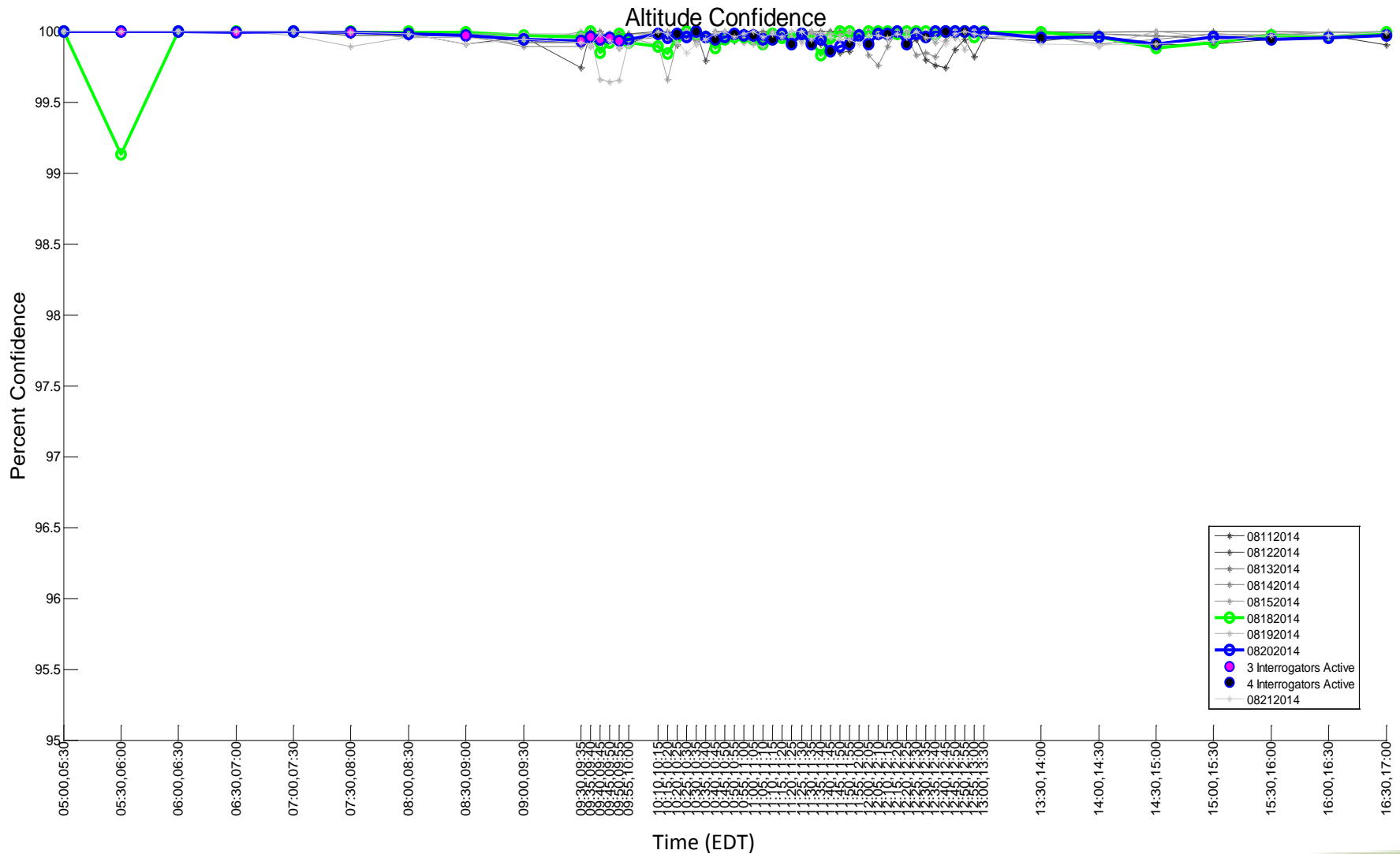
# Altitude (C) Confidence – August 19th



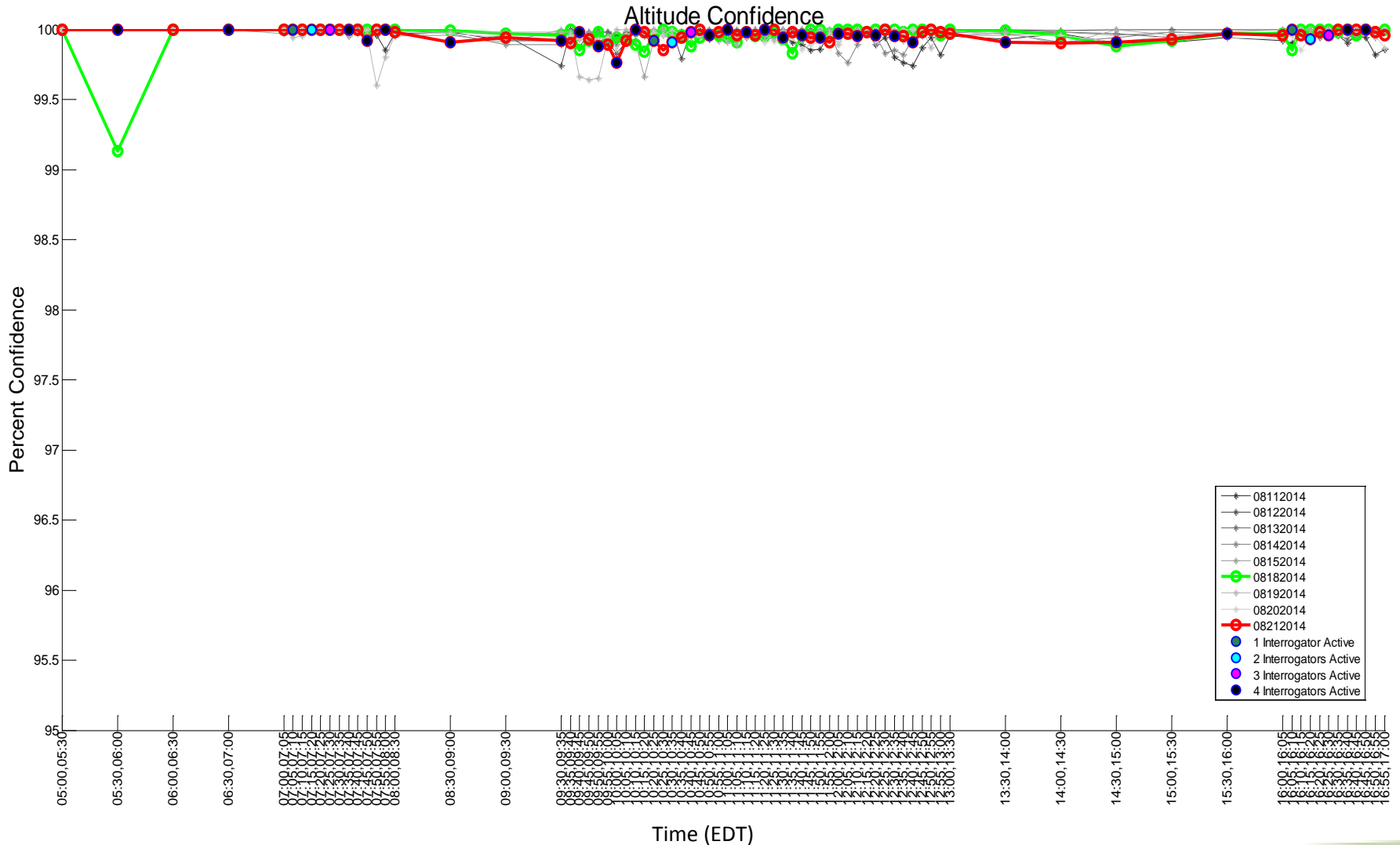
Geographic Filter: None  
Target Filter: None



# Altitude (C) Confidence – August 20<sup>th</sup>

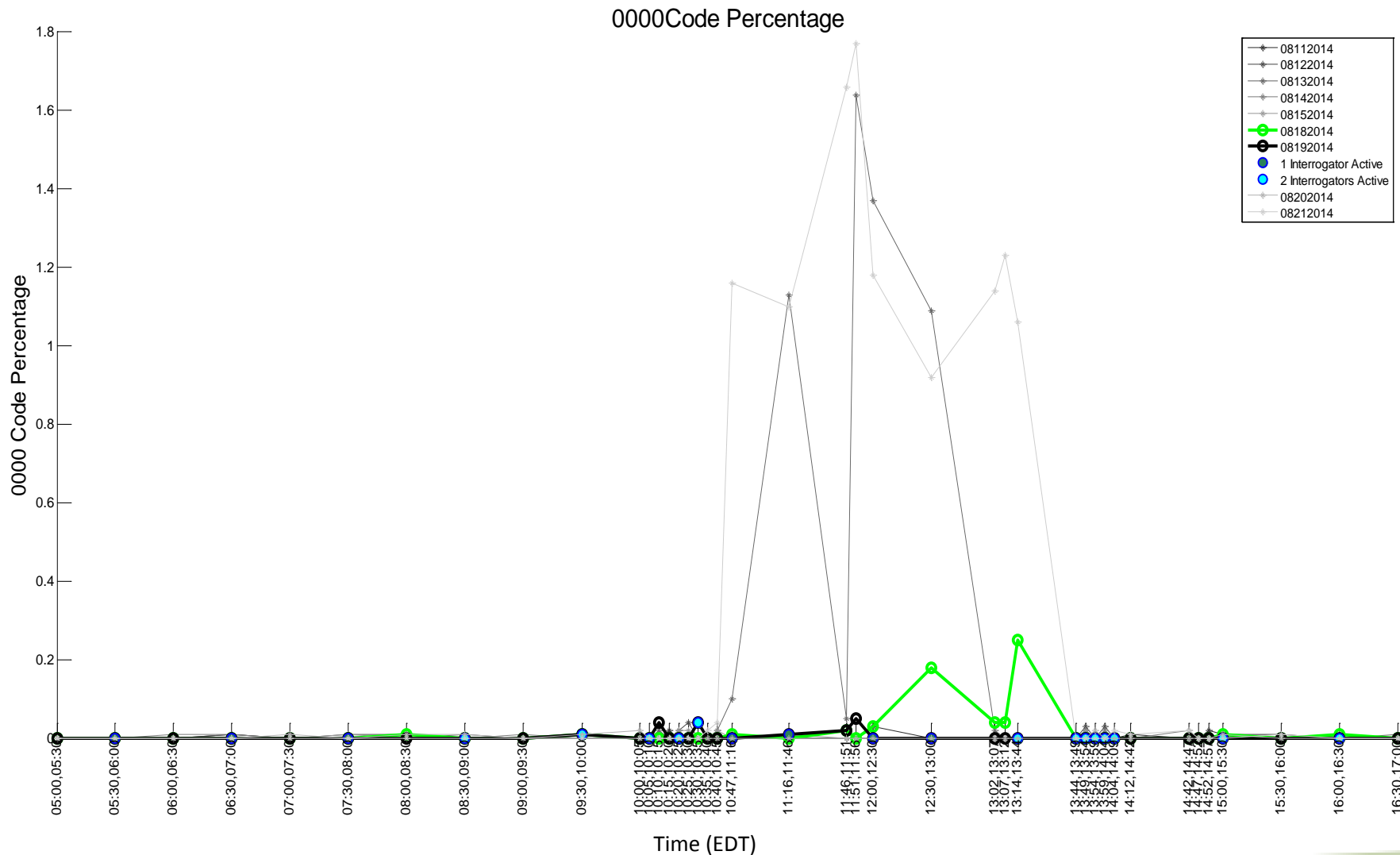


# Altitude (C) Confidence – August 21<sup>st</sup>



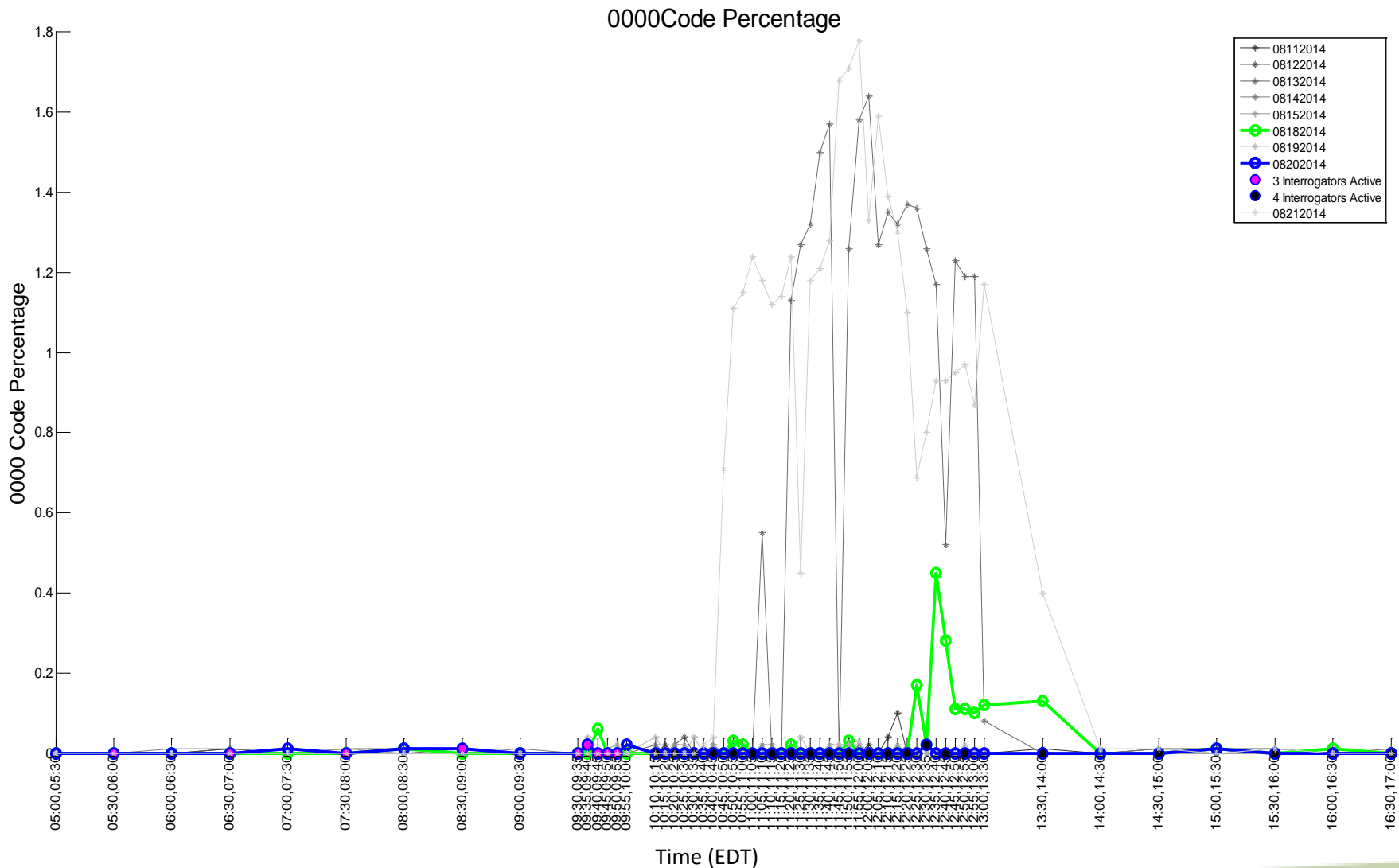
Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 19th



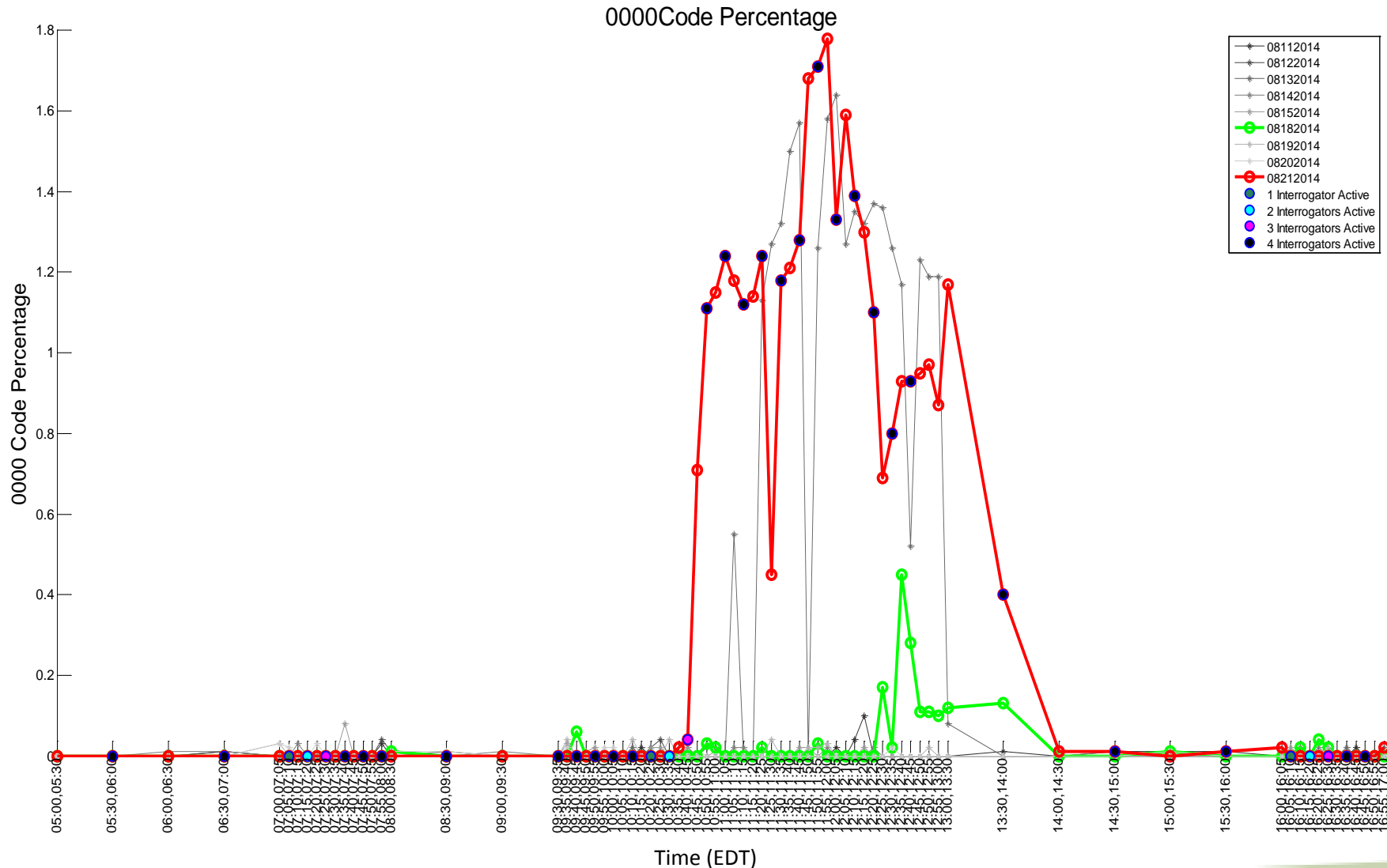
Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 20<sup>th</sup>



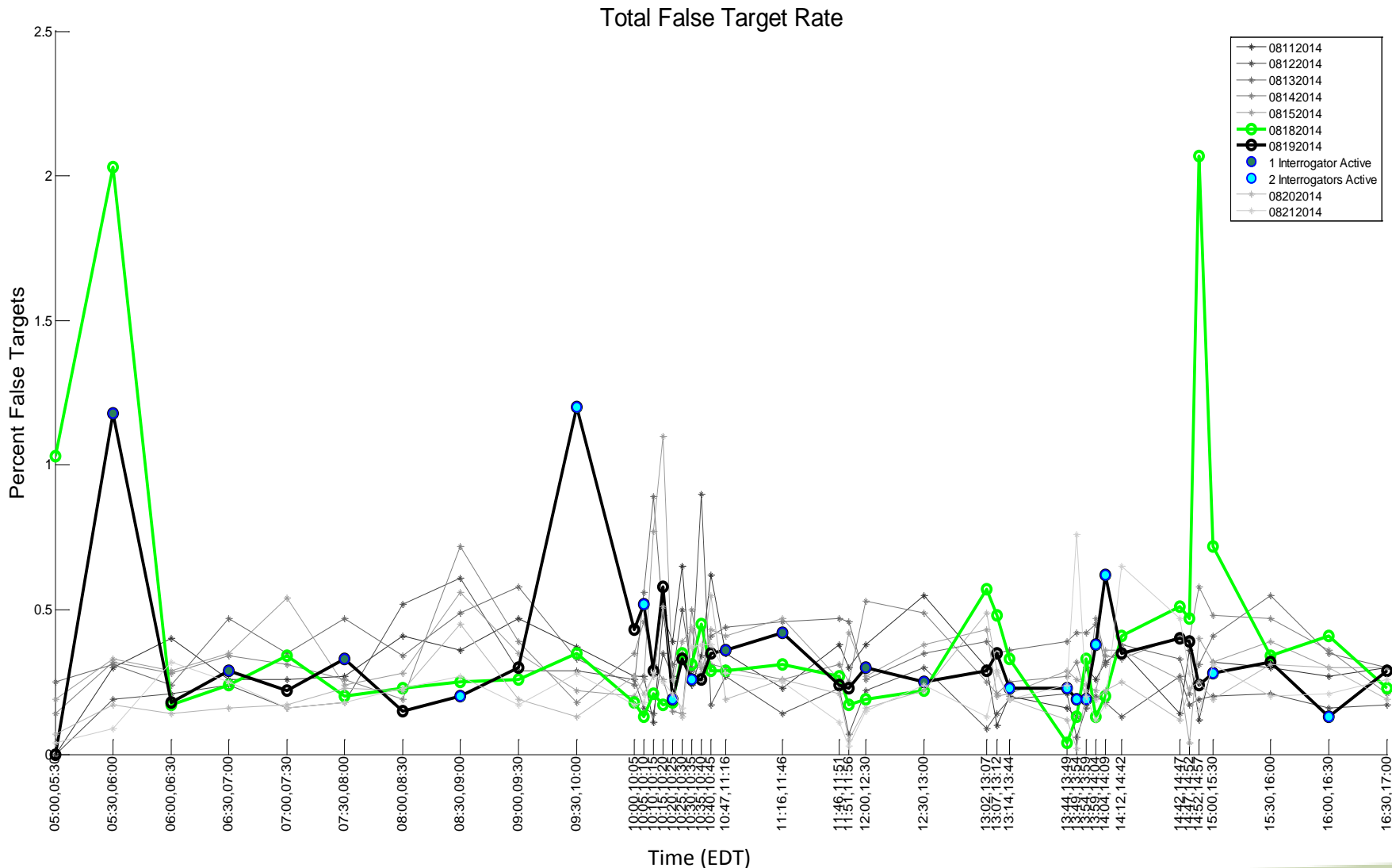
Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 21<sup>st</sup>



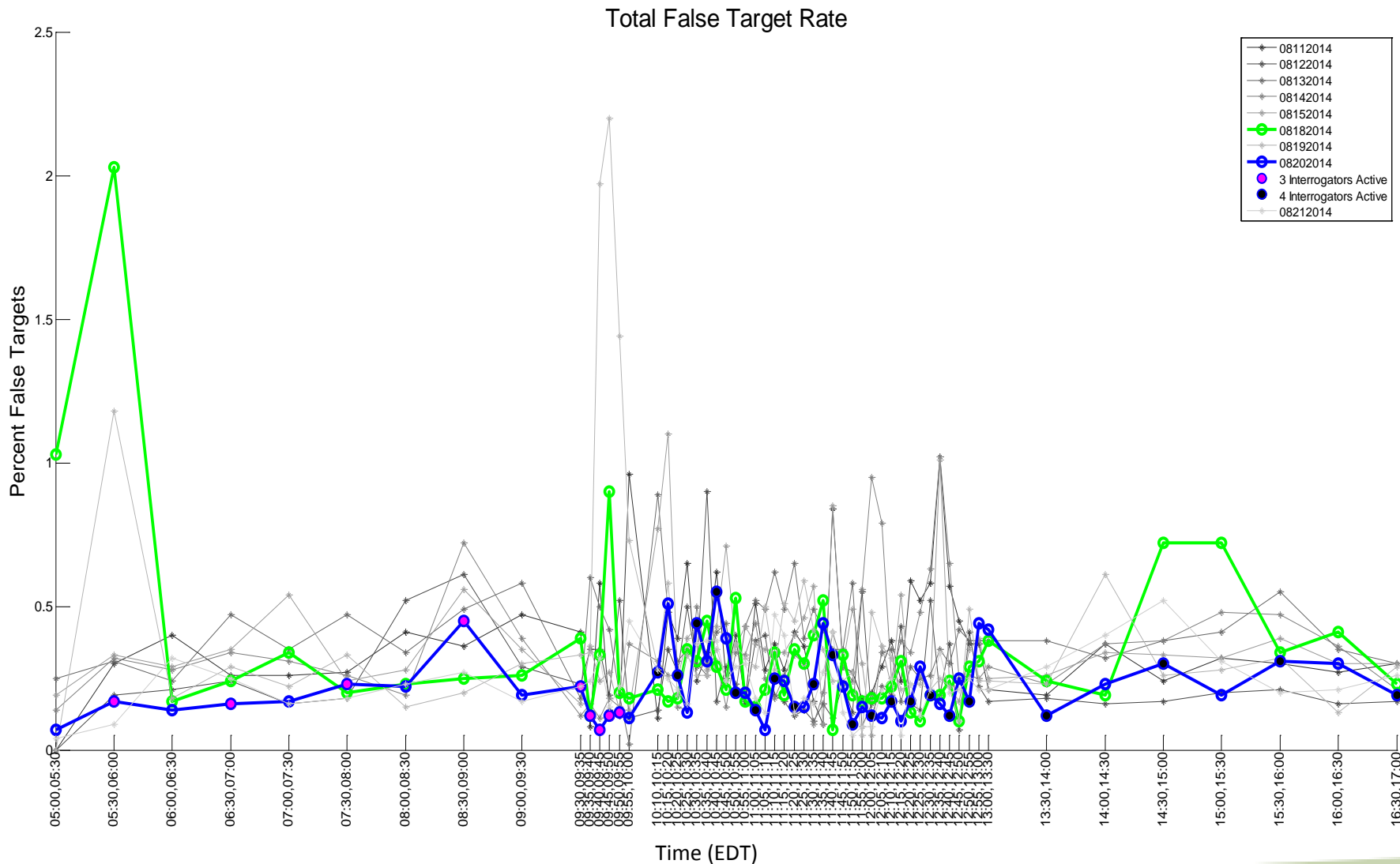
Geographic Filter: None  
Target Filter: None

# False Targets – August 19th



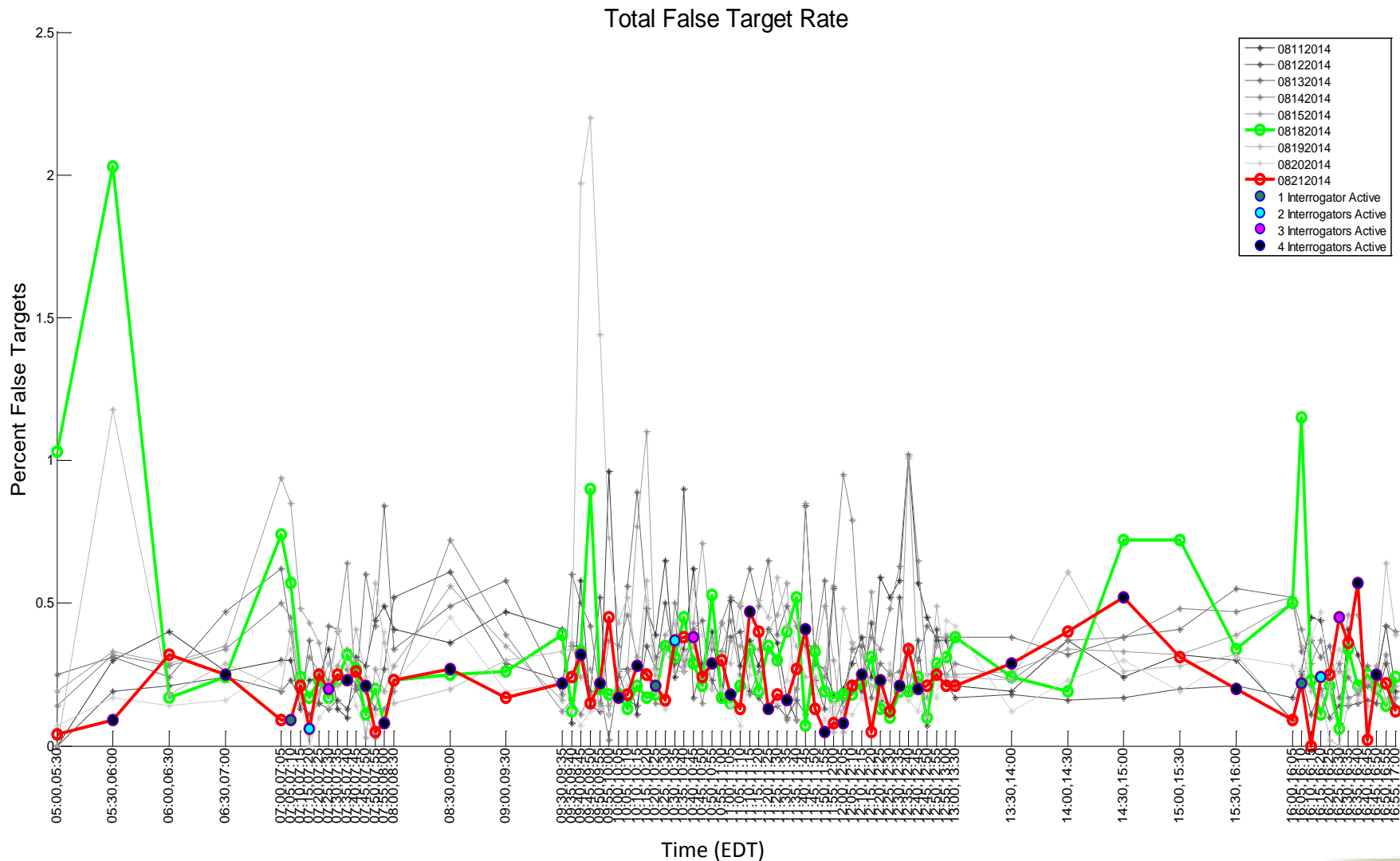
Geographic Filter: None  
Target Filter: None

# False Targets – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

# False Targets – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None



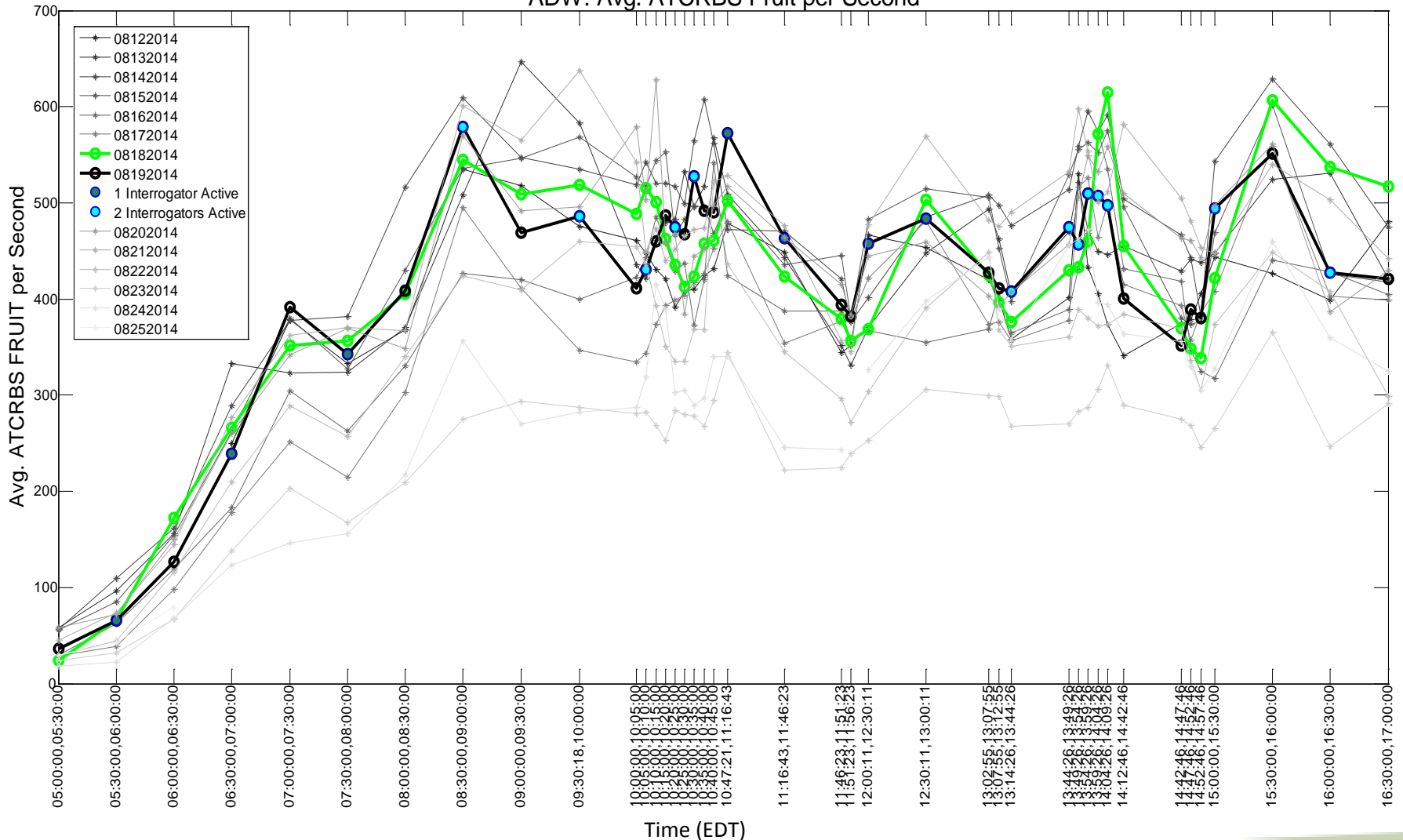
# Observations and Conclusions

- ❑ The Probability of Detection, Identity Reliability and Confidence, Altitude Reliability and Confidence, False Targets, 0000 Codes, and Targets per Scan exhibit no observable adverse trend with respect to periods of radiation by the AN/UPX-41(C) interrogator.
- ❑ During AN/UPX-41(C) interrogator radiation, the variations or volatility of the aforementioned metrics are within the bounds of the variations of the same metrics on non-test days (baseline).
- ❑ In determining possible cases of interference, targets at low elevation angles exhibited relatively low probabilities of detection regardless of Active/OFF period
  - This inherent skew creates many  $P_d$  outliers that mask the ability to notice downward  $P_d$  movement due to interference
  - An analysis excluding low elevation angle targets is available upon request, but the conclusions are no different than the first two bullets of this slide.

# Mode S Extraction Data Analysis

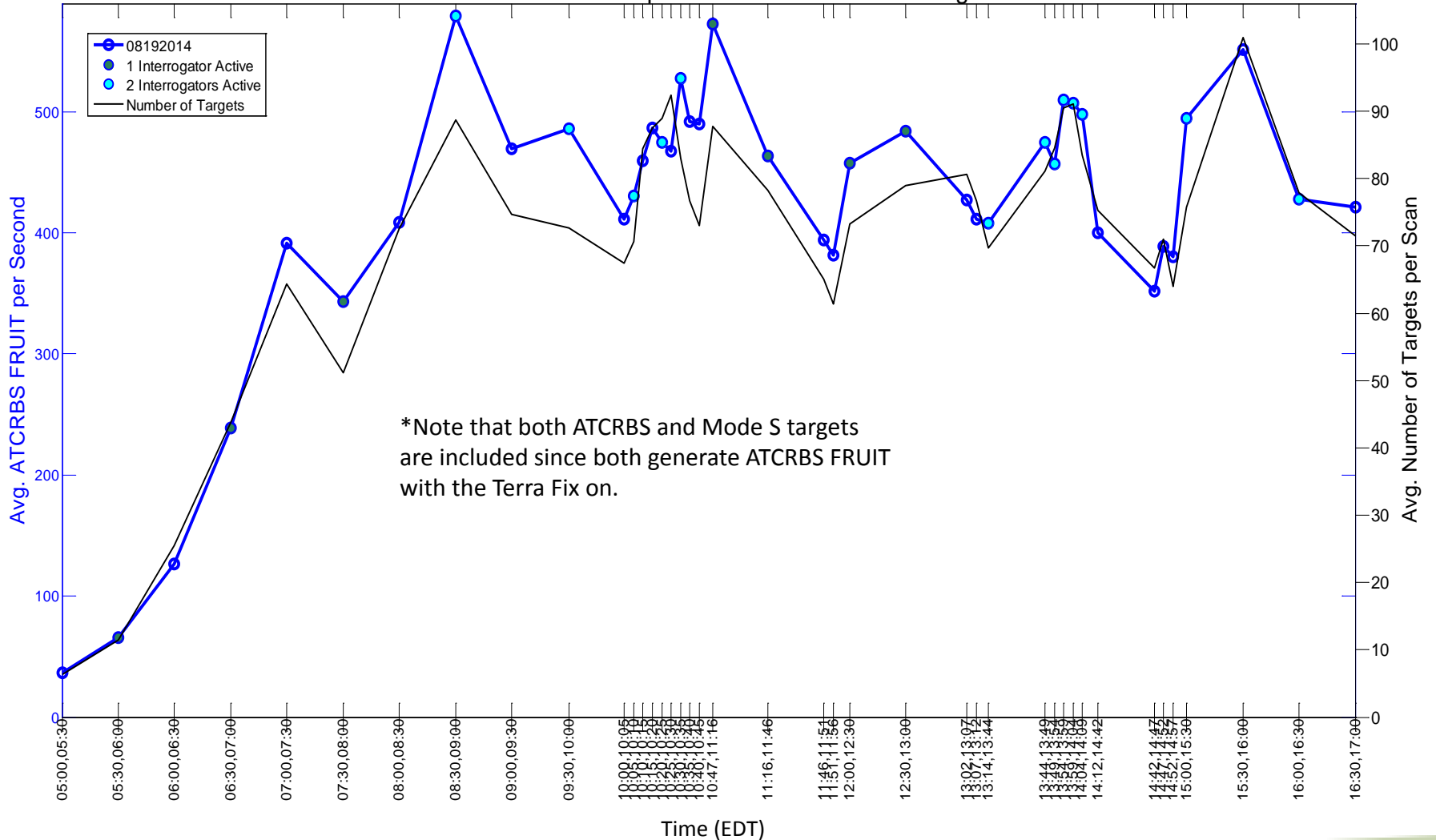
# ATCRBS FRUIT Rate – August 19<sup>th</sup>

ADW: Avg. ATCRBS Fruit per Second



# ATCRBS FRUIT Rate vs # of Targets–August 19<sup>th</sup>

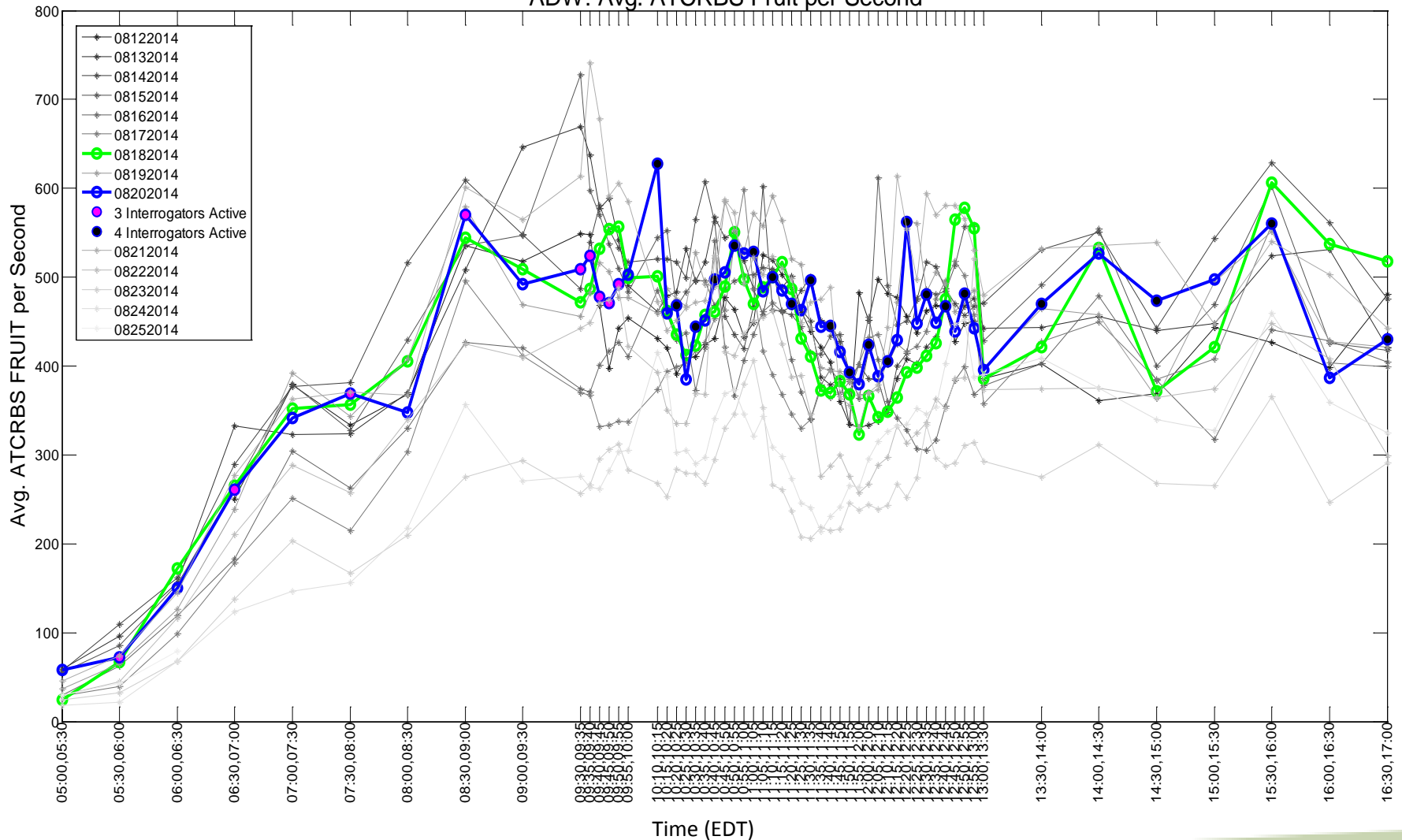
ADW: ATCRBS Fruit per Second vs Number of Targets



\*Note that both ATCRBS and Mode S targets are included since both generate ATCRBS FRUIT with the Terra Fix on.

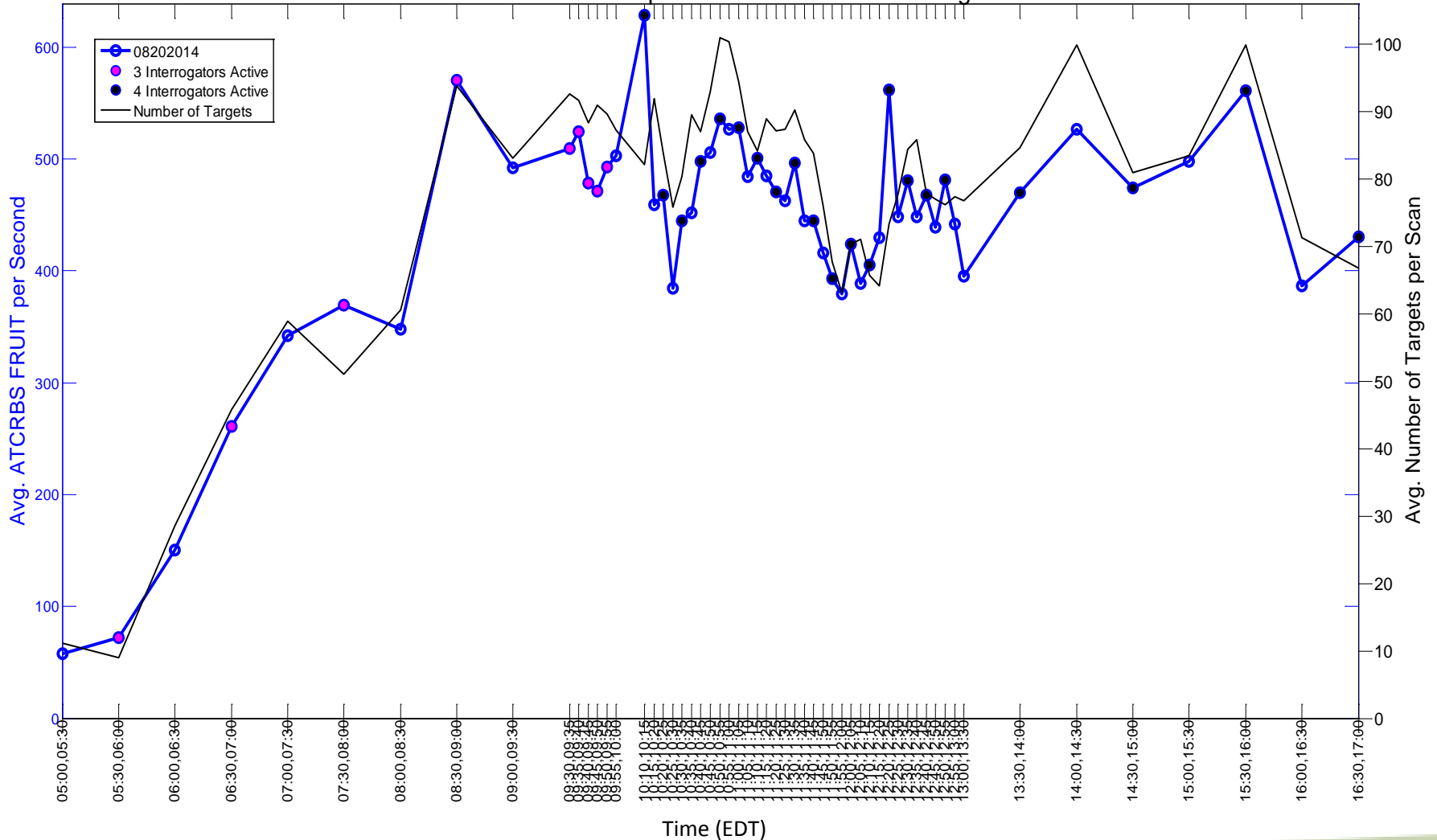
# ATCRBS FRUIT Rate – August 20<sup>th</sup>

ADW: Avg. ATCRBS Fruit per Second



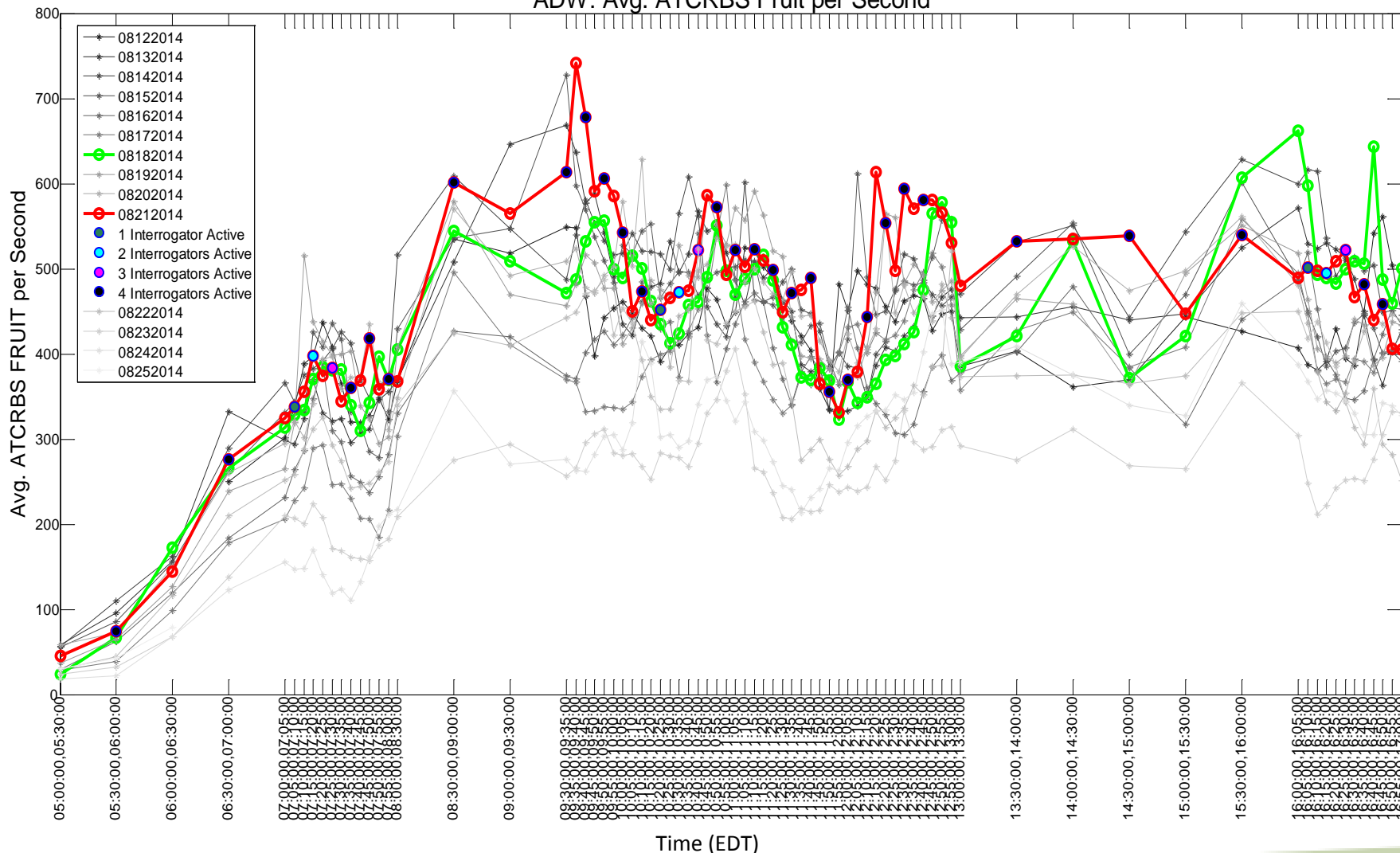
# ATCRBS FRUIT Rate vs # of Targets – August 20<sup>th</sup>

ADW: ATCRBS Fruit per Second vs Number of Targets



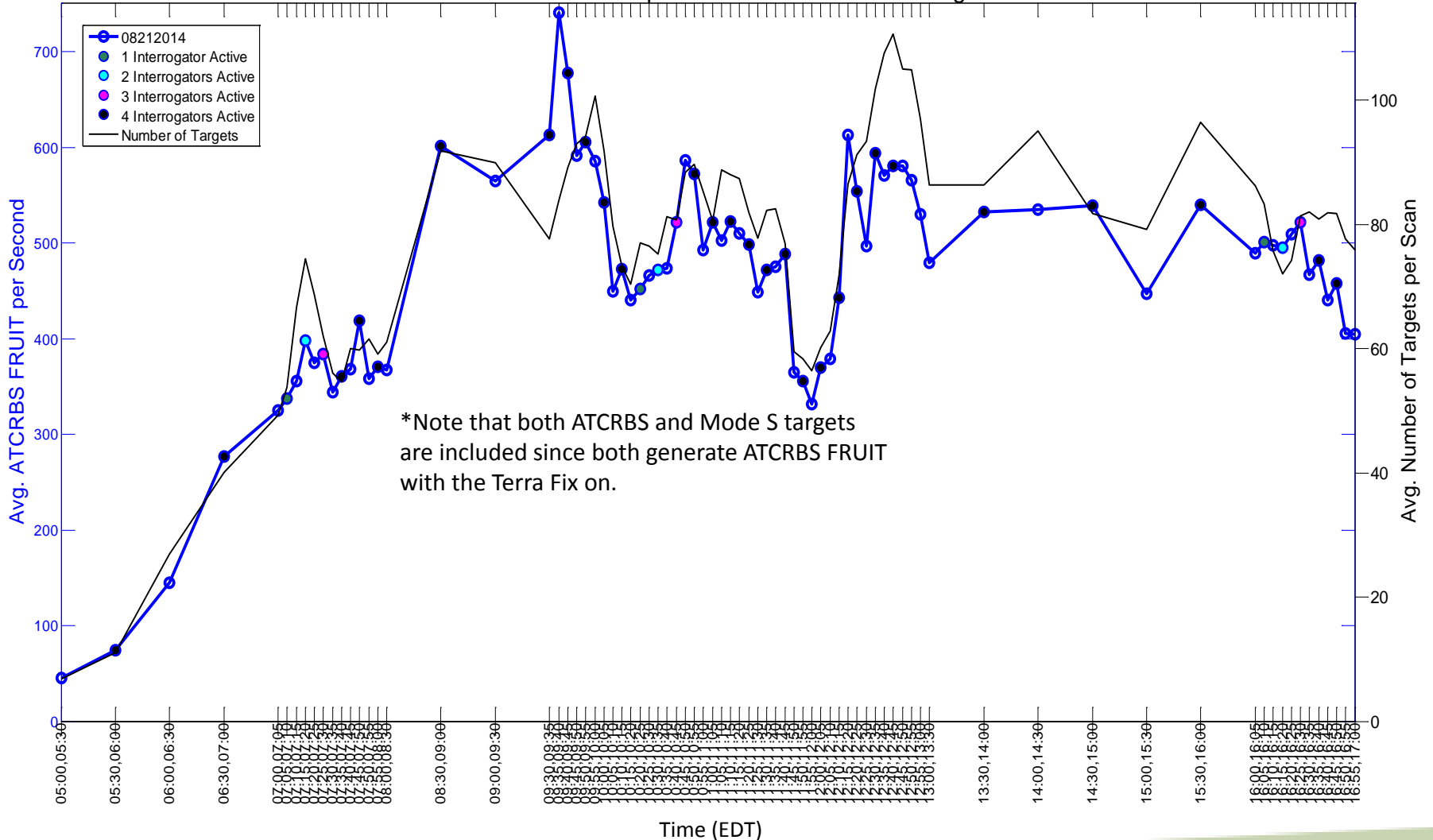
# ATCRBS FRUIT Rate – August 21<sup>st</sup>

ADW: Avg. ATCRBS Fruit per Second



# ATCRBS FRUIT Rate vs # of Targets–August 21<sup>st</sup>

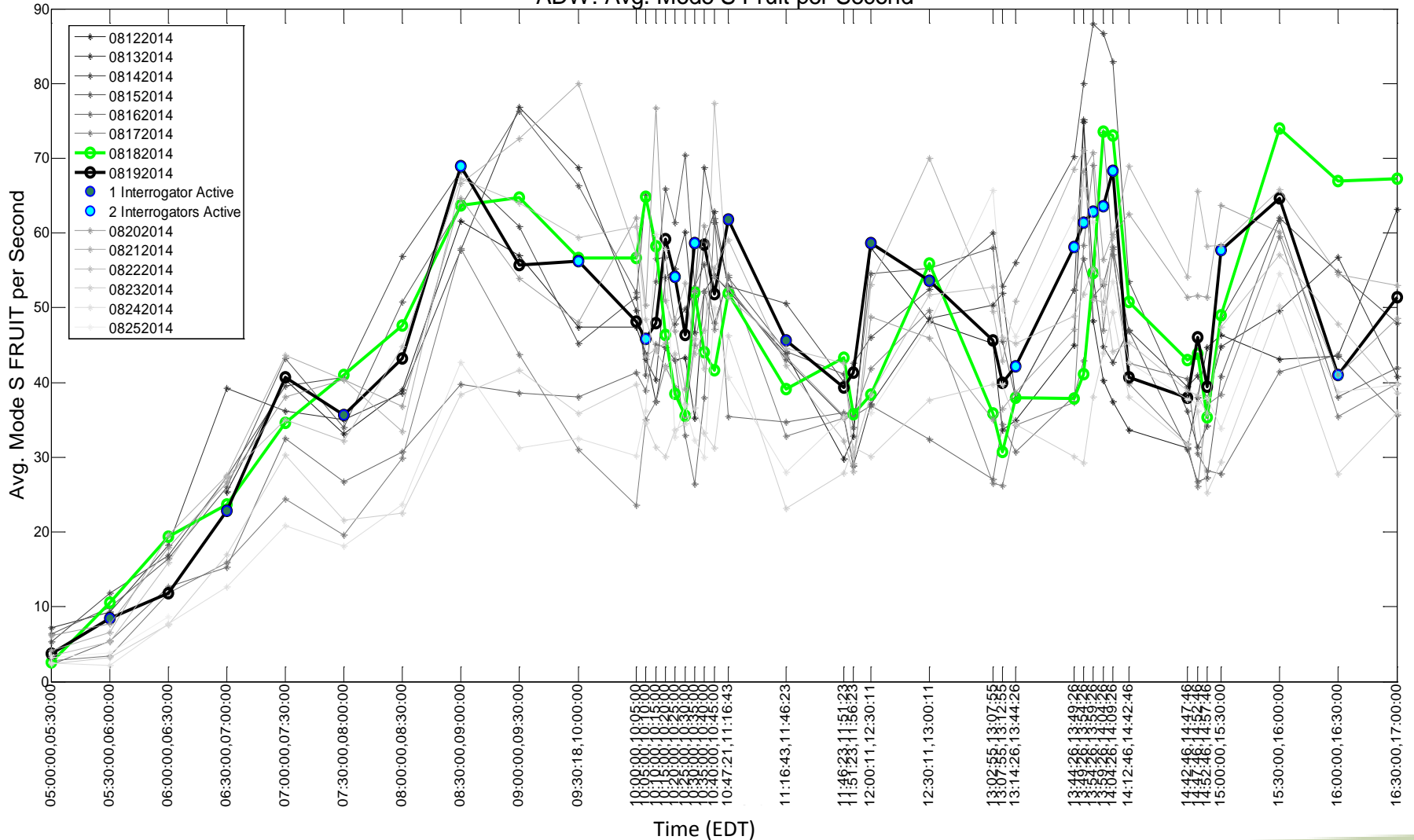
ADW: ATCRBS Fruit per Second vs Number of Targets





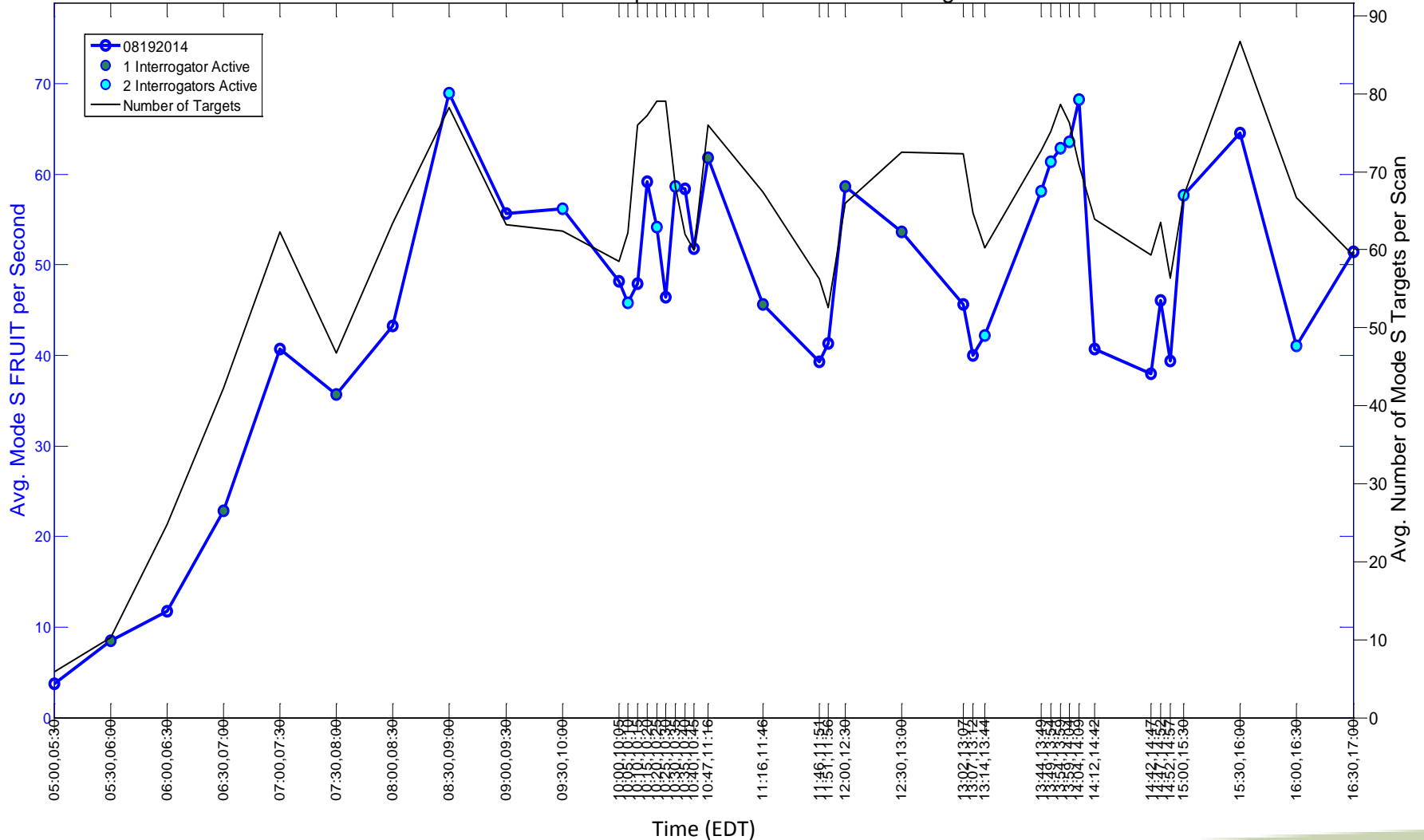
# Mode S FRUIT Rate – August 19<sup>th</sup>

ADW: Avg. Mode S Fruit per Second



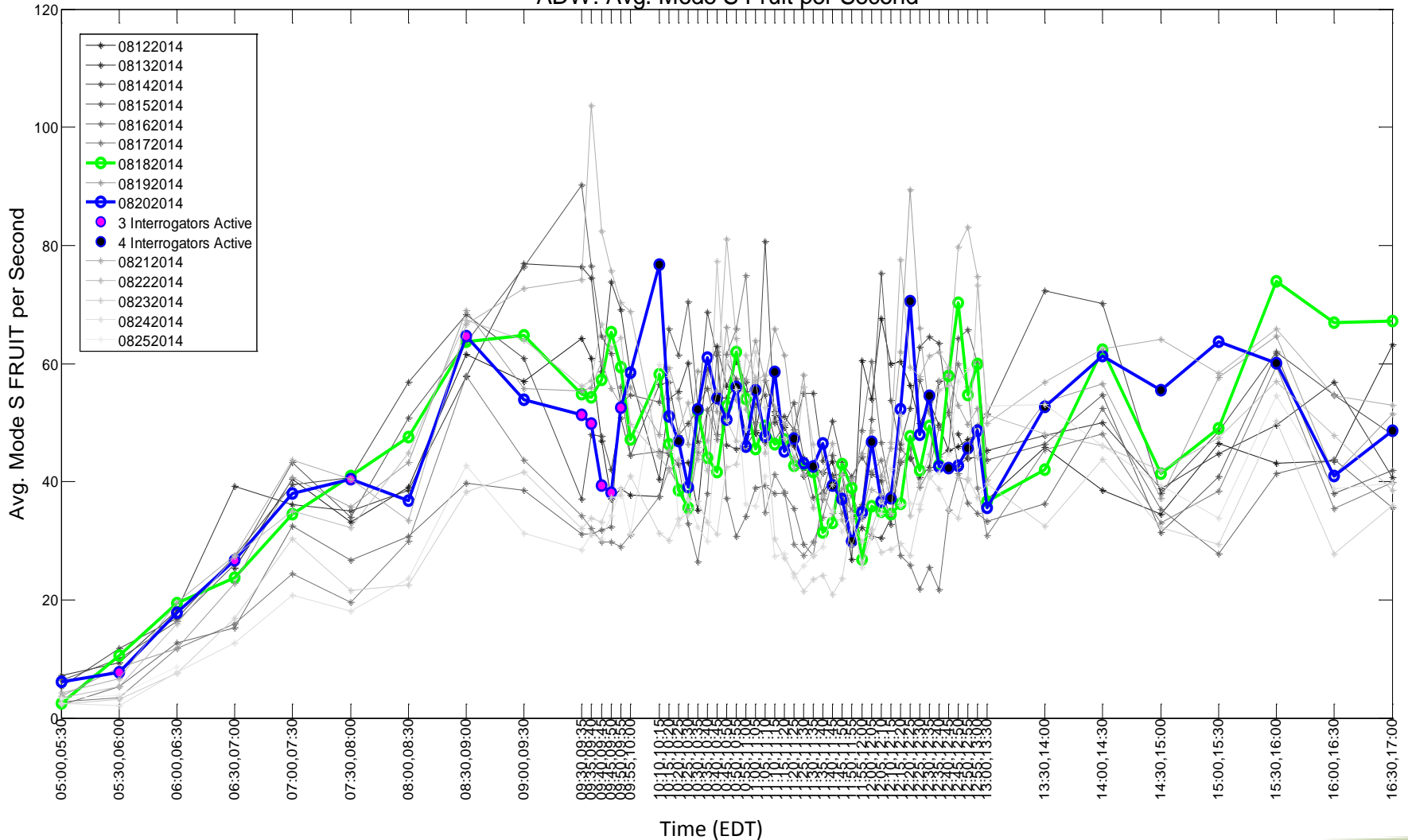
# Mode S FRUIT Rate vs # of Targets–August 19<sup>th</sup>

ADW: Mode S Fruit per Second vs Number of Targets



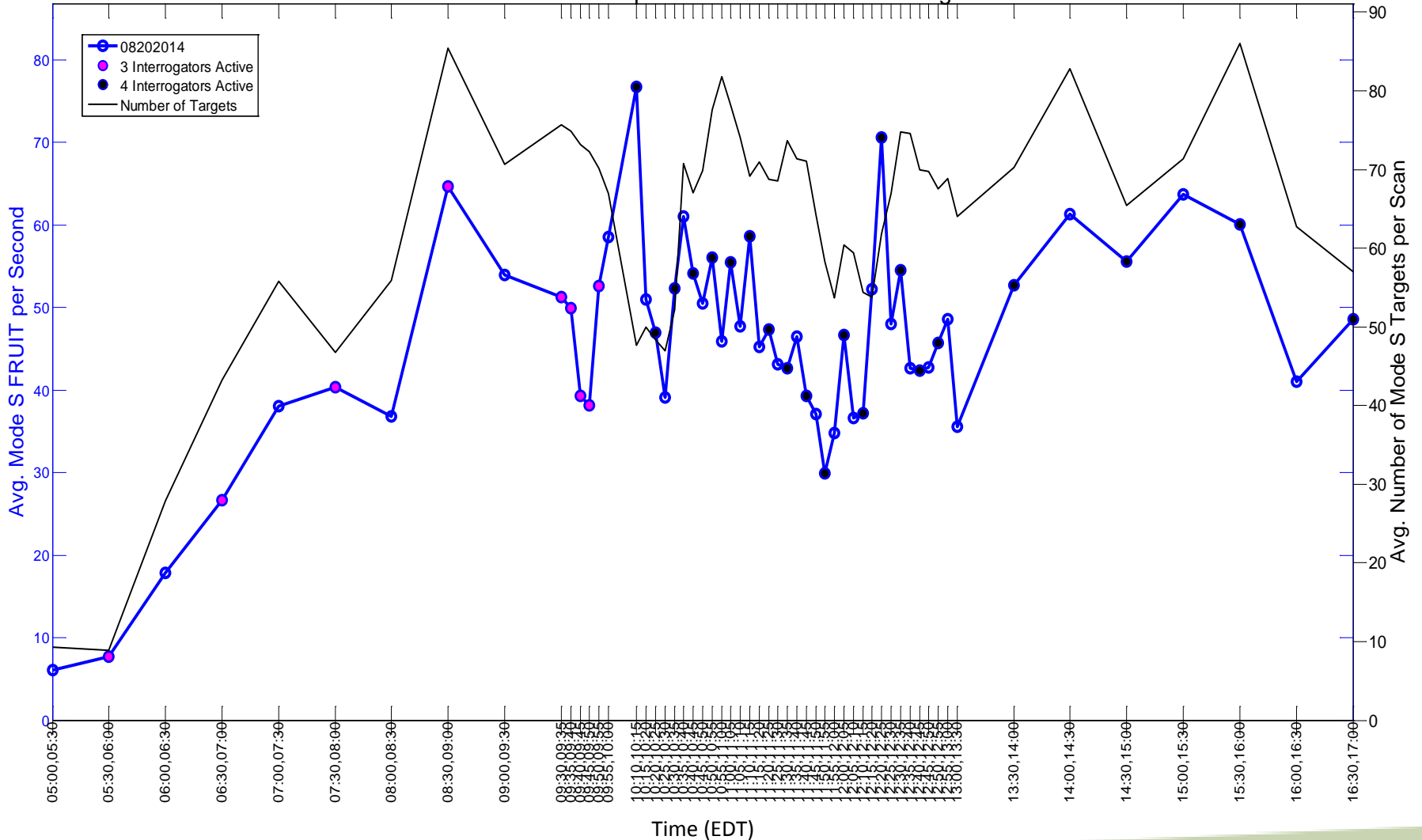
# Mode S FRUIT Rate – August 20<sup>th</sup>

ADW: Avg. Mode S Fruit per Second



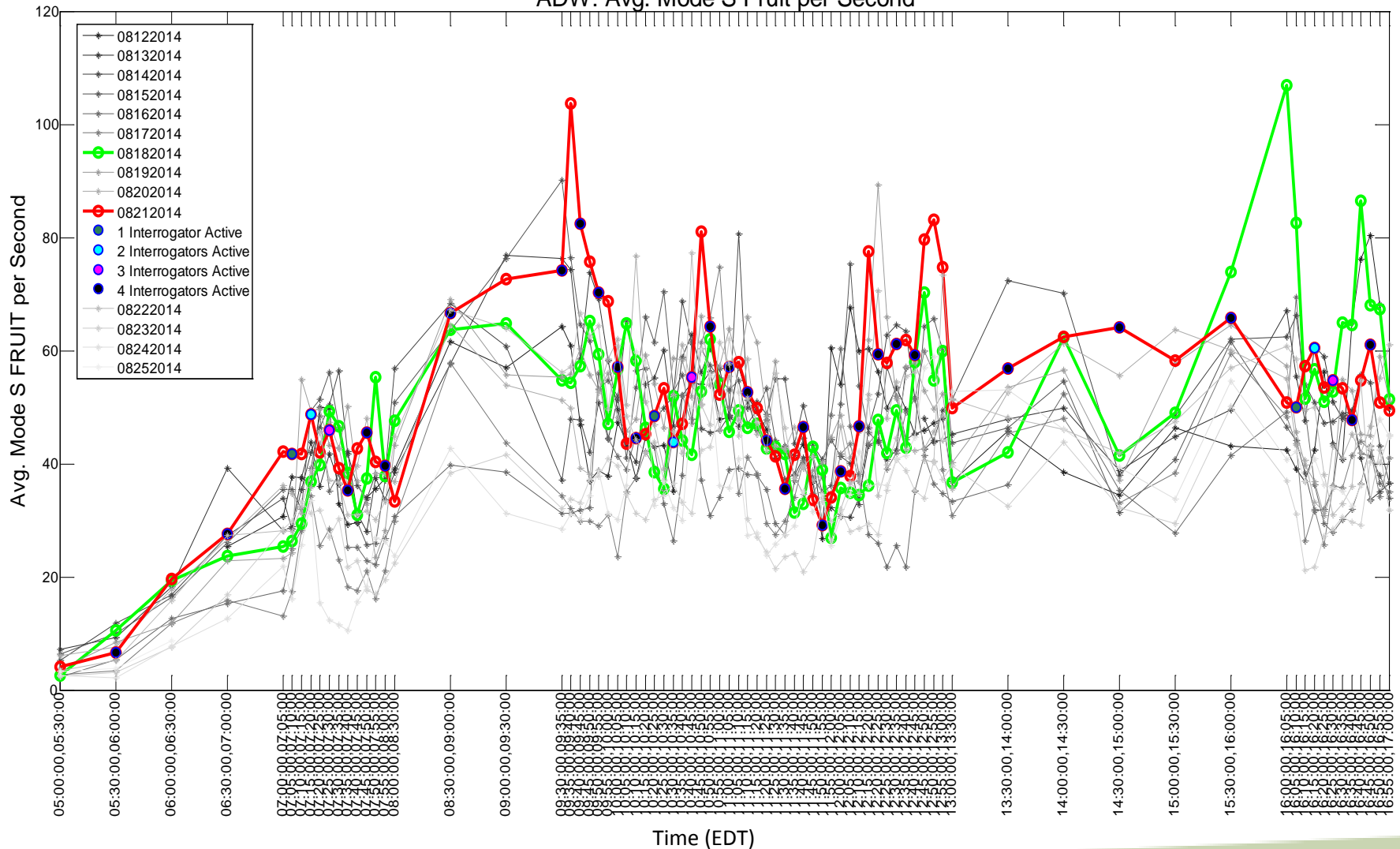
# Mode S FRUIT Rate vs # of Targets—August 20<sup>th</sup>

ADW: Mode S Fruit per Second vs Number of Targets



# Mode S FRUIT Rate – August 21<sup>st</sup>

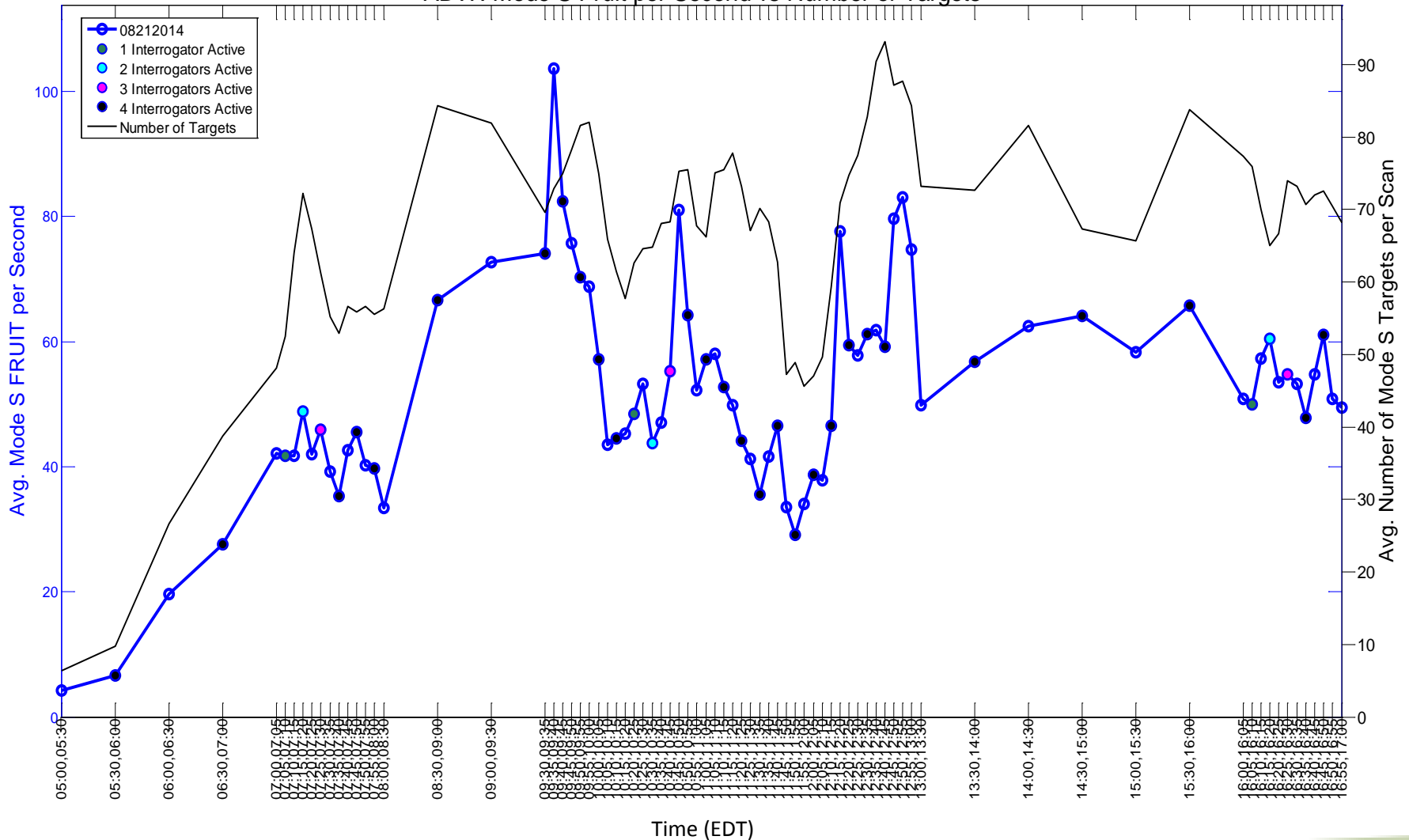
ADW: Avg. Mode S Fruit per Second



Geographic Filter: None  
Target Filter: None

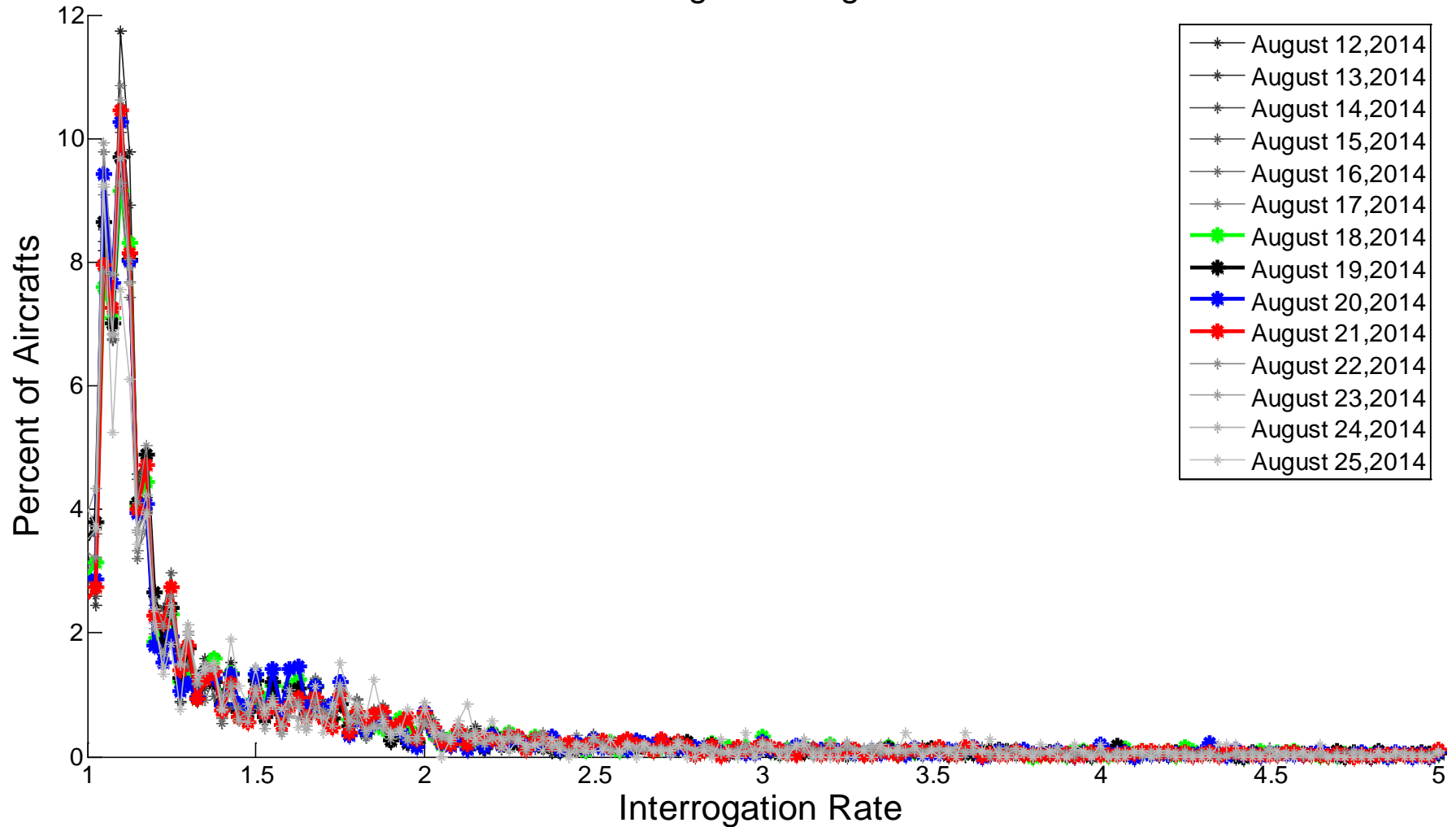
# Mode S FRUIT Rate vs # of Targets—August 21<sup>st</sup>

ADW: Mode S Fruit per Second vs Number of Targets



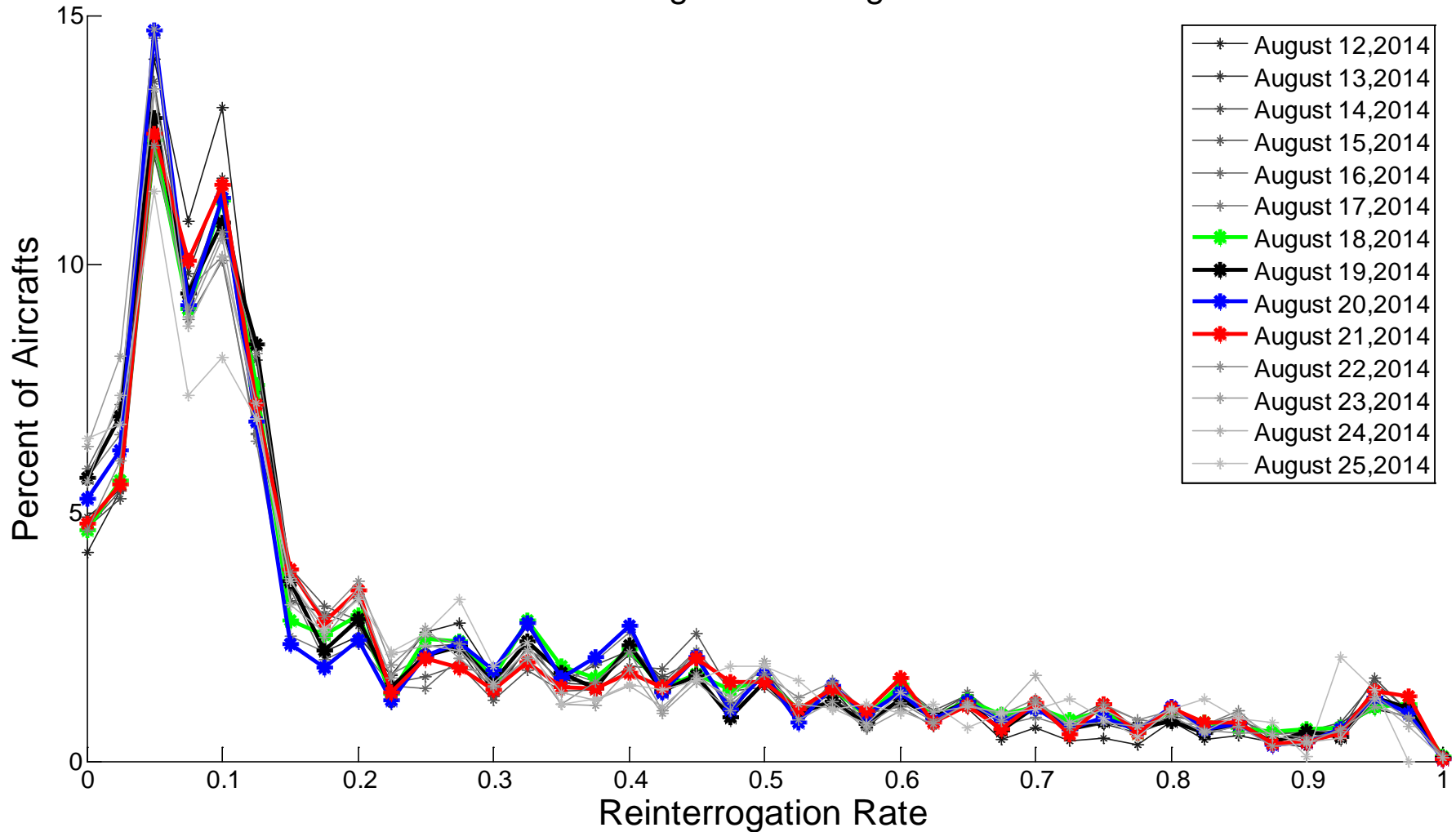
# Interrogation Rate – All Days

ADW:Average Interrogation Rate



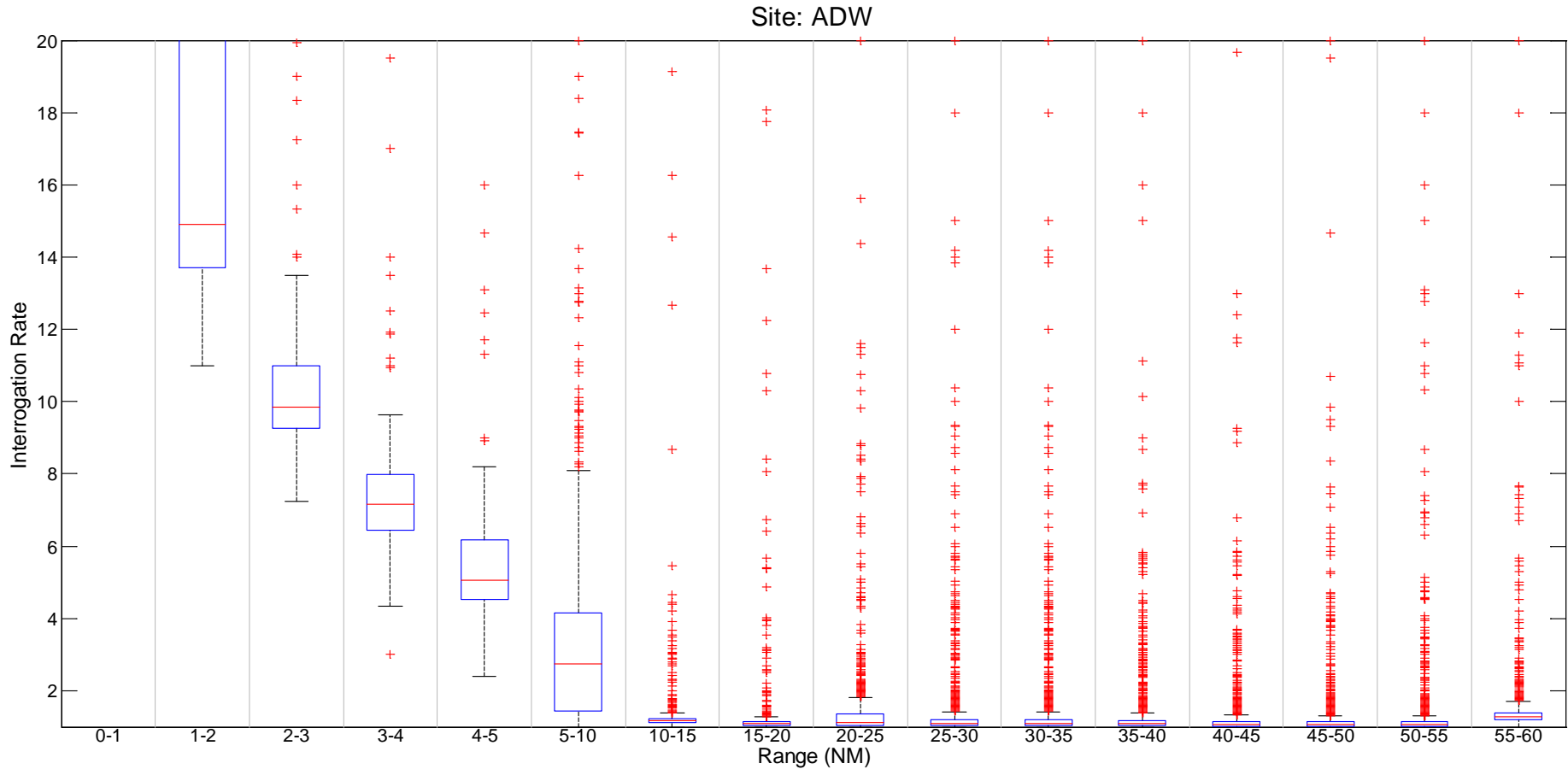
# Reinterrogation Rate – All Days

ADW: Average Reinterrogation Rate

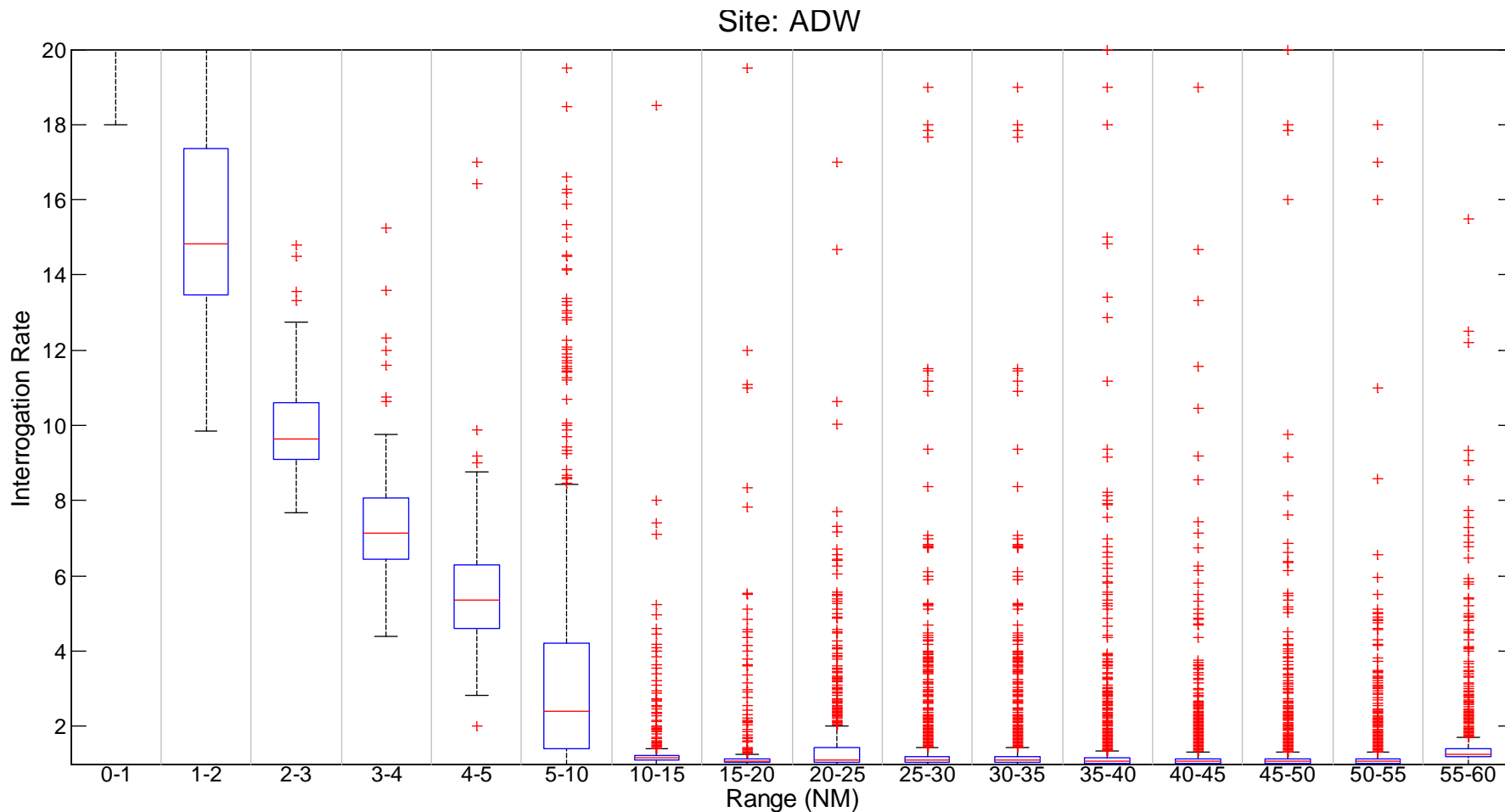




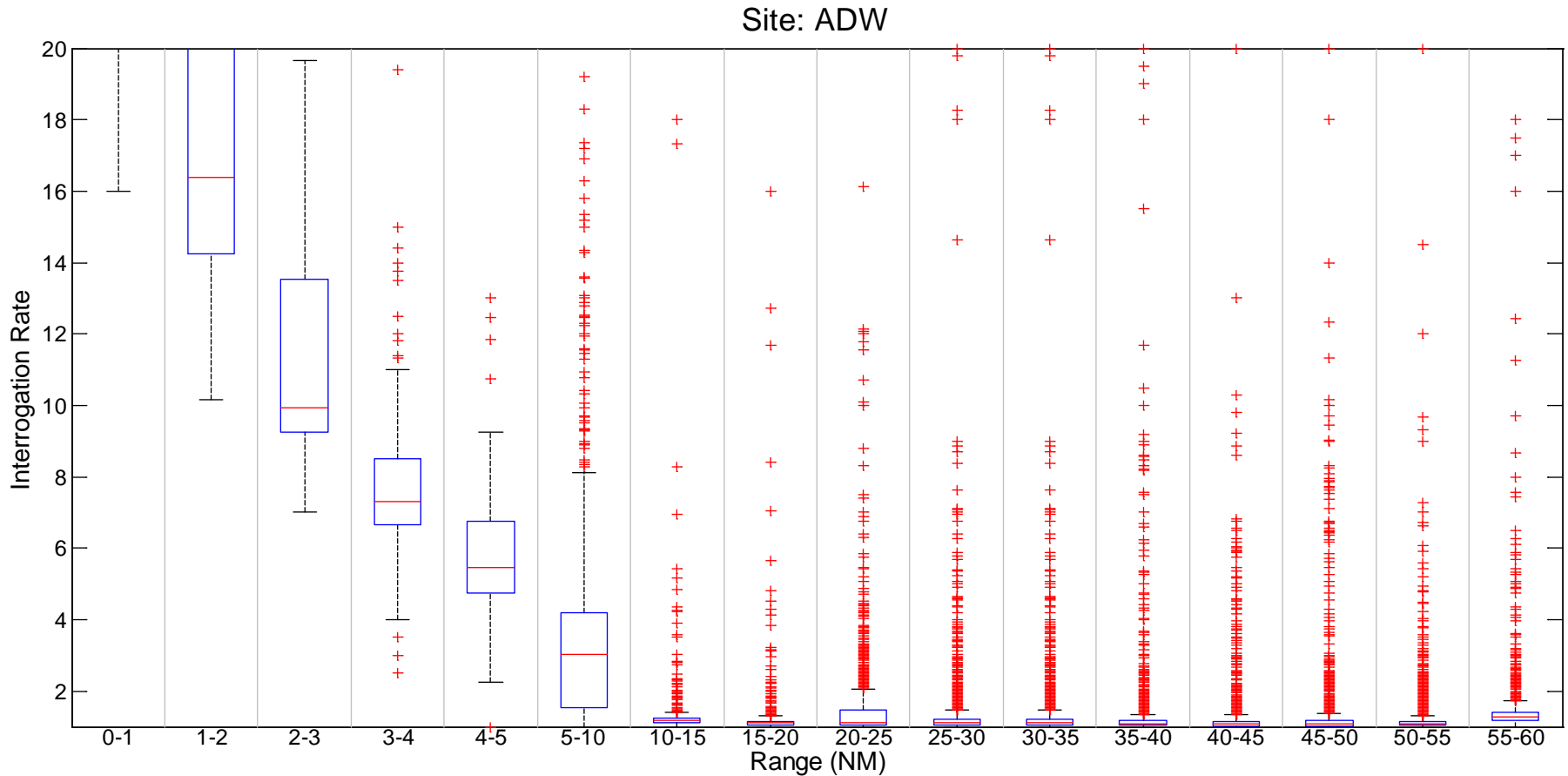
# Interrogation Rate vs Range – August 19<sup>th</sup>



# Interrogation Rate vs Range – August 20<sup>th</sup>

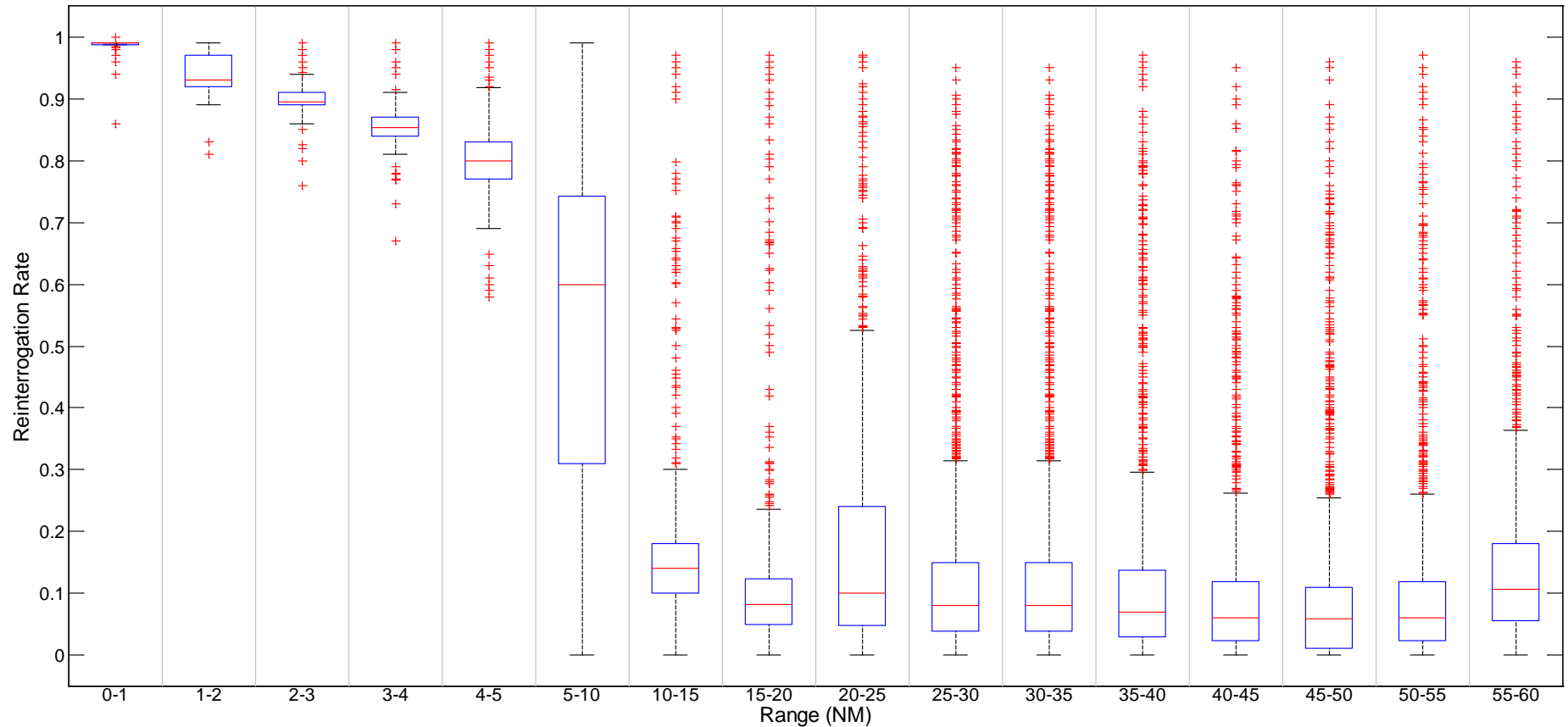


# Interrogation Rate vs Range – August 21<sup>st</sup>



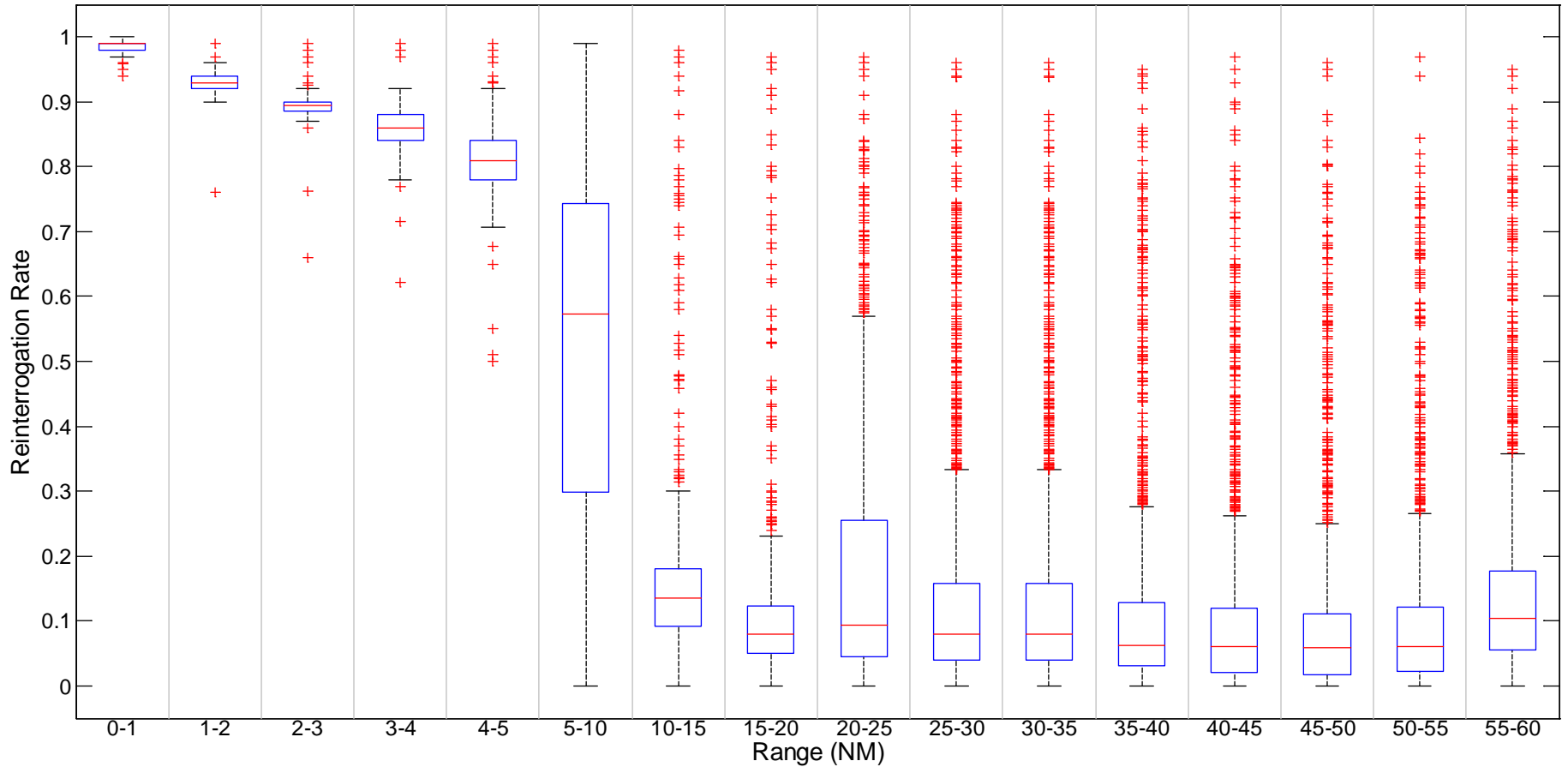
# Reinterrogation Rate vs Range – August 19<sup>th</sup>

Site: ADW

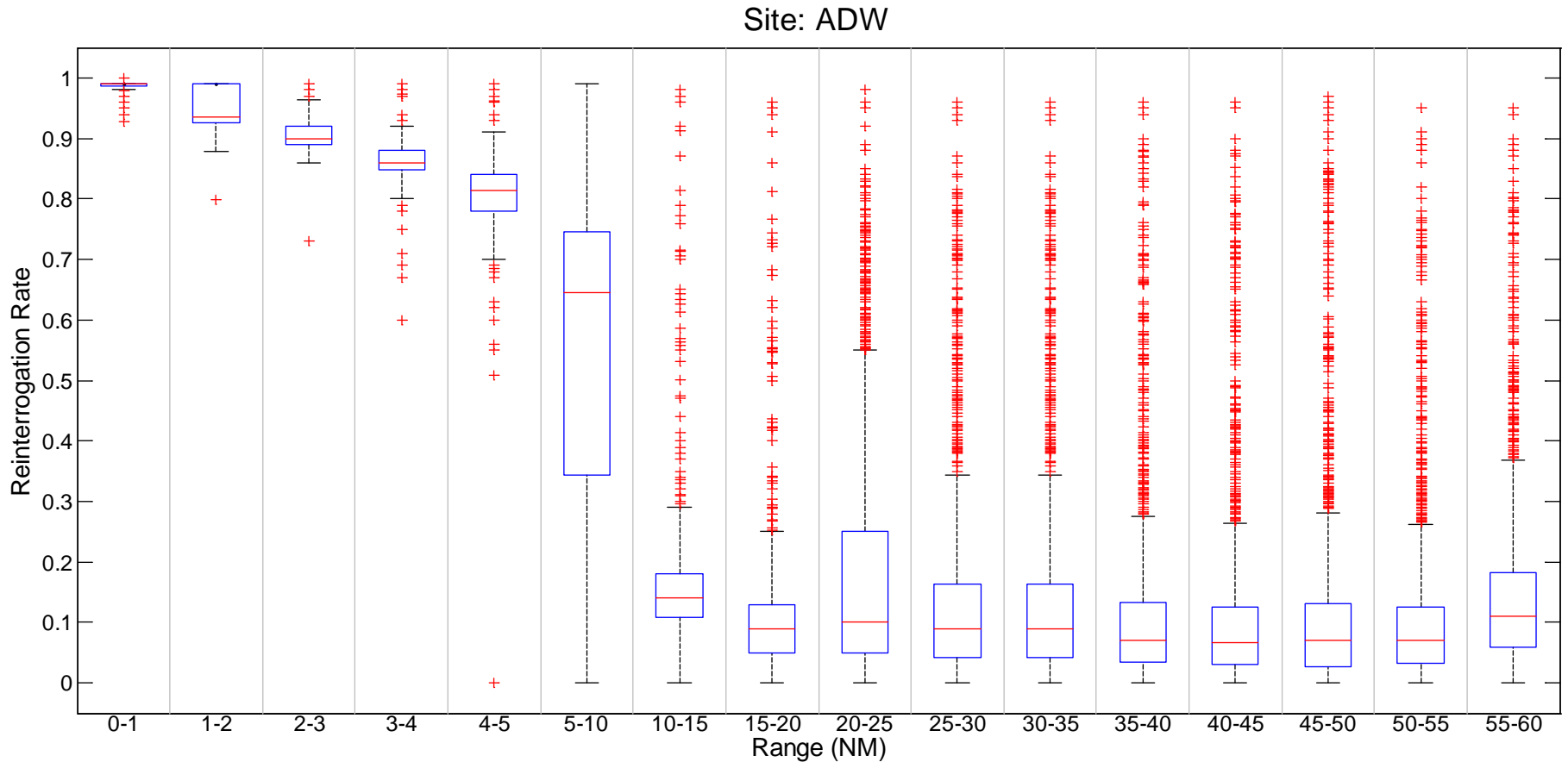


# Reinterrogation Rate vs Range – August 20<sup>th</sup>

Site: ADW



# Reinterrogation Rate vs Range – August 21<sup>st</sup>



# Observations and Conclusions

## ❑ FRUIT Analysis

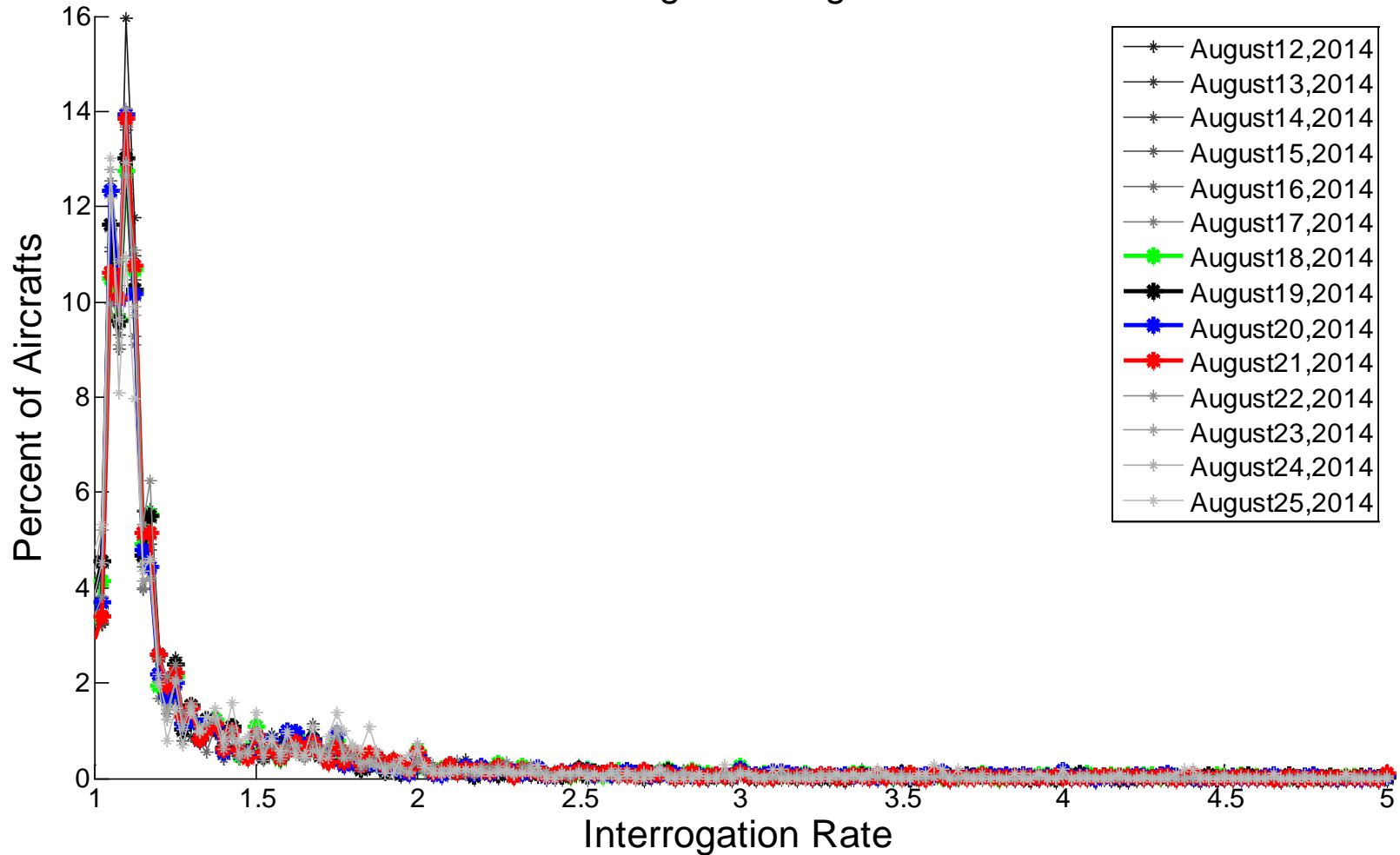
- ATCRBS FRUIT rates do not always increase when AN/UPX-41(C) interrogators are Active. This means the AN/UPX-41(C) FRUIT impact, for the Stage 4 configuration, generates less ATCRBS FRUIT than the normal daily fluctuations of ATCRBS FRUIT due to changes in traffic densities. This is also confirmed by the generally high correlation between traffic count and ATCRBS FRUIT rate movements.
- AN/UPX-41(C) interrogators should have produced no extra Mode S FRUIT and the plots confirm this.

## ❑ Channel Management Statistics

- Targets within 10 NM showed consistently high interrogation/reinterrogation rates
  - This phenomenon is due to the unpredictability of roll call target azimuths at close ranges. The Mode S roll call scheduler starts interrogations many degrees before the tracker's predicted azimuth to ensure that unknown changes in speed and heading will not limit the ability of the Mode S system to get an update on the target.
  - So while the reinterrogation rate is high within 10 NM, it is not due to transponder occupancy or receiver garble.
  - To notice any possible change in interrogation/reinterrogation rates between Active/OFF periods, targets within 10 NM of SSR site were excluded in the next section of analysis.

# Interrogation Rate – All Days

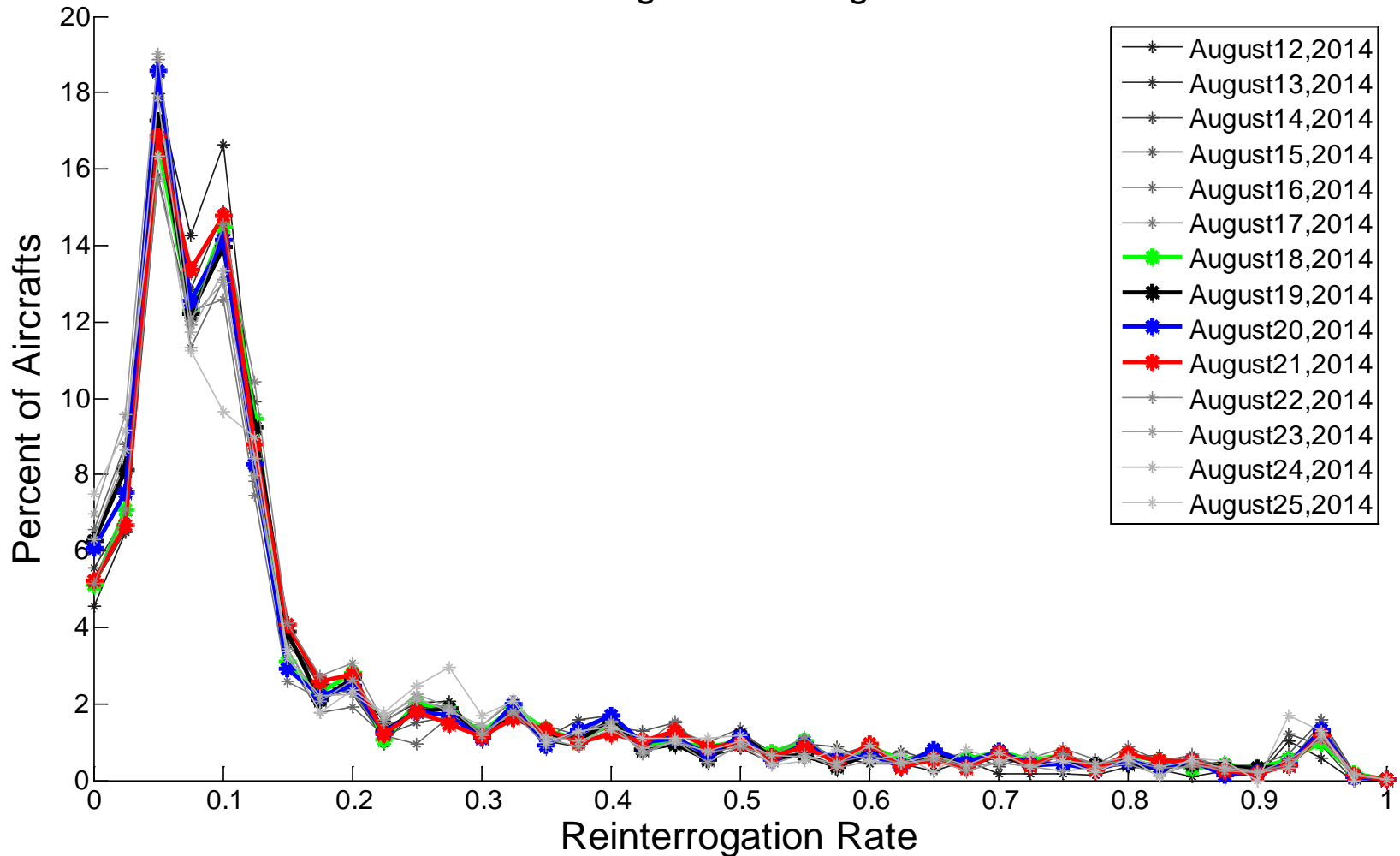
ADW: Average Interrogation Rate



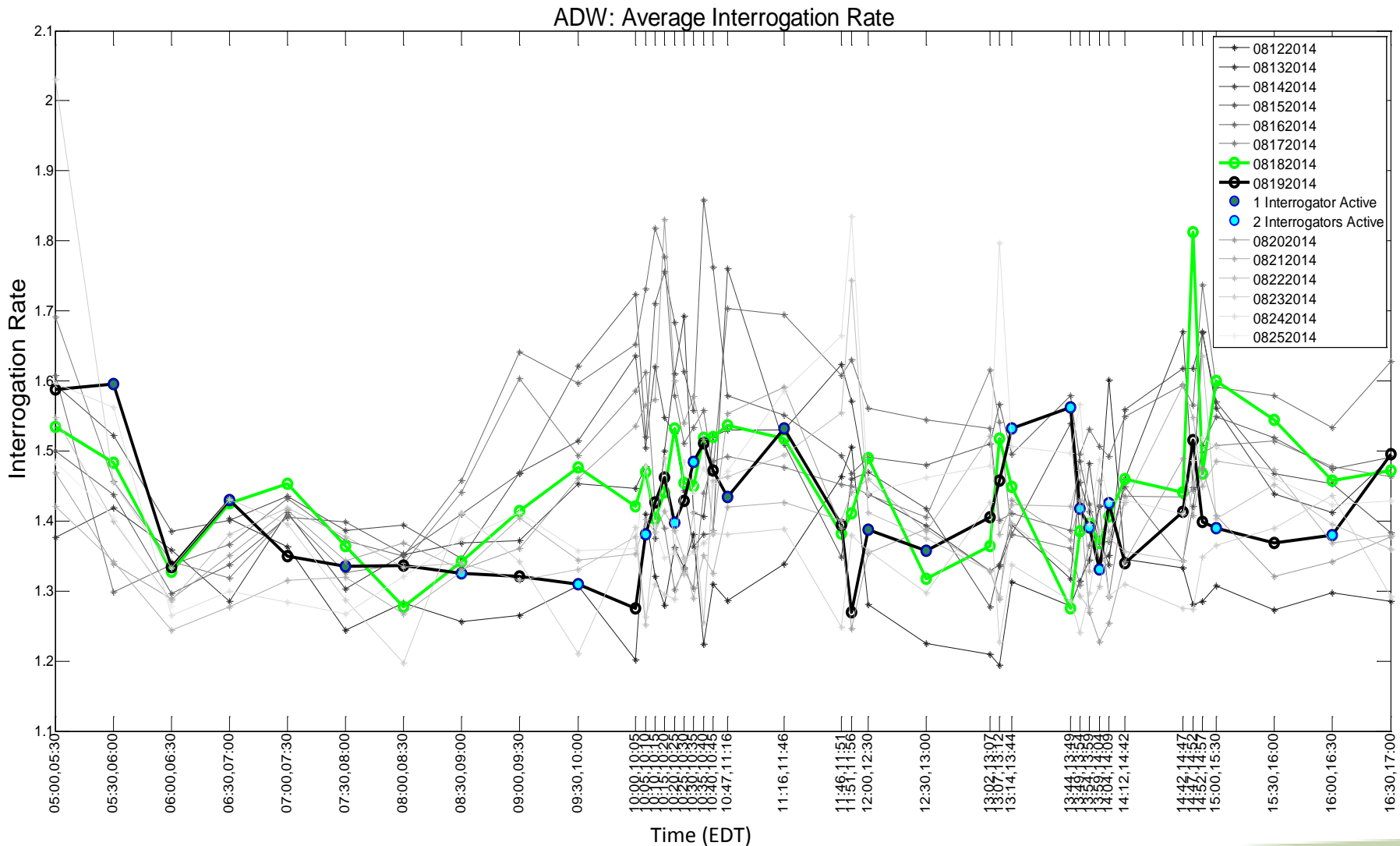


# Reinterrogation Rate – All Days

ADW:Average Reinterrogation Rate

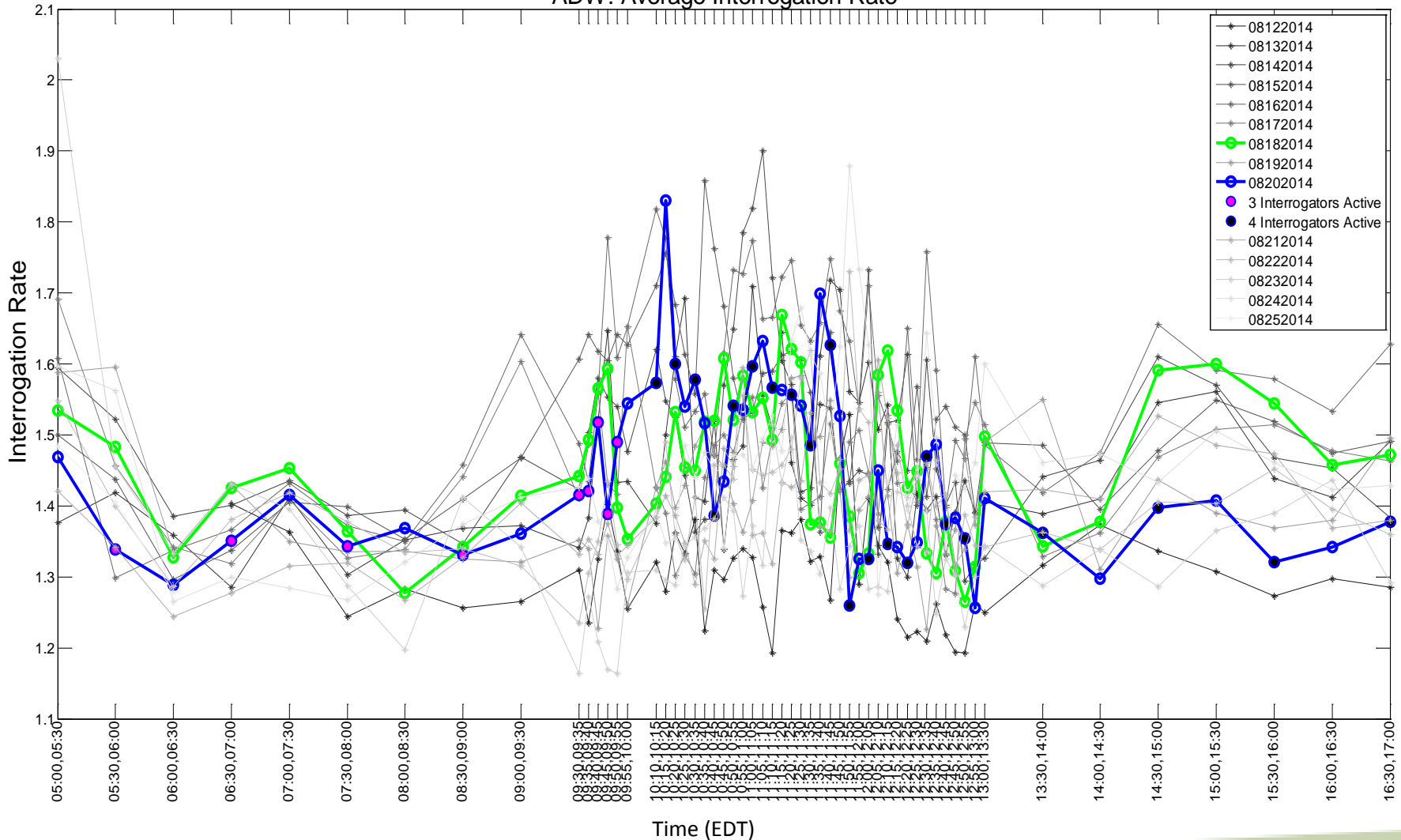


# Interrogation Rate – August 19<sup>th</sup>



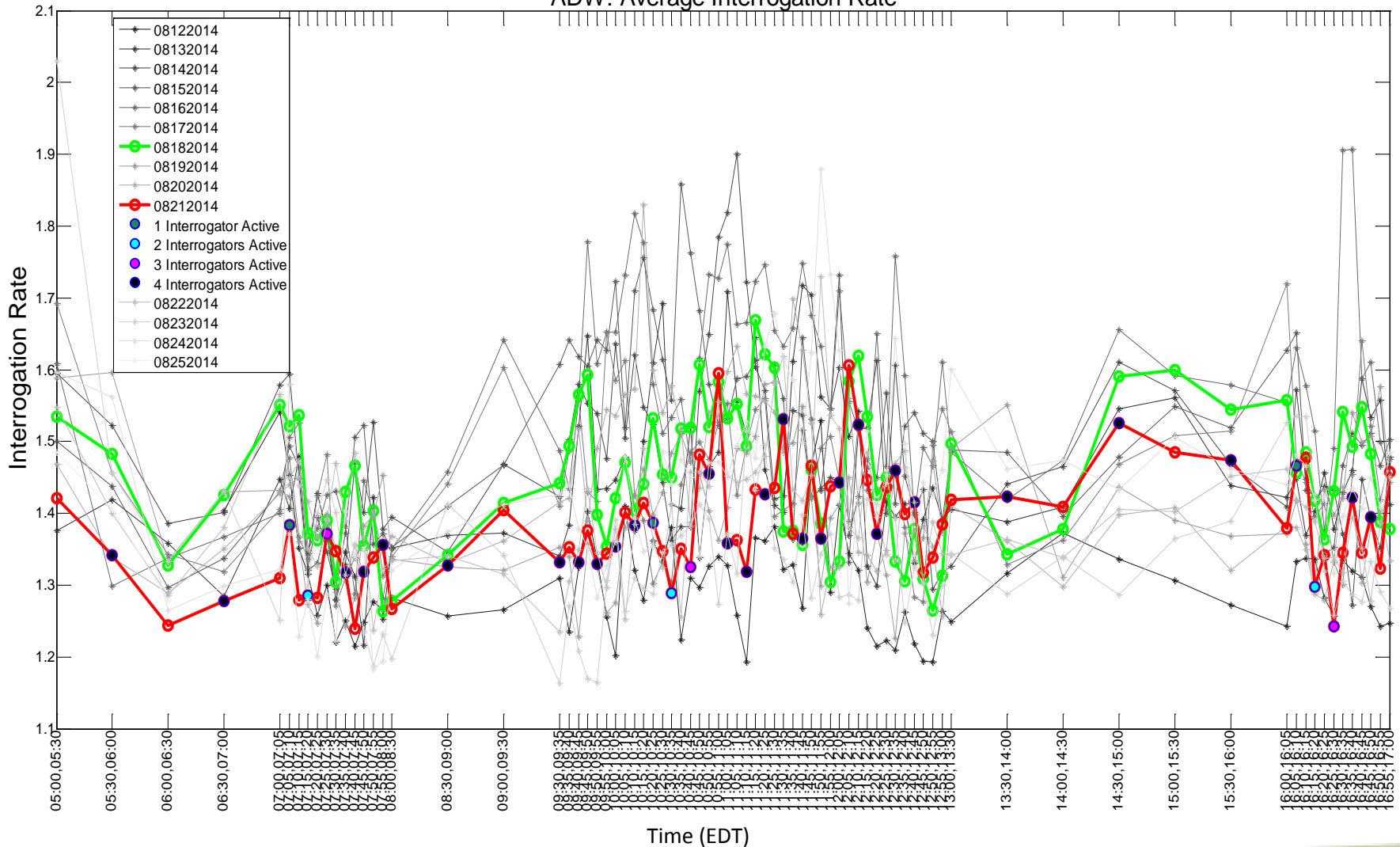
# Interrogation Rate – August 20<sup>th</sup>

ADW: Average Interrogation Rate



# Interrogation Rate – August 21<sup>st</sup>

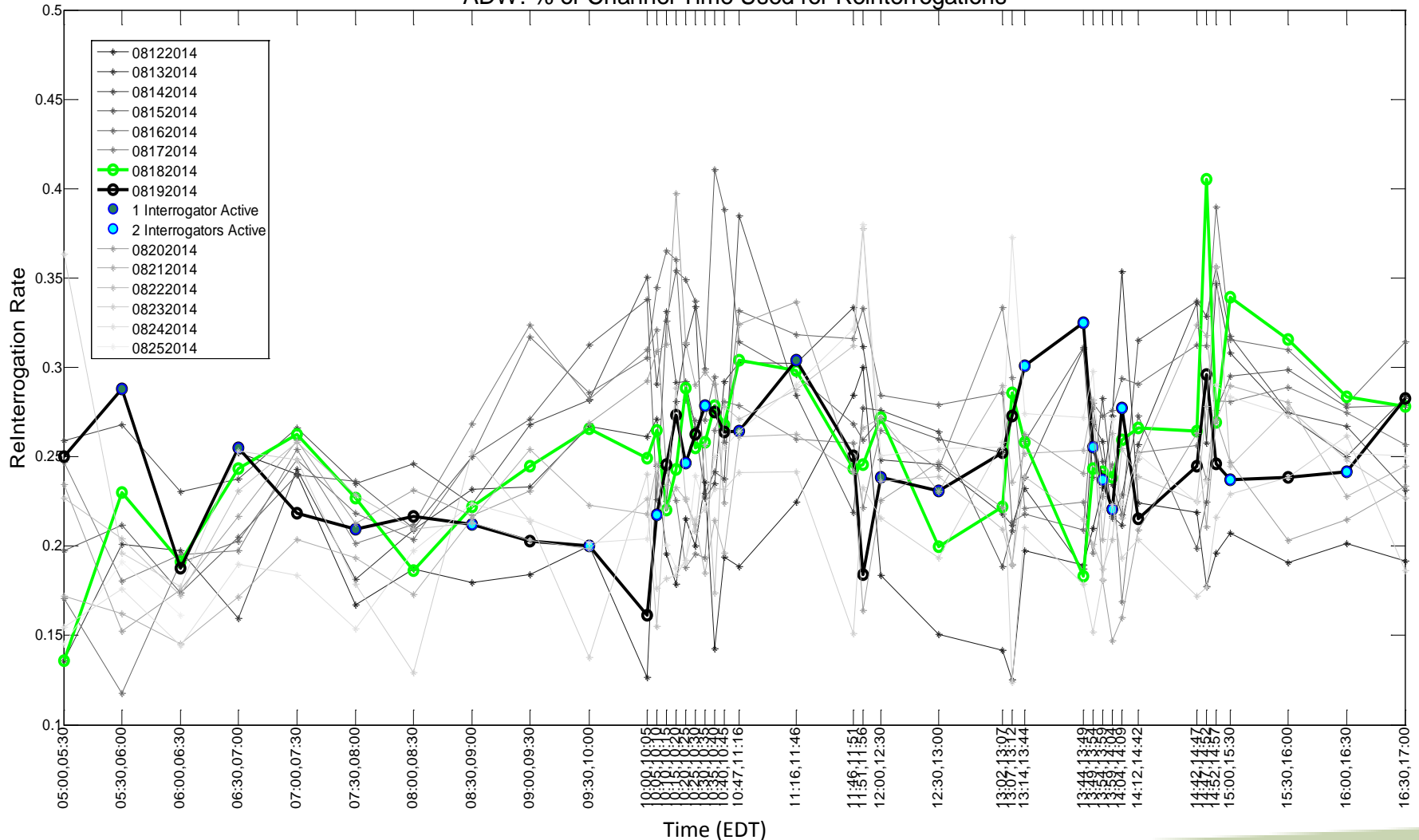
ADW: Average Interrogation Rate



Geographic Filter: None  
Target Filter: Targets > 10 NM from SSR

# Reinterrogation Rate – August 19<sup>th</sup>

ADW: % of Channel Time Used for Reinterrogations



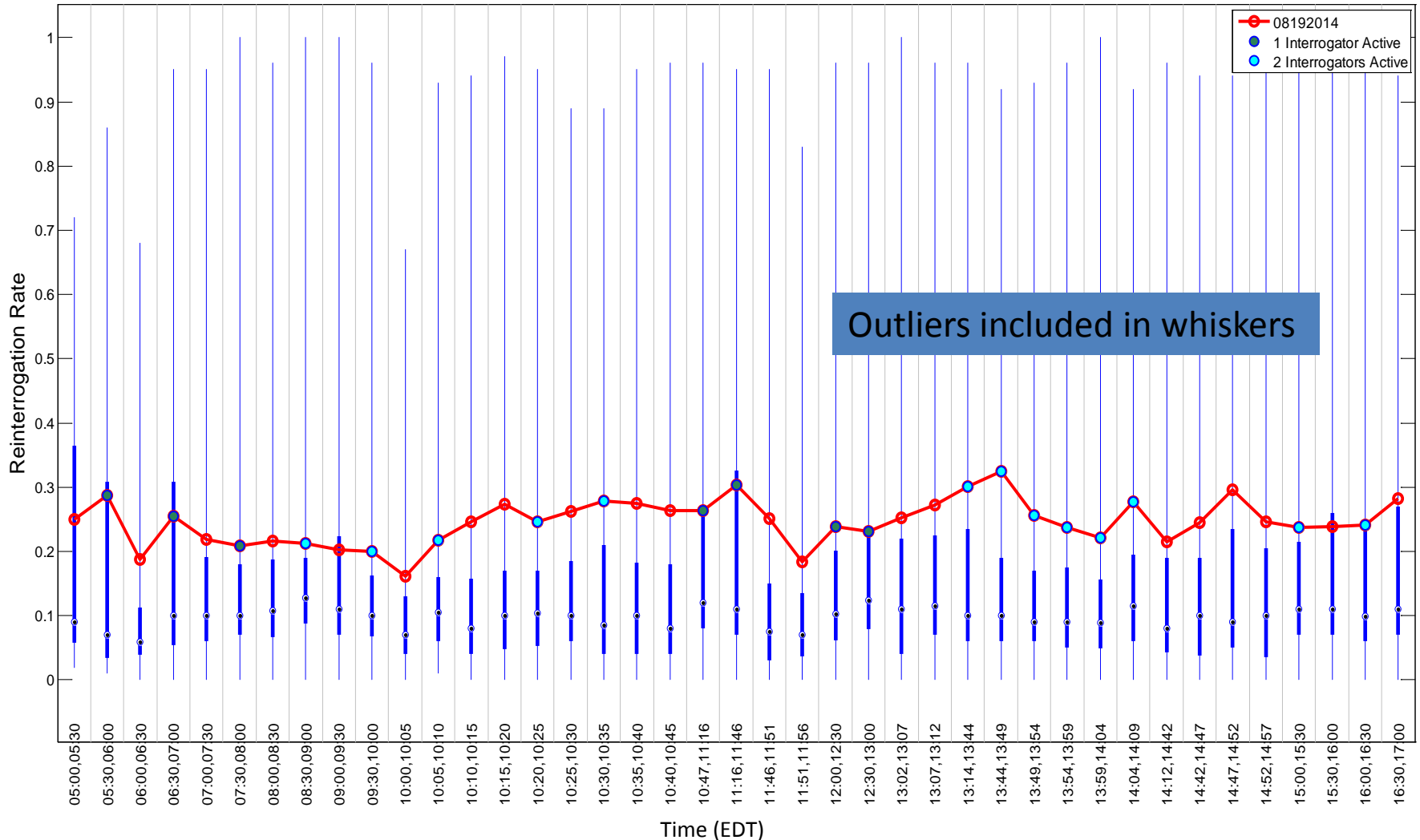
Geographic Filter: None

Target Filter: Targets > 10 NM from SSR

# Reinterrogation Rate – August 19<sup>th</sup>

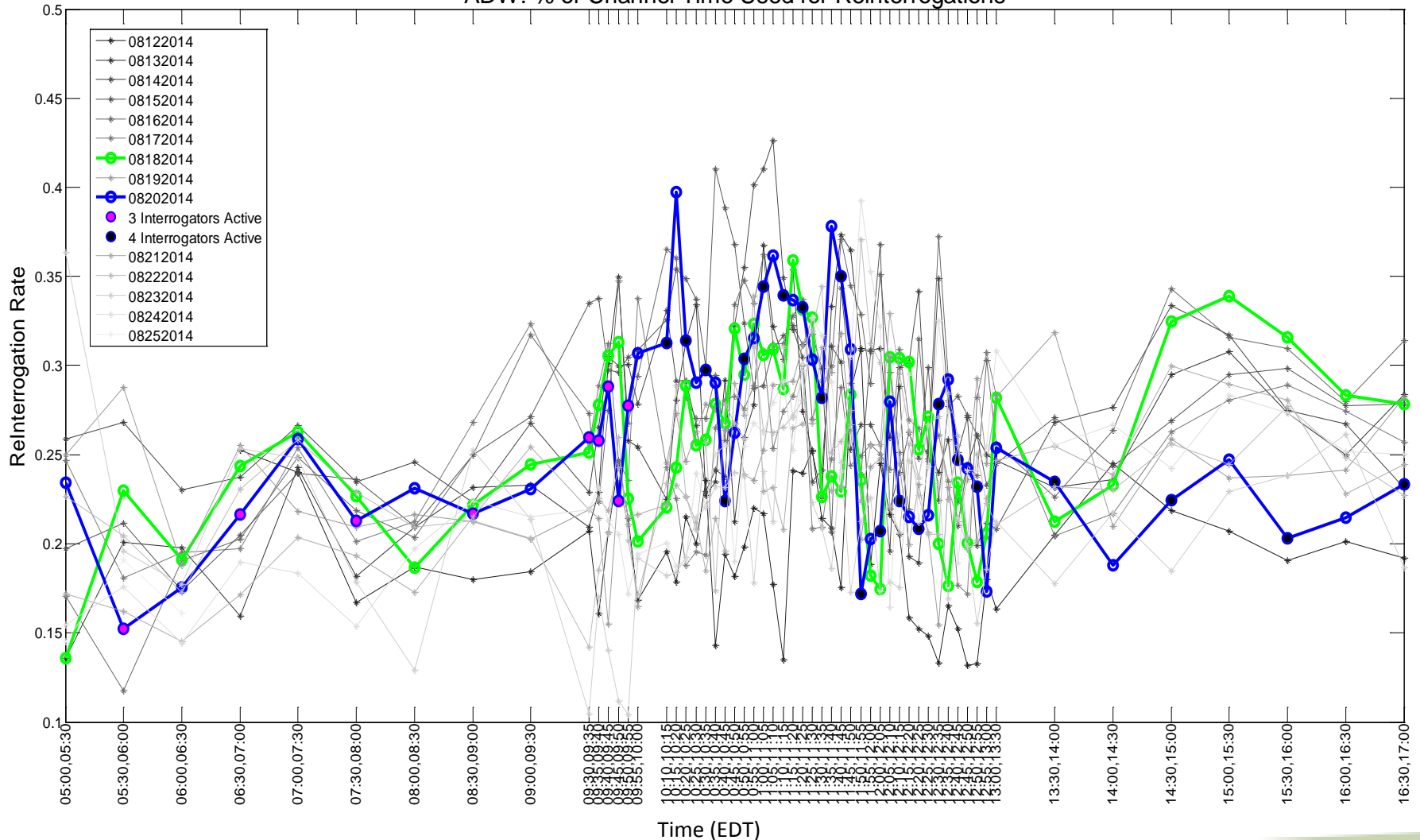
## Individual Aircraft Distribution

ADW: Reinterrogation Rate



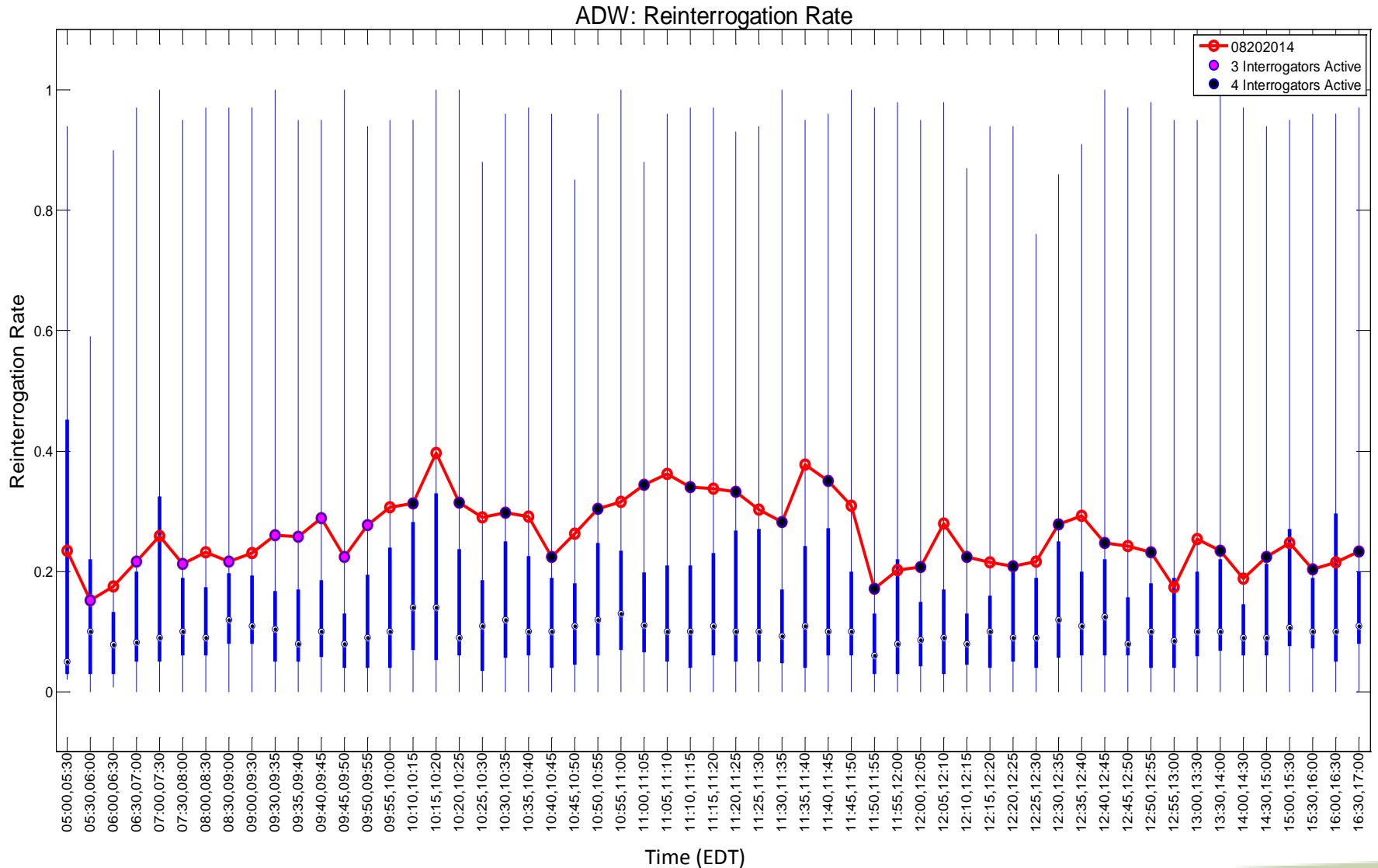
# Reinterrogation Rate – August 20<sup>th</sup>

ADW: % of Channel Time Used for Reinterrogations



# Reinterrogation Rate – August 20<sup>th</sup>

## Individual Aircraft Distribution



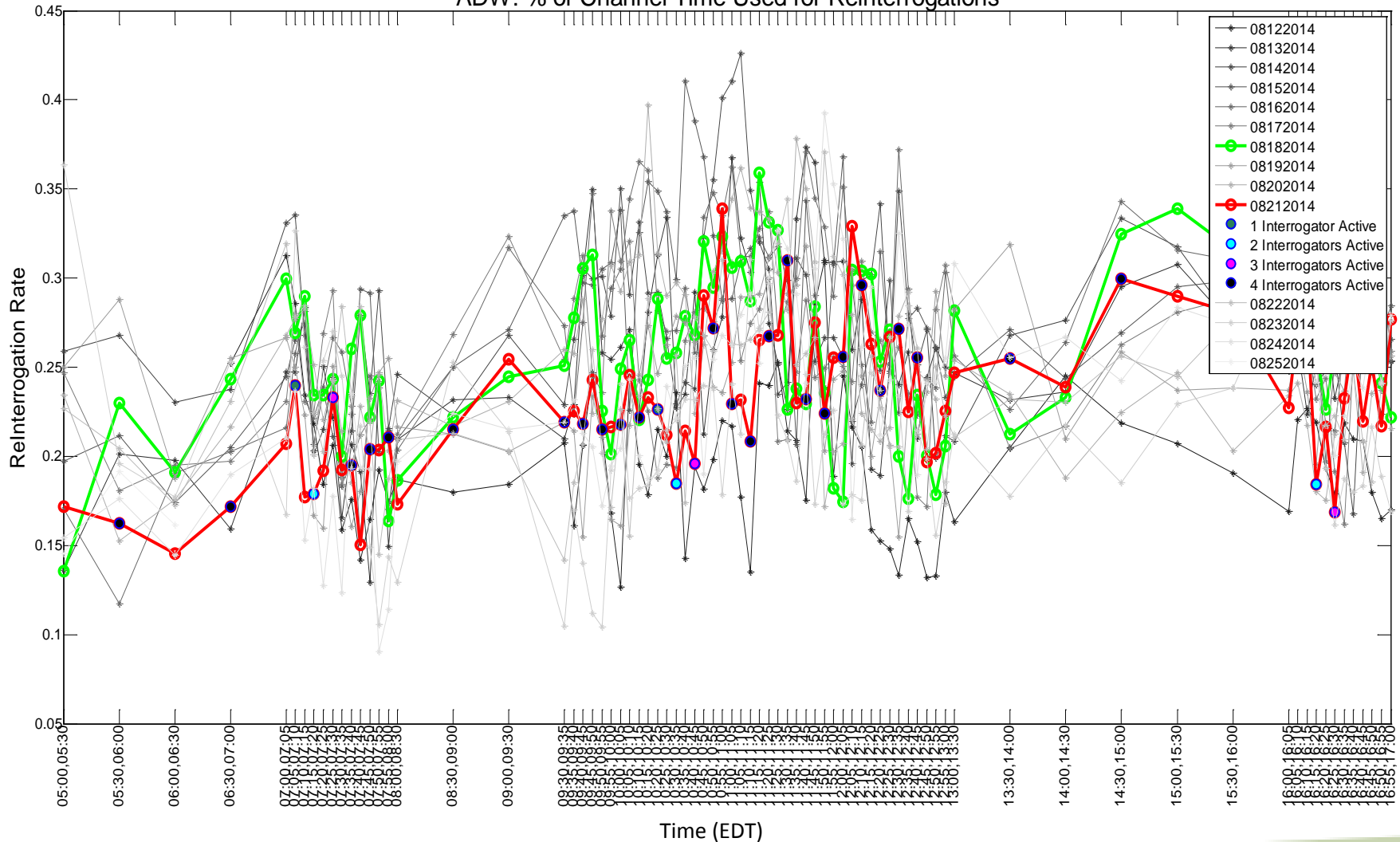
Geographic Filter: None

Target Filter: Targets > 10 NM from SSR



# Reinterrogation Rate – August 21<sup>st</sup>

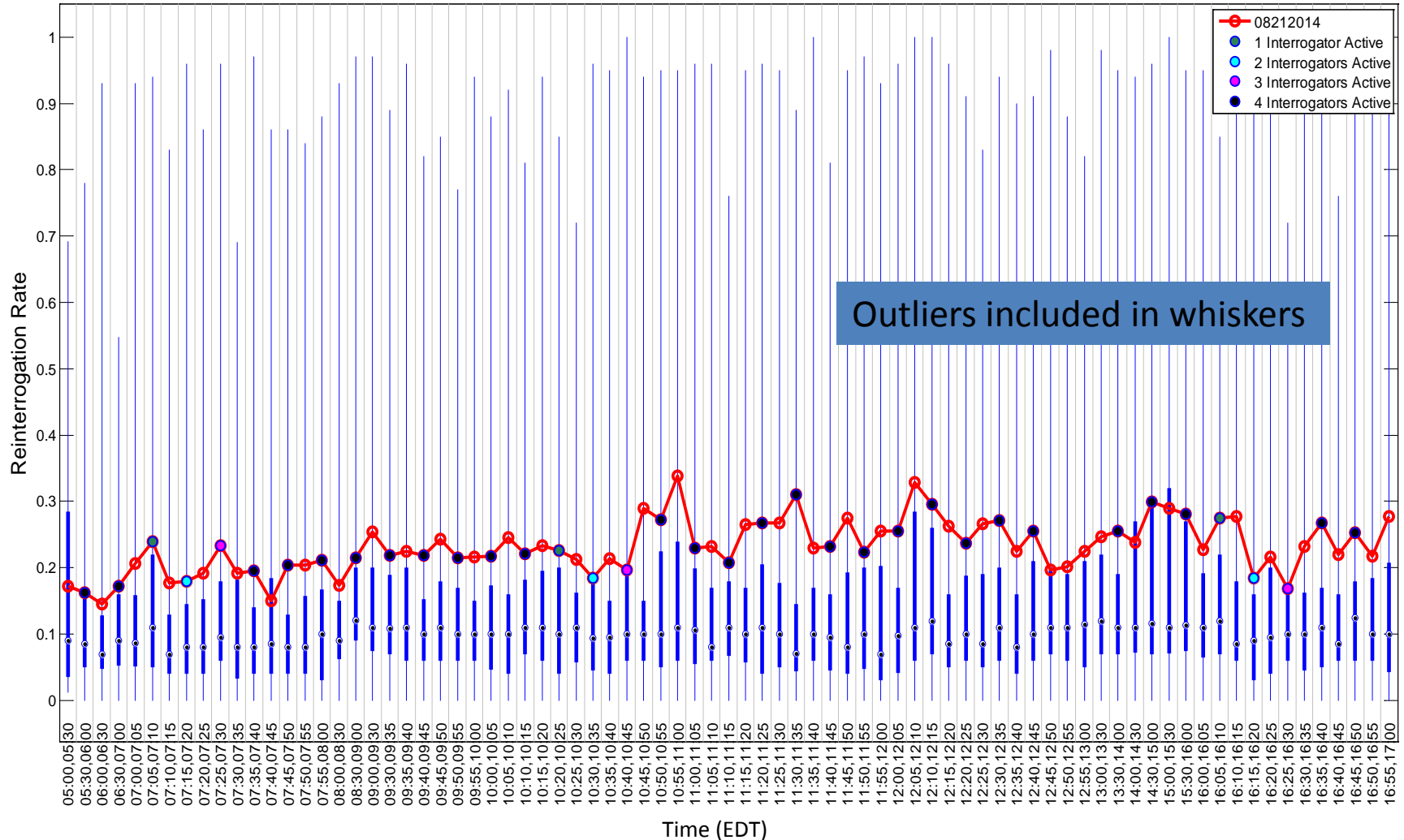
ADW: % of Channel Time Used for Reinterrogations



# Reinterrogation Rate – August 21<sup>st</sup>

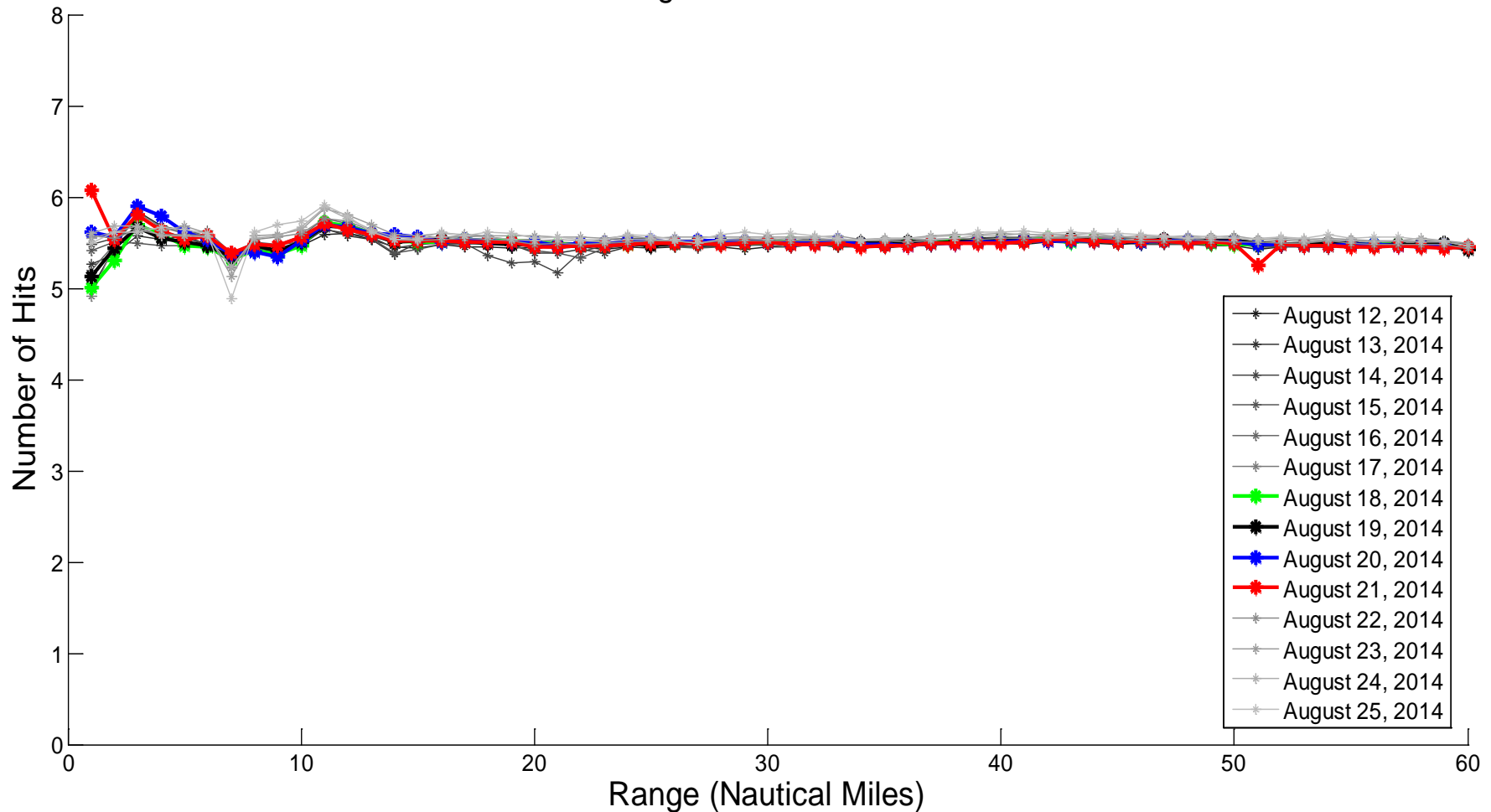
## Individual Aircraft Distribution

ADW: Reinterrogation Rate

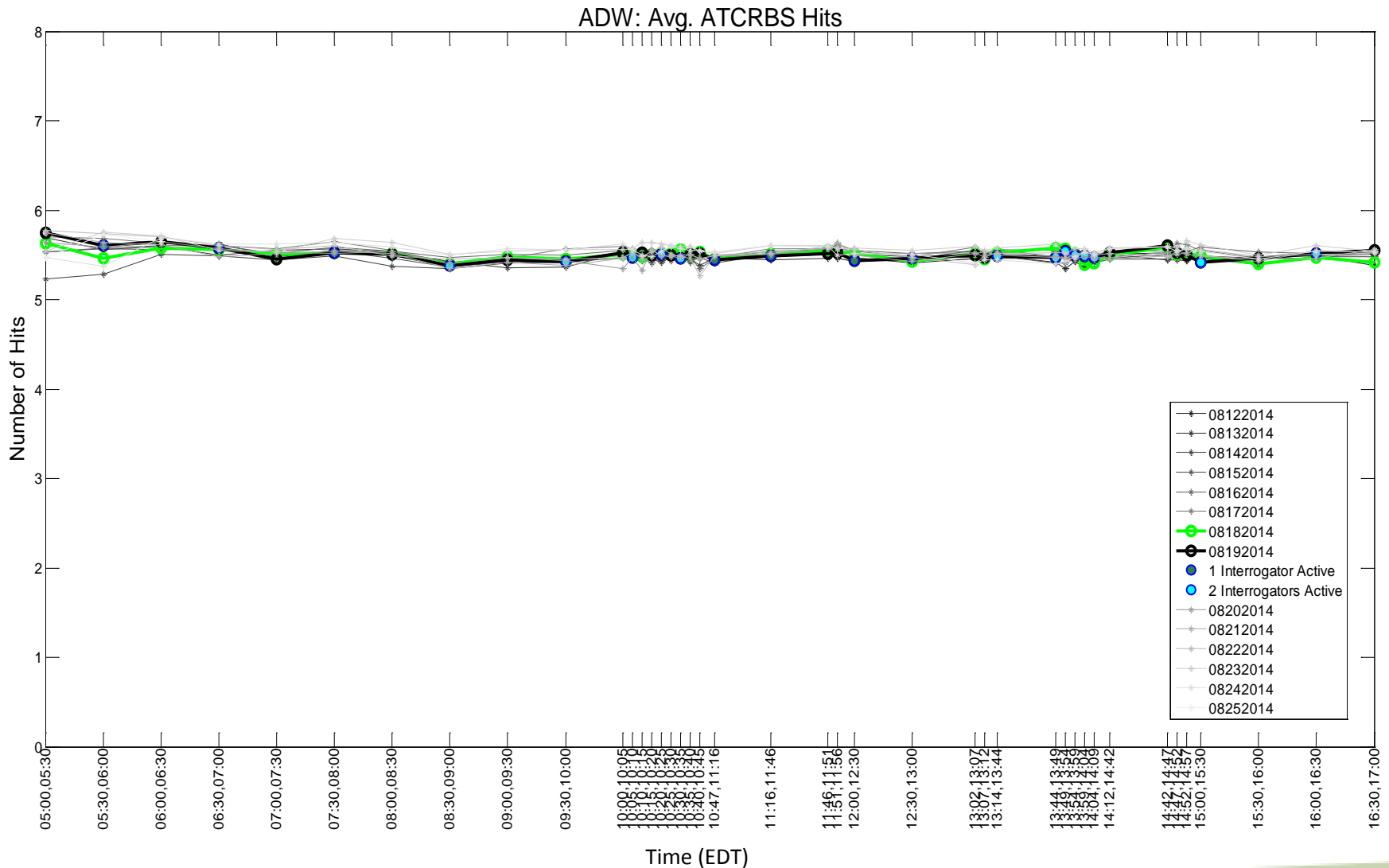


# ATCRBS Number of Hits vs Range – All Days

ADW: Average Number of ATCRBS Hits



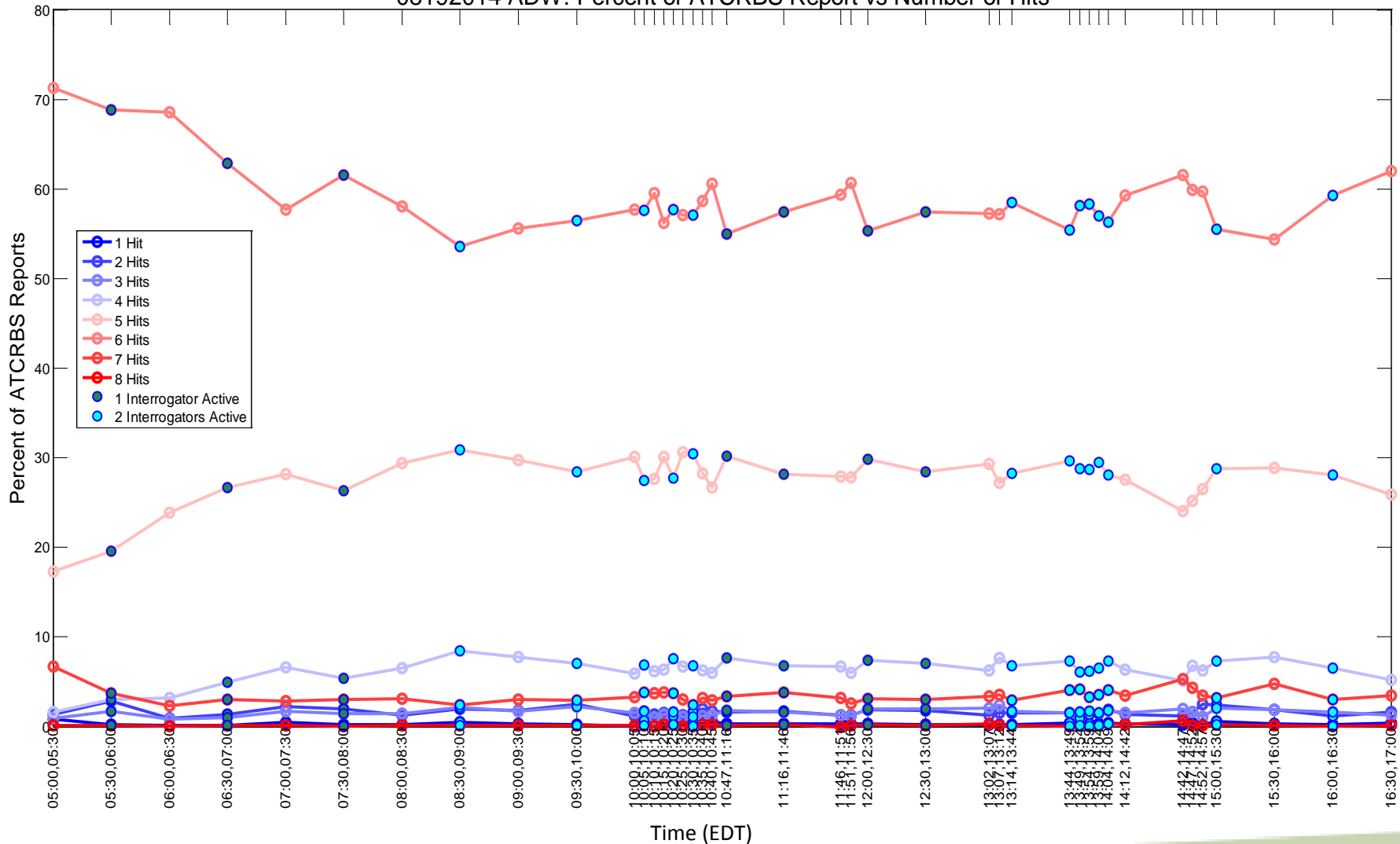
# ATCRBS Number of Hits – August 19<sup>th</sup>



# ATCRBS Number of Hits – August 19<sup>th</sup>

## Number of Hits Distribution

08192014 ADW: Percent of ATCRBS Report vs Number of Hits

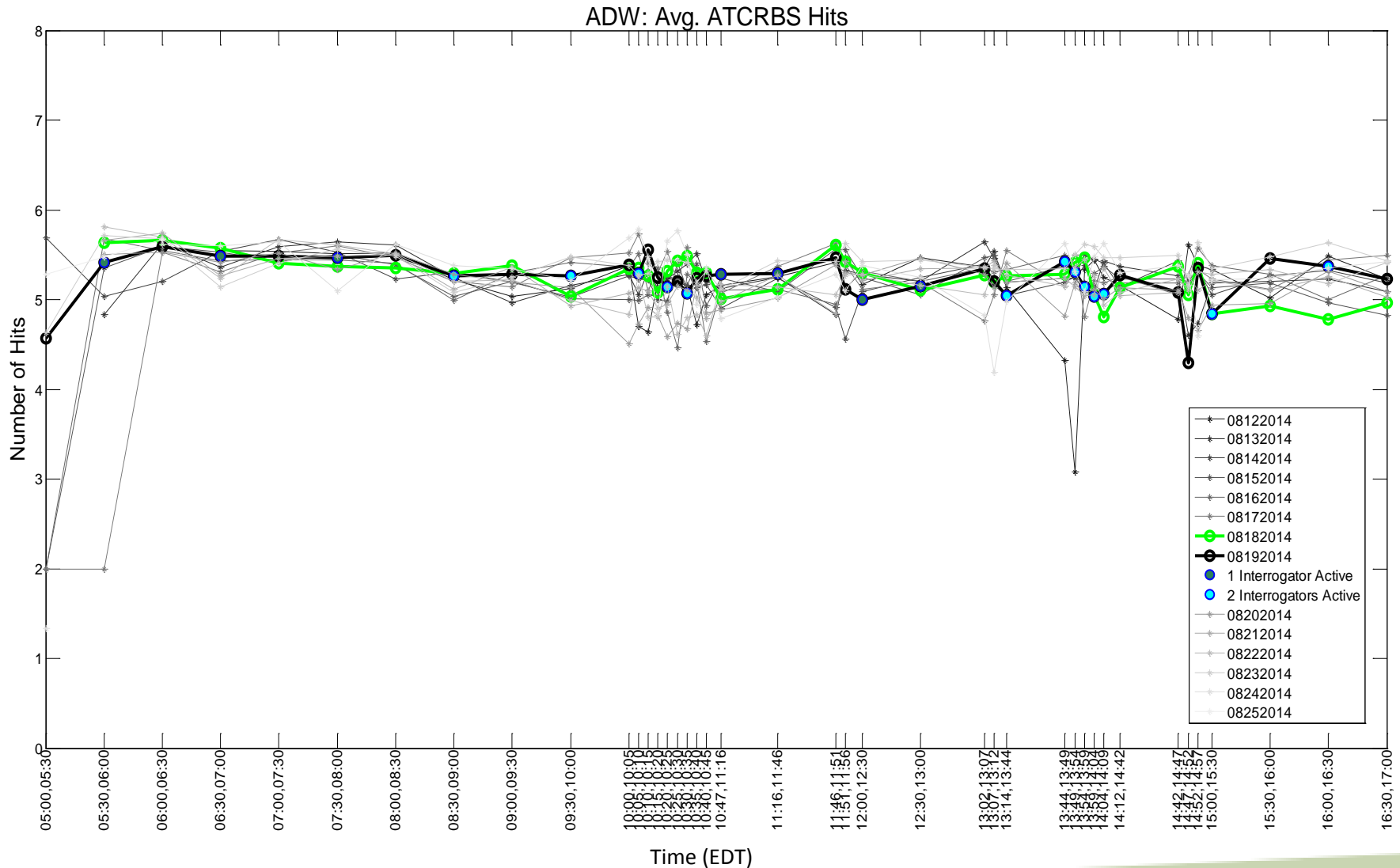


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 19<sup>th</sup>

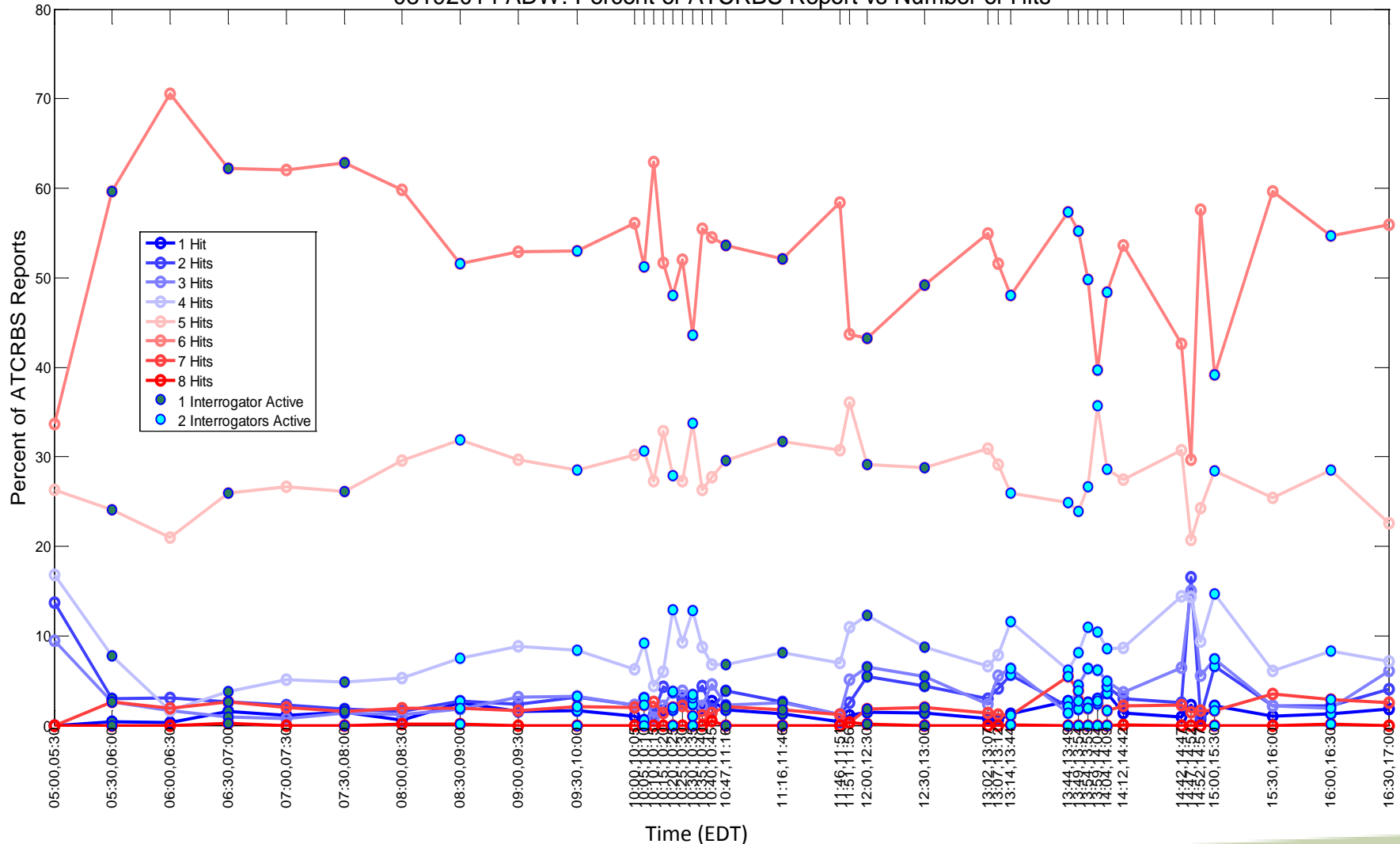
## 20 NM of AN/UPX-41(C) systems



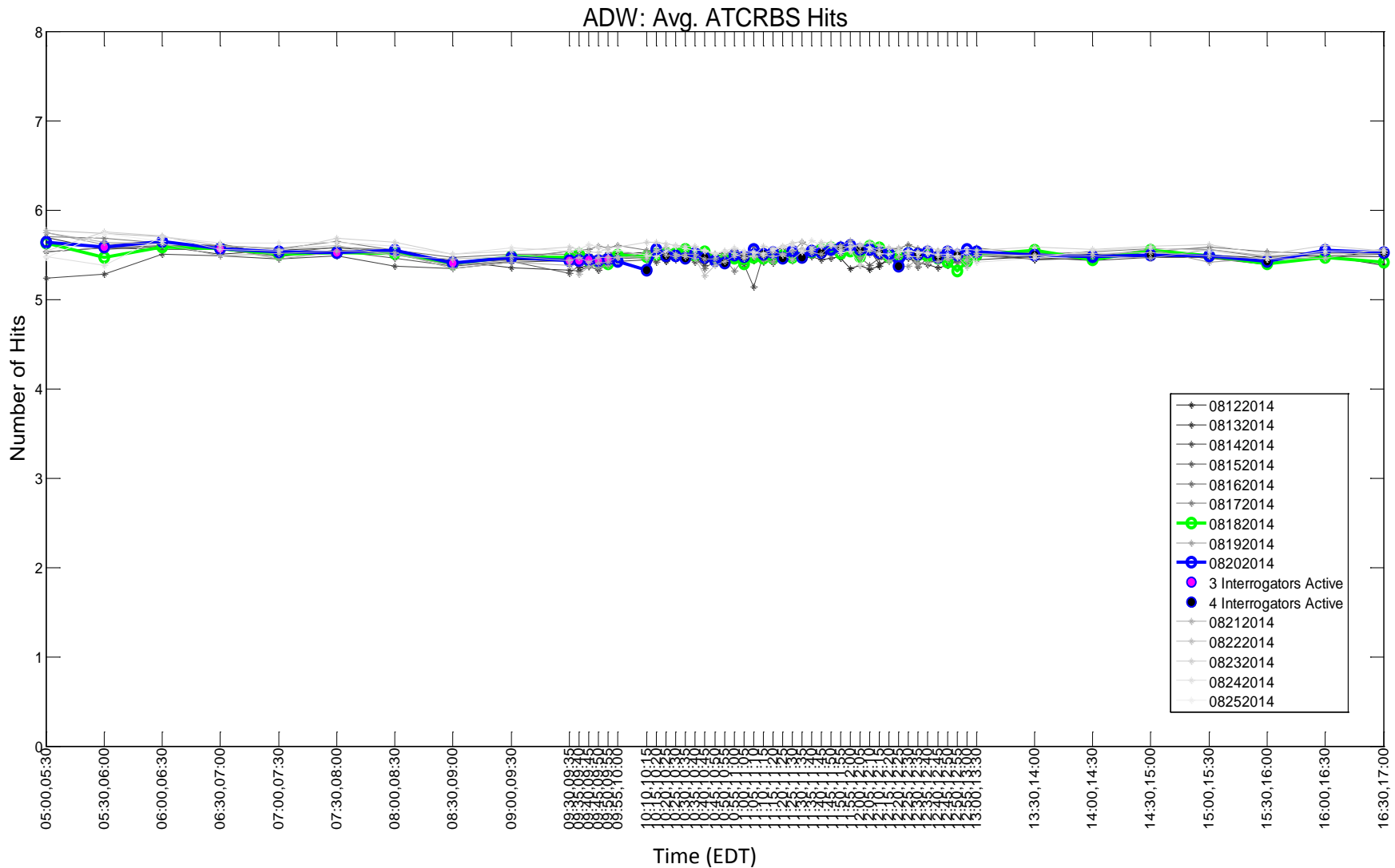
# ATCRBS Number of Hits – August 19<sup>th</sup>

## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution

08192014 ADW: Percent of ATCRBS Report vs Number of Hits



# ATCRBS Number of Hits – August 20<sup>th</sup>



Geographic Filter: None

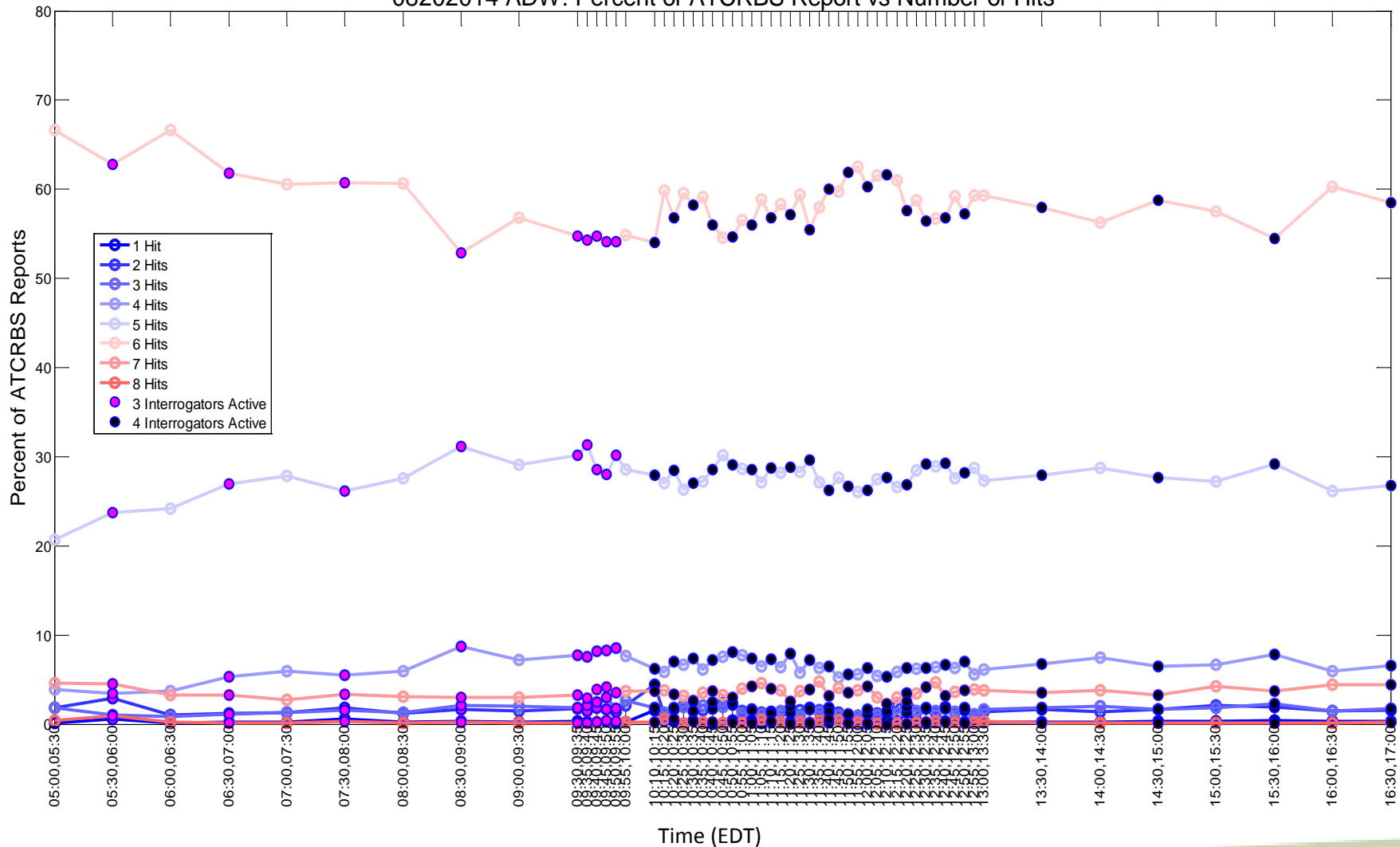
Target Filter: Exclude Targets with Elevation angle < 2°



# ATCRBS Number of Hits – August 20<sup>th</sup>

## Number of Hits Distribution

08202014 ADW: Percent of ATCRBS Report vs Number of Hits

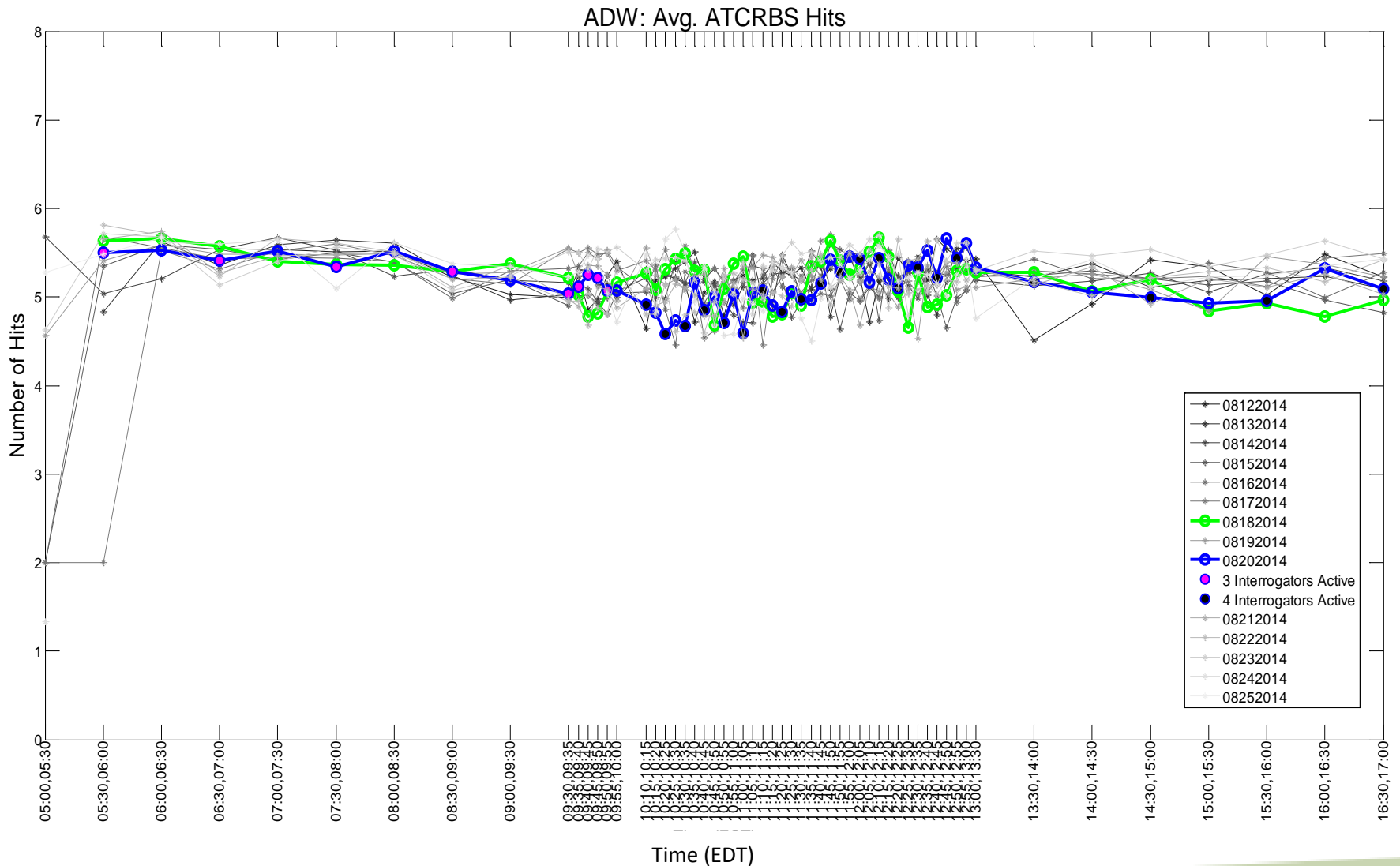


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

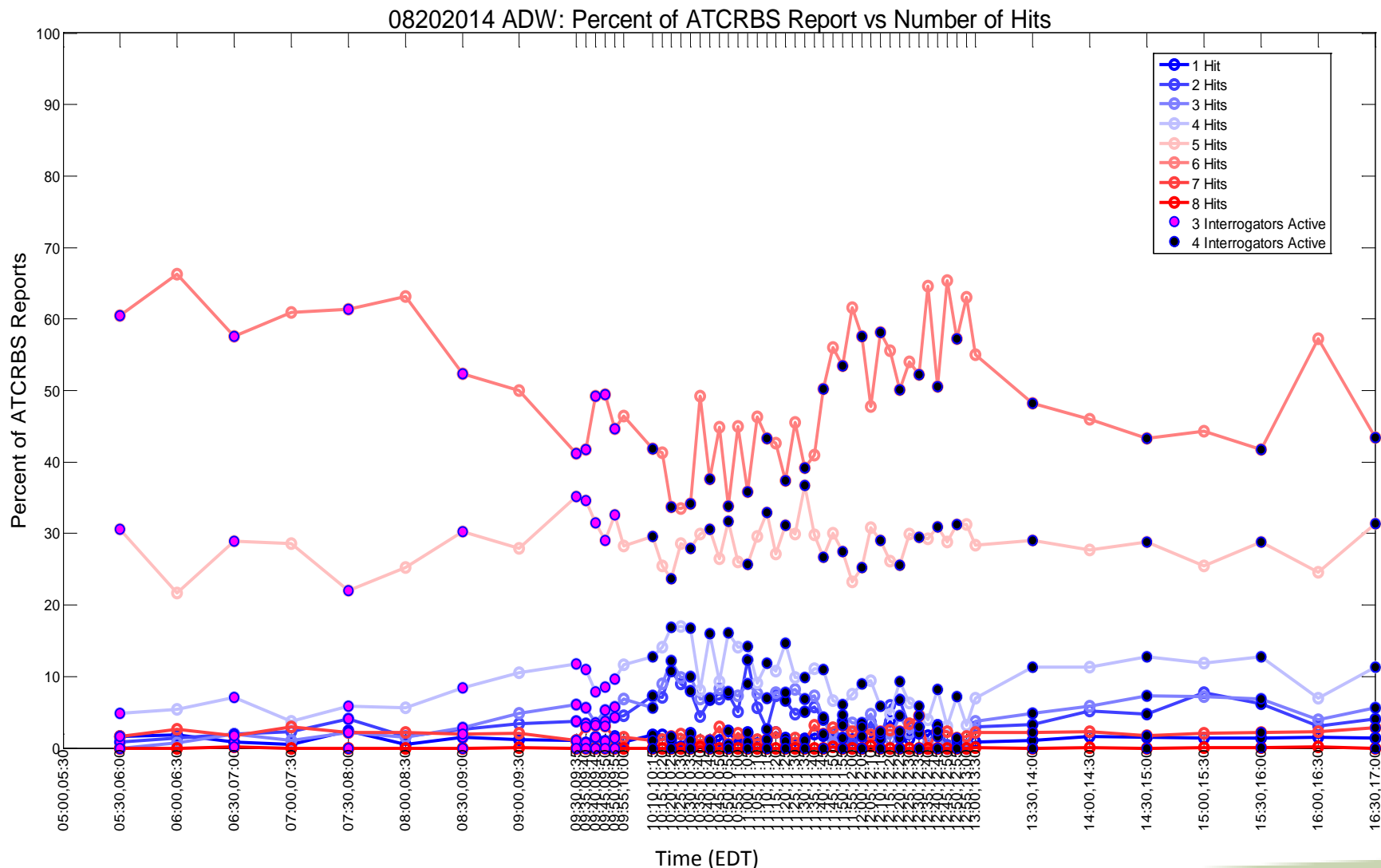
# ATCRBS Number of Hits – August 20<sup>th</sup>

## 20 NM of AN/UPX-41(C) systems

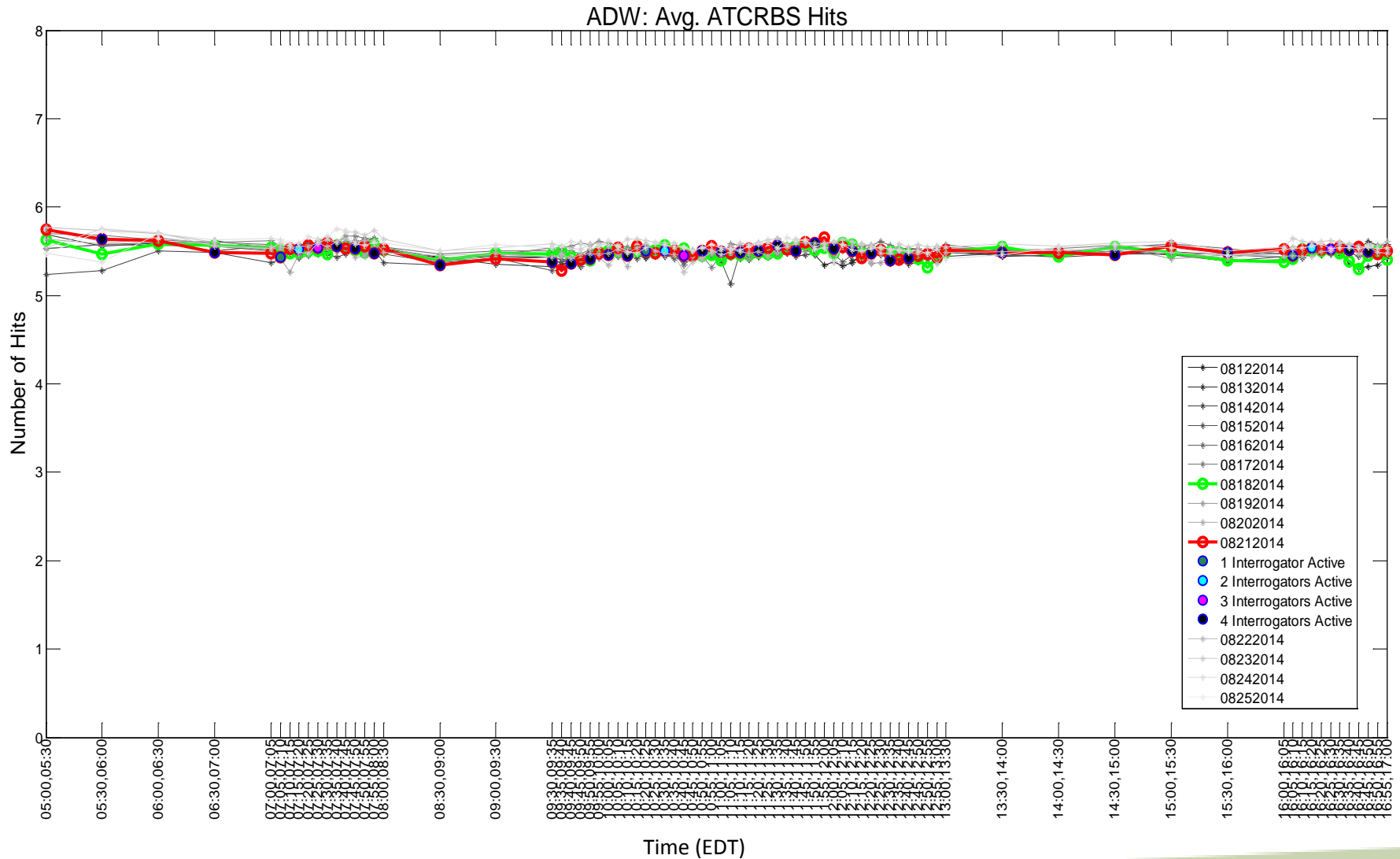


# ATCRBS Number of Hits – August 20<sup>th</sup>

## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution



# ATCRBS Number of Hits – August 21<sup>st</sup>



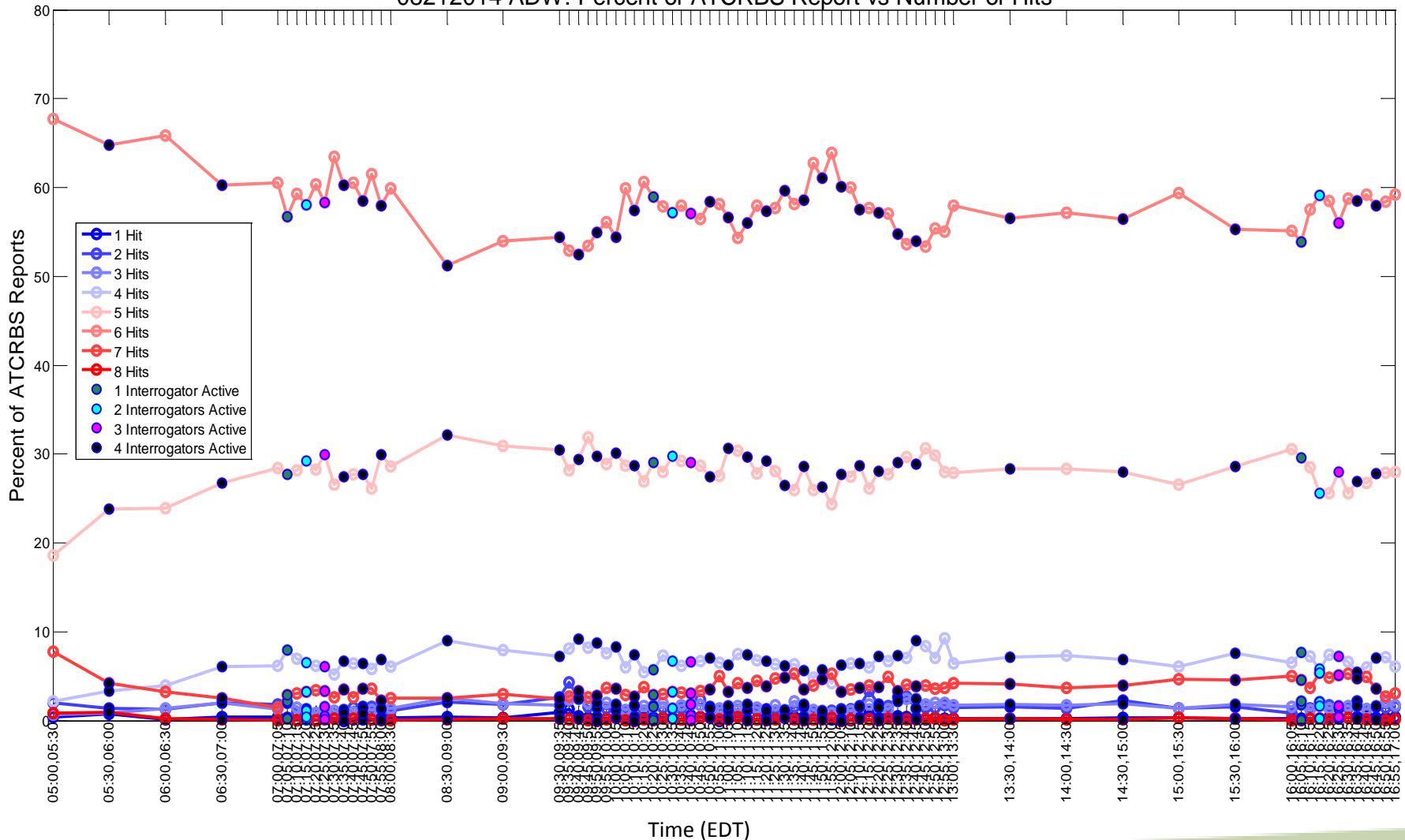
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 21<sup>st</sup>

## Number of Hits Distribution

08212014 ADW: Percent of ATCRBS Report vs Number of Hits

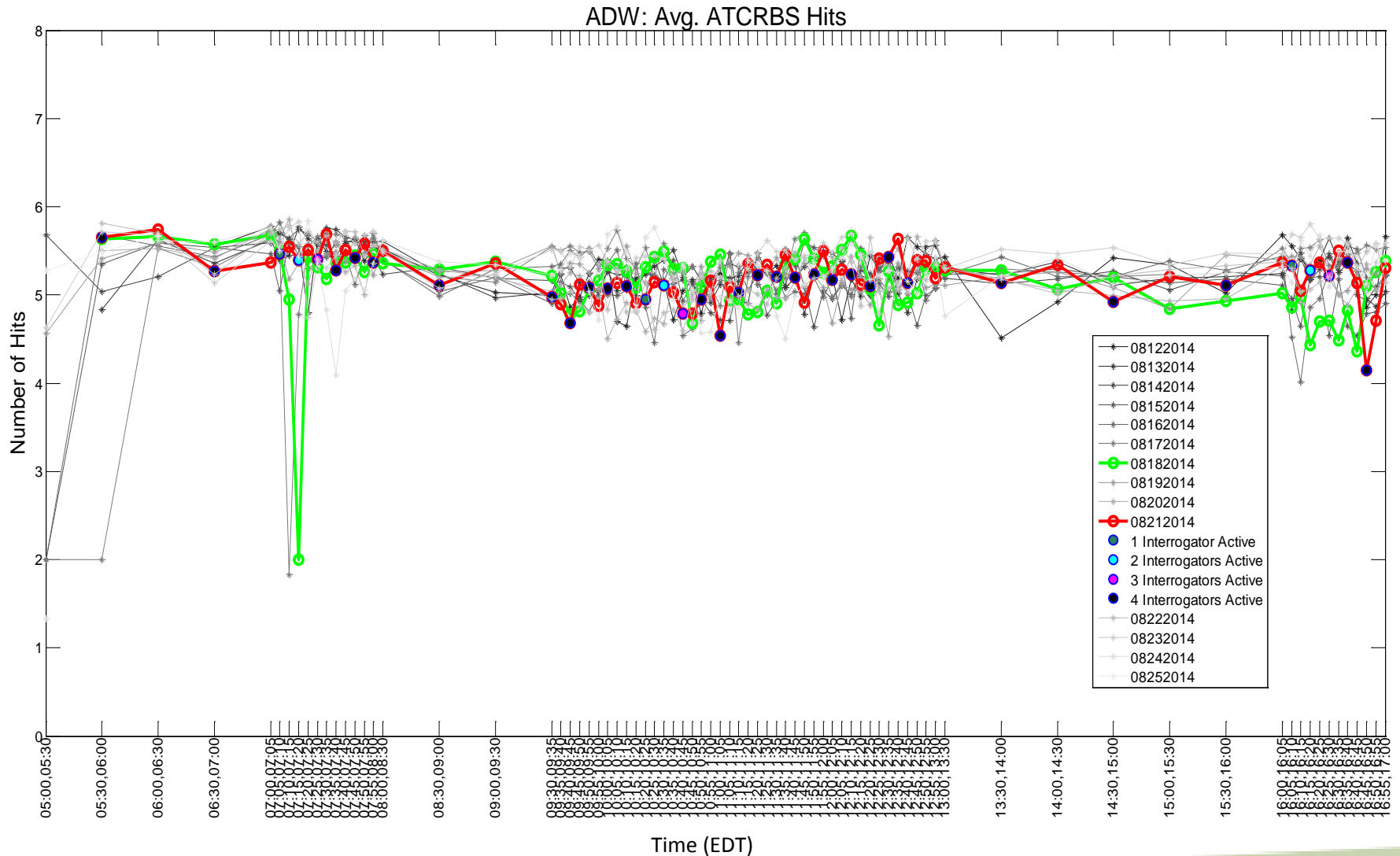


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 21<sup>st</sup>

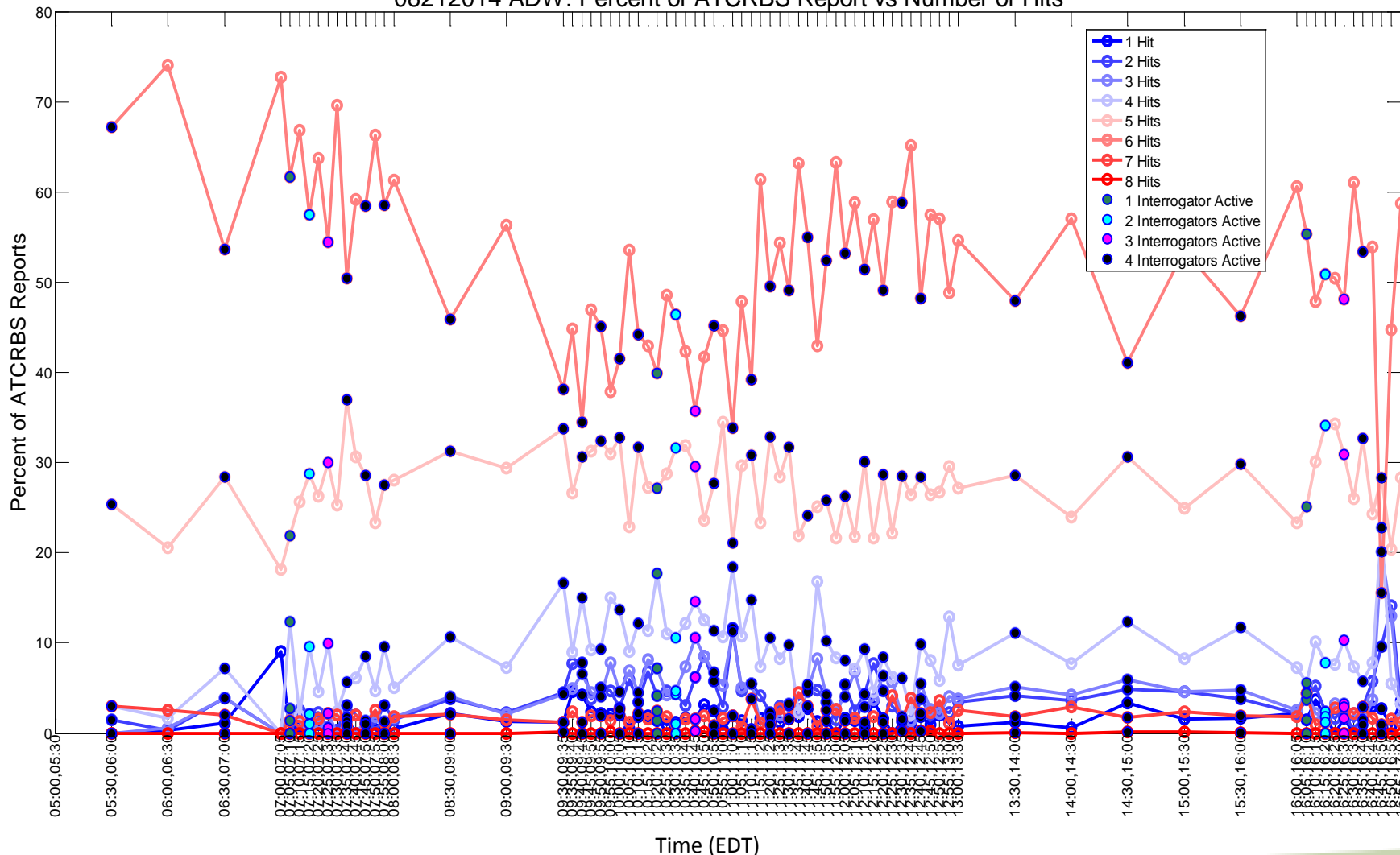
## 20 NM of AN/UPX-41(C) systems



# ATCRBS Number of Hits – August 21<sup>st</sup>

## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution

08212014 ADW: Percent of ATCRBS Report vs Number of Hits

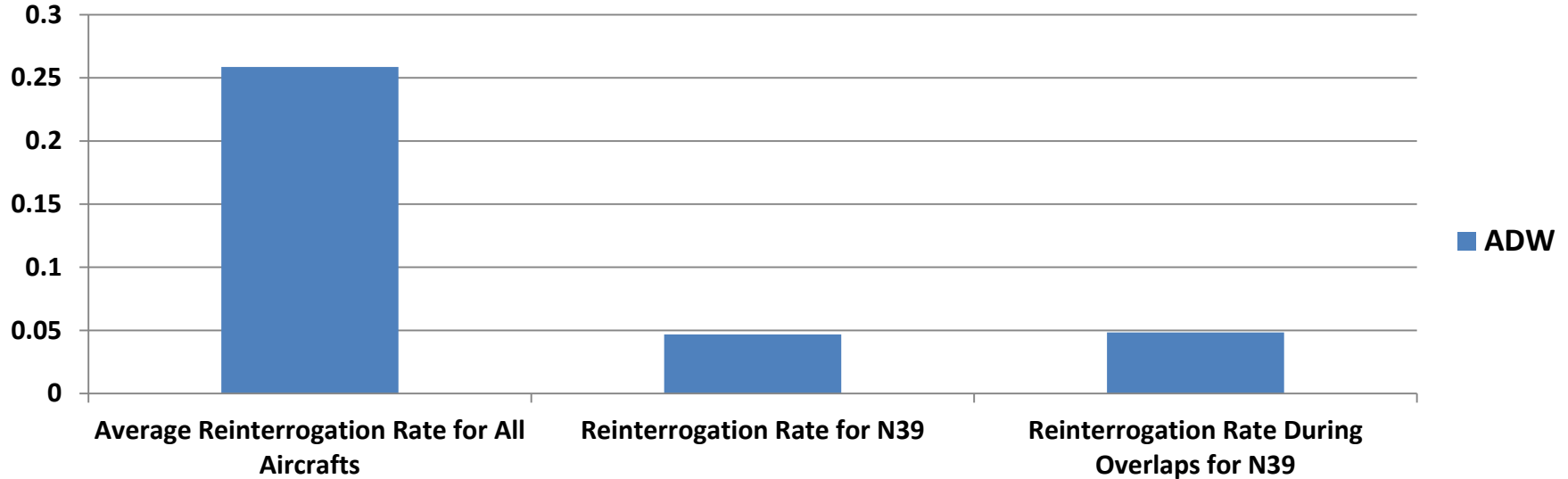


# N39 Statistics



# N39 Reinterrogation Rate – August 20<sup>th</sup>

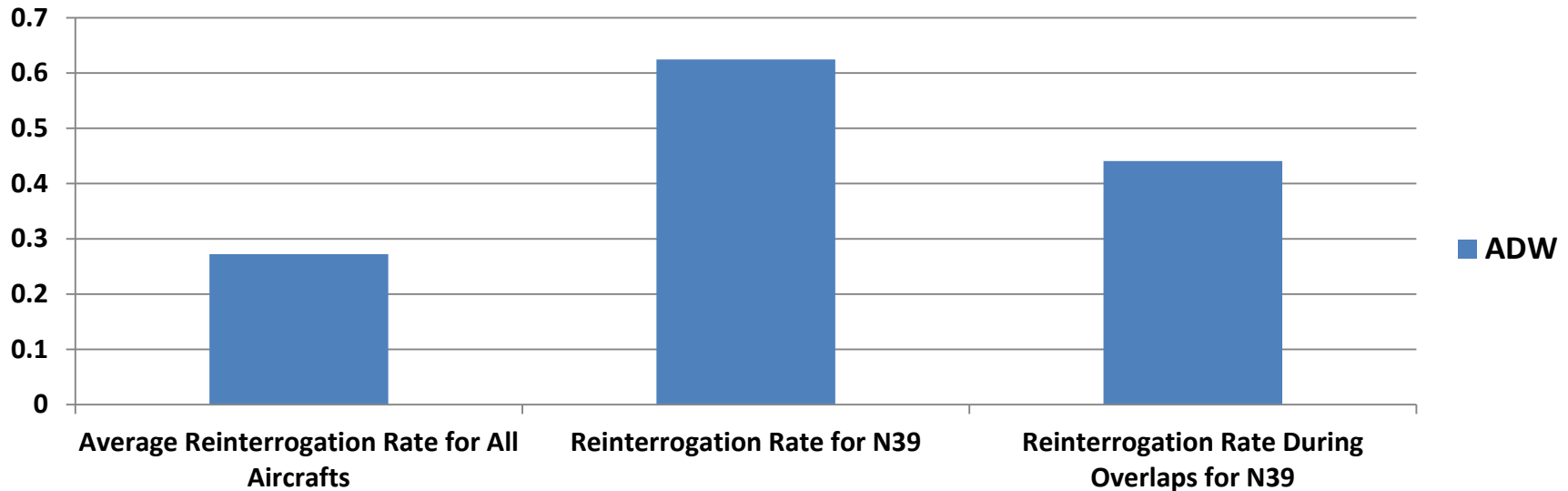
August 20, 2014



- Reinterrogation rate for N39 is lower than average reinterrogation rate for all aircrafts.
- Reinterrogation rate during overlaps of ADW and AN/UPX-41(C) mainbeams is about the same as when there are no overlaps.

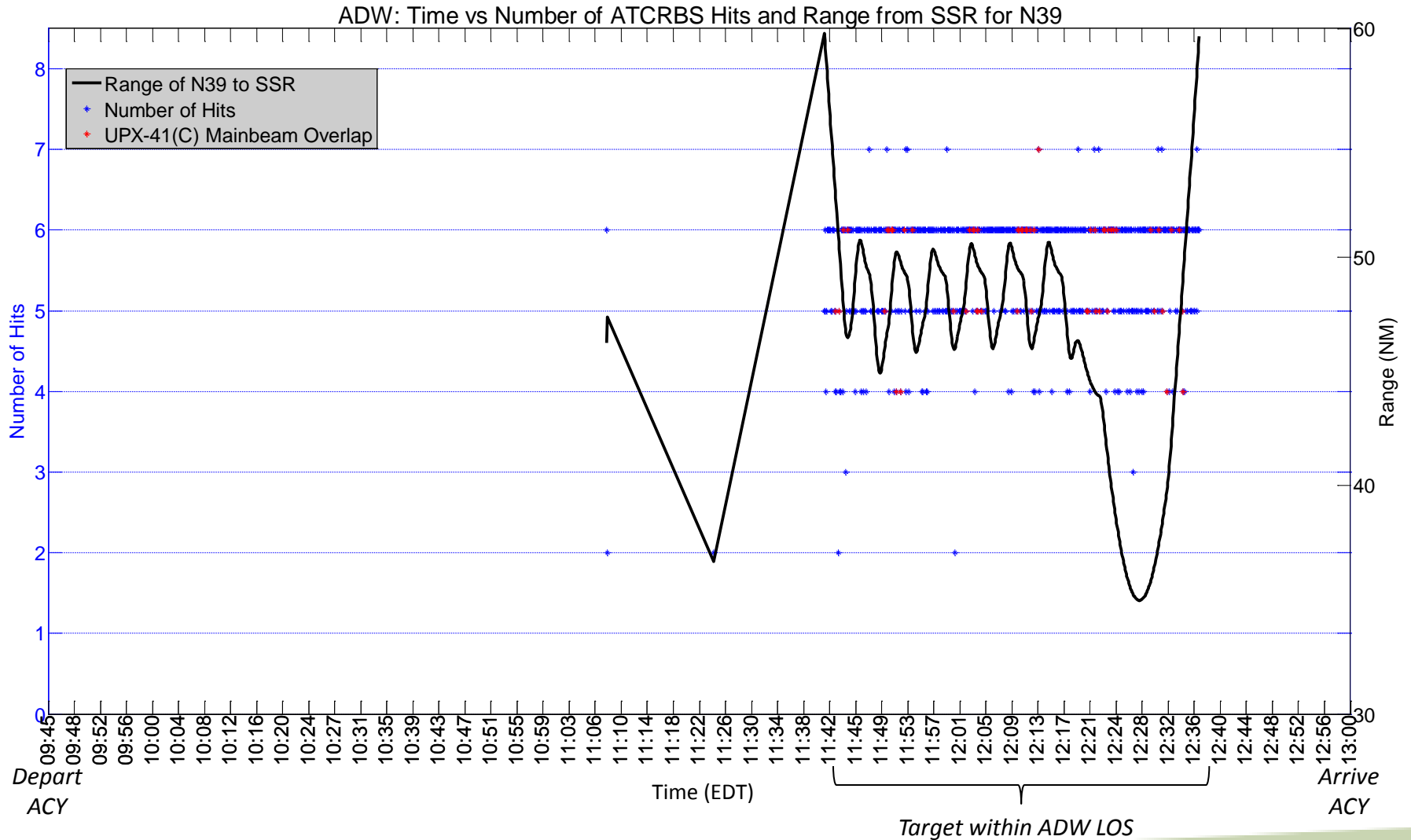
# N39 Reinterrogation Rate – August 21<sup>th</sup>

August 21, 2014



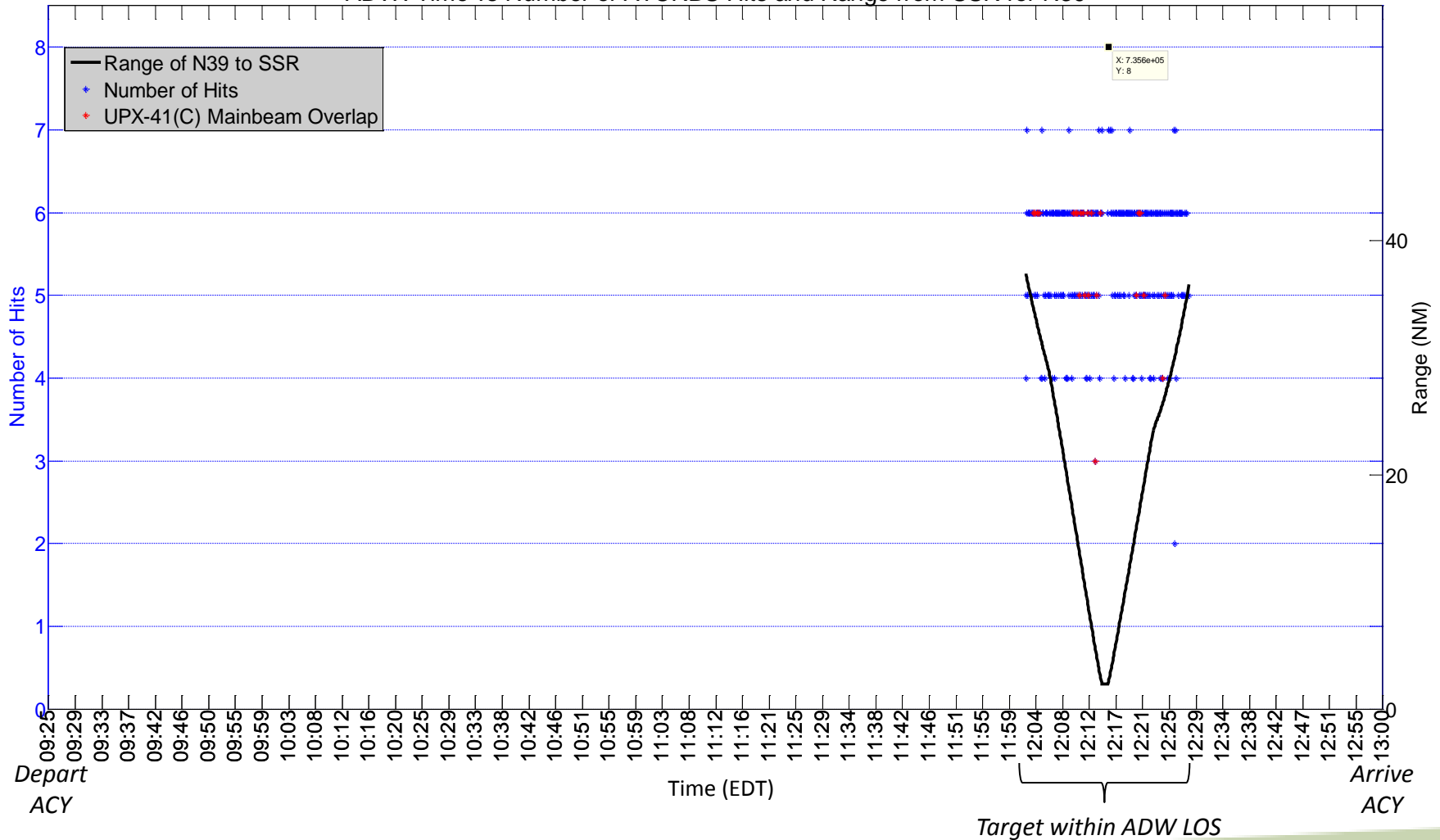
- Reinterrogation rate for N39 is higher than average reinterrogation rate for all aircrafts.
- N39 flew directly over ADW and is missing timing of 367 interrogations due to storage space limitations.
- Reinterrogation rate during overlaps of ADW is unreliable due to timing of interrogations missing when N39's interrogation data was not recorded.

# Time vs Range and Number of ATCRBS Hits on N39 – August 20<sup>th</sup>



# Time vs Range and Number of Hits on N39 – August 21<sup>st</sup>

ADW: Time vs Number of ATRBS Hits and Range from SSR for N39



# Observations and Conclusions

- ❑ Beyond 10 NM, where reinterrogation rates are not artificially high due to tracker predictor performance, changes in target reinterrogation rate average and distribution show no correlation with times when the AN/UPX-41(C) interrogators were active.
- ❑ When reinterrogation rates are compared with days when no AN/UPX-41(C) interrogators were active, the average shows no departure from the normal performance of the Mode S sensor.
- ❑ Similarly, ATCRBS hit count averages and distribution changes show no correlation with AN/UPX-41(C) active periods.
  - The one exception is August 21 when about 80% of the active periods showed a drop in percent of aircraft with hit count equal to six.
  - However, examination of the same day for the other three Mode S sites does not show this trend.

# Observations and Conclusions (cont'd)

- ❑ The Mode S data extraction files are the only ground sensor recorded data at the interrogation and reply level.
  - Degradation will begin here before it flows up to the track level (i.e.  $P_d$ , Conf., Rel.).
  - Hence, this analysis gives the clearest picture of spectrum interference that material affects the SSR surveillance environment.
- ❑ With virtually no observable change in reinterrogation rate and ATCRBS hit count, it is difficult to use this data to predict how more AN/UPX-41(C) interrogators, beyond the Stage 4 certification, would change the surveillance environment.
- ❑ Yet, by virtue of the fact that no change was observed at the interrogation and reply level, the Stage 4 certification restrictions are more than sufficient to protect FAA SSRs and relaxation of those restrictions should be considered to help the Navy meet its operational goals.



# Background

- ❑ The AN/UPX-41(C)\* Stage-4 operational transmit certification for AEGIS-Class ships was signed by NTIA on June 22, 2012 with geographic and platform number restrictions when operating in proximity to the NAS.<sup>†</sup>
- ❑ Additionally, the Stage-4 certification contained a requirement for a joint FAA-Navy test to validate the operational restrictions.
- ❑ The Volpe Center, in conjunction with the Navy, FAA Spectrum, and FAA aeronautical surveillance and collision avoidance systems (ASCAS) SMEs created a test plan to validate the operational restrictions.
- ❑ From August 18-21, 2014 the FAA and Navy conducted the above-mentioned joint test, under the management of the Volpe Center.
- ❑ Since the test, the Volpe Center has analyzed recorded data to look for instances of harmful interference that would affect ASCAS system performance.

\*AN/UPX-41(C) Digital Interrogator System when operated in conjunction with the OE-120 antenna, the AN/UPX-29(V) Identification Friend or Foe (IFF) system, and the AN/UPX-24 software interface Version 2.1.2, controlled by the Cooperative Engagement Capability (CEC), in Naval surface vessels

<sup>†</sup>See SPS-18778\_1 Navy AN-UPX-41 V5.5 St4



# Test Plan Refresher

## □ Baseline week: August 11<sup>th</sup> – 15<sup>th</sup>

- Baseline recording of data from 5 AM – 5 PM
  - No AN/UPX-41(C) systems Active

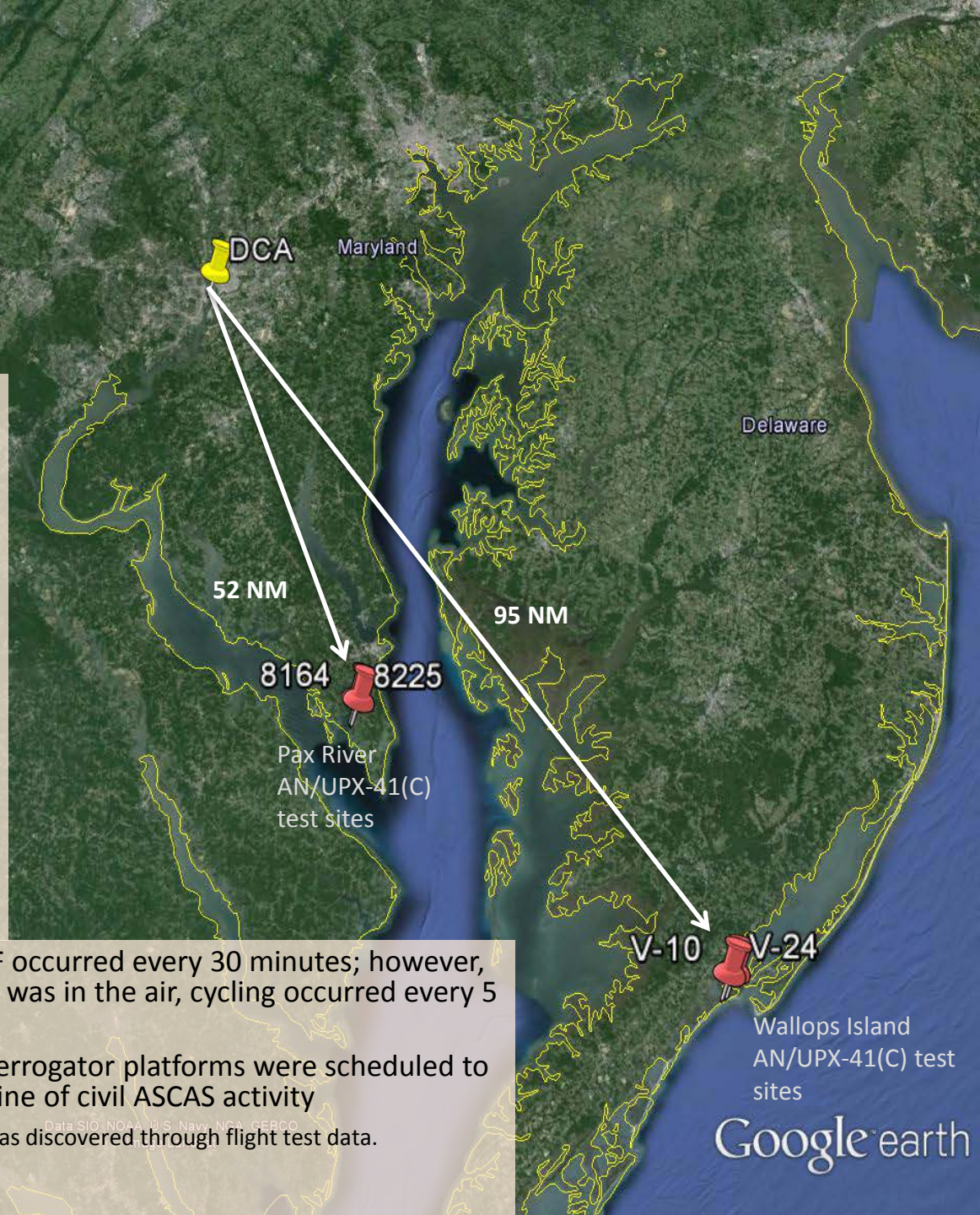
## □ Test week: August 18<sup>th</sup> – 21<sup>st</sup>

- August 18<sup>th</sup> – Baseline recording of data from 5 AM – 5 PM
  - No AN/UPX-41(C) systems Active
- August 19<sup>th</sup> – Record data from 5 AM – 5 PM
  - Cycle 1 and 2 AN/UPX-41(C) systems Active and OFF
- August 20<sup>th</sup> – Record data from 5 AM – 5 PM
  - Cycle 3 and 4 AN/UPX-41(C) systems Active and OFF
- August 21<sup>st</sup> – Record data from 5 AM – 5 PM
  - Cycle 1, 2, 3, and 4 AN/UPX-41(C) systems Active and OFF

- Cycling of AN/UPX-41(C) systems Active/OFF occurred every 30 minutes; however, if N39 (Tech Center signal recording aircraft) was in the air, cycling occurred every 5 minutes

- During the test week, non-essential DoD interrogator platforms were scheduled to be inactive in order to get an accurate baseline of civil ASCAS activity

- This did not occur. Non-test platform radiation was discovered through flight test data.



# Data Recording

- ❑ During the August test, Enroute Common Gateway (ECG) data was recorded at the Tech Center from the DCA site.
- ❑ The Radar Beacon Analysis Tool (RBAT) was used to analyze ECG data to produce statistics for the following list of parameters:
  - Targets per Scan
  - Probability of Detection
  - Identity Reliability
  - Identity Confidence
  - Altitude Reliability
  - Altitude Confidence
  - False Target Percentage
  - 0000 Code Percentage
- ❑ Mode S system version D22020 was used to record data extraction files by Mode S SSR technicians at the SSR Site.
- ❑ Mode S Analysis Tool (MSAT) was used to analyze extraction files to produce statistics for the following list of parameters:
  - FRUIT Rates
  - Interrogation/Reinterrogation Rates
  - ATCRBS Hit count statistics

# Data Analysis

- ❑ Applied time bins that corresponded to the AN/UPX-41(C) Active/OFF periods from test days (August 19<sup>th</sup>-21<sup>st</sup>) to baseline days to produce baseline statistics for all parameters
- ❑ Processed RBAT data through Surveillance Analysis, Scan Summary, and Beacon False Target Summary programs to find parameters of interest for each time bin without geographic or target filters
- ❑ Processed MSAT data through Channel Management Statistics and FRUIT Analysis programs to find parameters of interest for each time bin
  - 1) No geographic or target filters
  - 2) >10 NM filter
- ❑ Produced interrogation, reinterrogation, and hit count statistics for the Tech Center Aircraft (N39) as it flew within the SSRs LOS
  - Focused on possible interference during mainbeam overlap with V10, 8164, and 8225 sites

# Analysis Limitations

- ❑ The theoretical or textbook definition of probability of detection is a function of interrogation/reply round reliability.
- ❑ However, probability of detection in RBAT is the percentage of target updates versus total number of beam dwells over all targets.
- ❑ Therefore, the ability for probability of detection calculated by RBAT to properly represent theoretical probability of detection is minimized as the sample size decreases (either through geographical or time constraints) since it no longer reliably reflects the target population mean.
- ❑ Example: A target population of two where both targets miss one update out of ten scans (approximately 50 seconds) results in a probability of detection of 90%. While this is unacceptable by QARS blip/scan minimums, we have no knowledge of the updates that occurred outside of the given time constraint . If both targets received ten out of ten updates for the previous as well as the next 10 scans, the probability of detection is now 96.7%.

# Mode S Data Extraction Issues

- ❑ Noticed series of messages displayed by MSAT : Interrogation does not match frame table
  - The interrogation type does not match the expected type from the frame table or the time difference is more than 16 USECs
  - 02:34:23.445
  - Frame table not synched with actual periods
  - Try filtering the data starting at a later time or rerun the data
- ❑ After talking with Jim Davis, it was found that these errors occurred when CMS was unable to synchronize the interrogation data with the expected interrogation types from frame table and/or it was not able to maintain synchronization once it was achieved.
  - CMS was unable to synchronize due to interrogation data missing in the beginning of the file. Starting 1-5 seconds later fixed this.
  - CMS was losing sync due to interrogation data missing at a later time in the file.
- ❑ In a single beam dwell, the Mode S sensor records the first 21 interrogations and the rest are thrown away because of data storage space limitations.
- ❑ However, the Mode S sensor does record the number of interrogations past 21 that occurred and stores that amount in a **retry overflow count** field.
- ❑ Originally, MSAT did not count interrogations past 21 because they were not recorded by the Mode S sensor. Now, MSAT has been updated to account for the missing interrogations by considering the retry overflow count as interrogations without replies.
- ❑ Example: if in a beam dwell there are 25 interrogations, the Mode S sensor will record the first 21 and the retry overflow count would be 4.

# Mode S Data Extraction Issues (cont'd)

## All call data for DCA

13:38:17.336	INT	AC	27.58	itime=3cc490	MODE_3A
13:38:17.336	INT	AC	27.64	itime=3d02b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.344	INT	AC	28.19	itime=3ebcf0	MODE_C
13:38:17.344	INT	AC	28.26	itime=3effa0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.352	INT	AC	28.78	itime=409c00	MODE_3A
13:38:17.352	INT	AC	28.85	itime=40dd10	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.359	INT	AC	29.38	itime=427b00	MODE_C
13:38:17.359	INT	AC	29.44	itime=42bb50	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.367	INT	AC	29.99	itime=445890	MODE_3A
13:38:17.367	INT	AC	30.06	itime=4499b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.375	INT	AC	30.59	itime=4639f0	MODE_C
13:38:17.484	INT	AC	39.05	itime=60a300	MODE_C
13:38:17.484	INT	AC	39.11	itime=60e350	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.492	INT	AC	39.62	itime=628090	MODE_3A
13:38:17.492	INT	AC	39.68	itime=62c1b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.500	INT	AC	40.23	itime=6461f0	MODE_C

Data loss through  
about 8.5°

- ❑ Previous accounts of lost interrogation data at the Mode S sites was accounted for using the retry overflow count that was being reported by the Mode S sensor.
- ❑ However, as the analysis progressed, instances were found where the Mode S site was not reporting loss of data, but we can clearly see there is a loss of data (see highlighted above).
- ❑ The site did not report any missing data, but CMS produced a fatal error due to data not being present and having no record of data being lost.
- ❑ This was not discovered previously due to Probability of Detection changing ever so slightly in the absence of 8 degrees of data for a given time period. This fluctuation of probability of detection could be due to many reasons. (low elevation angle, non-compliant transponder, aircraft turning, etc.)

# Analysis Objective

- ❑ We are attempting to observe distinct patterns of change in the metrics of interest between times when the AN/UPX-41(C) systems are OFF and when they are Active.
- ❑ While geographic and time filters reduces target update sample sizes such that a small sample size itself influences the metric of interest, it is more important to focus on the change from Off to Active since both the Off and Active periods have the same constraints applied.

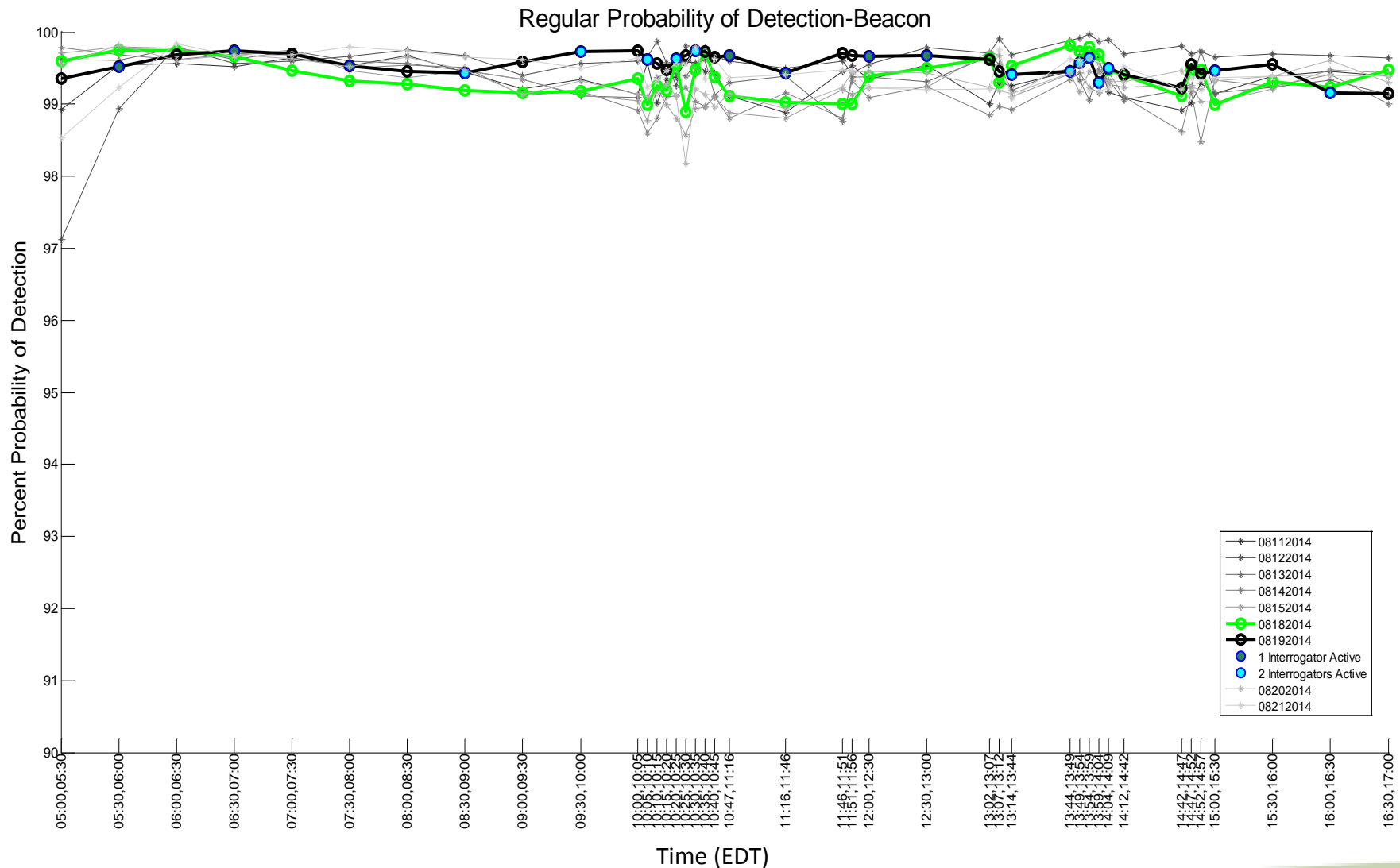
# Plot Guide

- ❑ Plots with multiple days of data utilize the time filters from the Active/Off periods for the date given in the slide's title
- ❑ Plots that use boxplots
  - The edges of the box are the 25<sup>th</sup> and 75<sup>th</sup> percentiles. The maximum whisker length represents approximately 2.7 sigma (99.3%). Points in red are shown as outliers.
    - Exception: Box plots for reinterrogation rate vs time filters have whiskers that reach to the extent of the furthest outlier.
  - For five minute time bins, there are only 65 DCA scans and, if you miss one target update,  $P_d$  will automatically drop to 98.4% (24 out of 25 possible target reports).
  - Horizontal axis 30-min and 5-min time bins are not scaled according to duration.



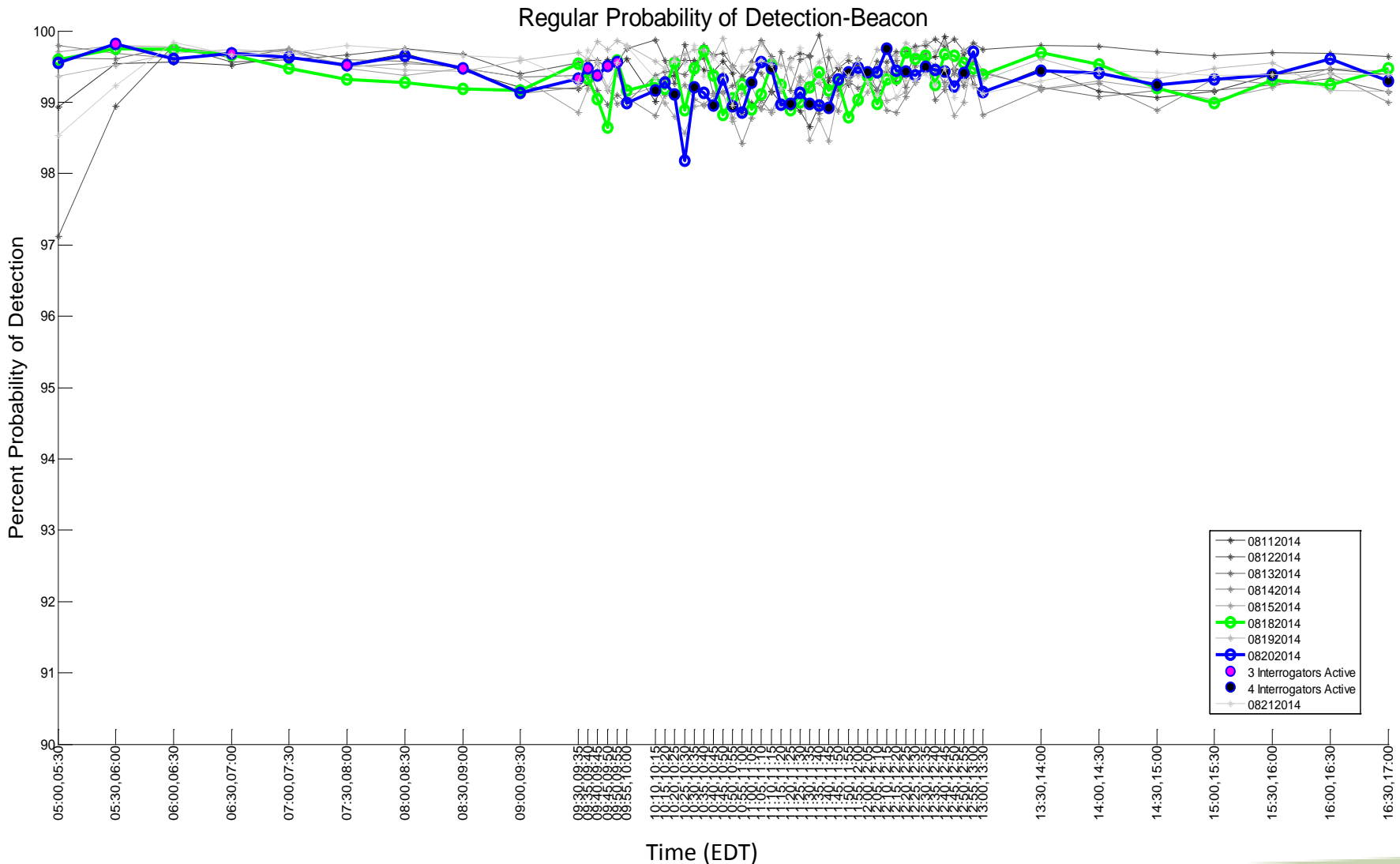
# Target Metrics with No Filter

# Probability of Detection – August 19<sup>th</sup>



Geographic Filter: None  
Target Filter: None

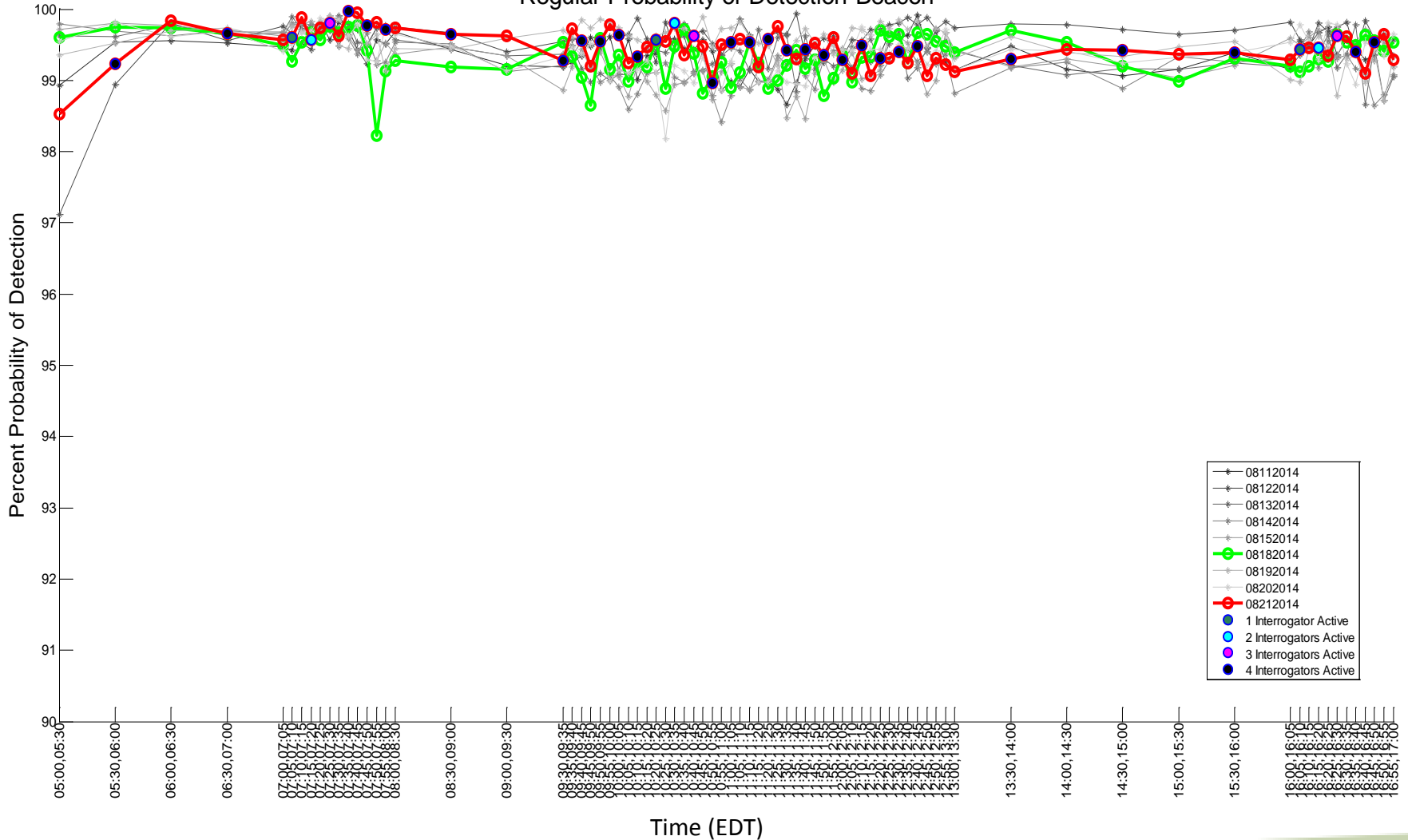
# Probability of Detection – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

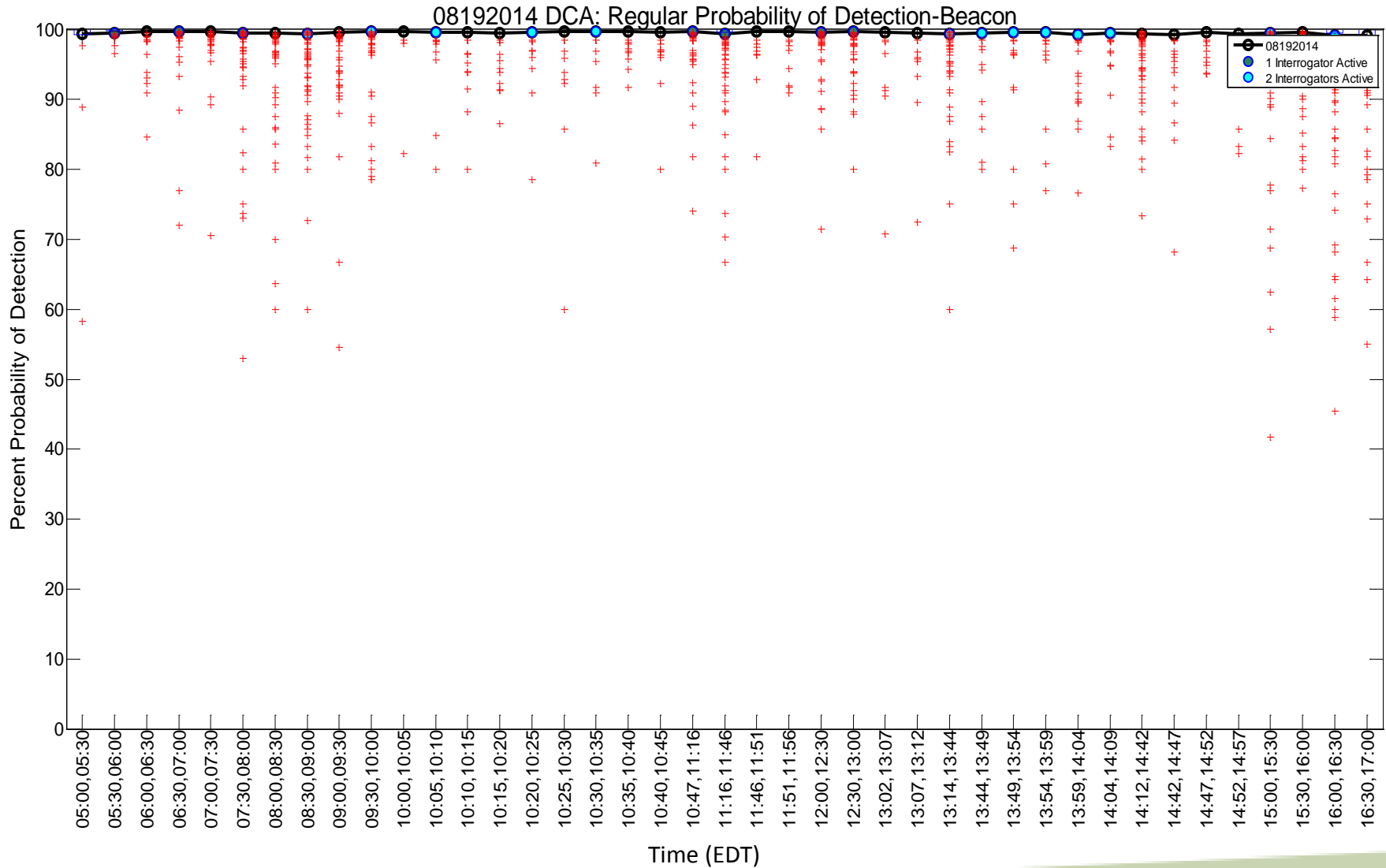
Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution

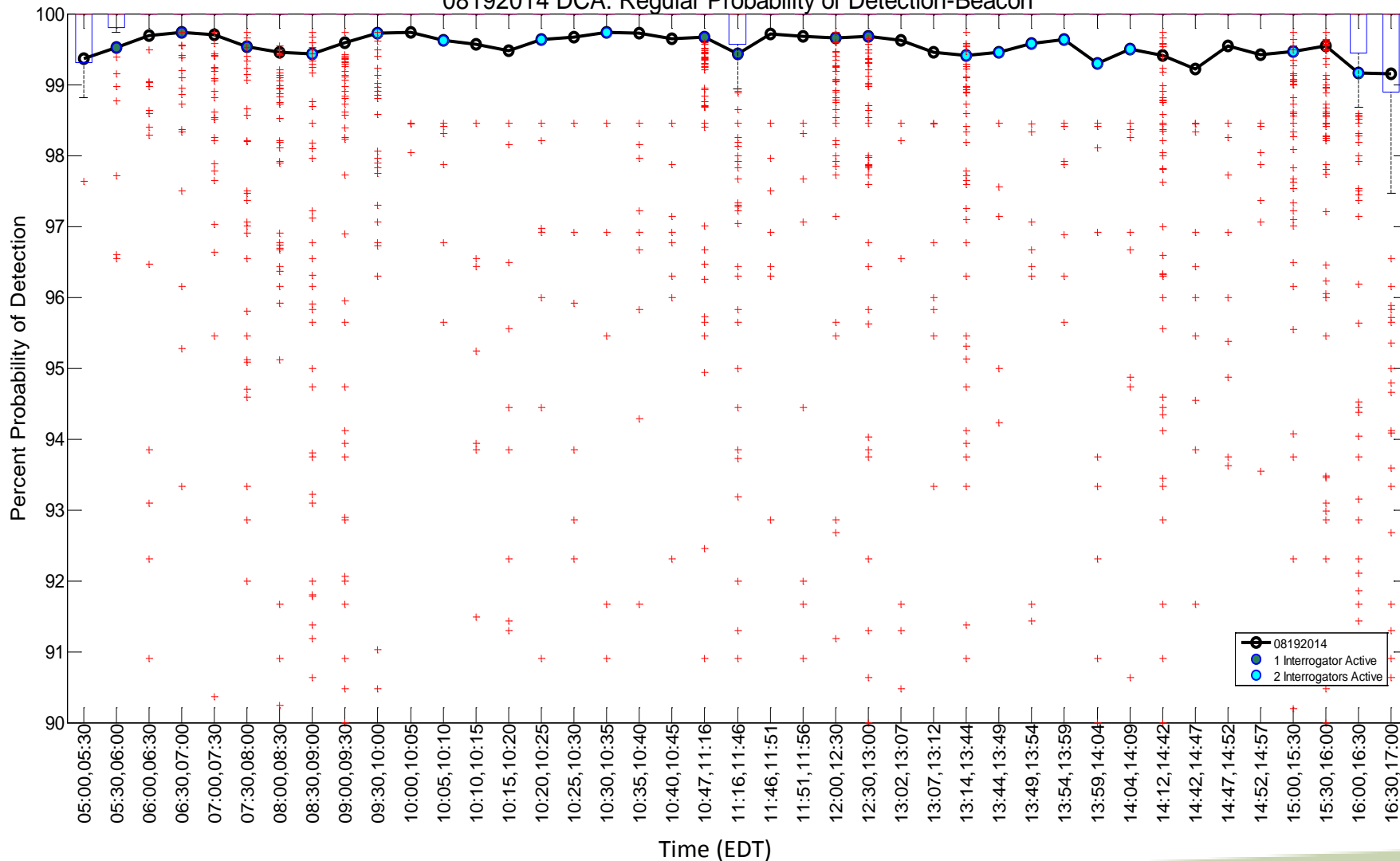


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

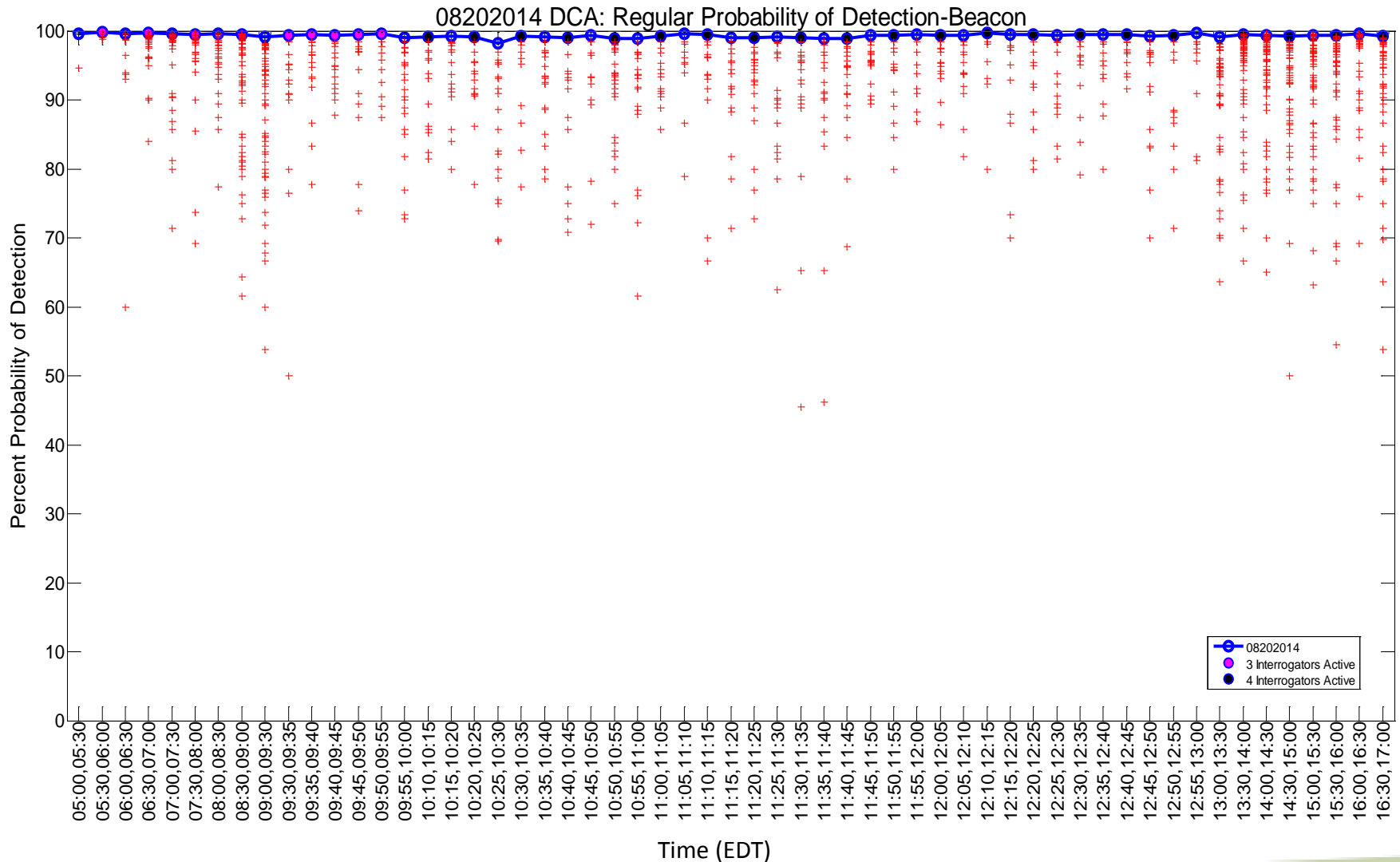
08192014 DCA: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

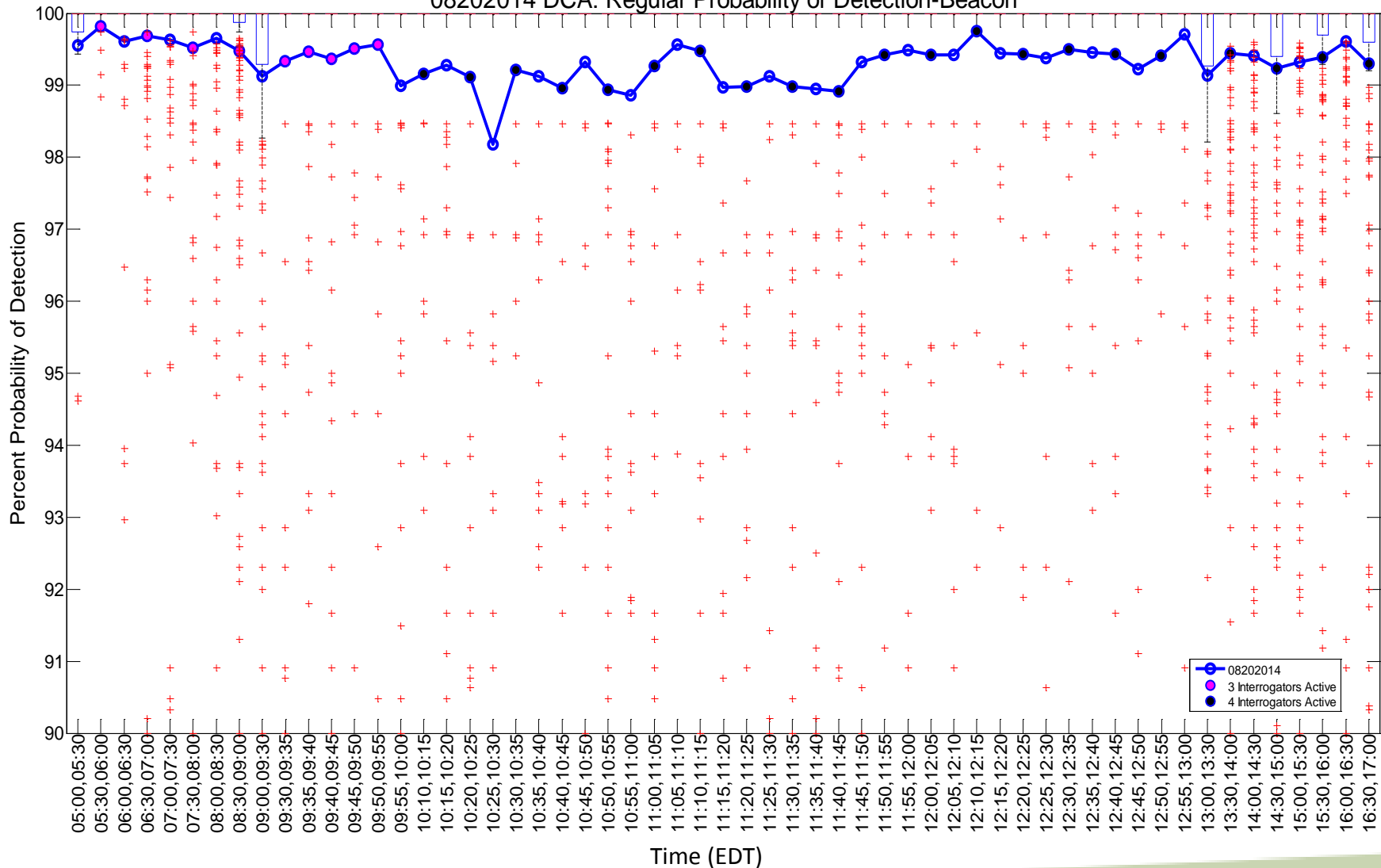
## Individual Aircraft Distribution



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08202014 DCA: Regular Probability of Detection-Beacon

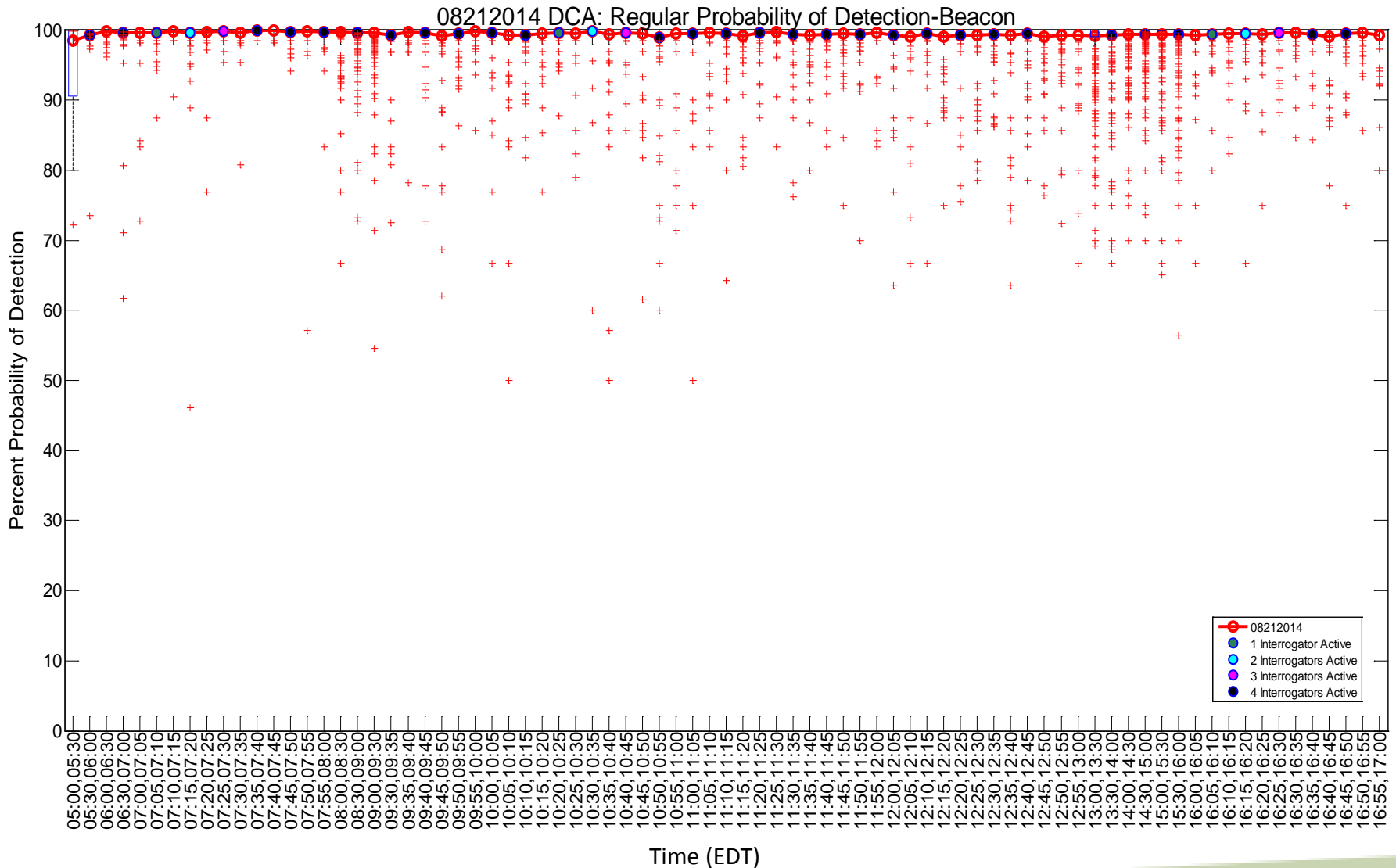


Geographic Filter: None  
Target Filter: None



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

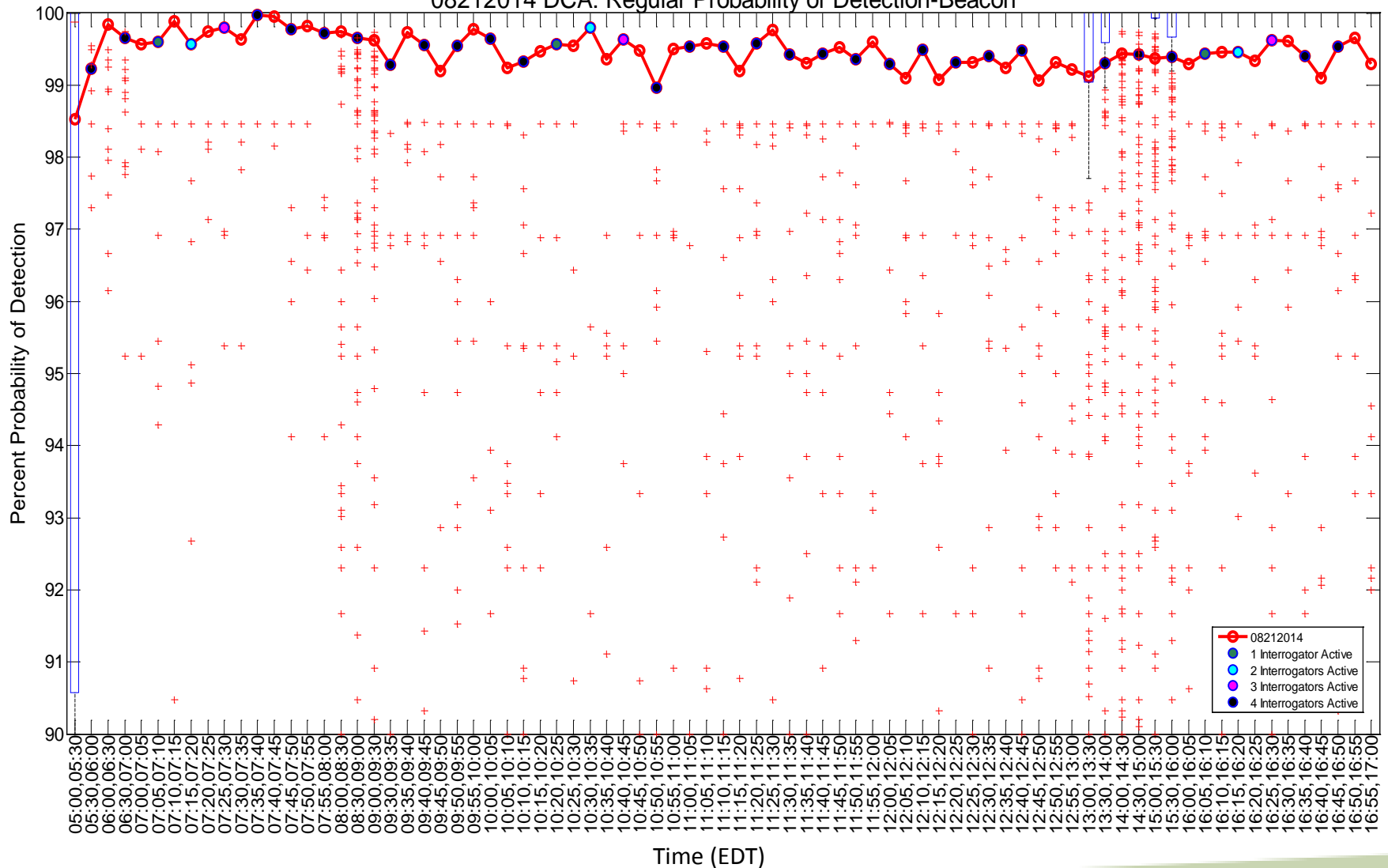


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)

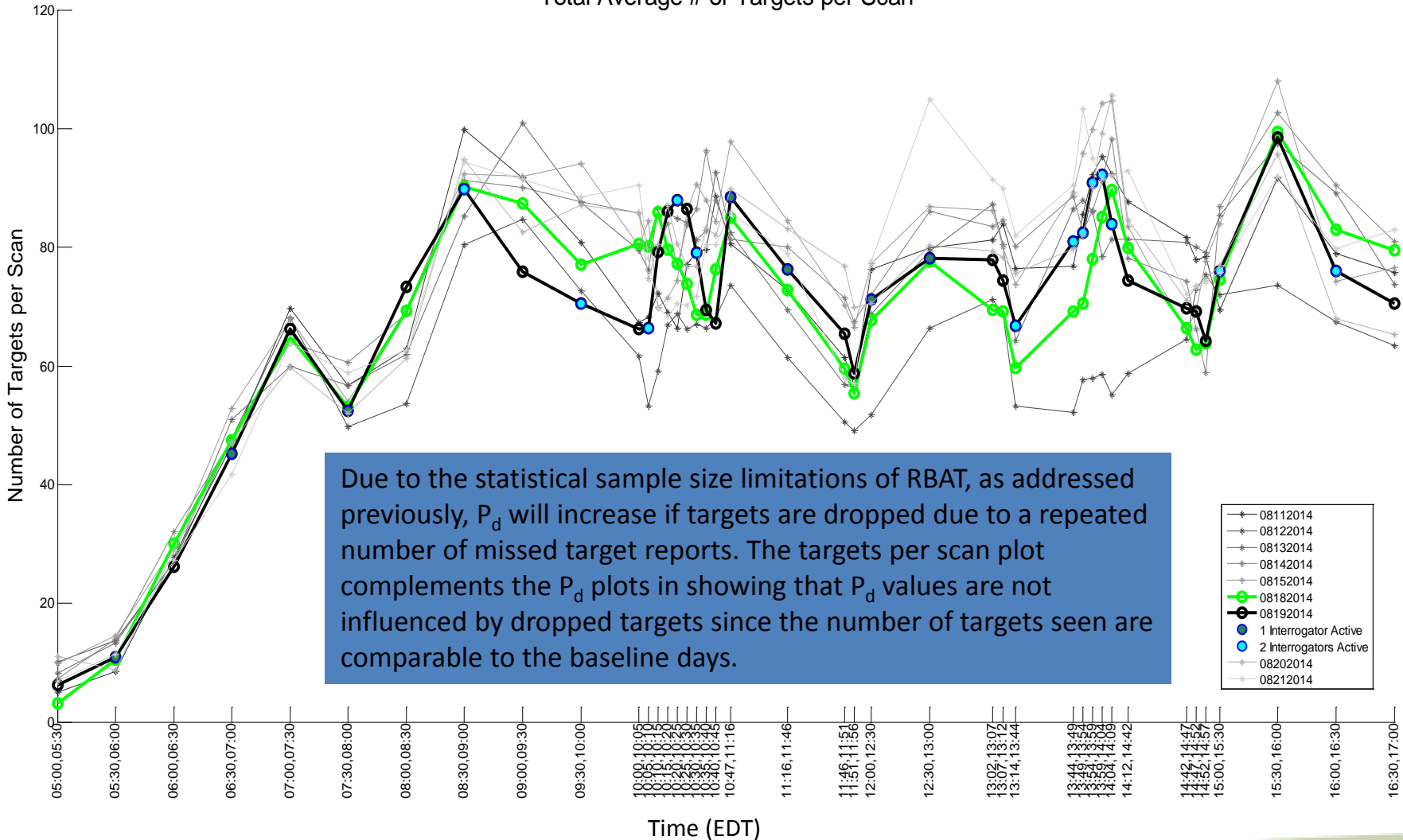
08212014 DCA: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 19<sup>th</sup>

Total Average # of Targets per Scan

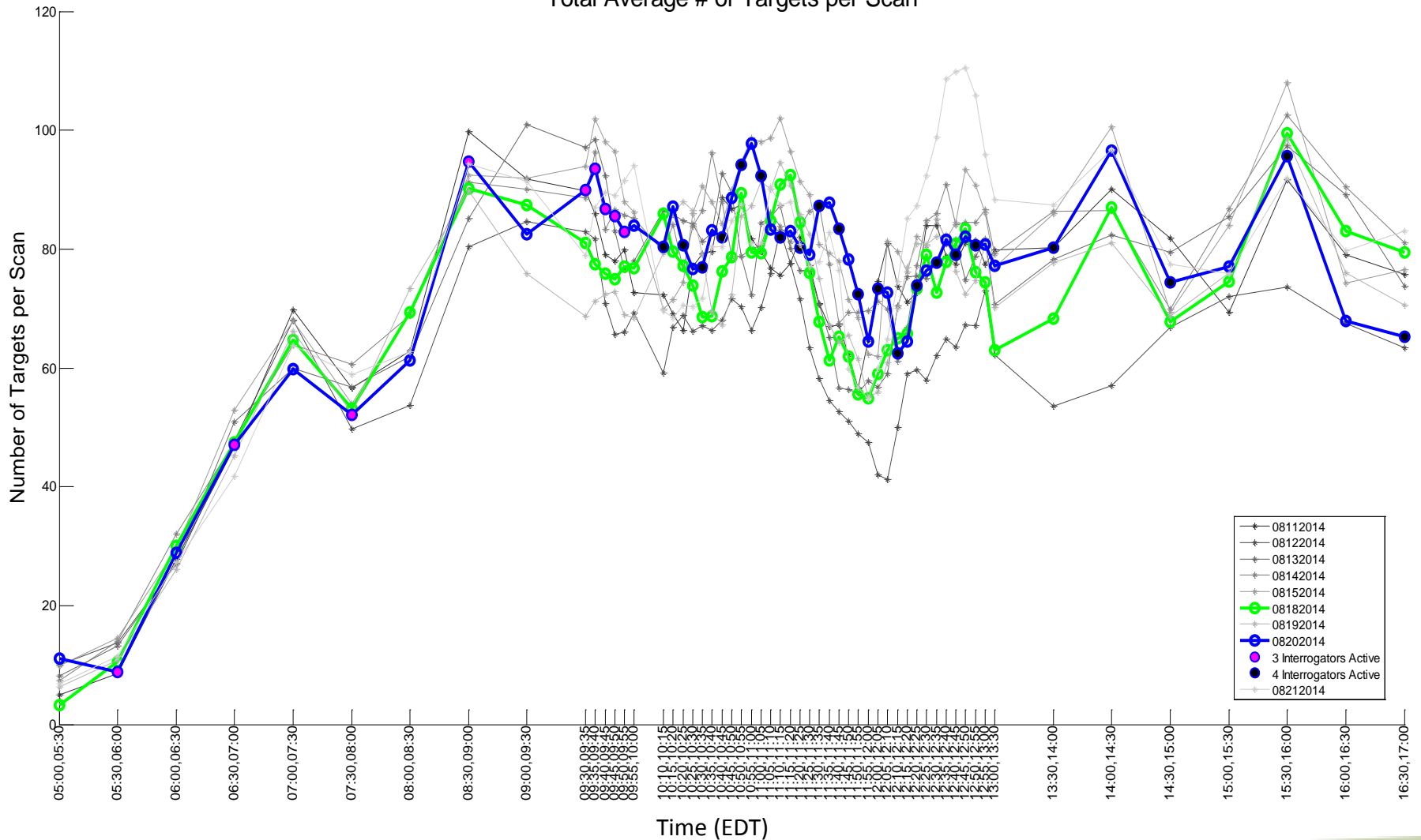


Due to the statistical sample size limitations of RBAT, as addressed previously,  $P_d$  will increase if targets are dropped due to a repeated number of missed target reports. The targets per scan plot complements the  $P_d$  plots in showing that  $P_d$  values are not influenced by dropped targets since the number of targets seen are comparable to the baseline days.

Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 20<sup>th</sup>

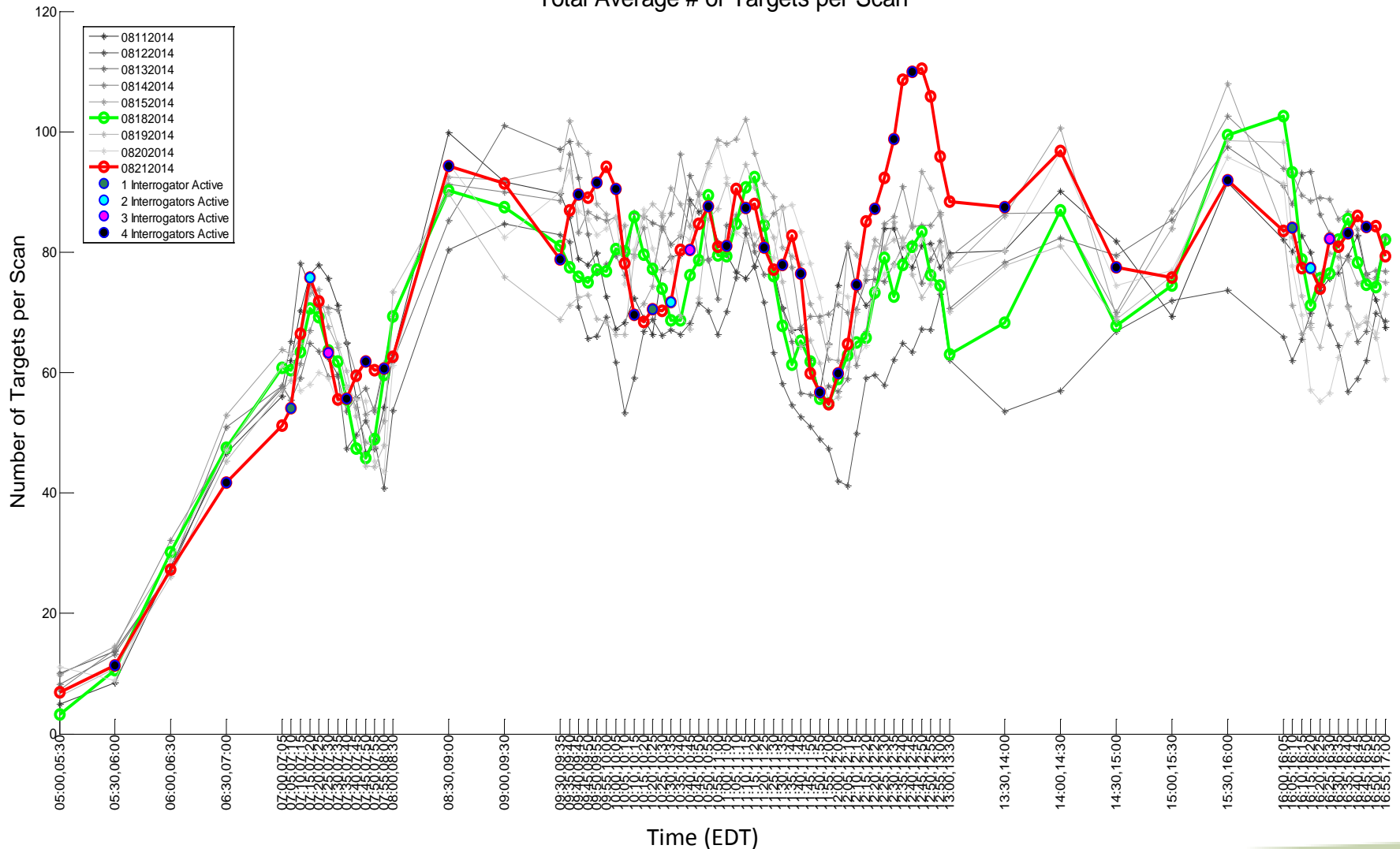
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 21<sup>st</sup>

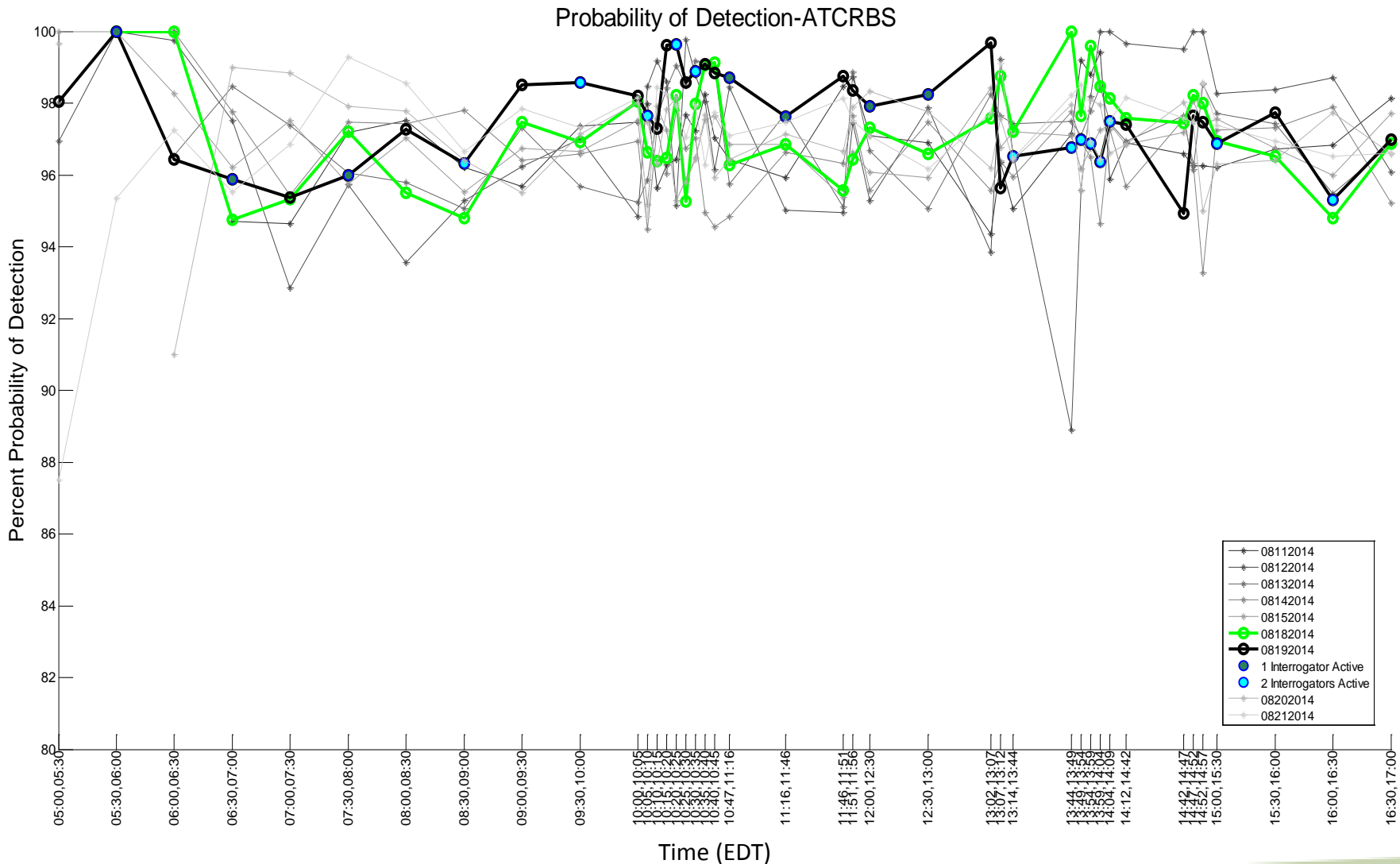
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

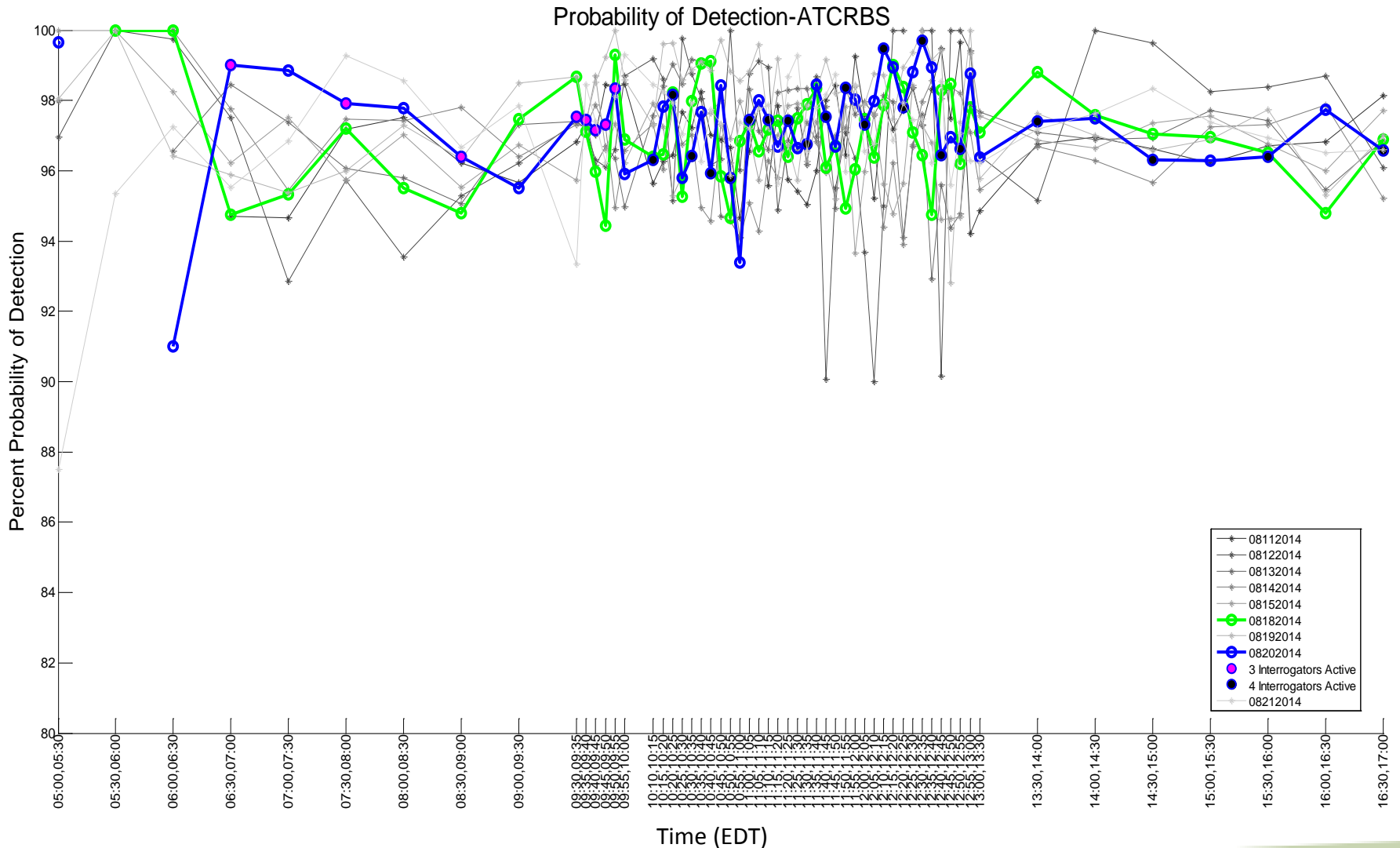
## ATCRBS Targets - Discrete



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

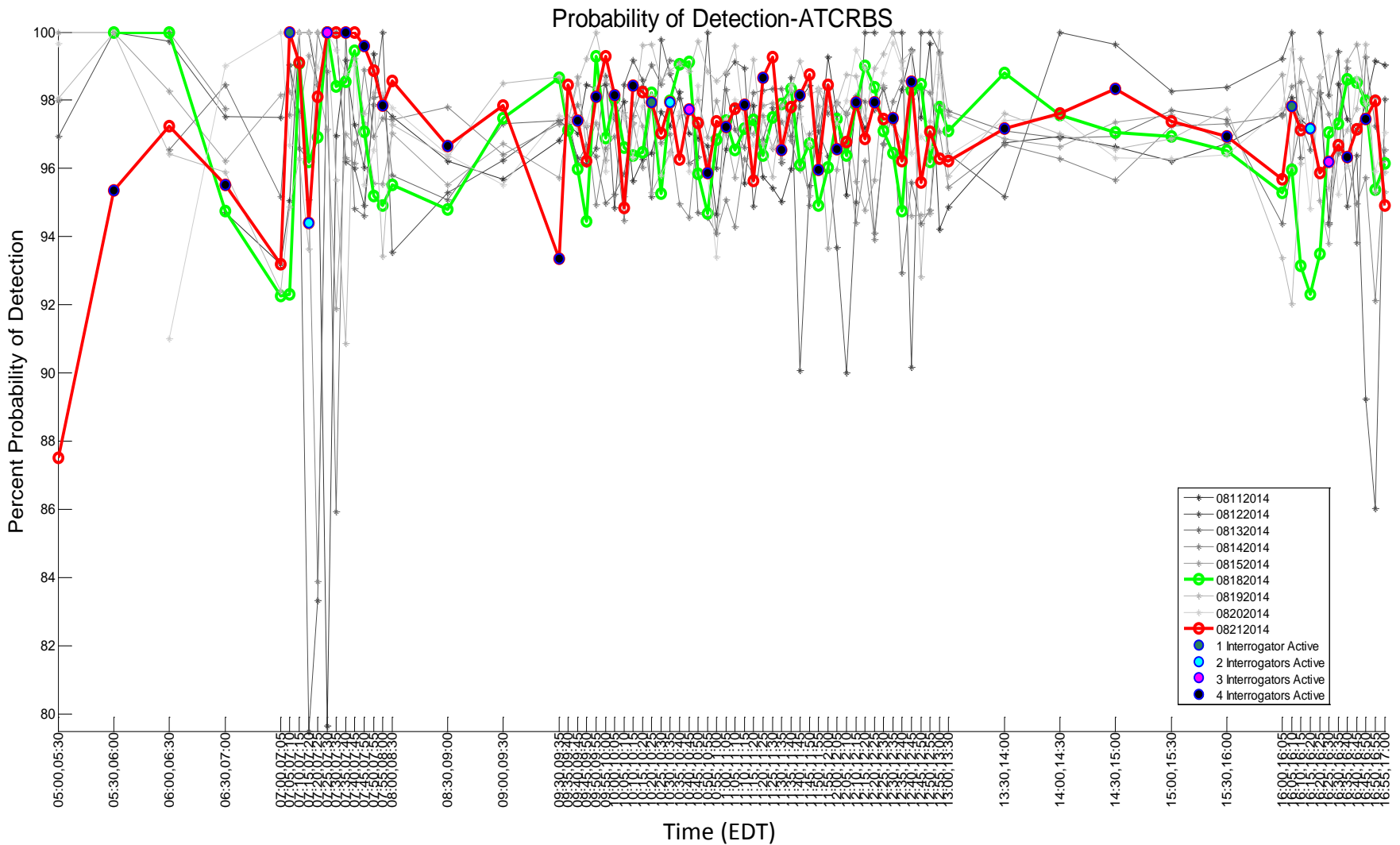
## ATCRBS Targets - Discrete



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

## ATCRBS Targets - Discrete

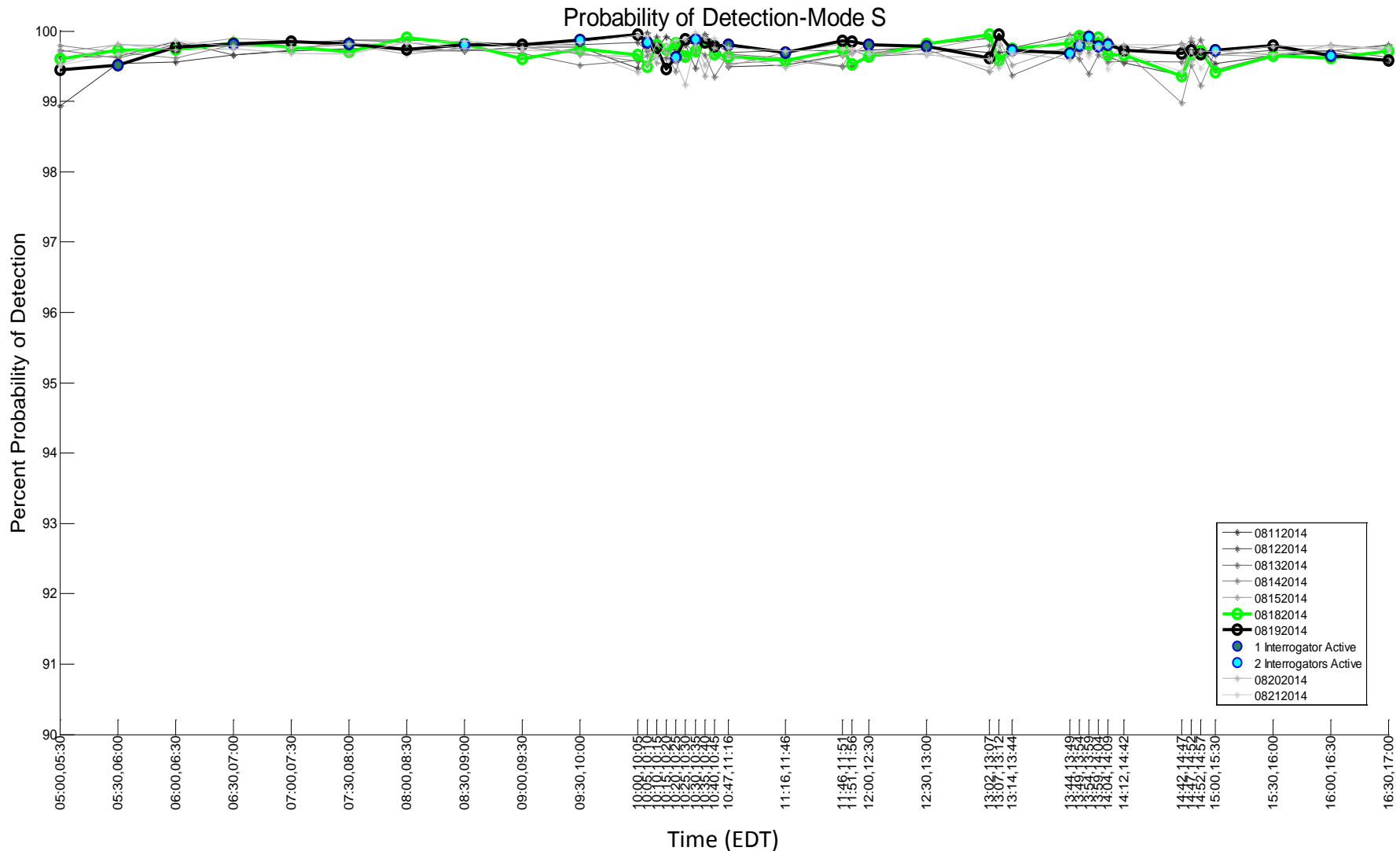


Geographic Filter: None  
Target Filter: None



# Probability of Detection – August 19<sup>th</sup>

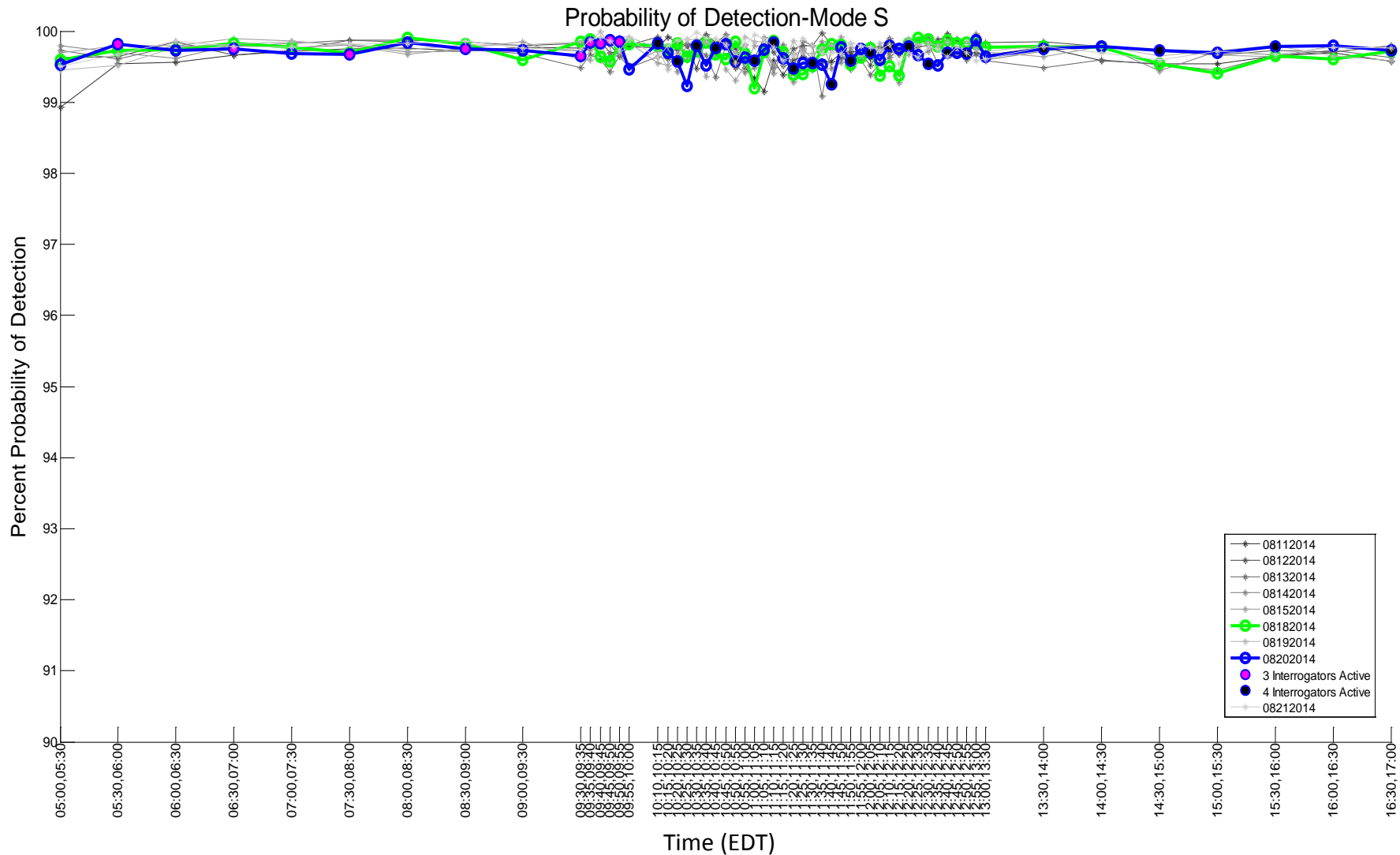
## Mode S Targets



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

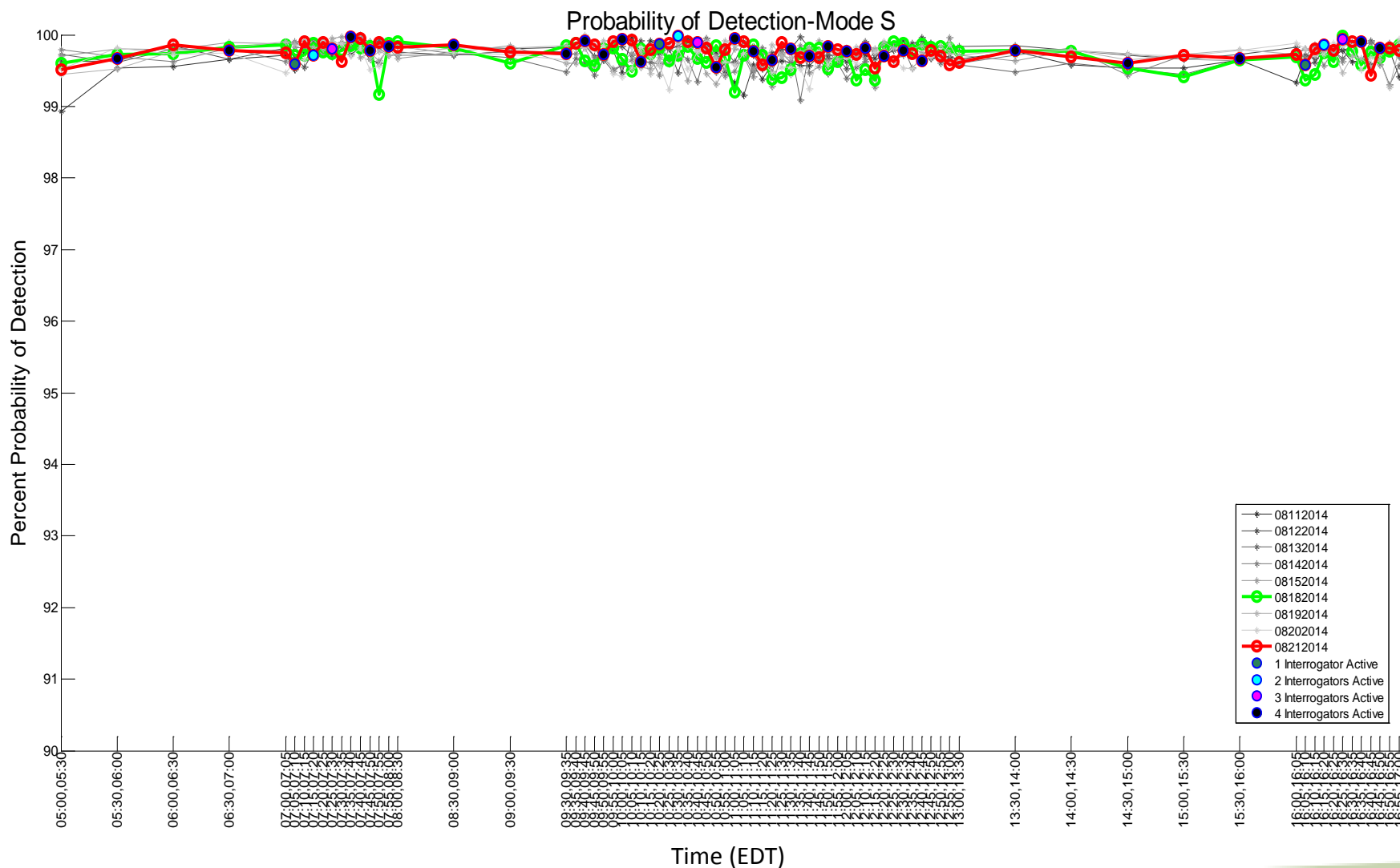
## Mode S Targets



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

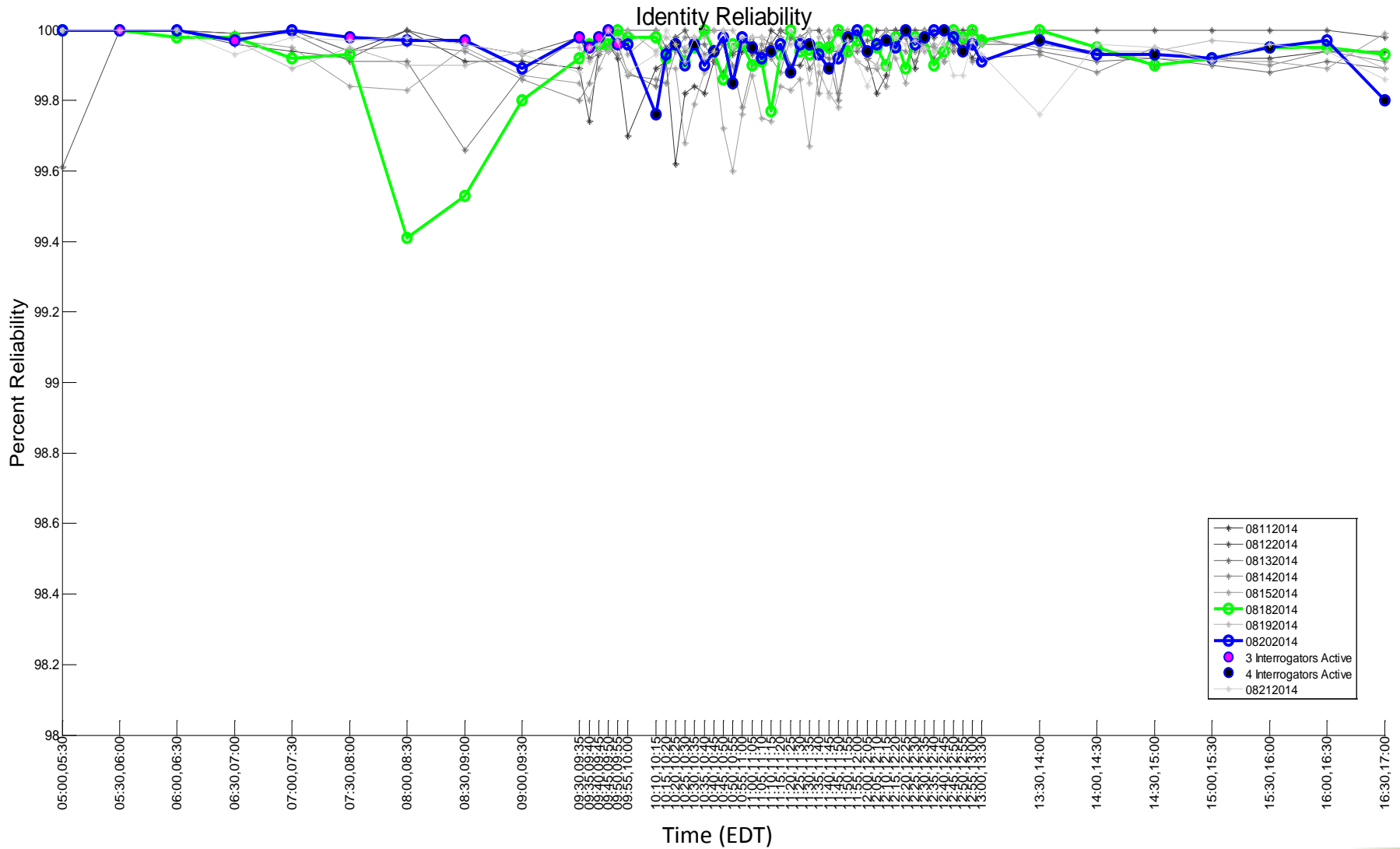
## Mode S Targets



Geographic Filter: None  
Target Filter: None

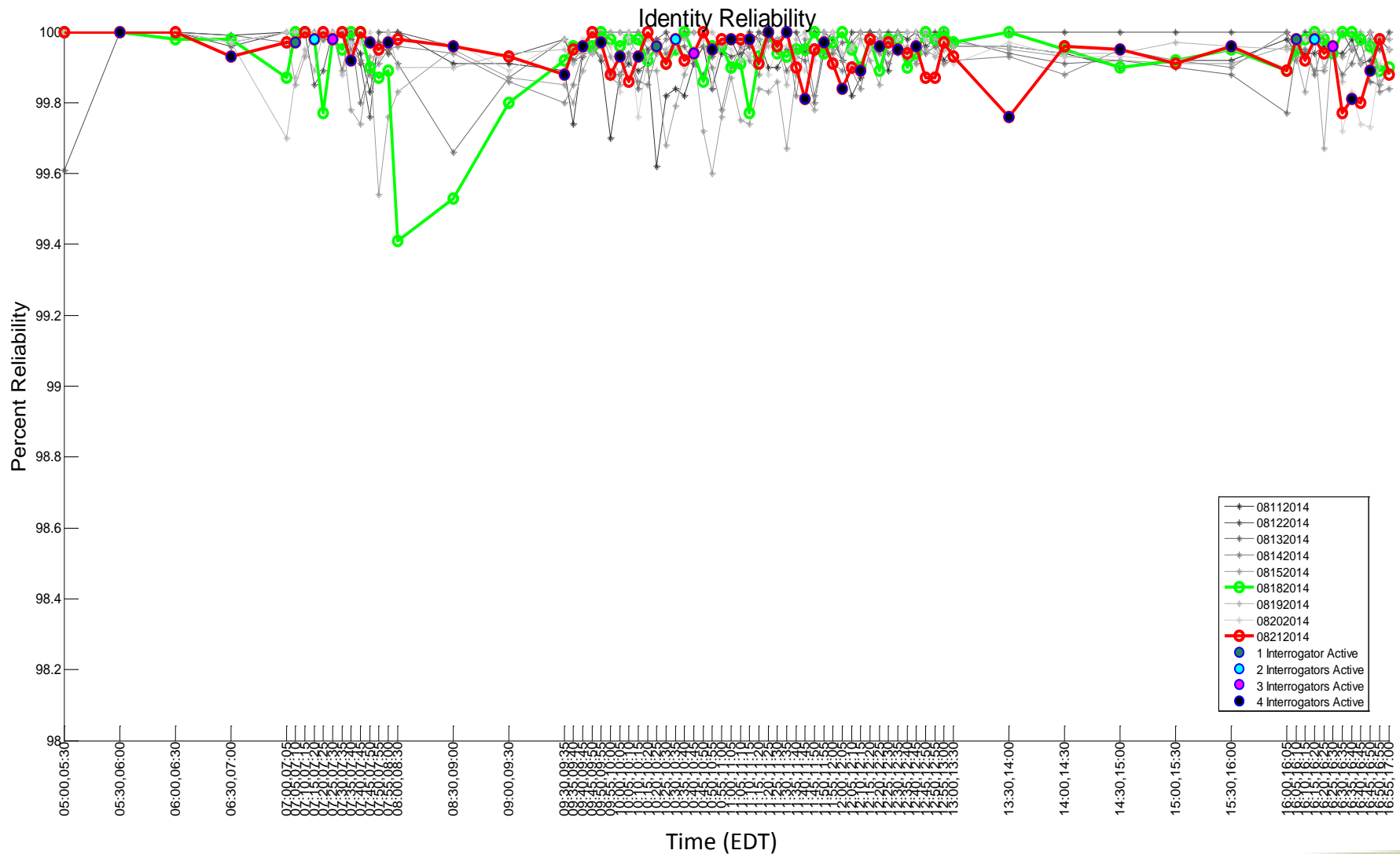


# Identity (3/A) Reliability – August 20<sup>th</sup>



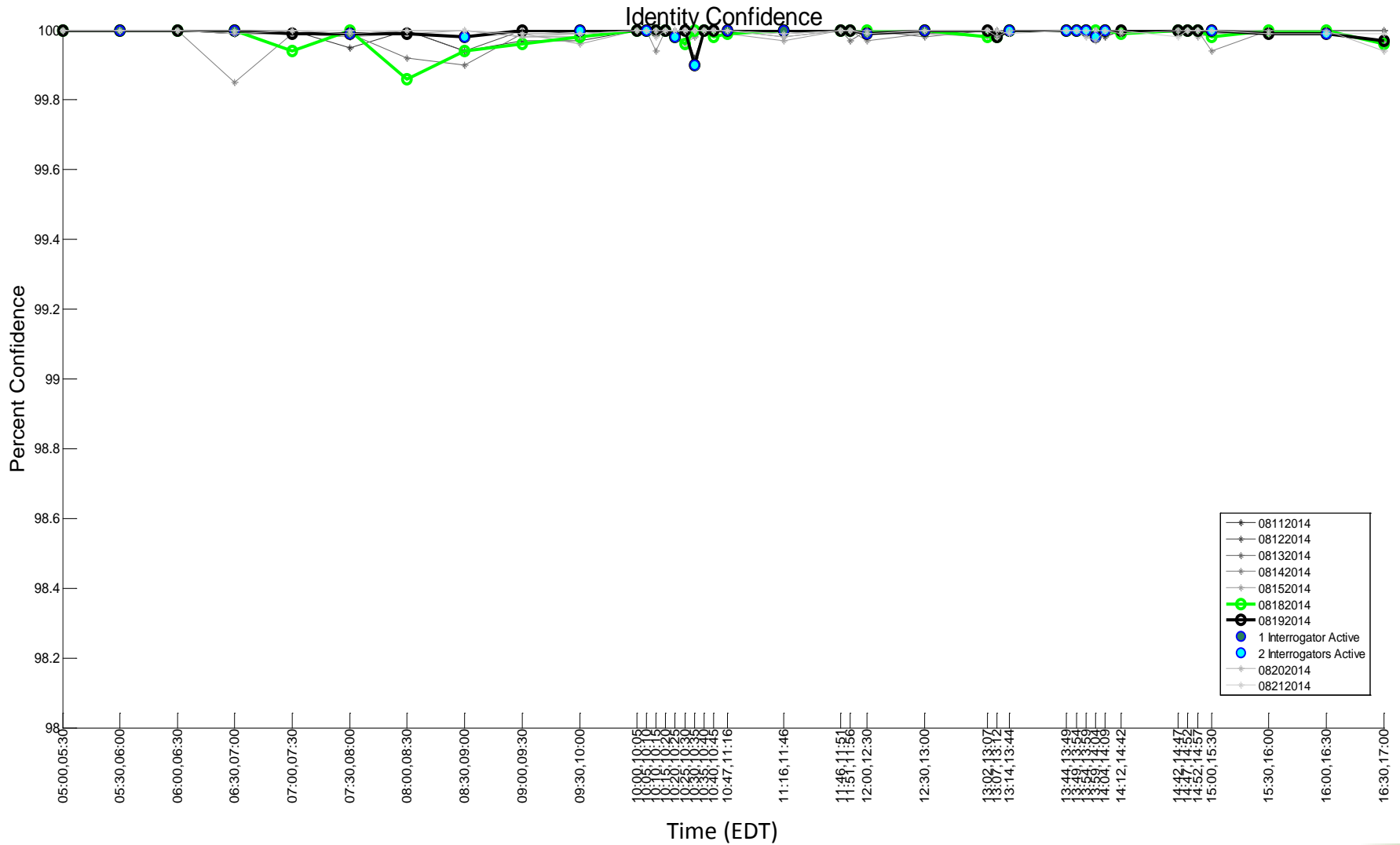
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 21<sup>st</sup>



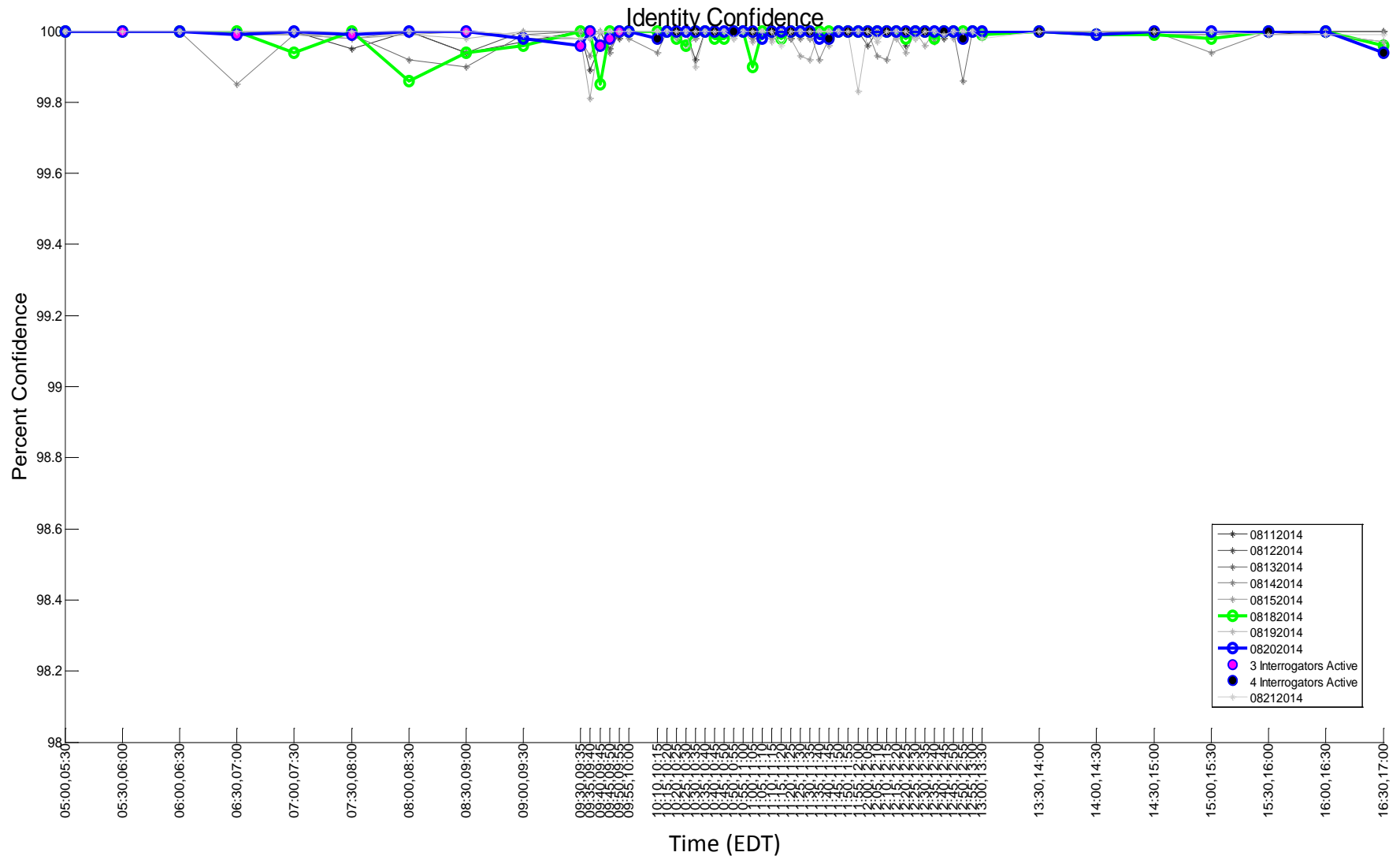
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 19th



Geographic Filter: None  
Target Filter: None

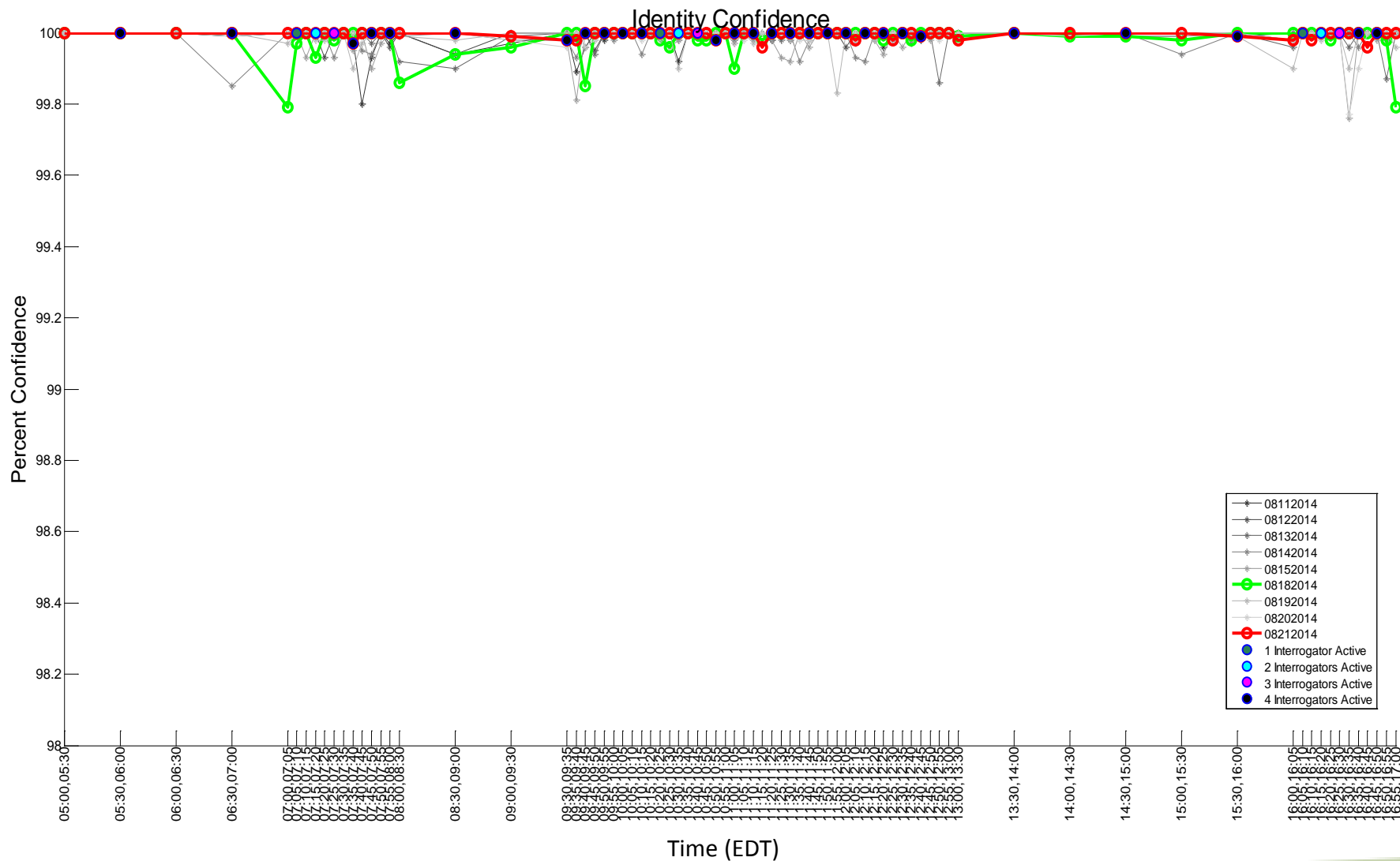
# Identity (3/A) Confidence – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

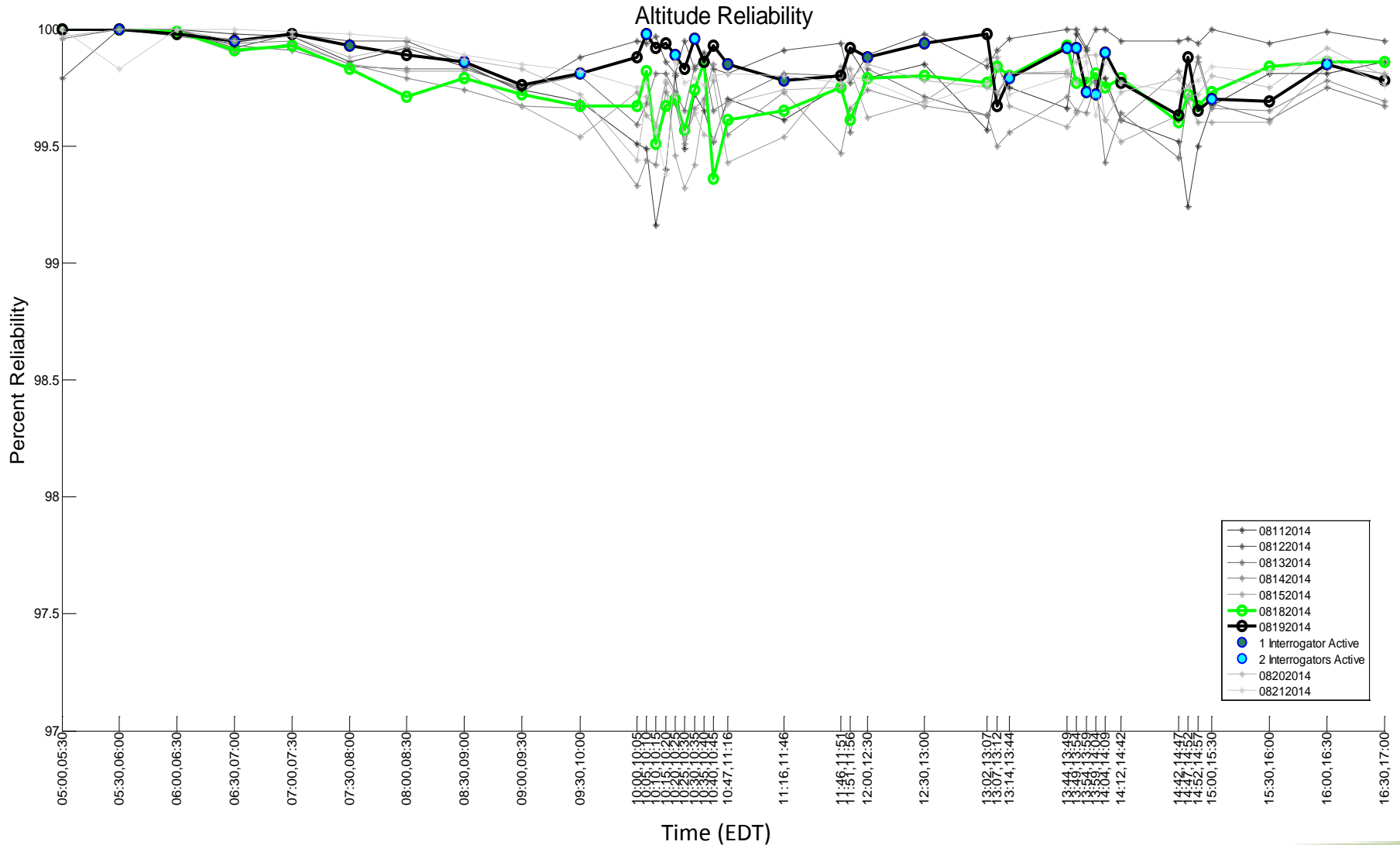


# Identity (3/A) Confidence – August 21<sup>st</sup>



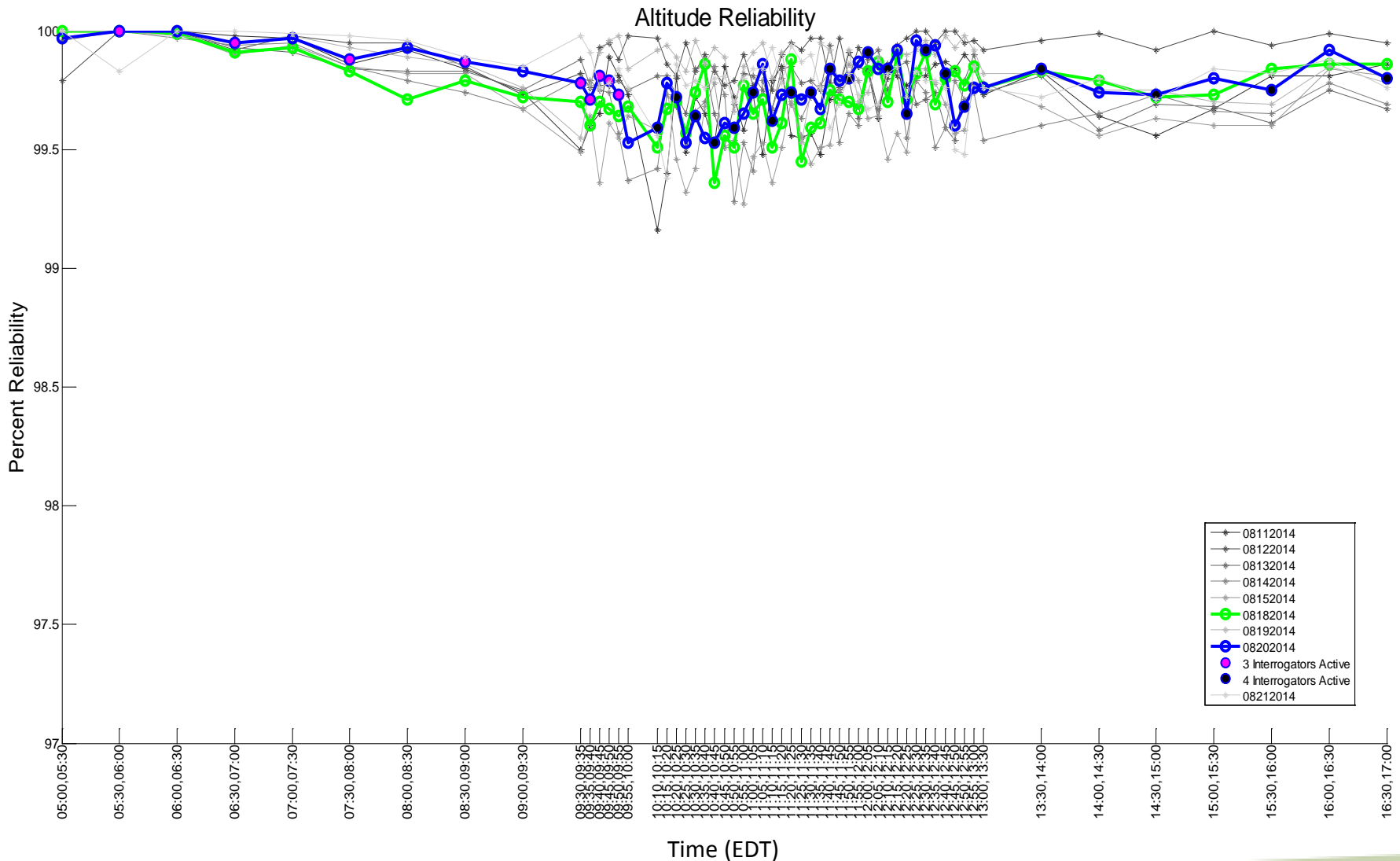
Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 19th

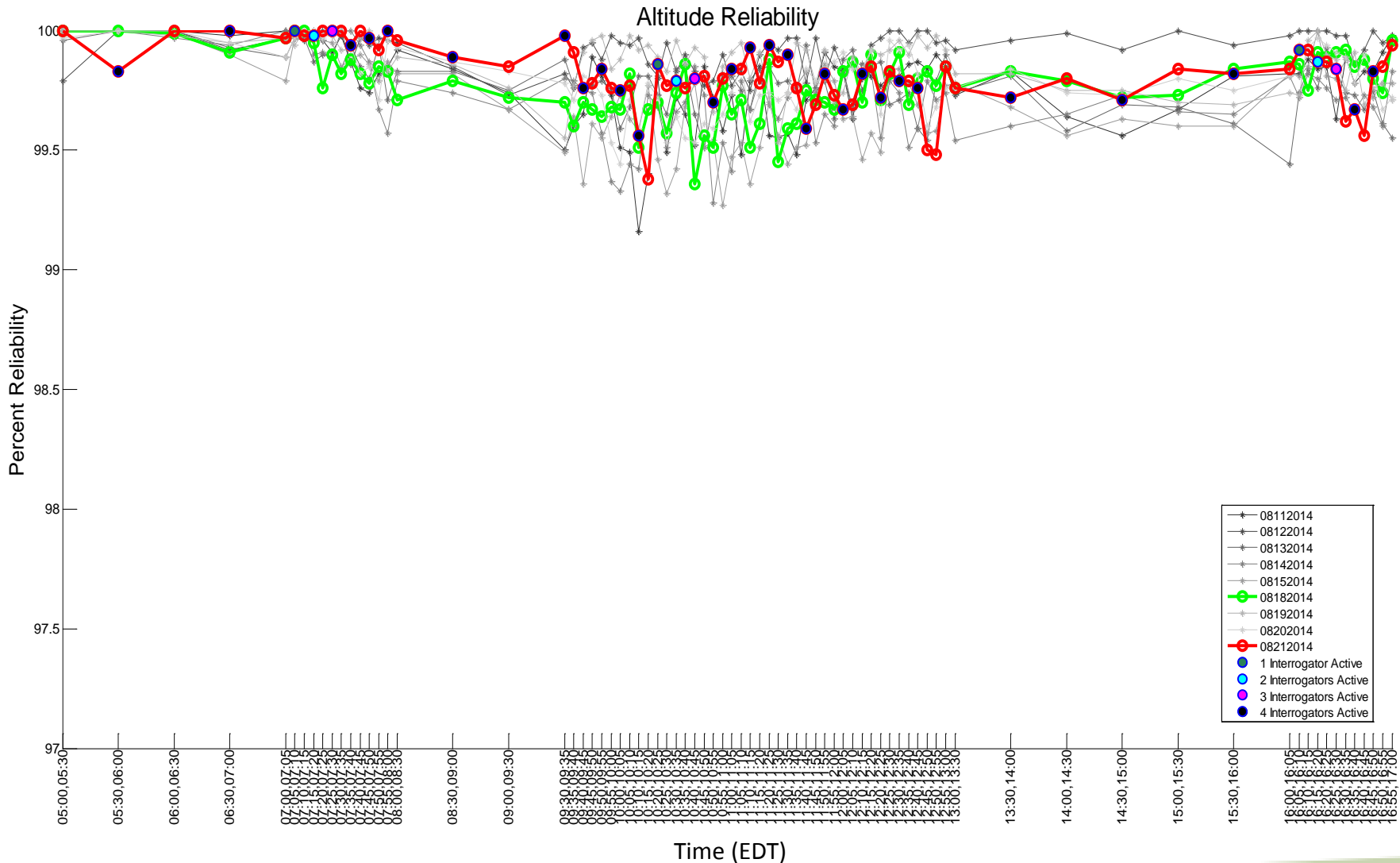


Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 20<sup>th</sup>

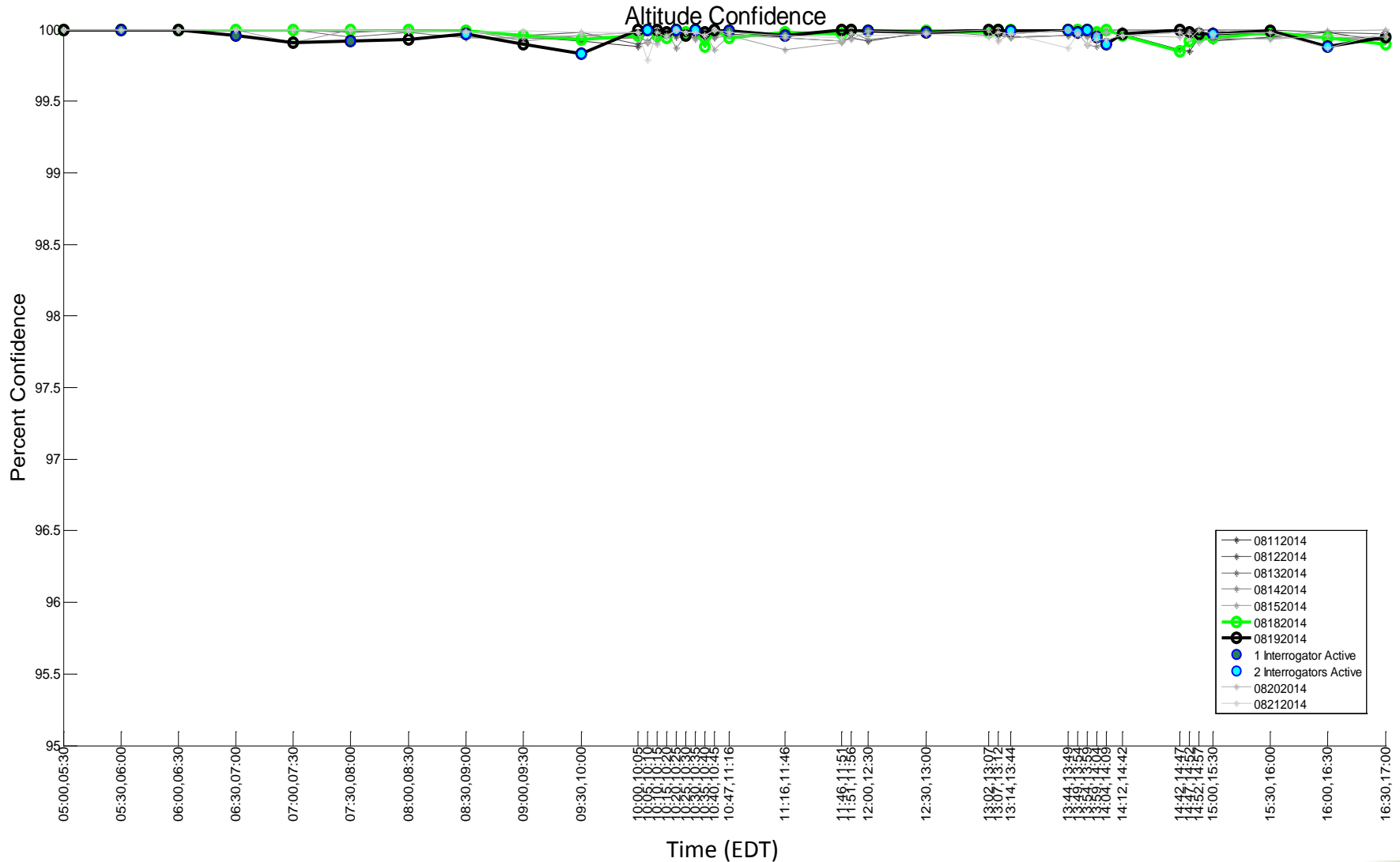


# Altitude (C) Reliability – August 21<sup>st</sup>



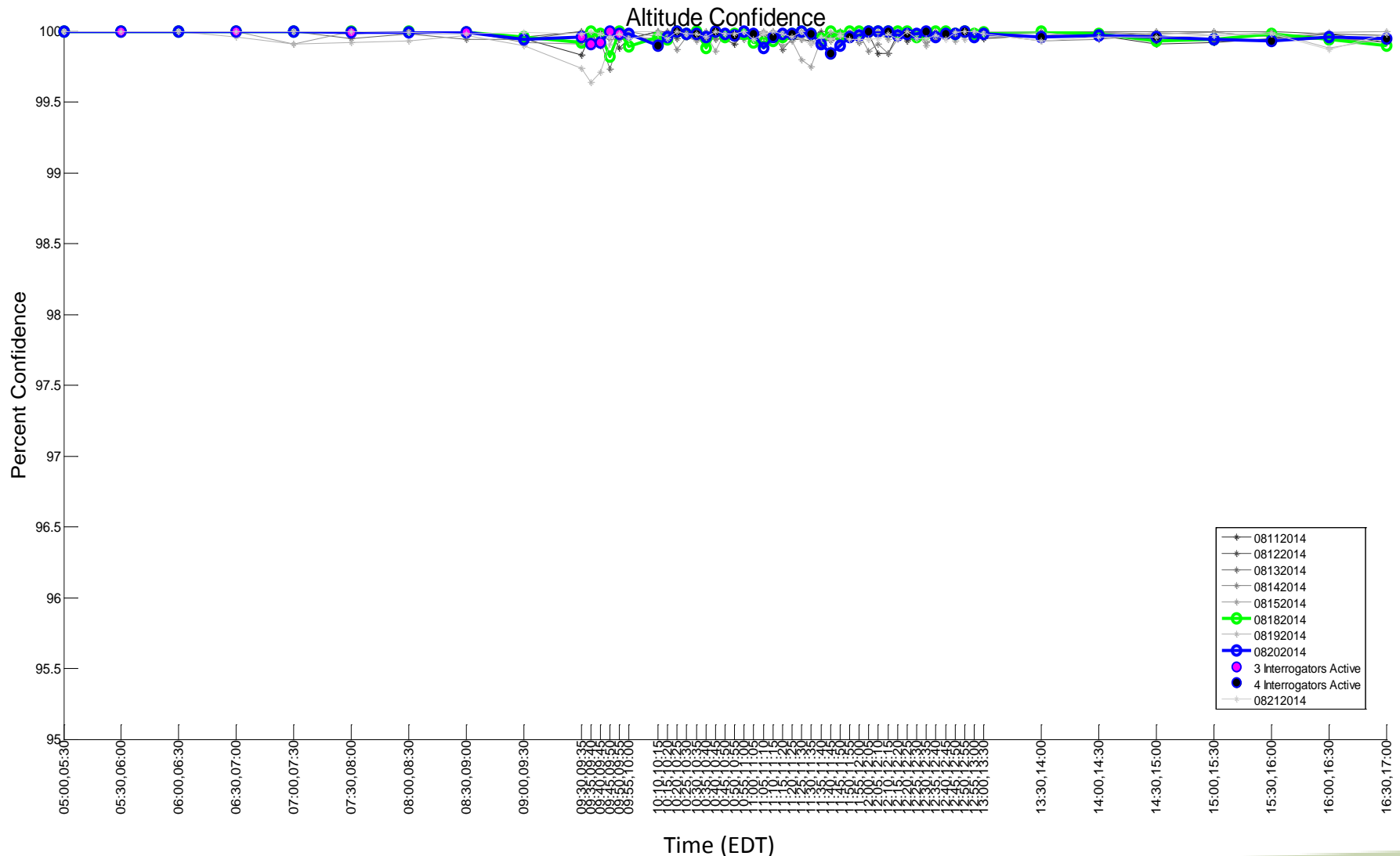
Geographic Filter: None  
Target Filter: None

# Altitude (C) Confidence – August 19th



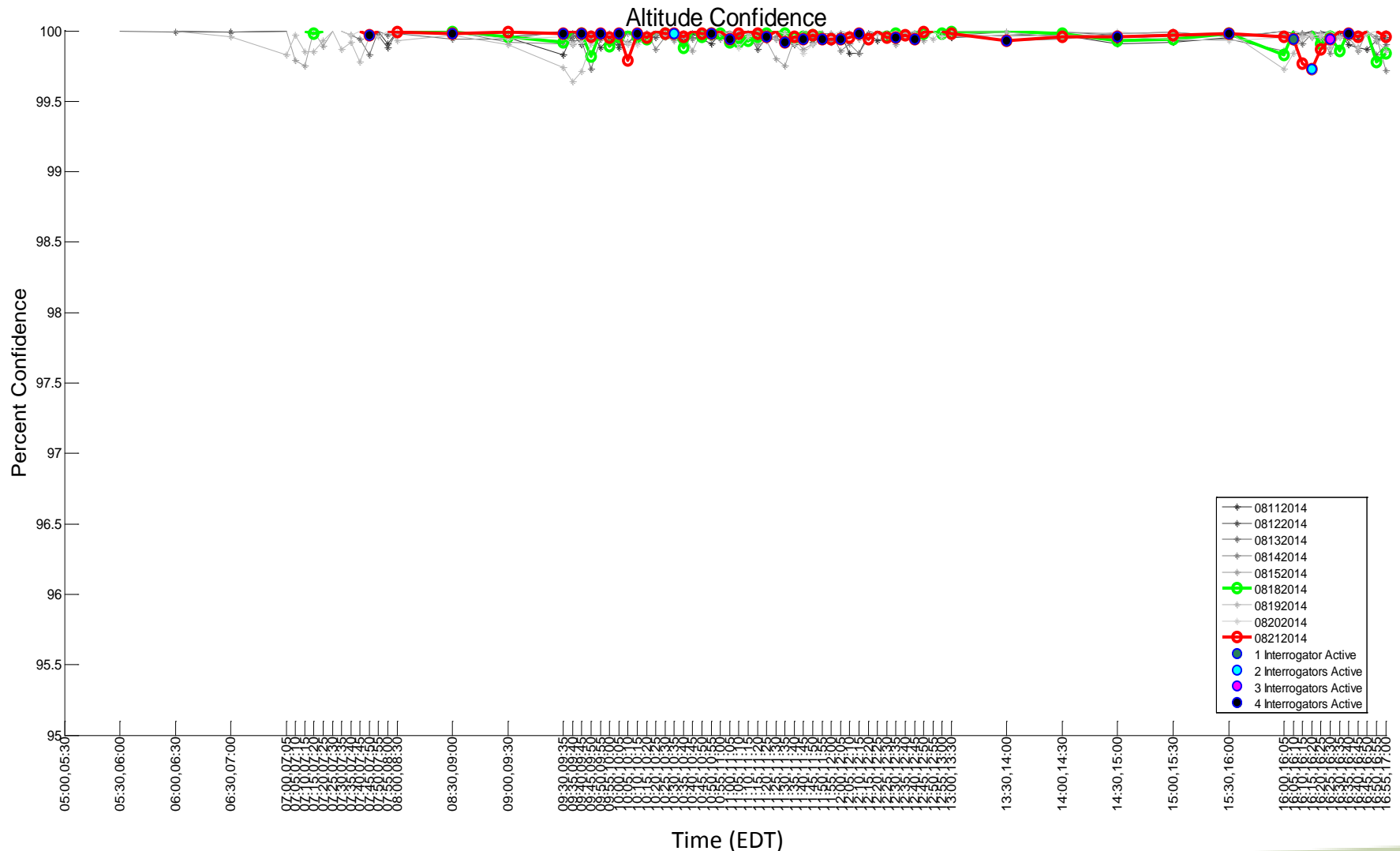
Geographic Filter: None  
Target Filter: None

# Altitude (C) Confidence – August 20<sup>th</sup>



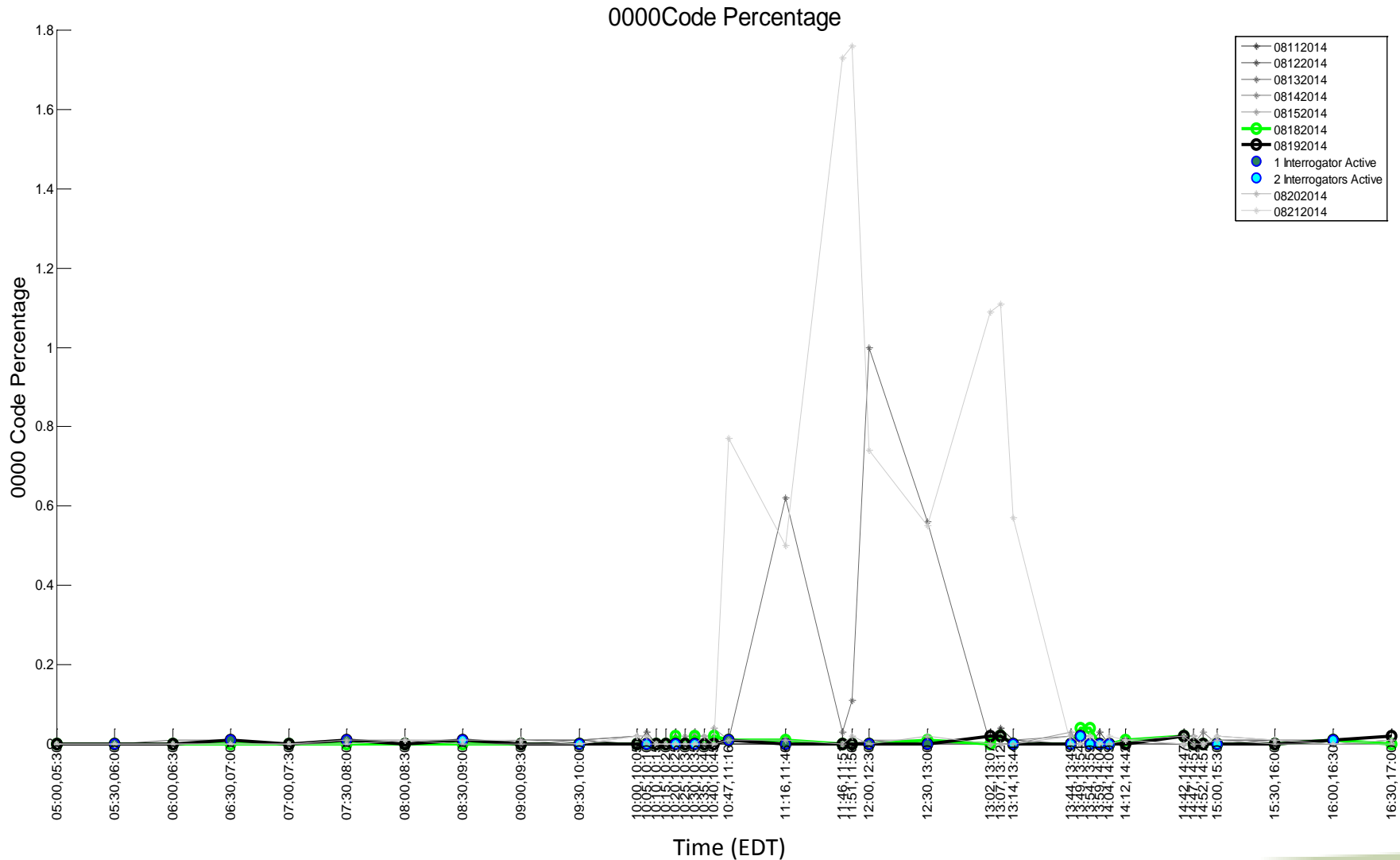
Geographic Filter: None  
Target Filter: None

# Altitude (C) Confidence – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

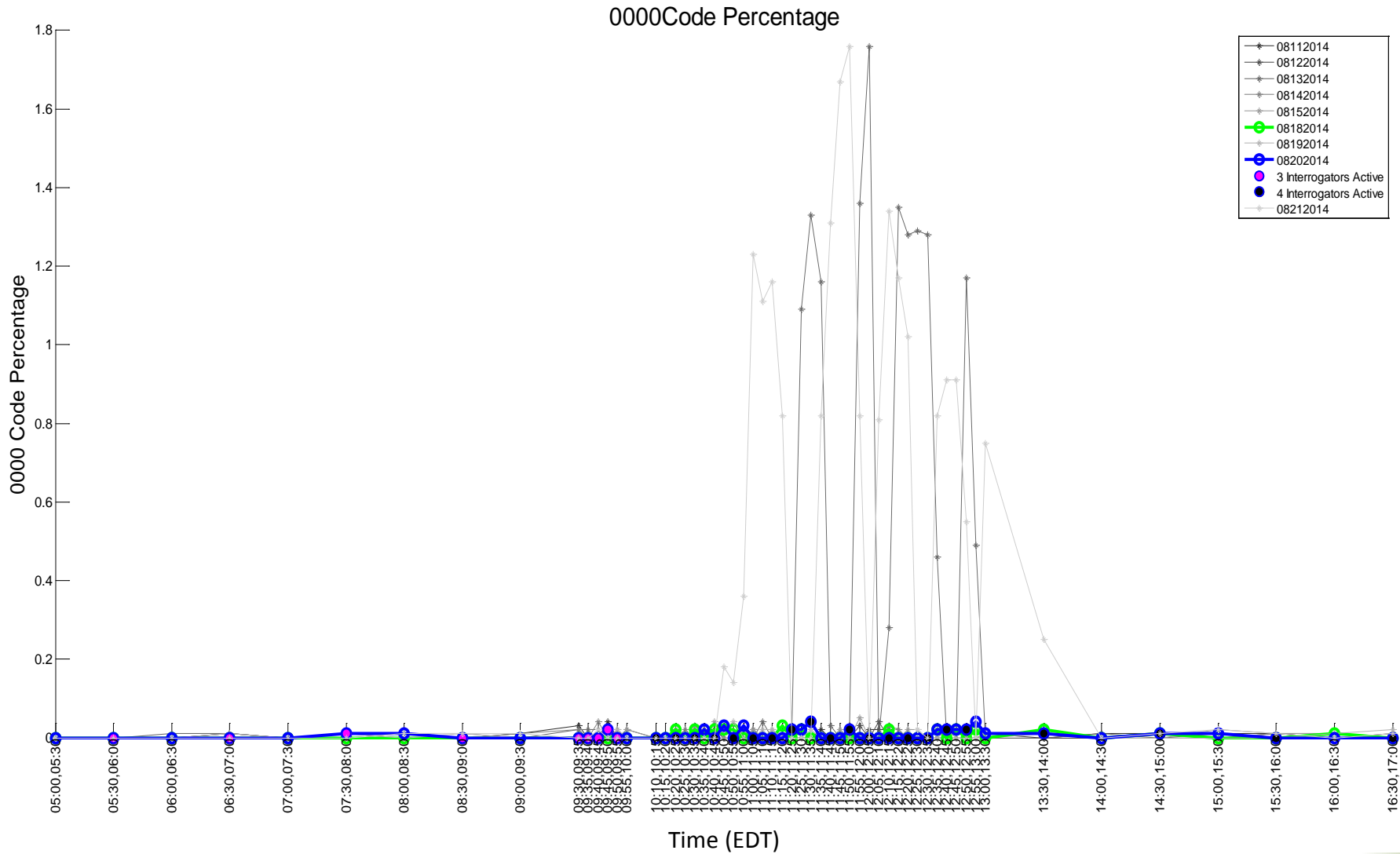
# 0000 Codes – August 19th



Geographic Filter: None  
Target Filter: None

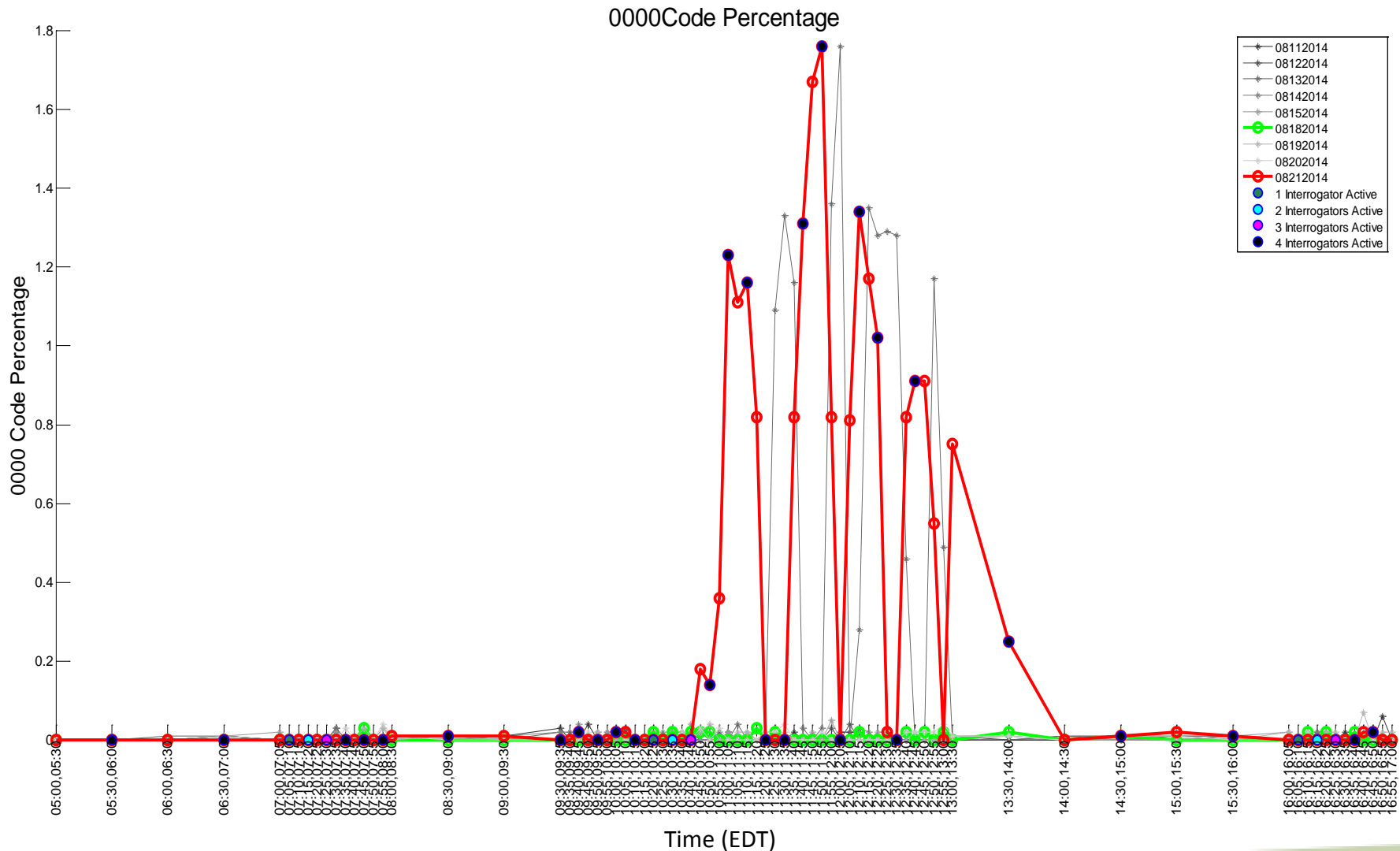


# 0000 Codes – August 20<sup>th</sup>



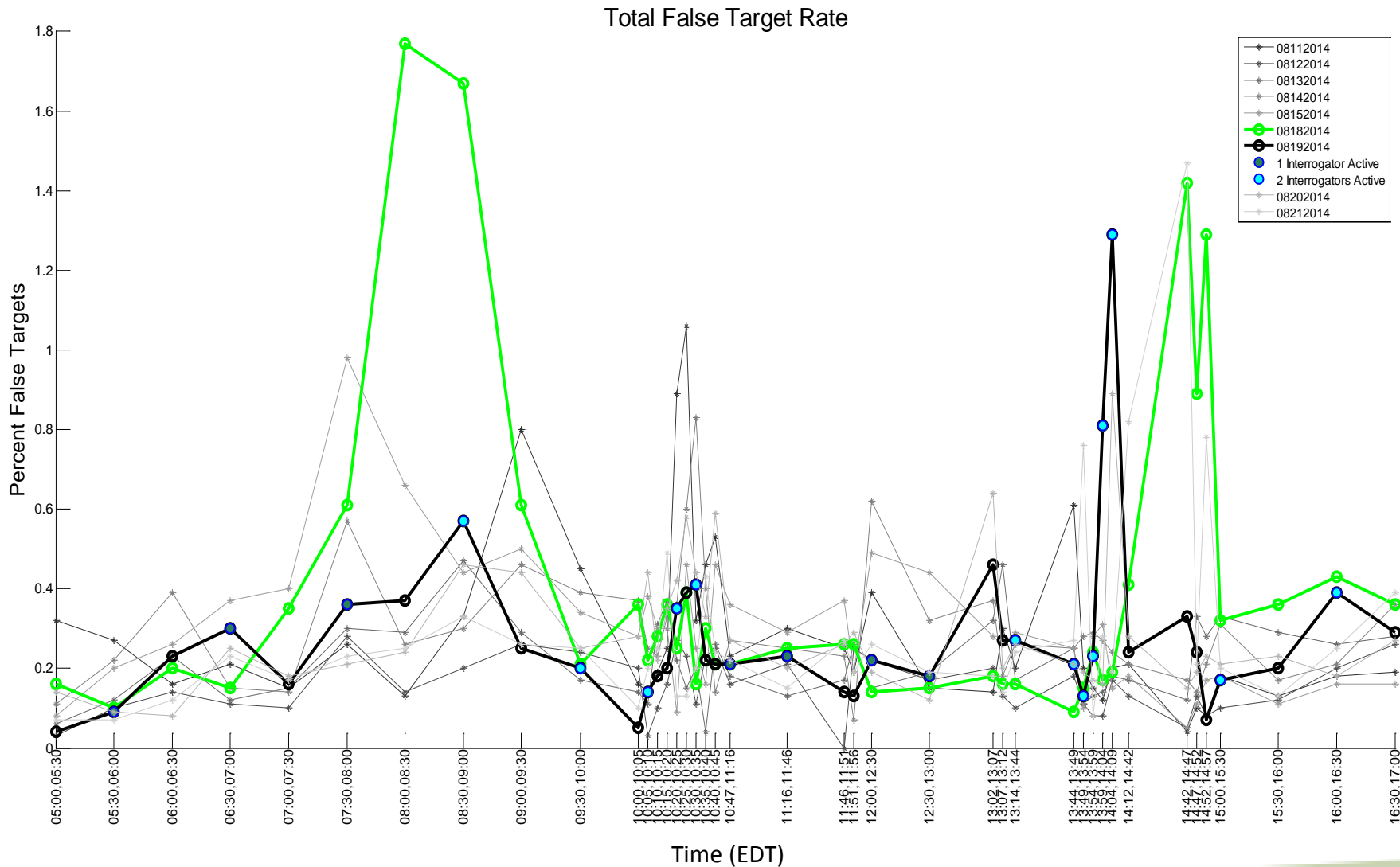
Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 21<sup>st</sup>



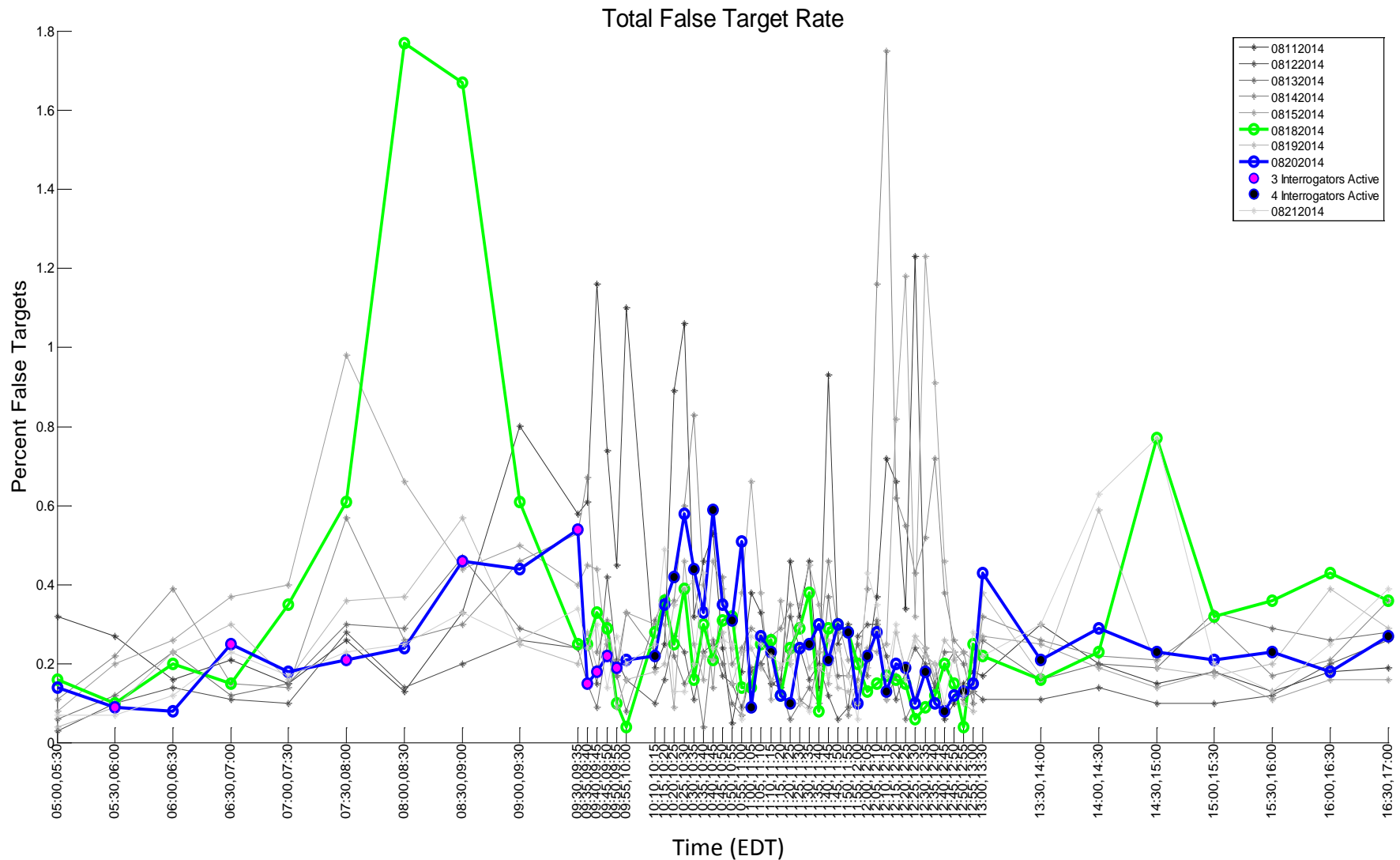
Geographic Filter: None  
Target Filter: None

# False Targets – August 19th



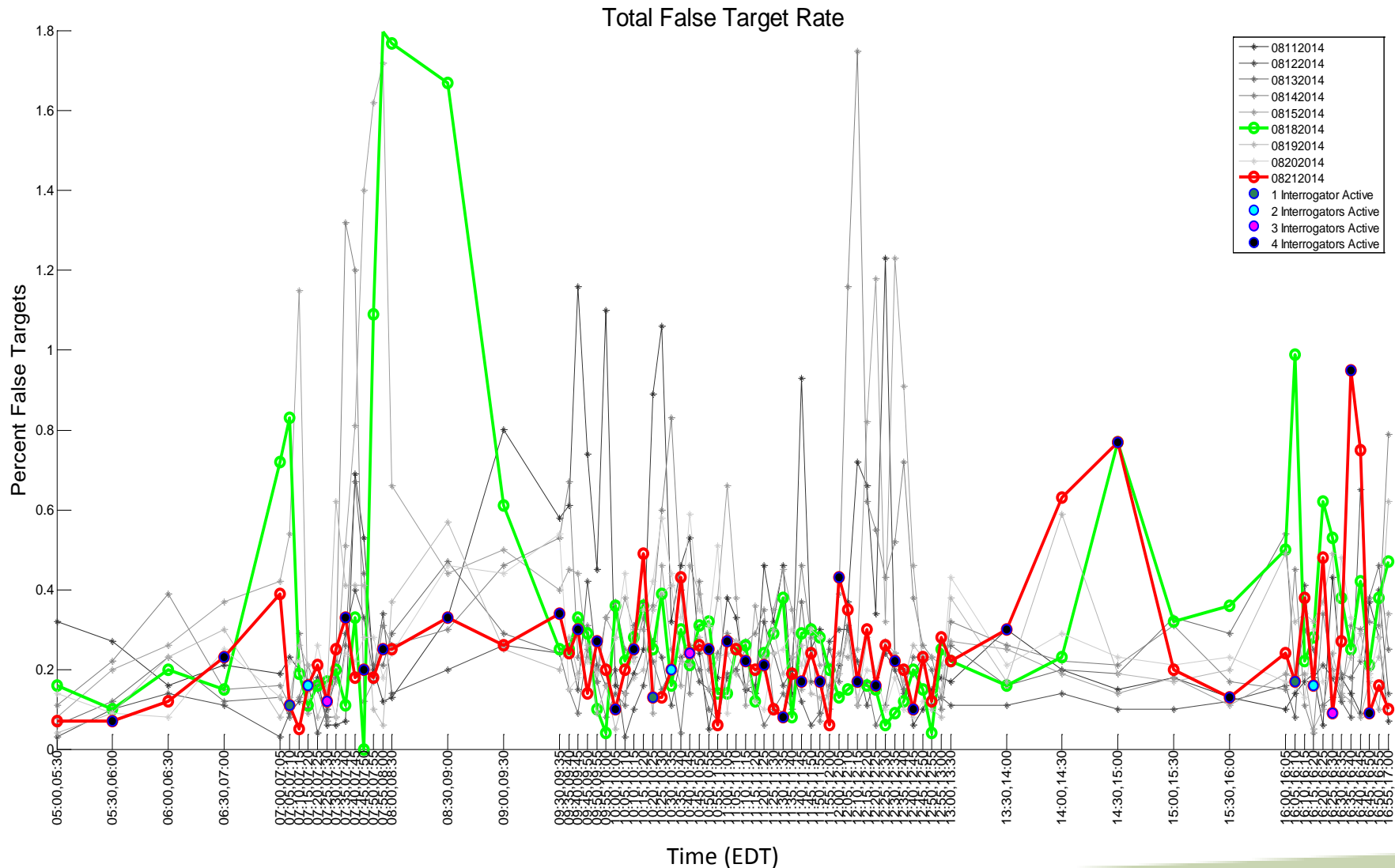
Geographic Filter: None  
Target Filter: None

# False Targets – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

# False Targets – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

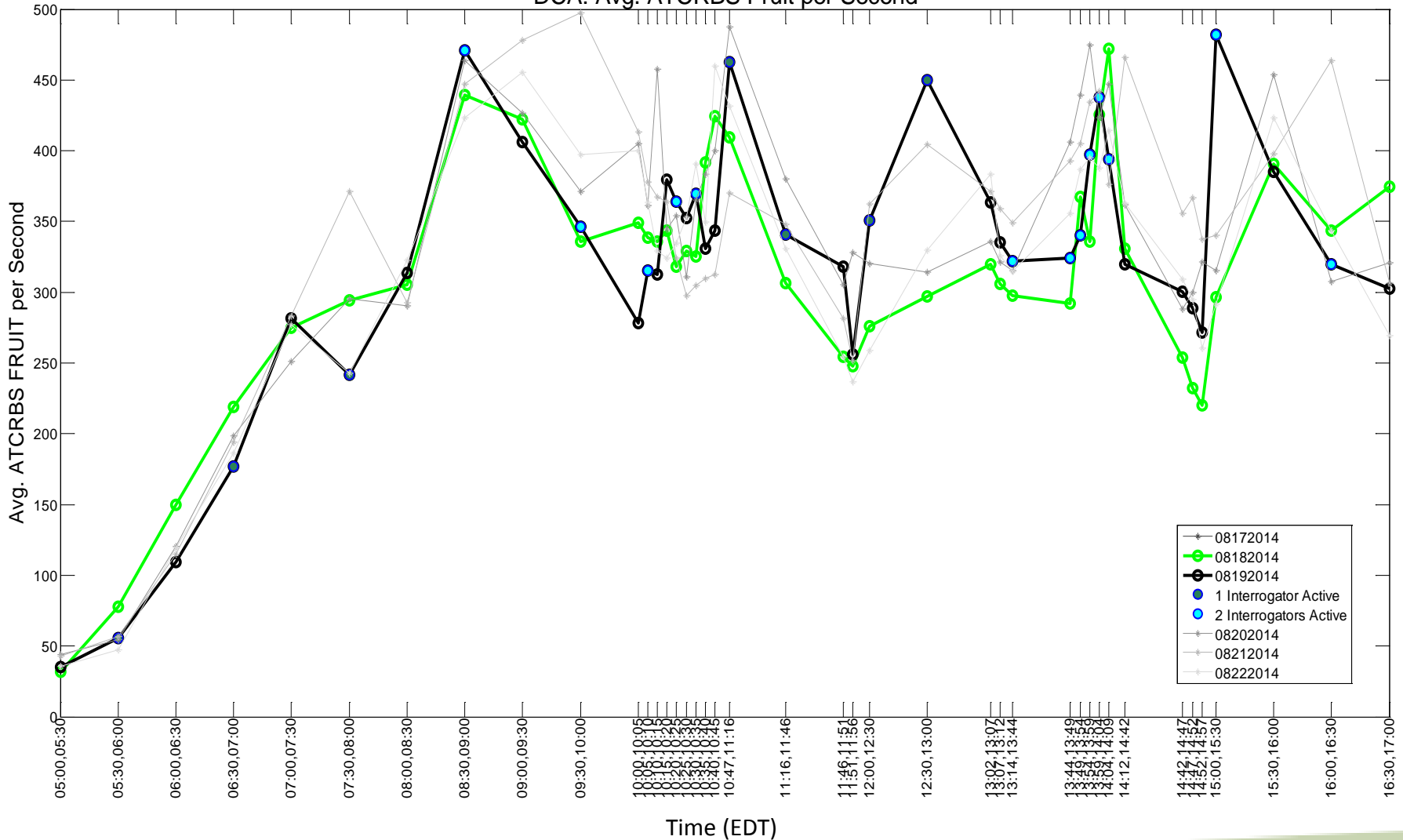
# Observations and Conclusions

- ❑ The Probability of Detection, Identity Reliability and Confidence, Altitude Reliability and Confidence, False Targets, 0000 Codes, and Targets per Scan exhibit no observable adverse trend with respect to periods of radiation by the AN/UPX-41(C) interrogator.
- ❑ During AN/UPX-41(C) interrogator radiation, the variations or volatility of the aforementioned metrics are within the bounds of the variations of the same metrics on non-test days (baseline).
- ❑ In determining possible cases of interference, targets at low elevation angles exhibited relatively low probabilities of detection regardless of Active/OFF period
  - This inherent skew creates many  $P_d$  outliers that mask the ability to notice downward  $P_d$  movement due to interference
  - An analysis excluding low elevation angle targets is available upon request, but the conclusions are no different than the first two bullets of this slide.

# Mode S Extraction Data Analysis

# ATCRBS FRUIT Rate – August 19<sup>th</sup>

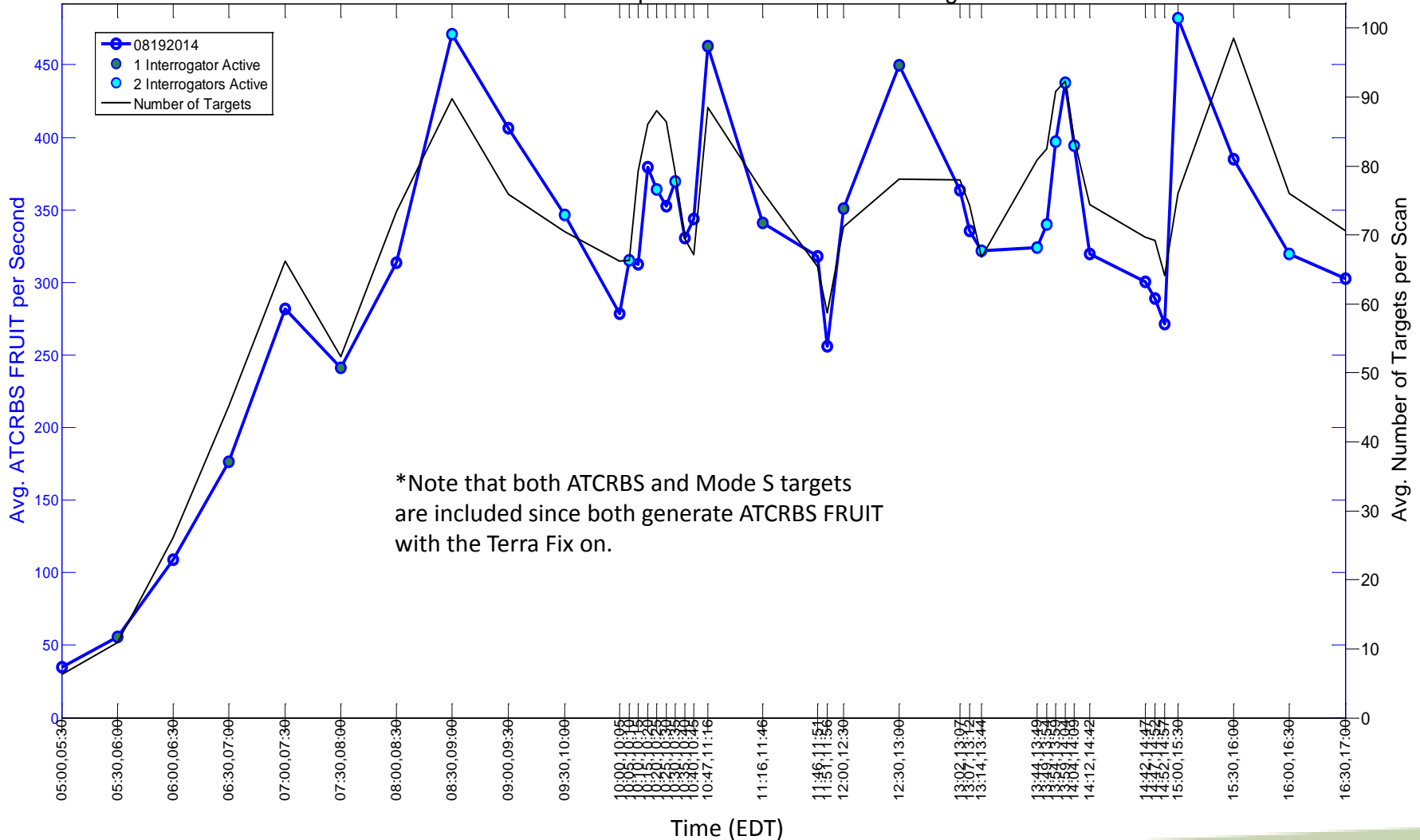
DCA: Avg. ATCRBS Fruit per Second





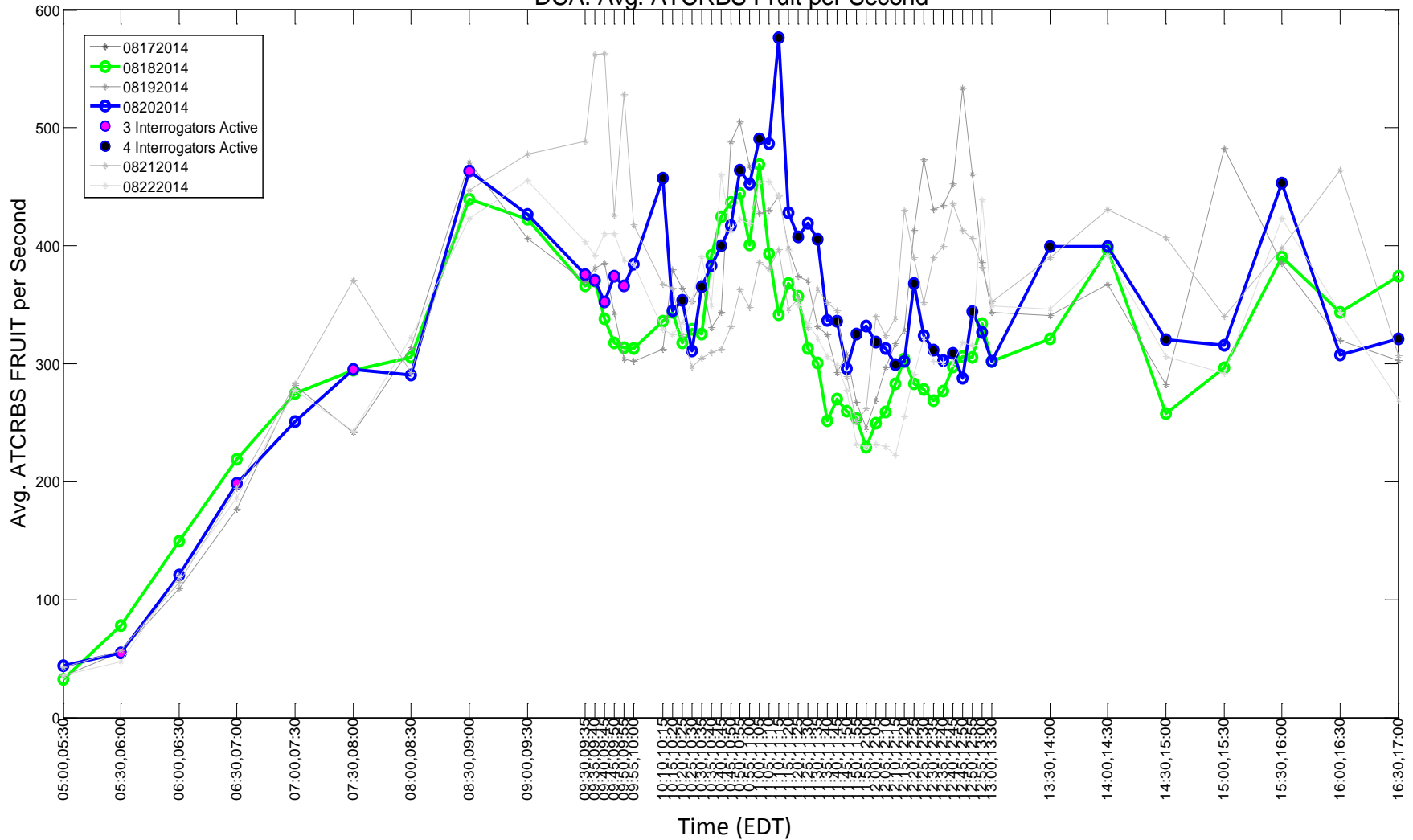
# ATCRBS FRUIT Rate vs # of Targets–August 19<sup>th</sup>

DCA: ATCRBS Fruit per Second vs Number of Targets



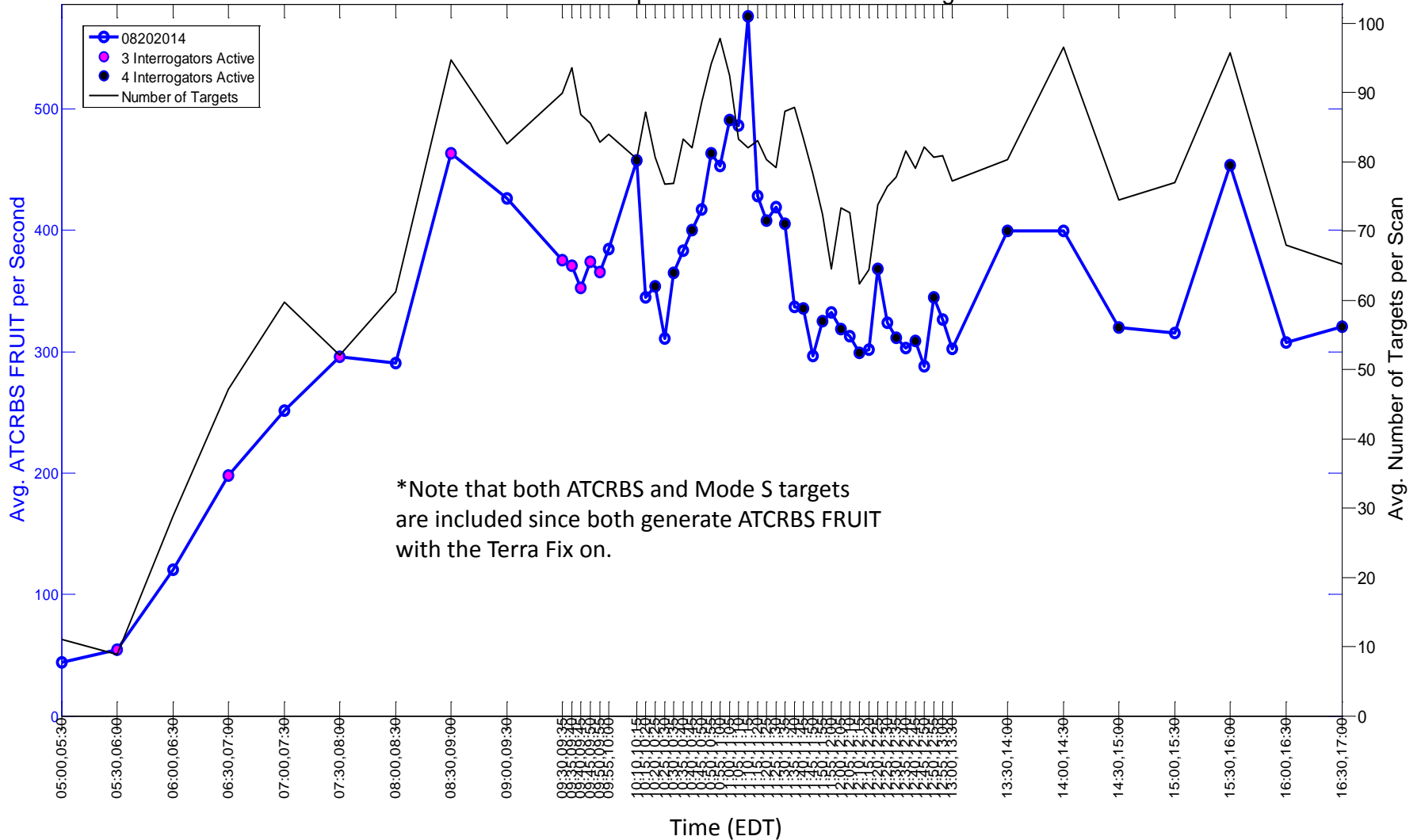
# ATCRBS FRUIT Rate – August 20<sup>th</sup>

DCA: Avg. ATCRBS Fruit per Second



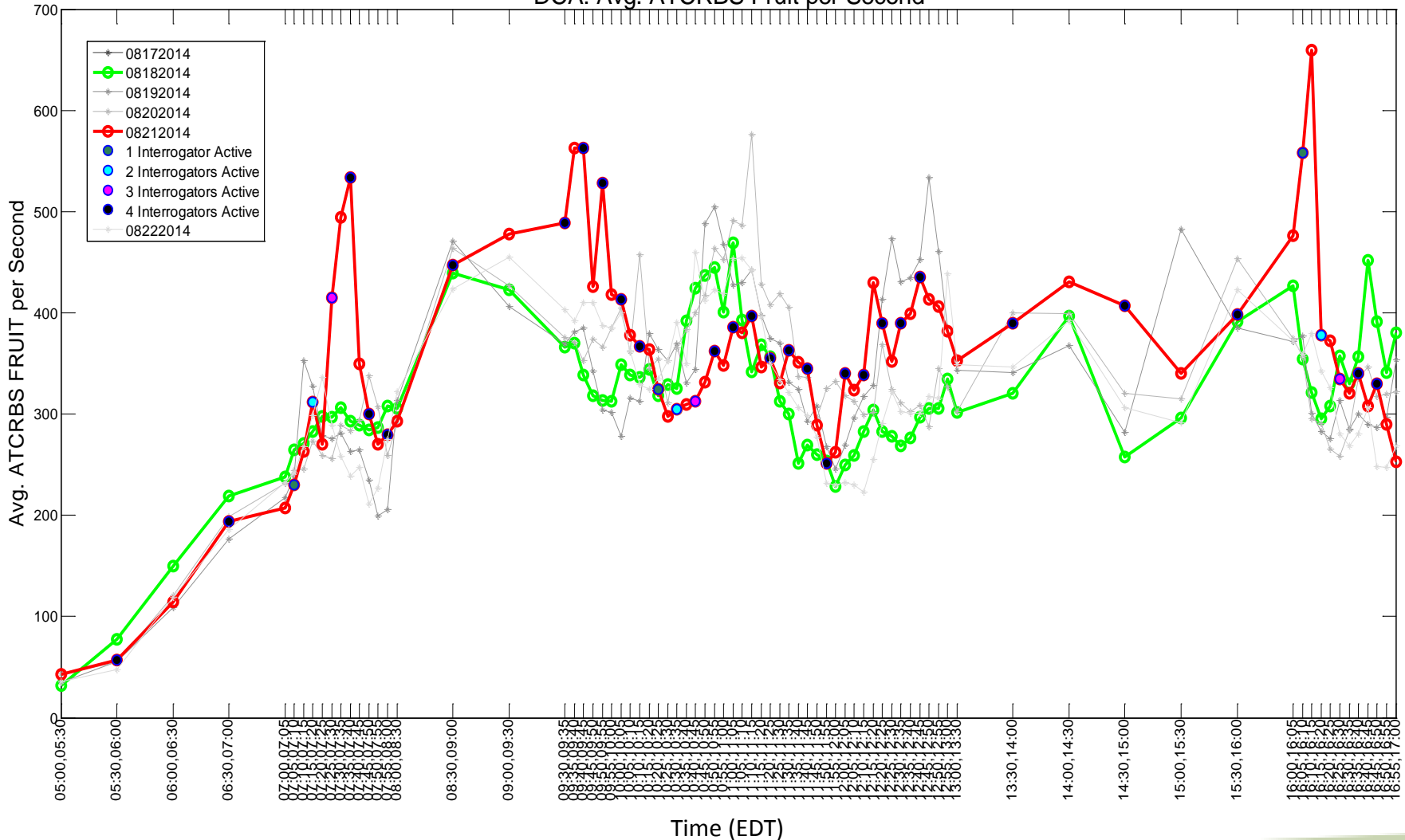
# ATCRBS FRUIT Rate vs # of Targets – August 20<sup>th</sup>

DCA: ATCRBS Fruit per Second vs Number of Targets



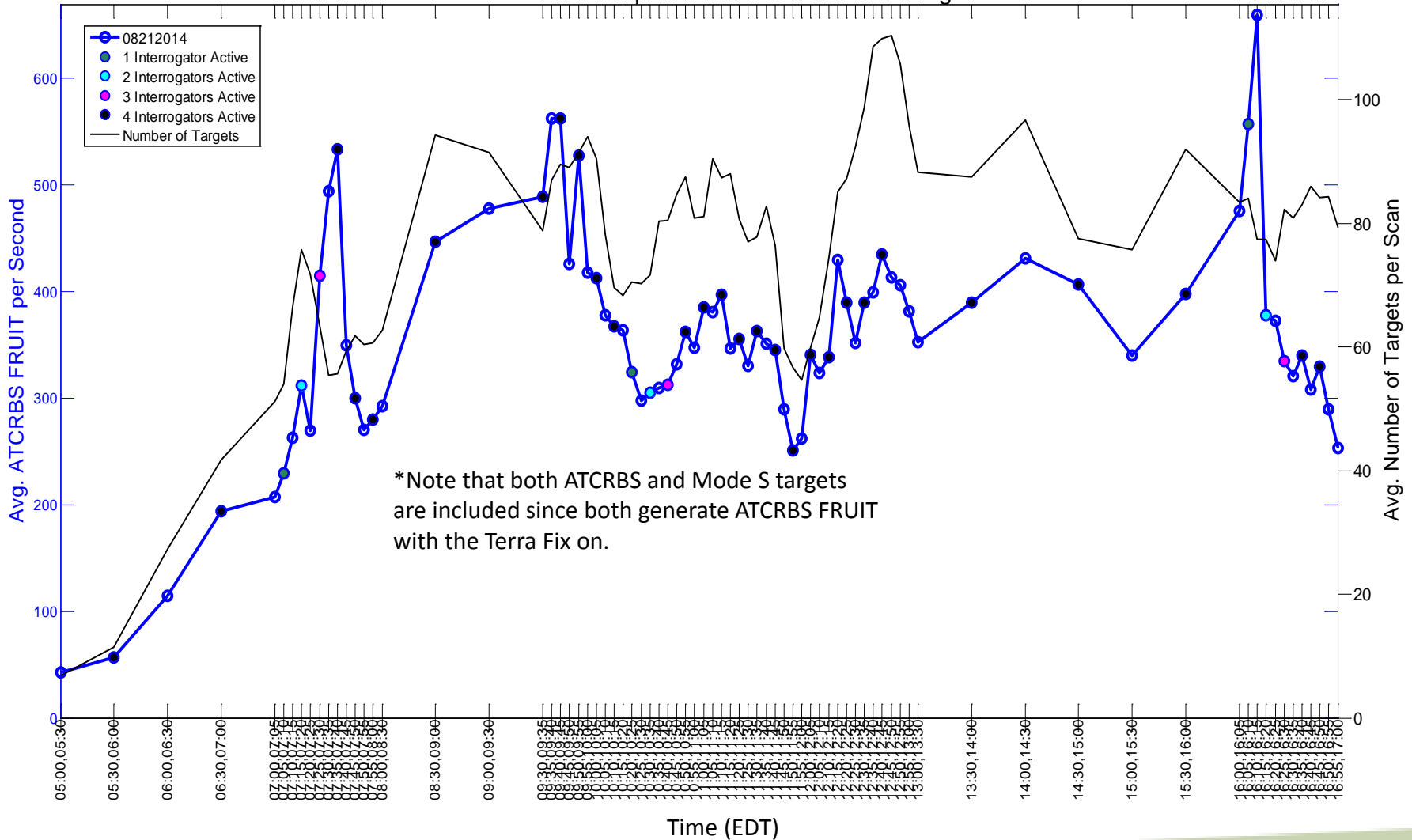
# ATCRBS FRUIT Rate – August 21<sup>st</sup>

DCA: Avg. ATCRBS Fruit per Second



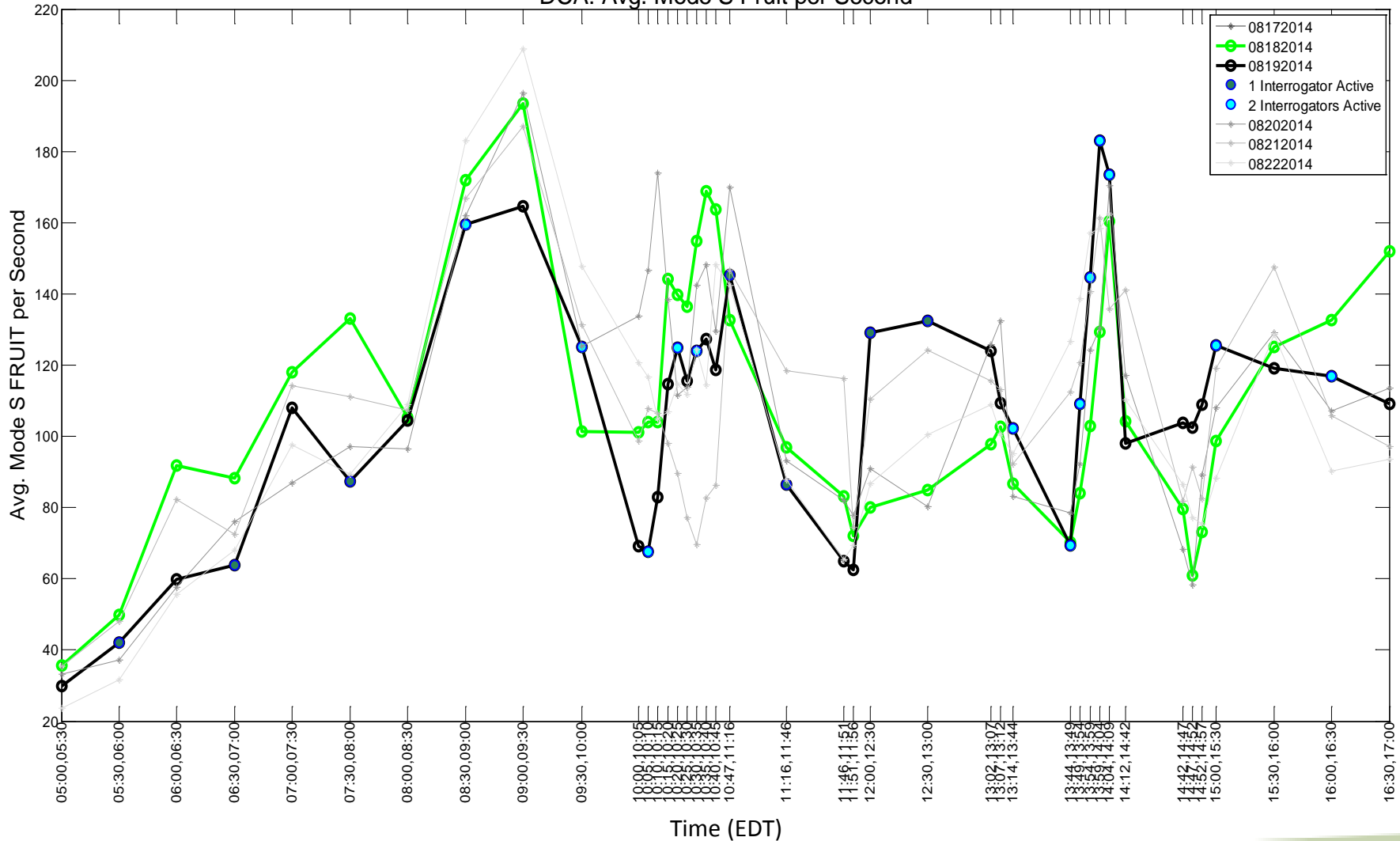
# ATCRBS FRUIT Rate vs # of Targets–August 21<sup>st</sup>

DCA: ATCRBS Fruit per Second vs Number of Targets



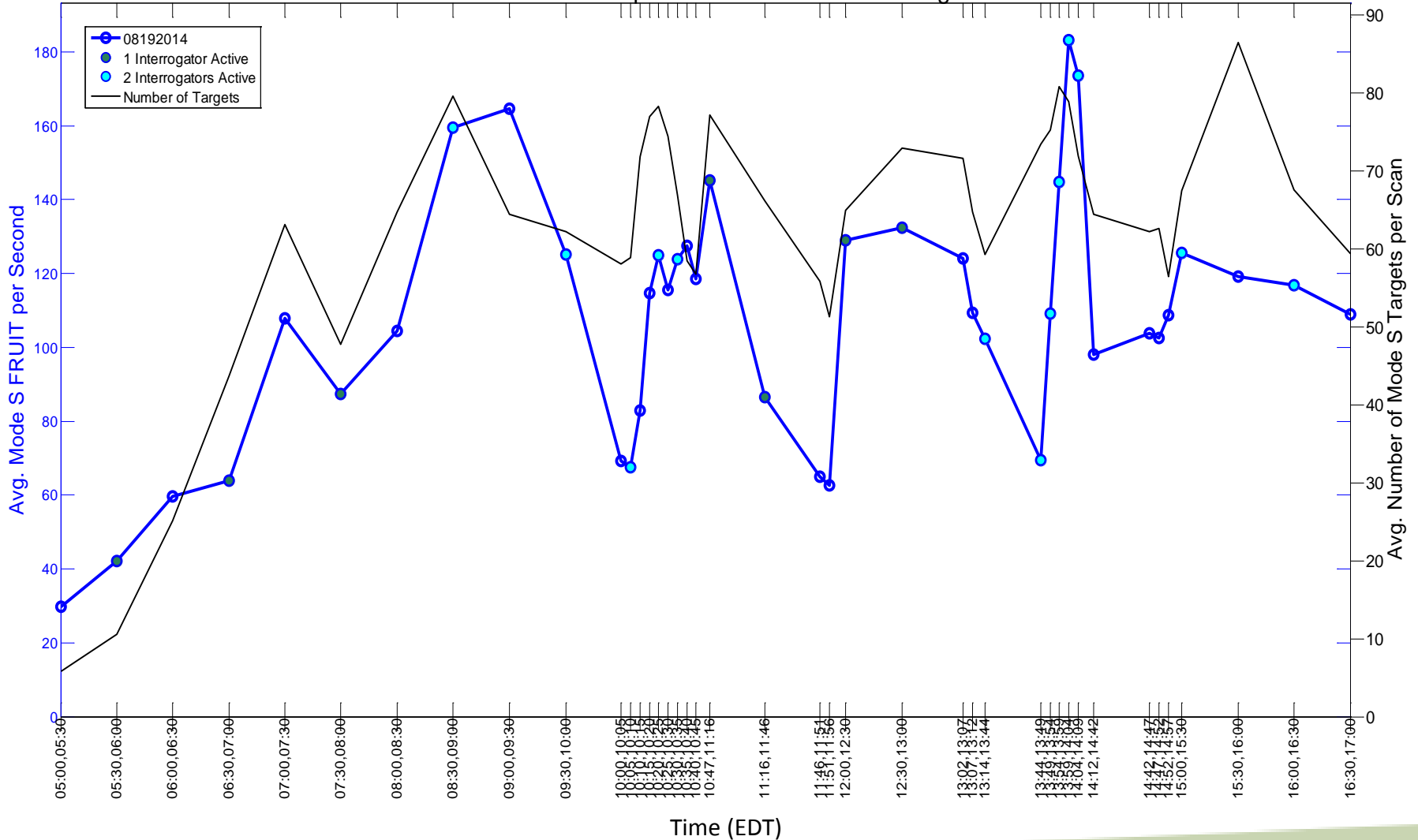
# Mode S FRUIT Rate – August 19<sup>th</sup>

DCA: Avg. Mode S Fruit per Second



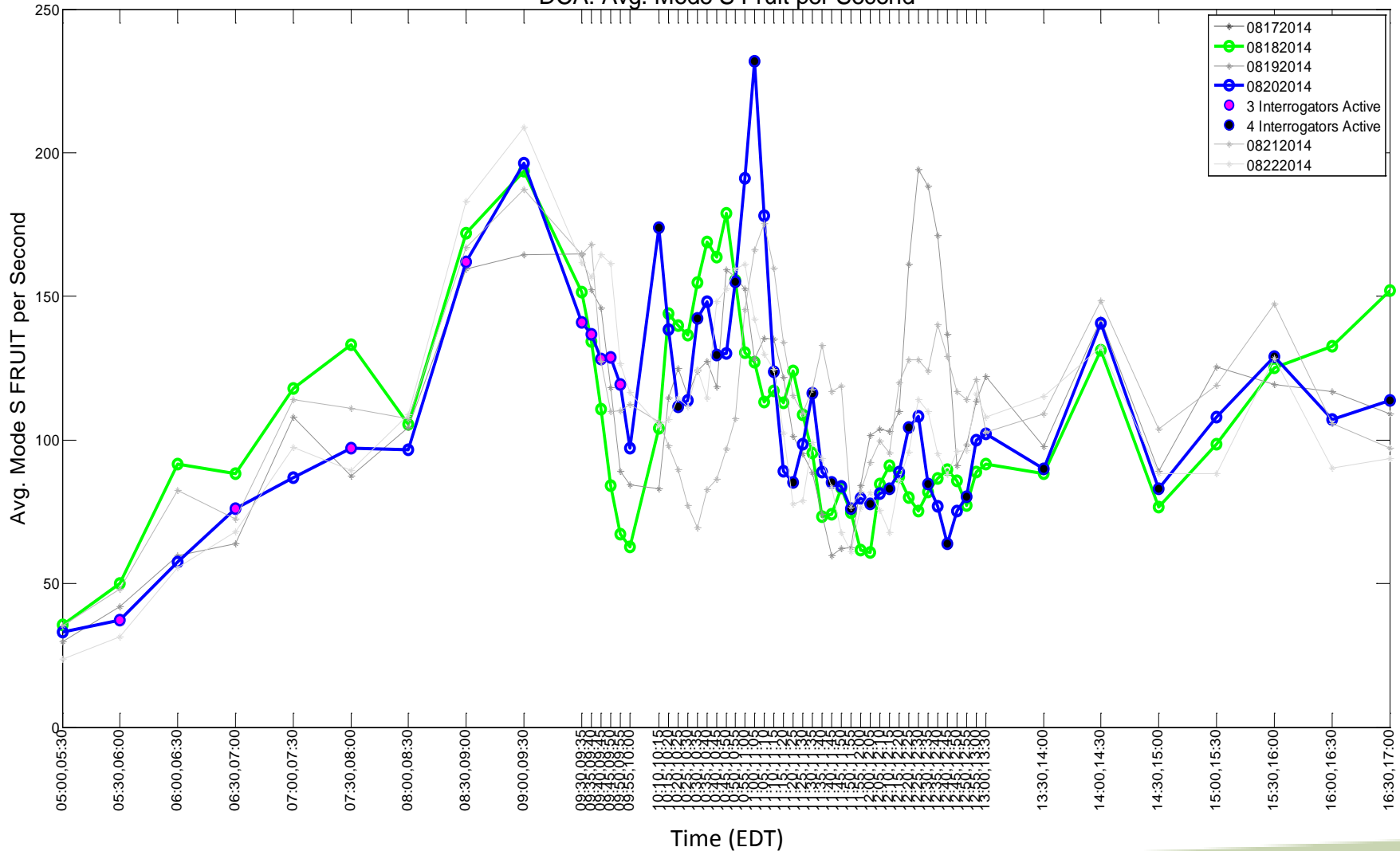
# Mode S FRUIT Rate vs # of Targets—August 19<sup>th</sup>

DCA: Mode S Fruit per Second vs Number of Targets



# Mode S FRUIT Rate – August 20<sup>th</sup>

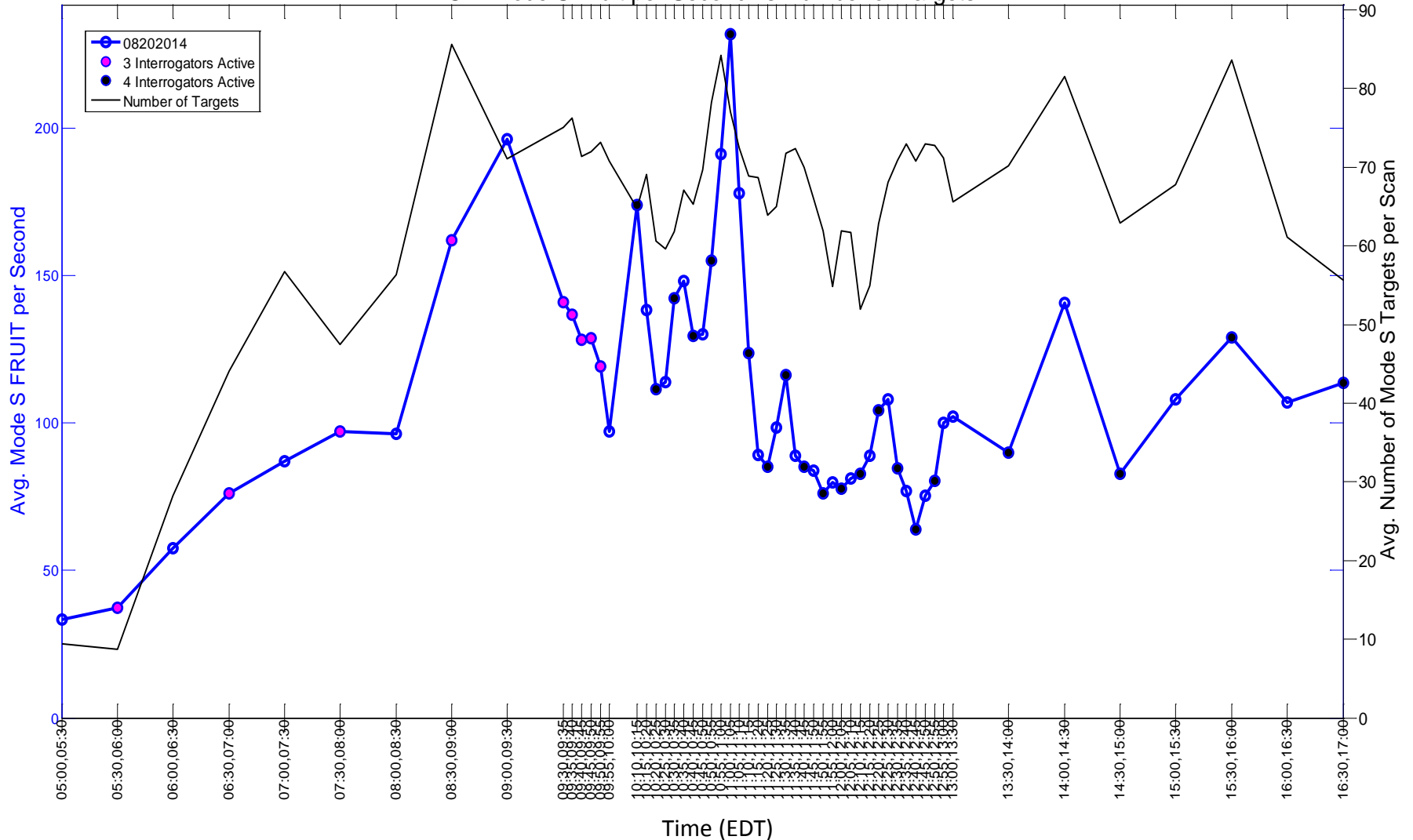
DCA: Avg. Mode S Fruit per Second





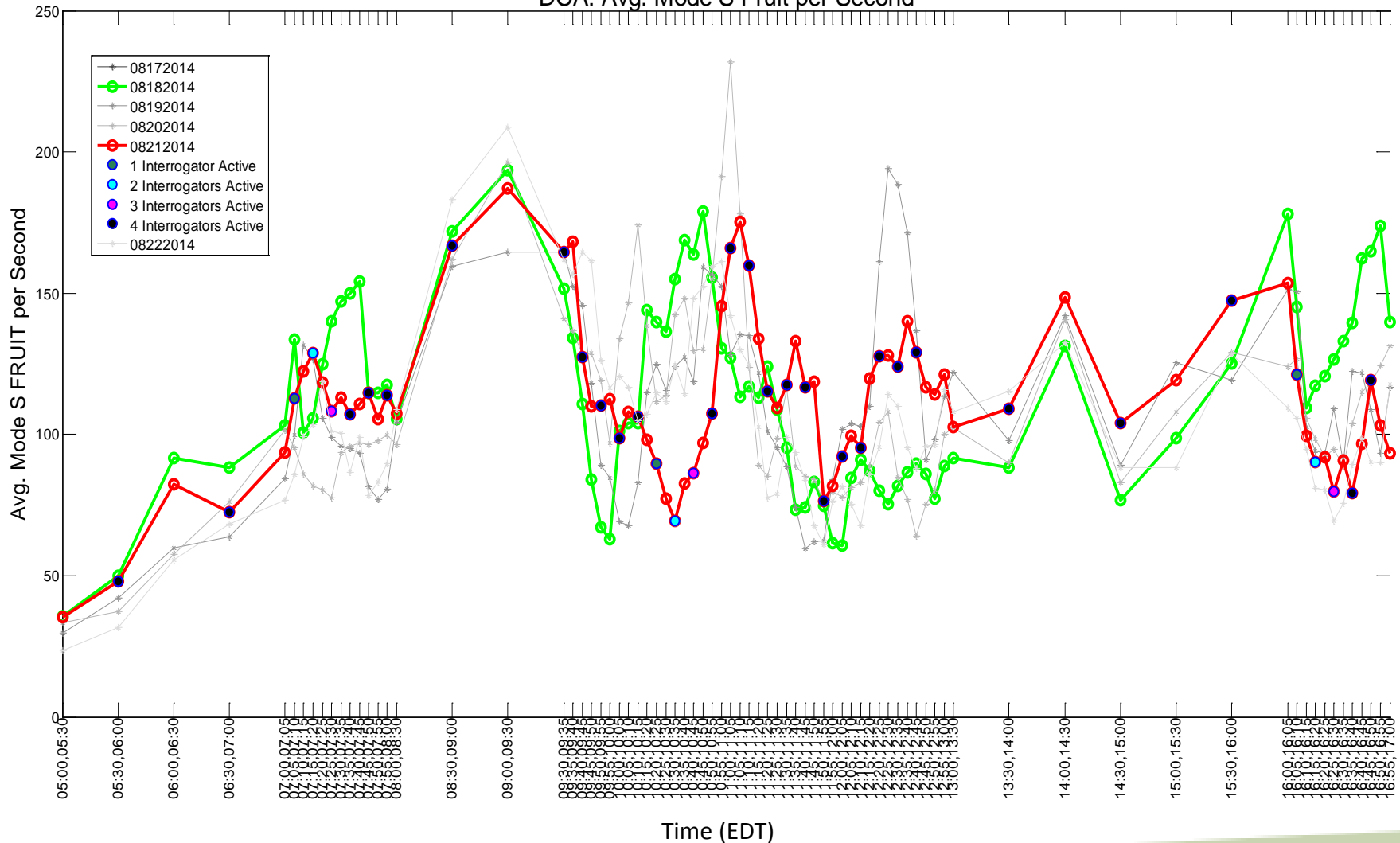
# Mode S FRUIT Rate vs # of Targets—August 20<sup>th</sup>

DCA: Mode S Fruit per Second vs Number of Targets



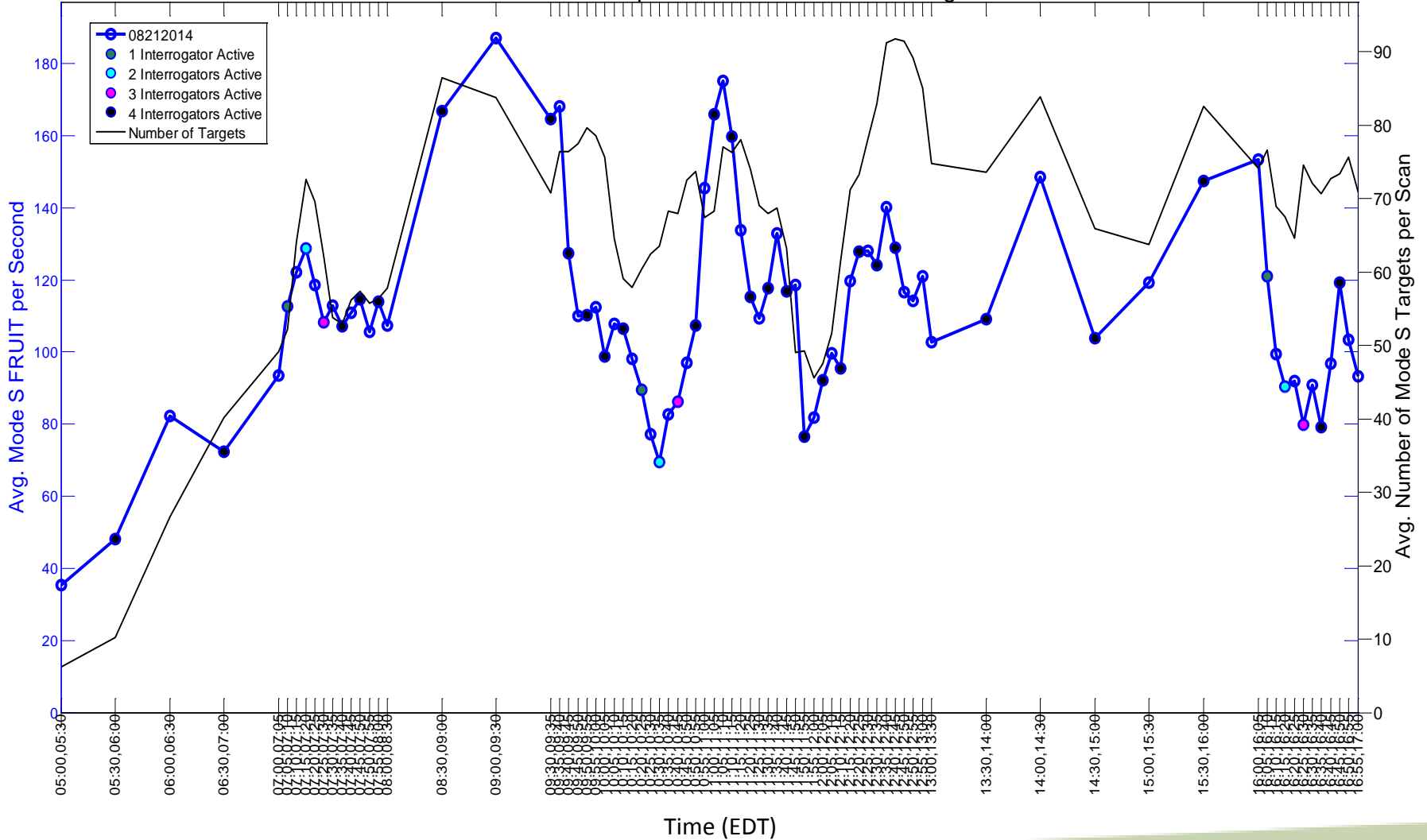
# Mode S FRUIT Rate – August 21<sup>st</sup>

DCA: Avg. Mode S Fruit per Second



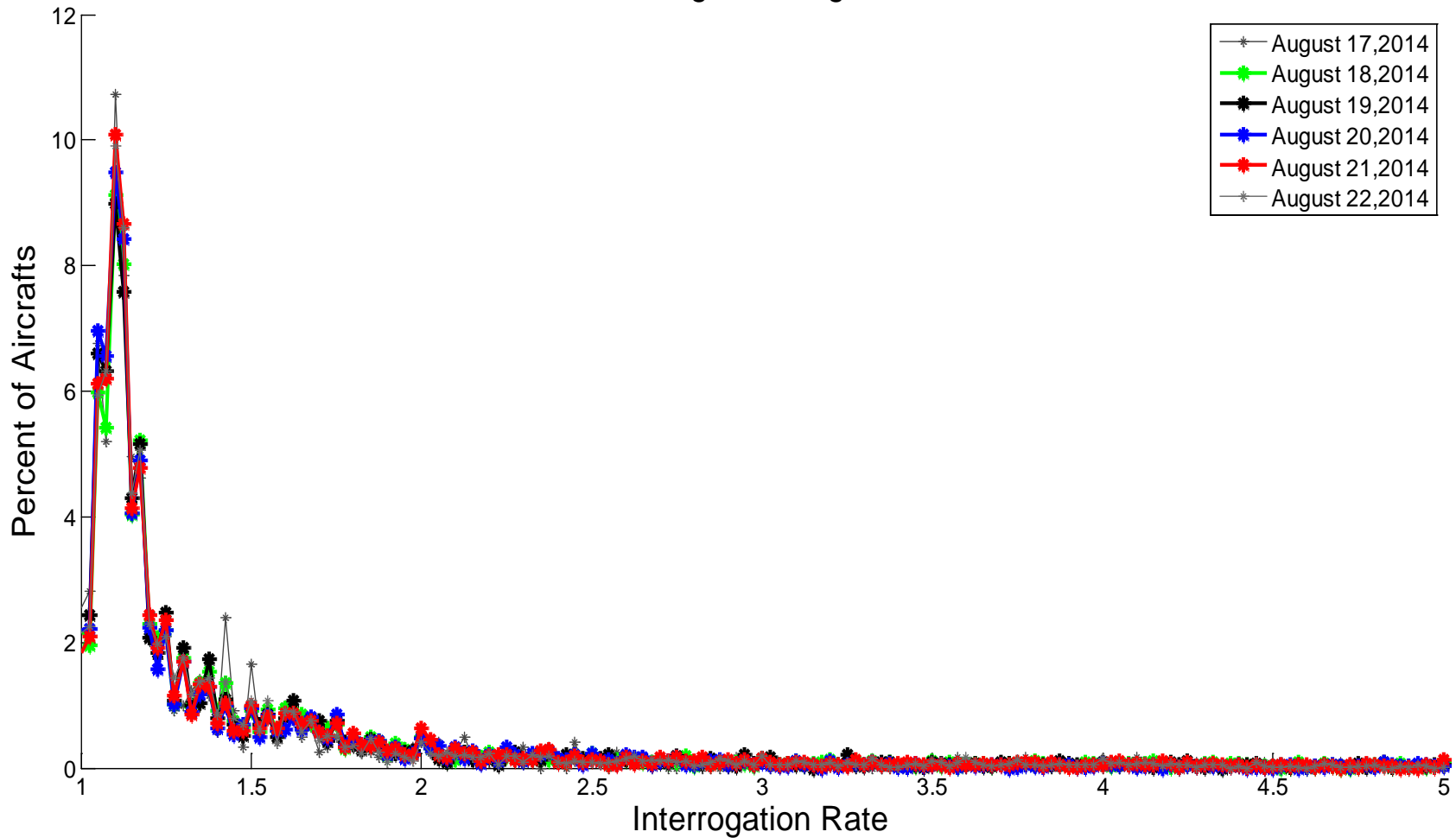
# Mode S FRUIT Rate vs # of Targets—August 21<sup>st</sup>

DCA: Mode S Fruit per Second vs Number of Targets



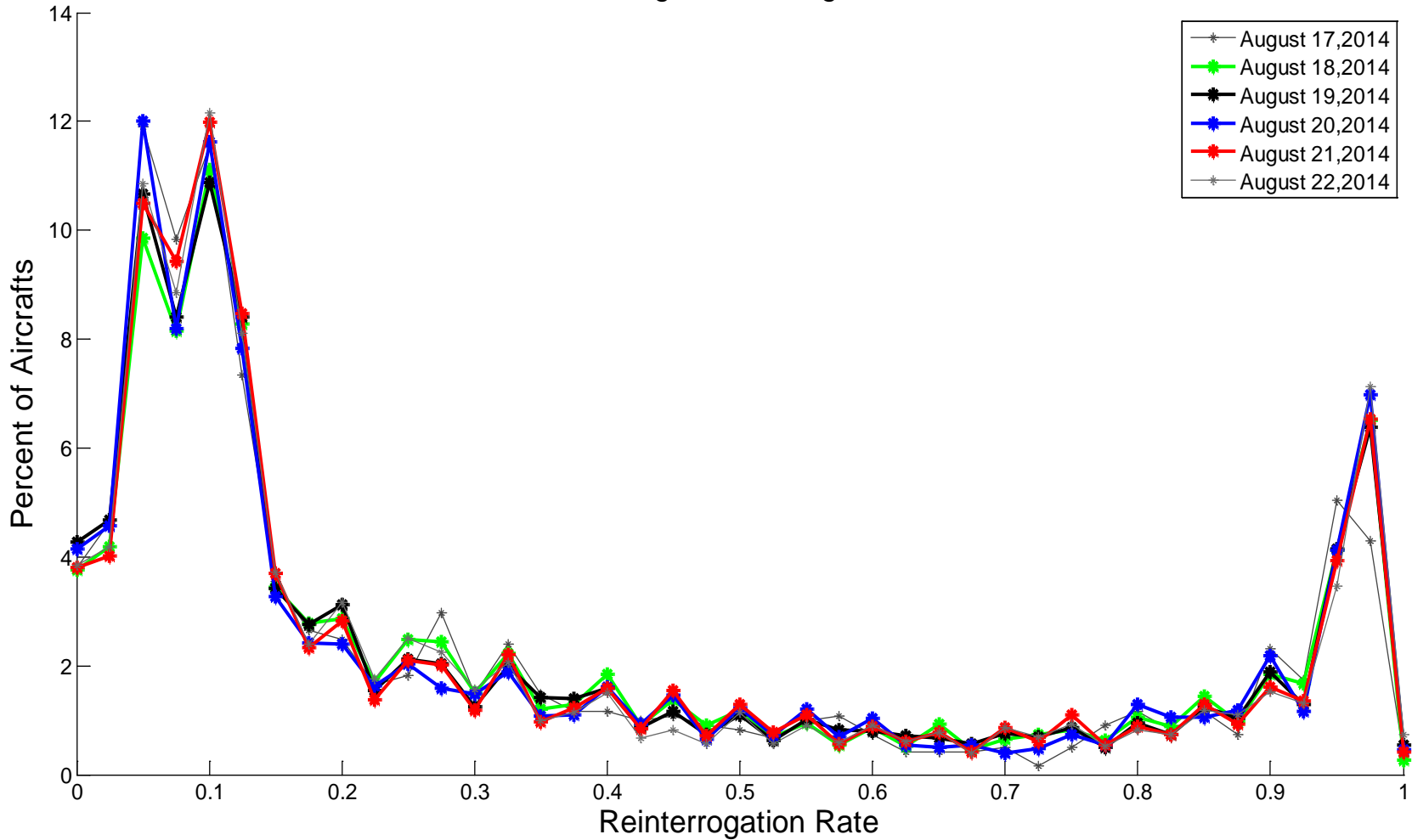
# Interrogation Rate – All Days

DCA:Average Interrogation Rate



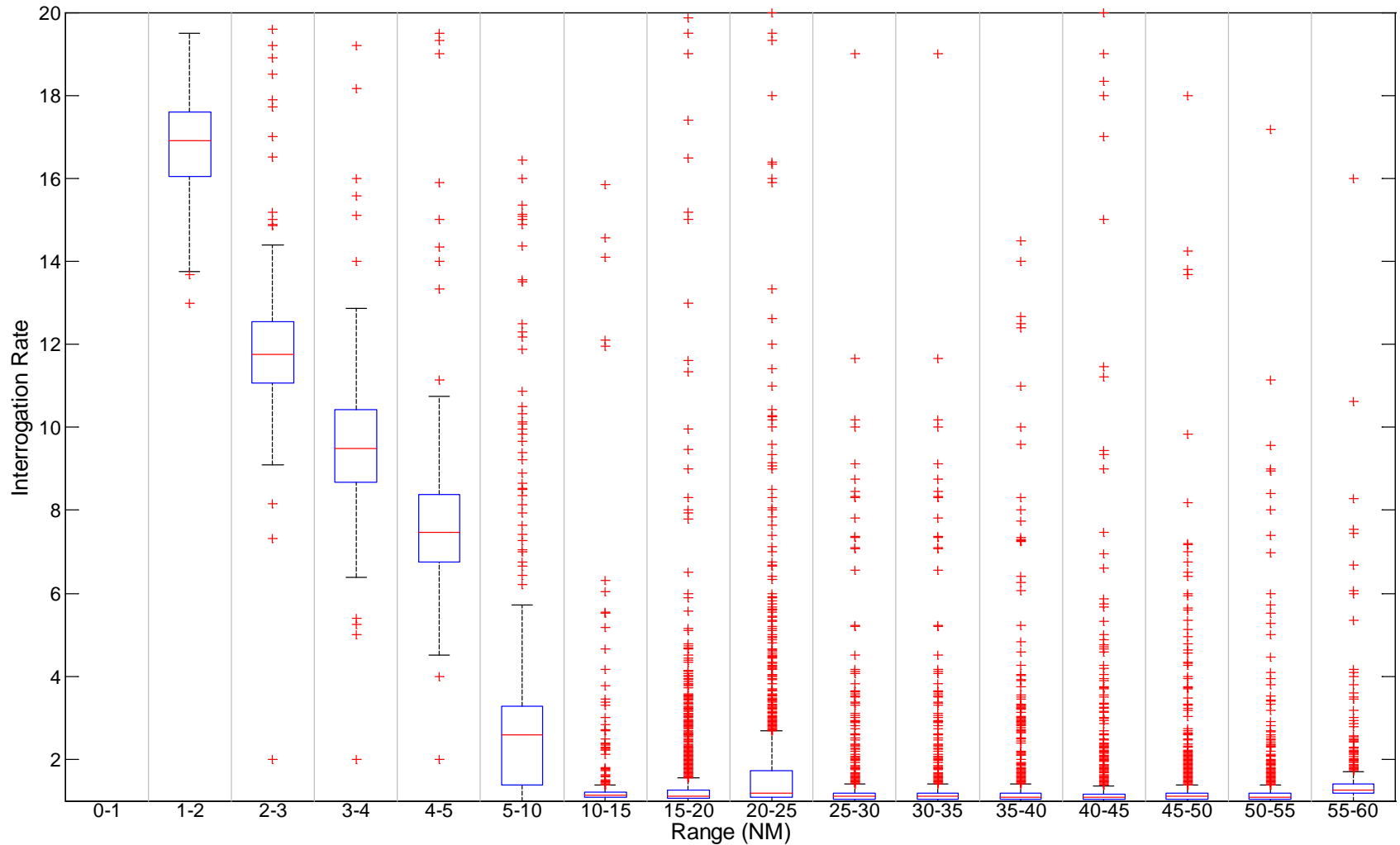
# Reinterrogation Rate – All Days

DCA:Average Reinterrogation Rate



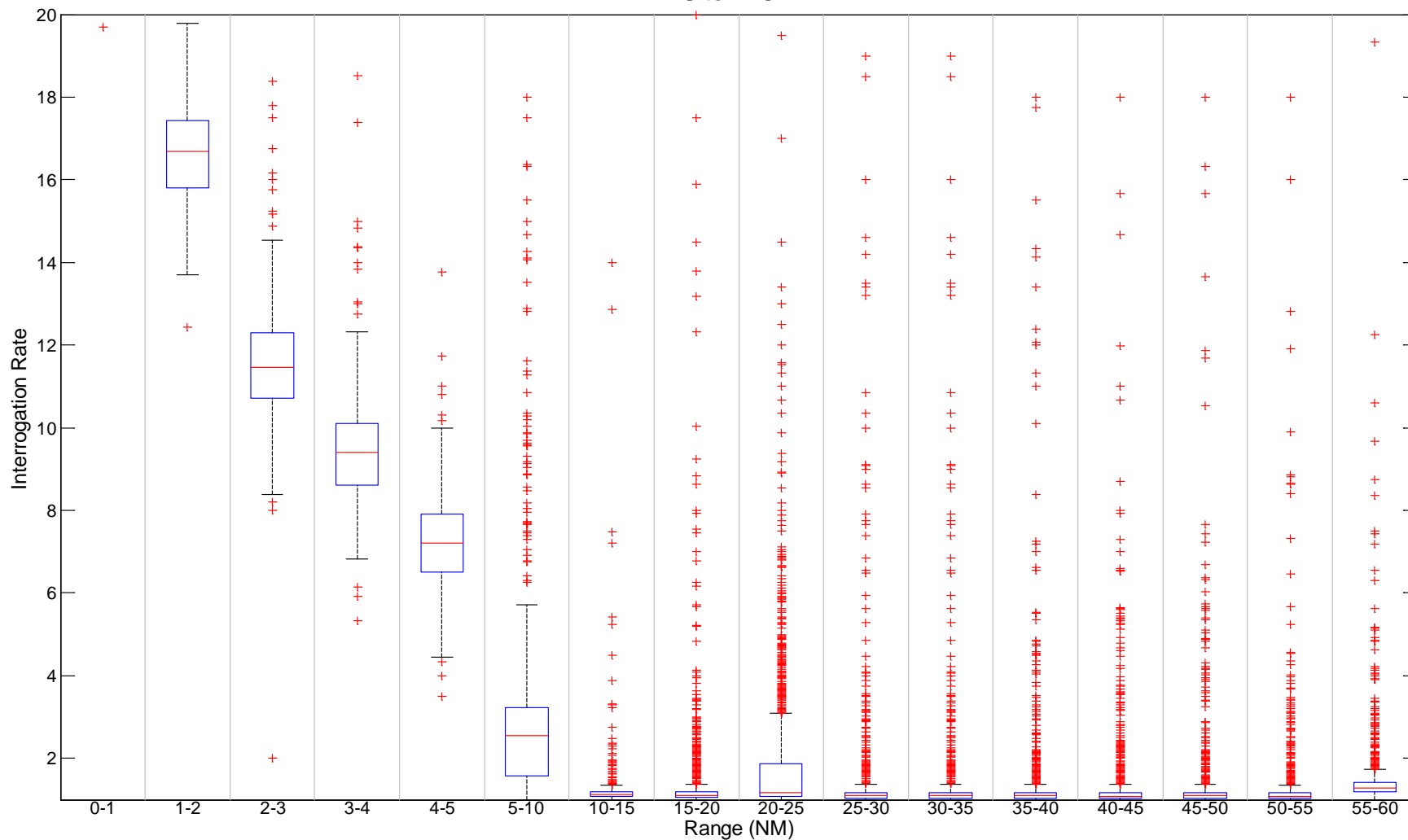
# Interrogation Rate vs Range – August 19<sup>th</sup>

Site: DCA



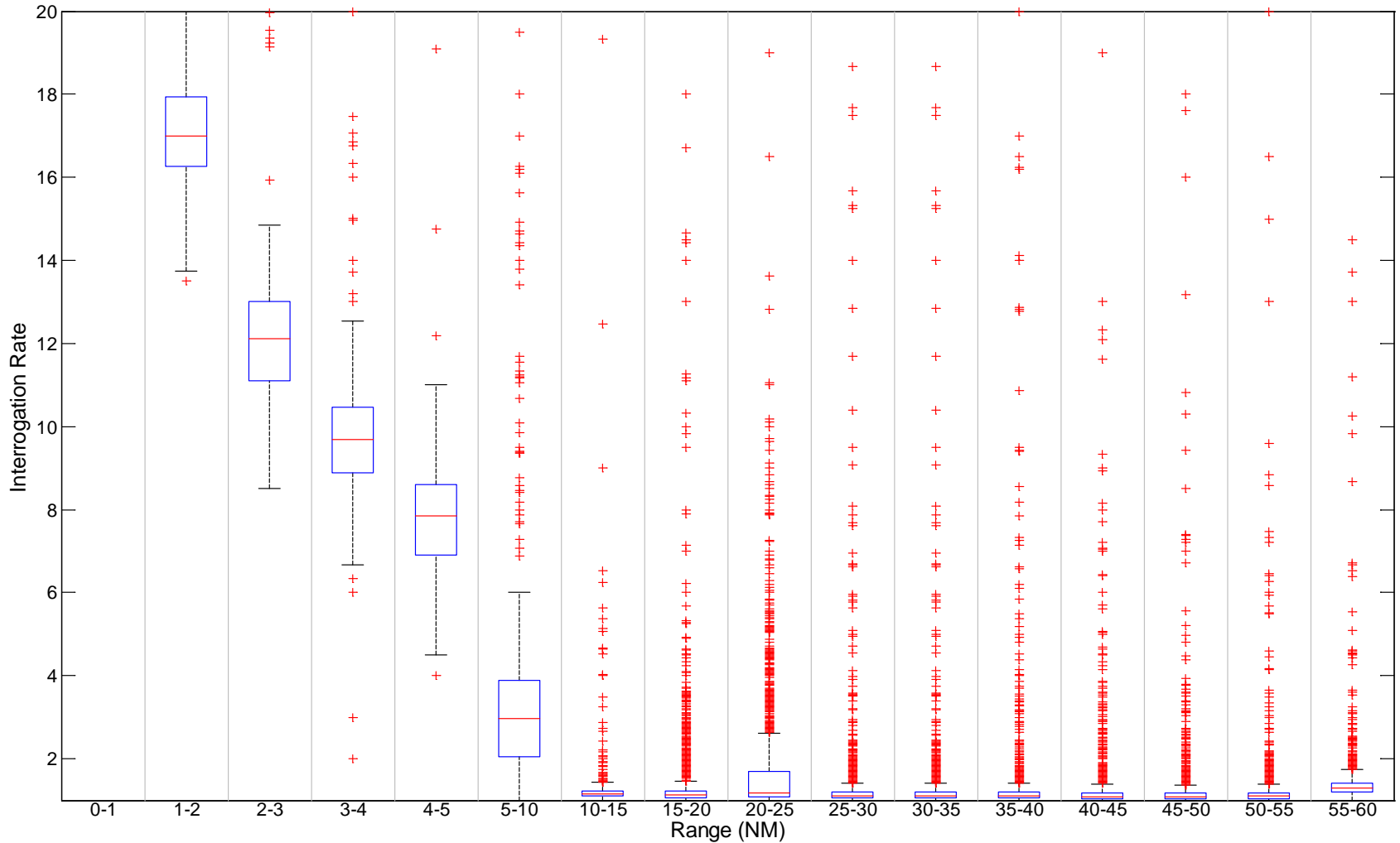
# Interrogation Rate vs Range – August 20<sup>th</sup>

Site: DCA



# Interrogation Rate vs Range – August 21<sup>st</sup>

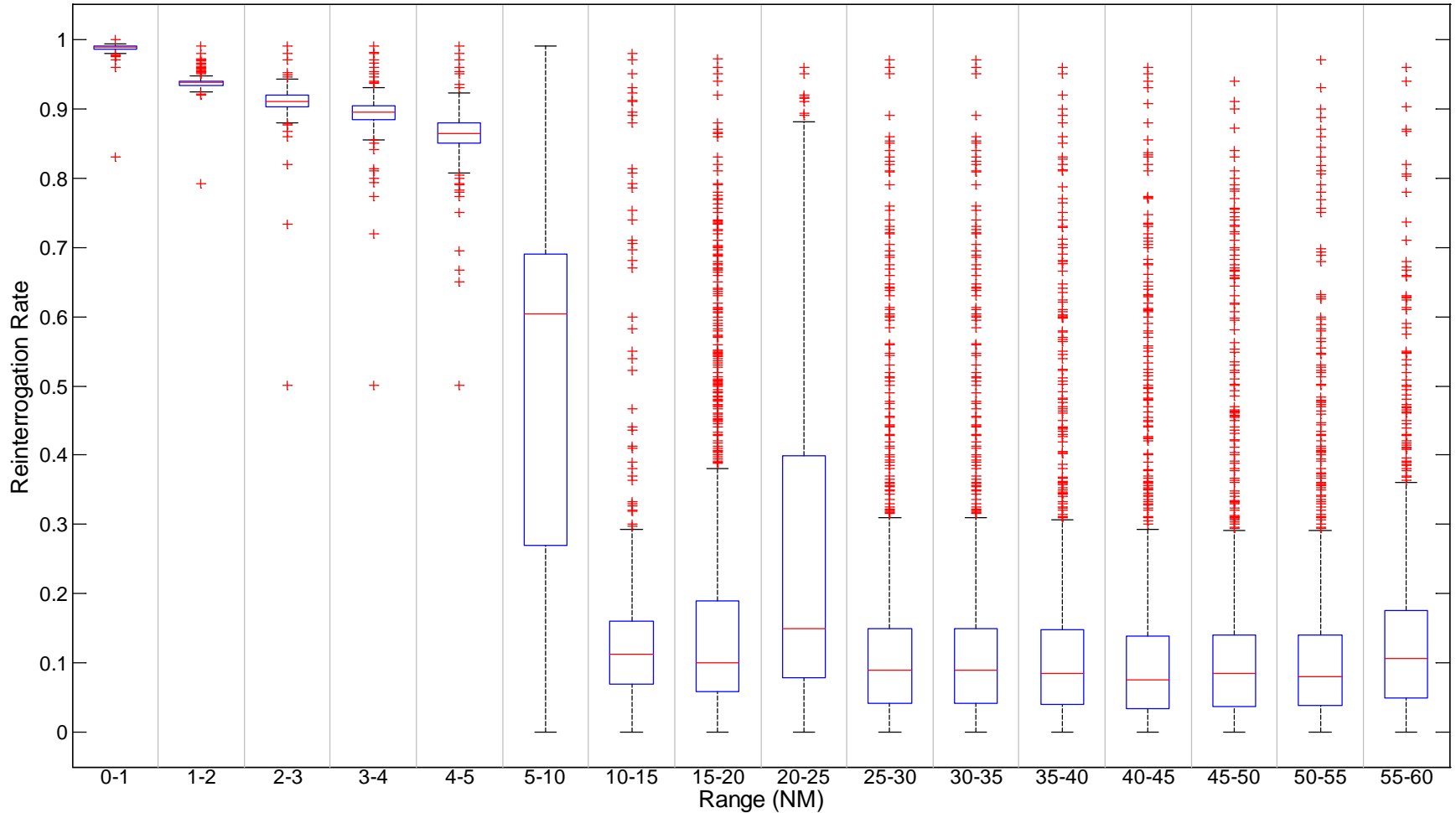
Site: DCA





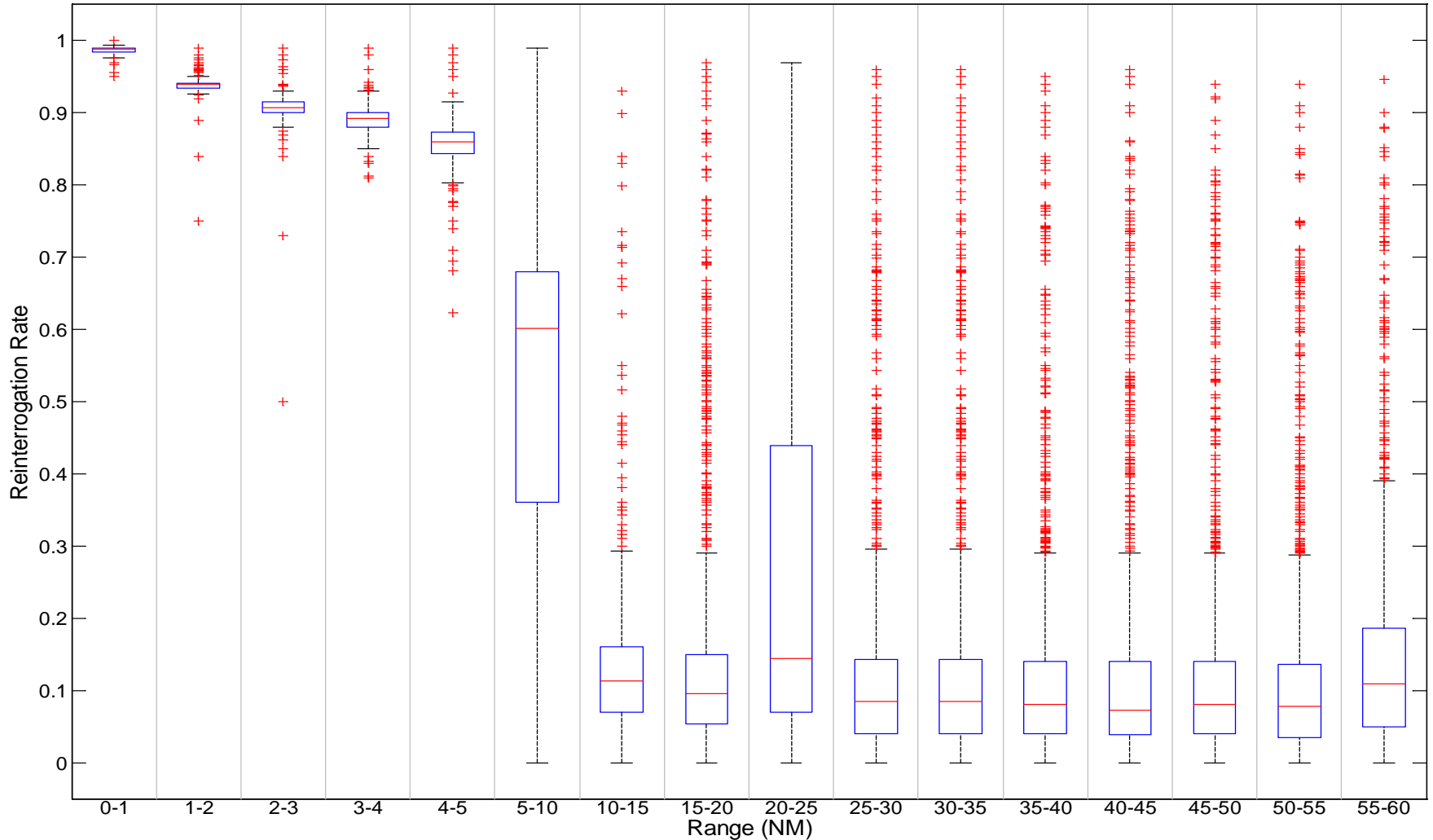
# Reinterrogation Rate vs Range – August 19<sup>th</sup>

Site: DCA



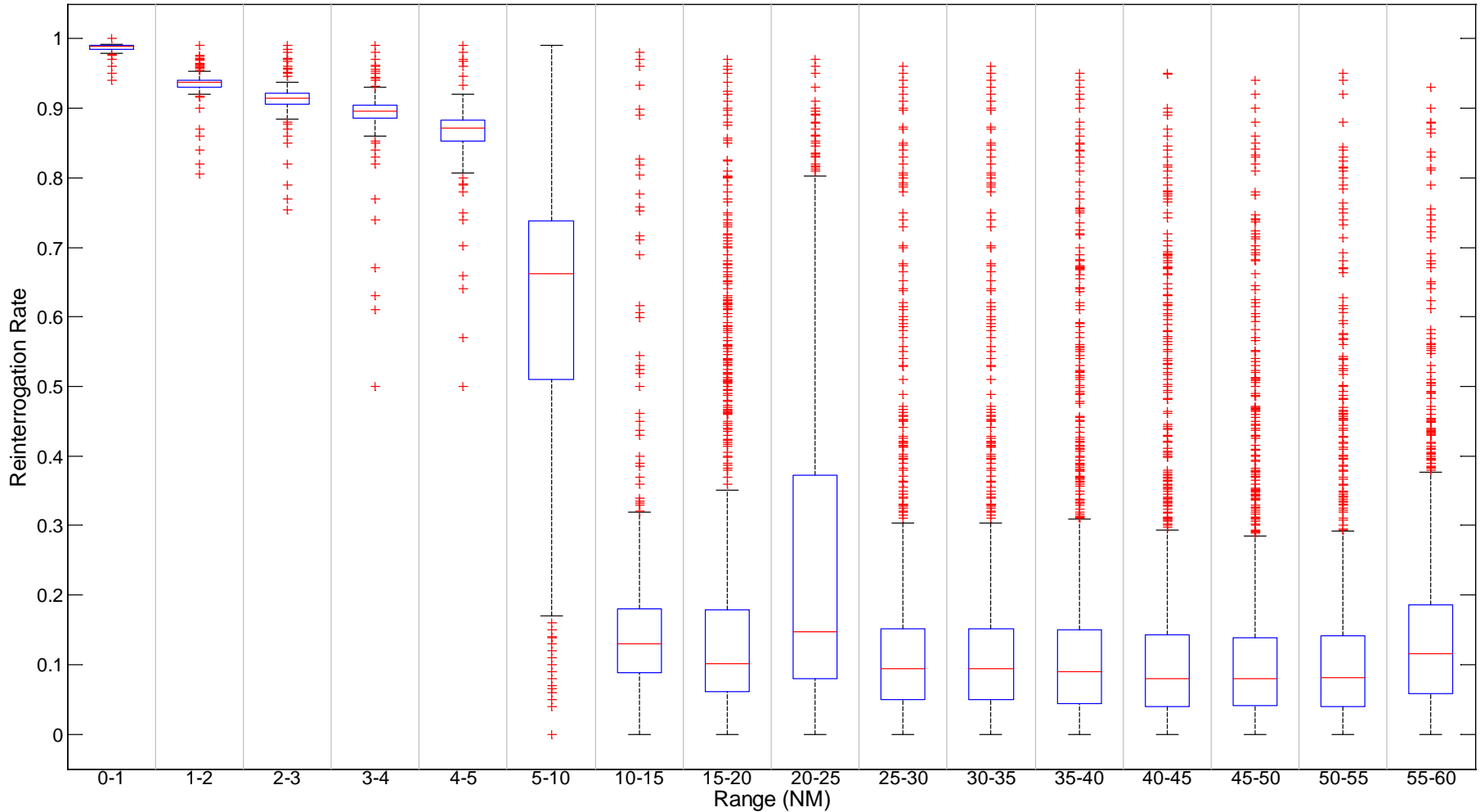
# Reinterrogation Rate vs Range – August 20<sup>th</sup>

Site: DCA



# Reinterrogation Rate vs Range – August 21<sup>st</sup>

Site: DCA



# Observations and Conclusions

## ❑ FRUIT Analysis

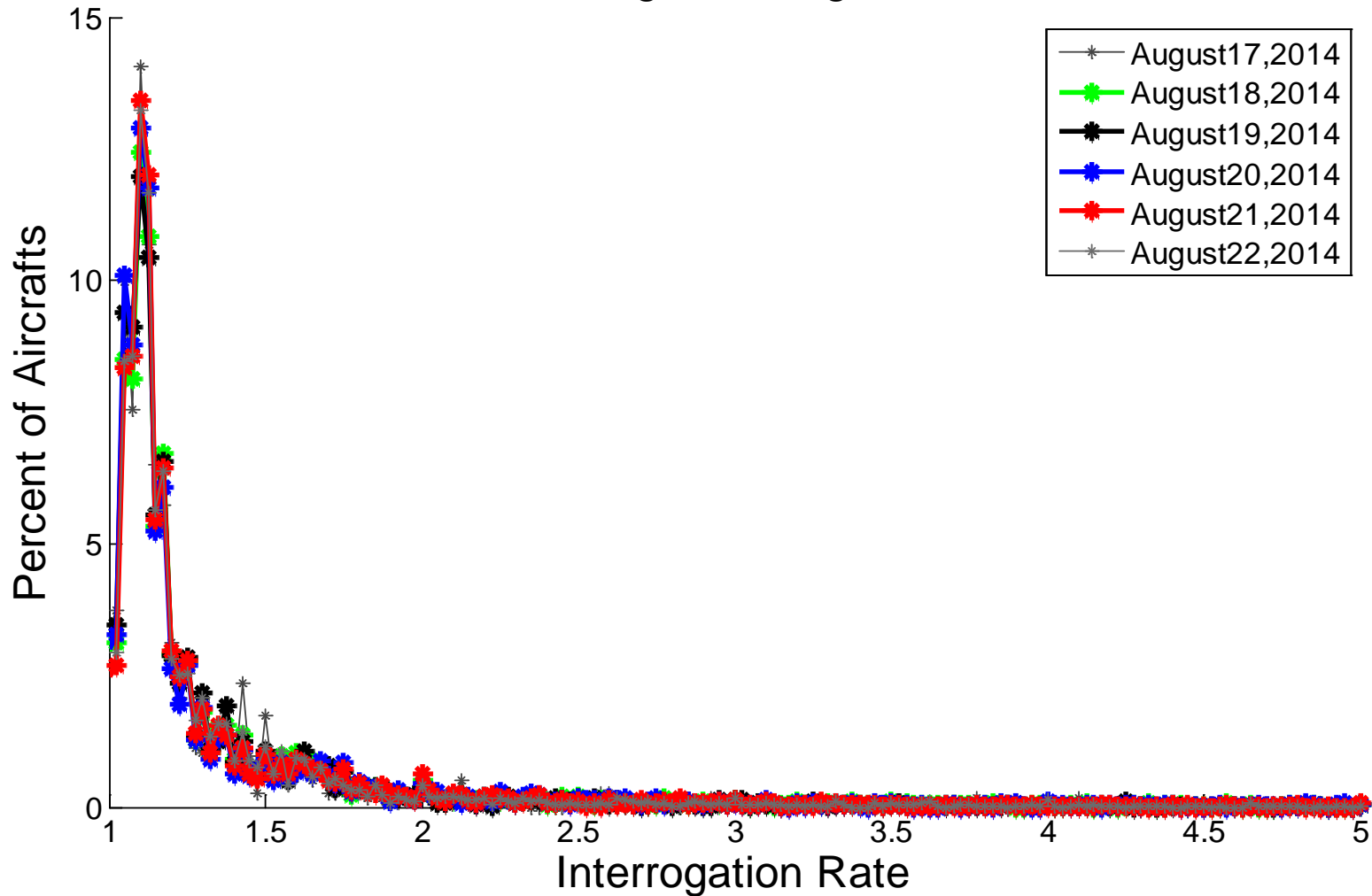
- ATCRBS FRUIT rates do not always increase when AN/UPX-41(C) interrogators are Active. This means the AN/UPX-41(C) FRUIT impact, for the Stage 4 configuration, generates less ATCRBS FRUIT than the normal daily fluctuations of ATCRBS FRUIT due to changes in traffic densities. This is also confirmed by the generally high correlation between traffic count and ATCRBS FRUIT rate movements.
- AN/UPX-41(C) interrogators should have produced no extra Mode S FRUIT and the plots confirm this.

## ❑ Channel Management Statistics

- Targets within 10 NM showed consistently high interrogation/reinterrogation rates
  - This phenomenon is due to the unpredictability of roll call target azimuths at close ranges. The Mode S roll call scheduler starts interrogations many degrees before the tracker's predicted azimuth to ensure that unknown changes in speed and heading will not limit the ability of the Mode S system to get an update on the target.
  - So while the reinterrogation rate is high within 10 NM, it is not due to transponder occupancy or receiver garble.
  - To notice any possible change in interrogation/reinterrogation rates between Active/OFF periods, targets within 10 NM of SSR site were excluded in the next section of analysis.

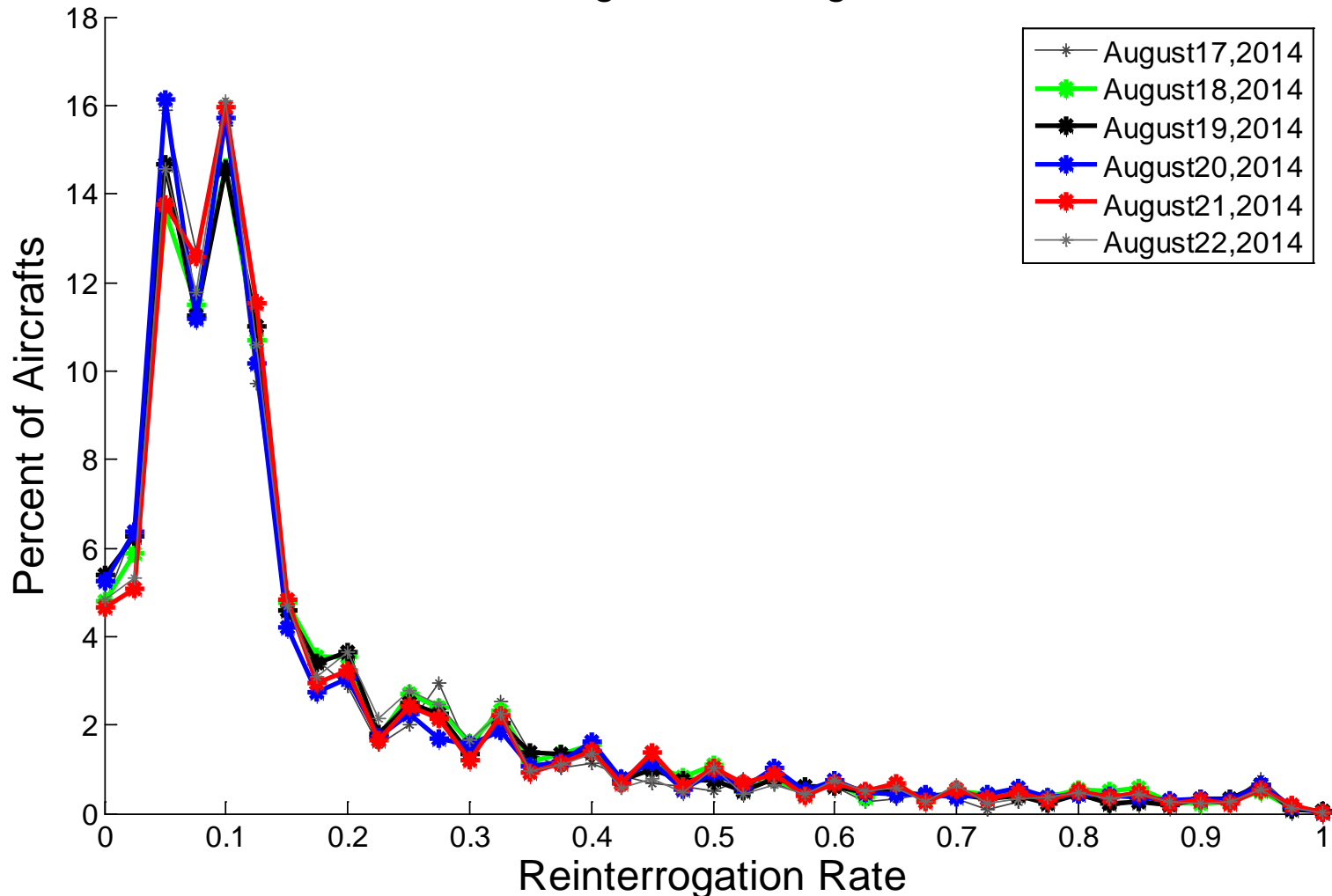
# Interrogation Rate – All Days

DCA:Average Interrogation Rate



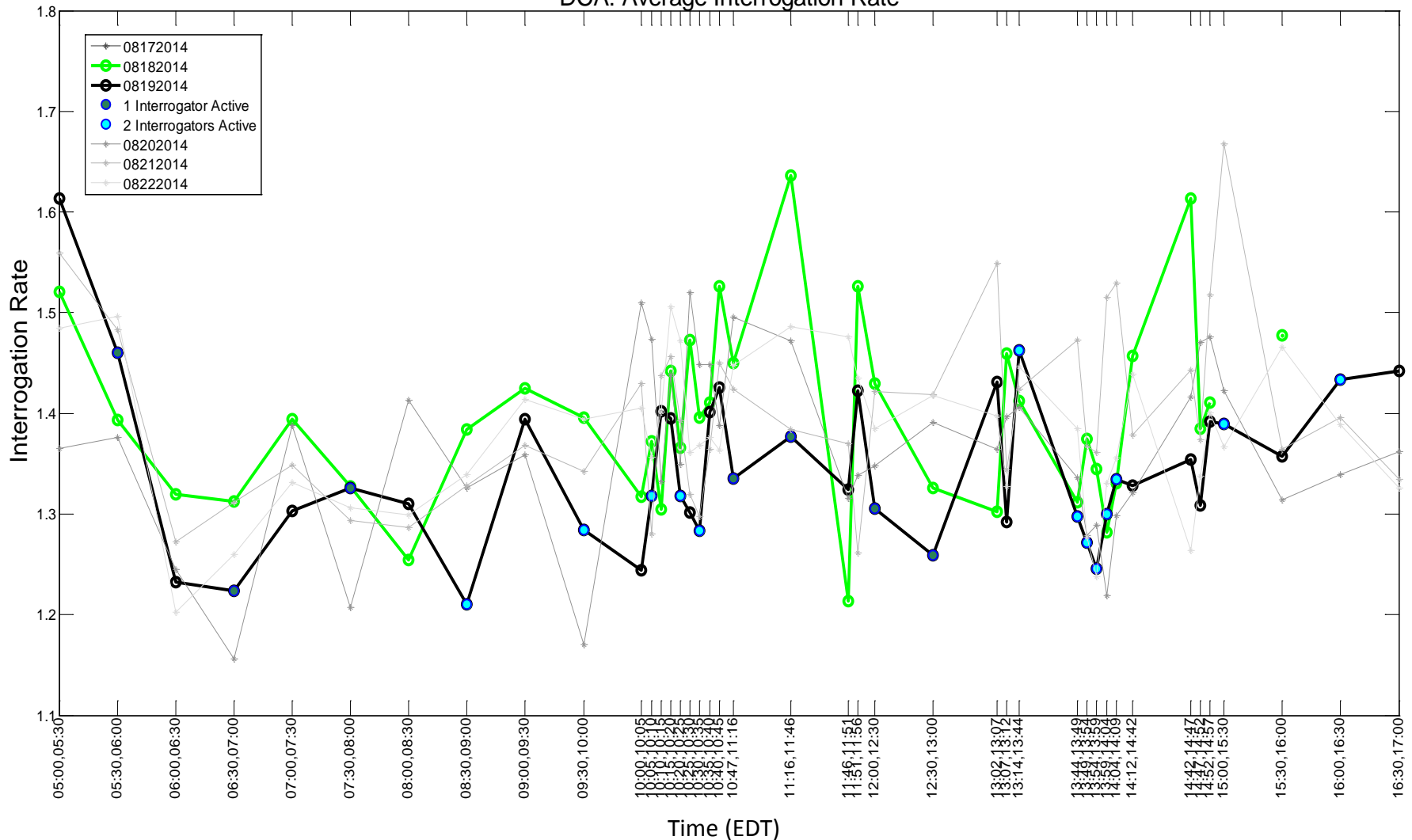
# Reinterrogation Rate – All Days

DCA:Average Reinterrogation Rate



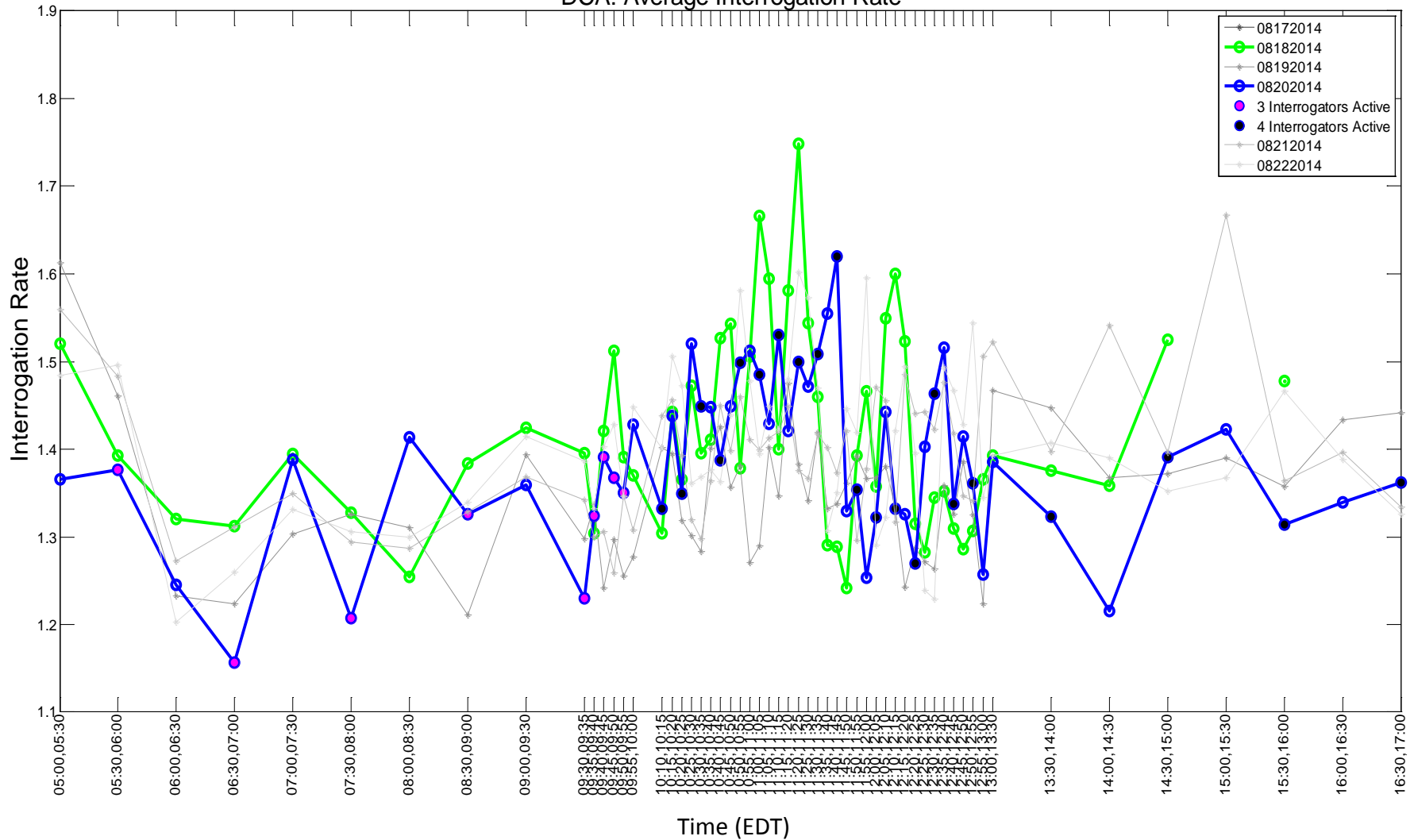
# Interrogation Rate – August 19<sup>th</sup>

DCA: Average Interrogation Rate



# Interrogation Rate – August 20<sup>th</sup>

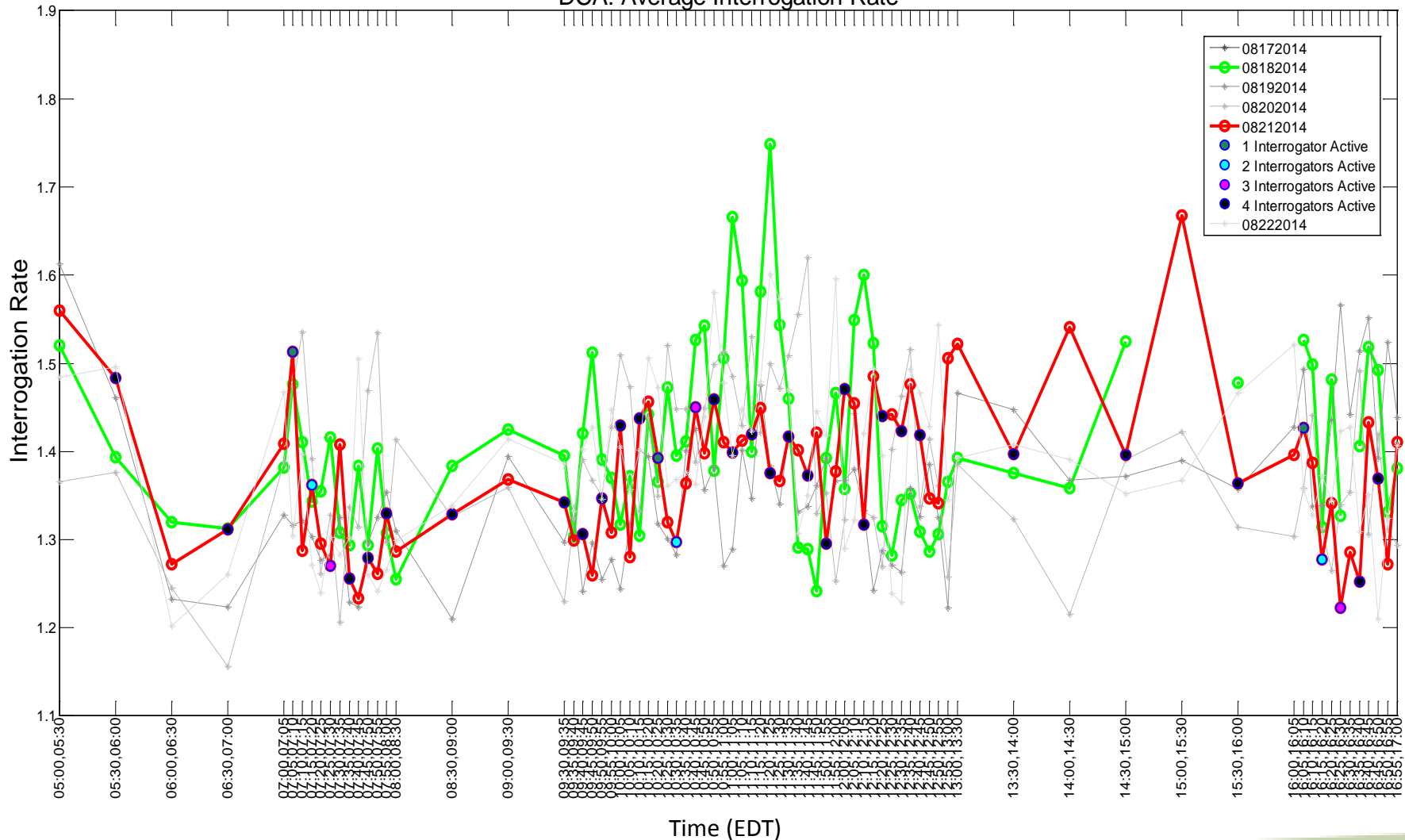
DCA: Average Interrogation Rate





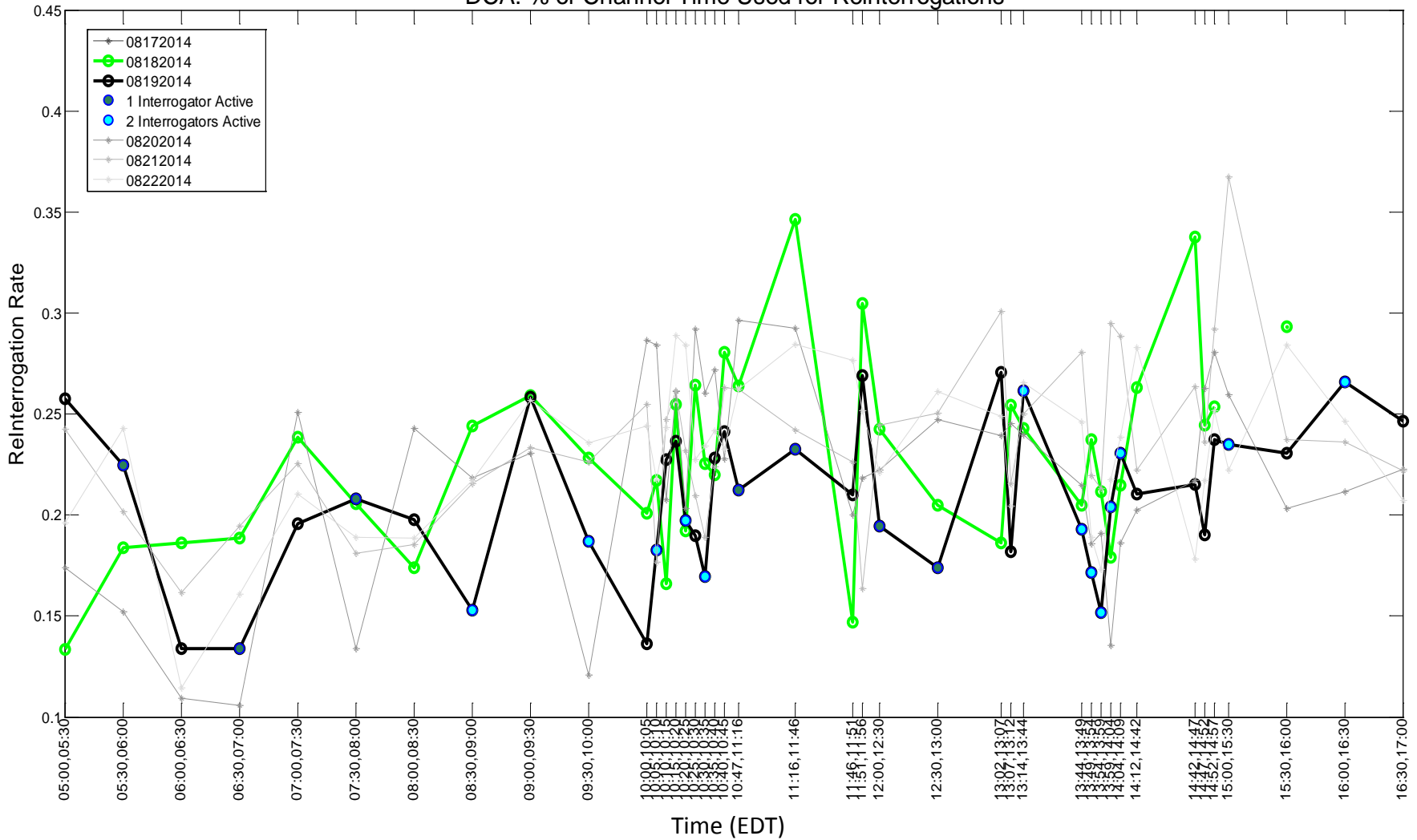
# Interrogation Rate – August 21<sup>st</sup>

DCA: Average Interrogation Rate



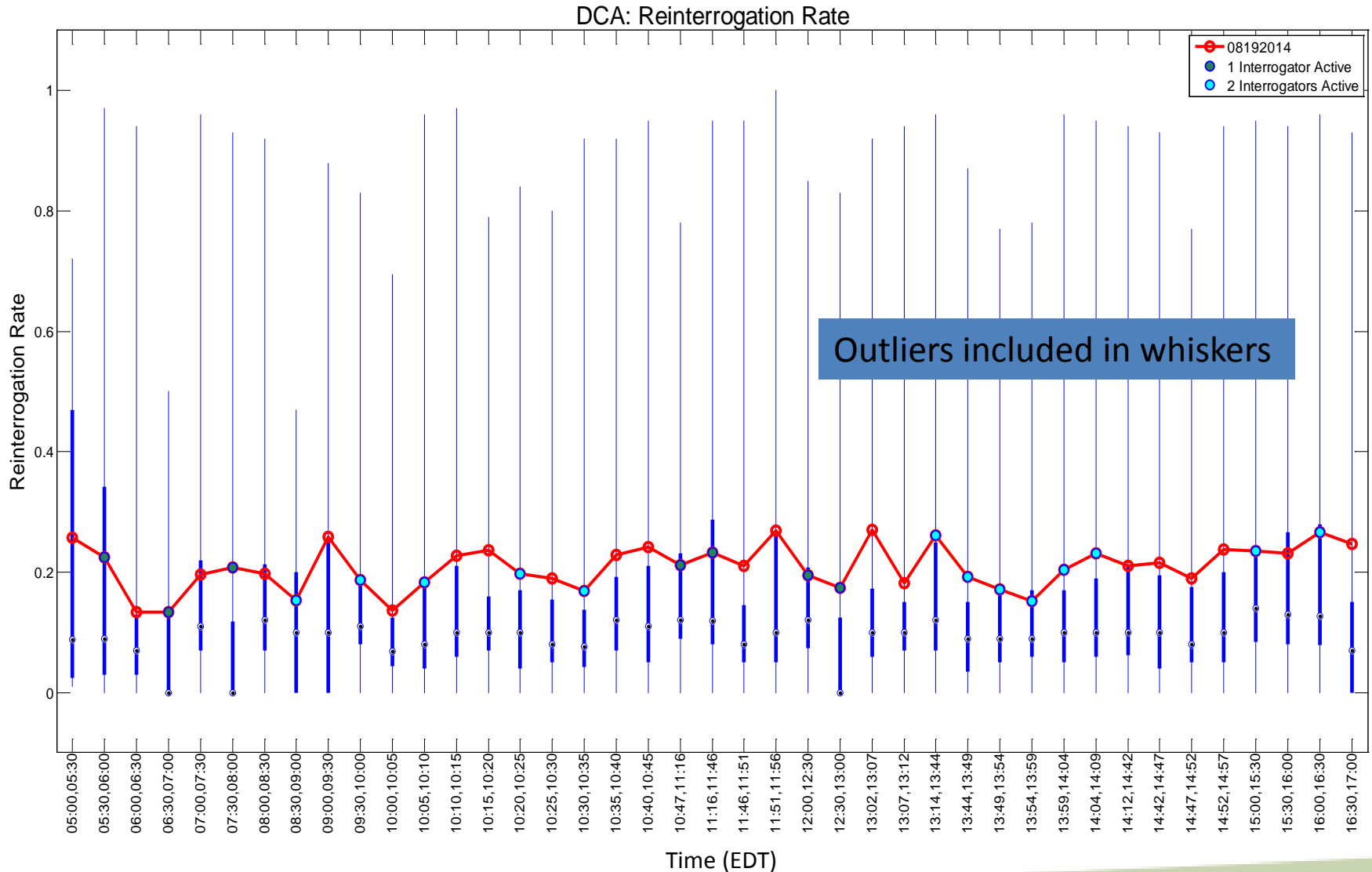
# Reinterrogation Rate – August 19<sup>th</sup>

DCA: % of Channel Time Used for Reinterrogations



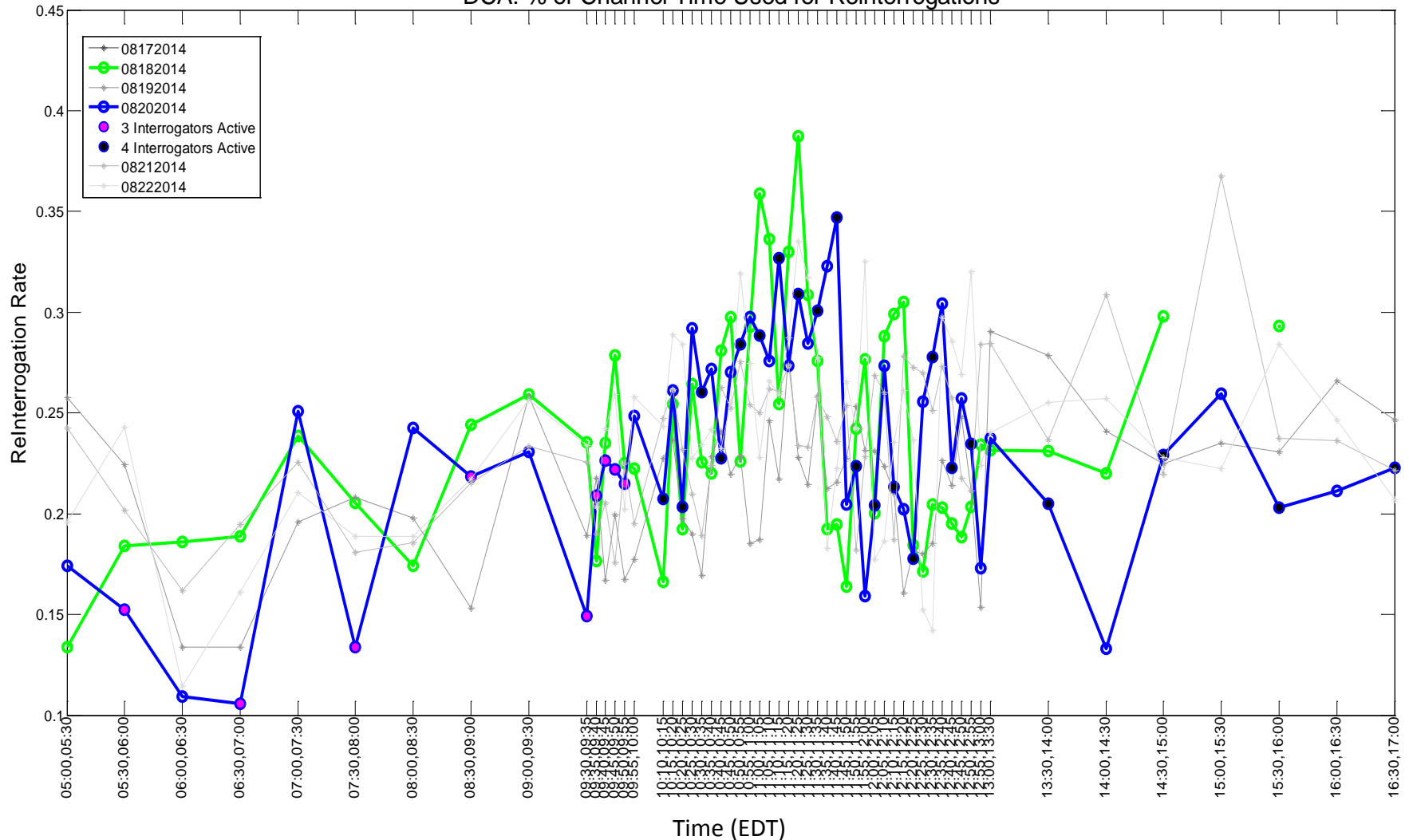
# Reinterrogation Rate – August 19<sup>th</sup>

## Individual Aircraft Distribution



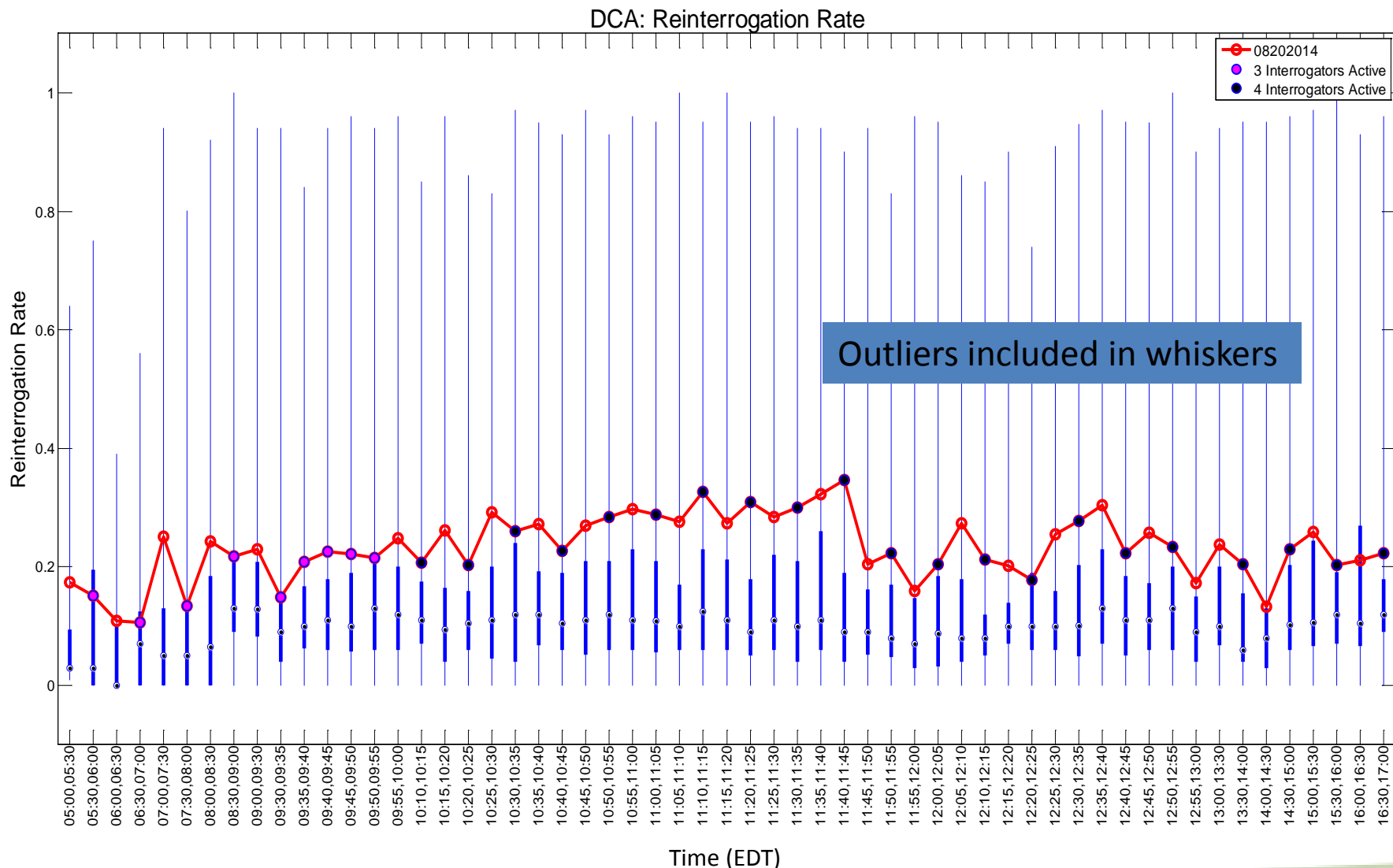
# Reinterrogation Rate – August 20<sup>th</sup>

DCA: % of Channel Time Used for Reinterrogations



# Reinterrogation Rate – August 20<sup>th</sup>

## Individual Aircraft Distribution

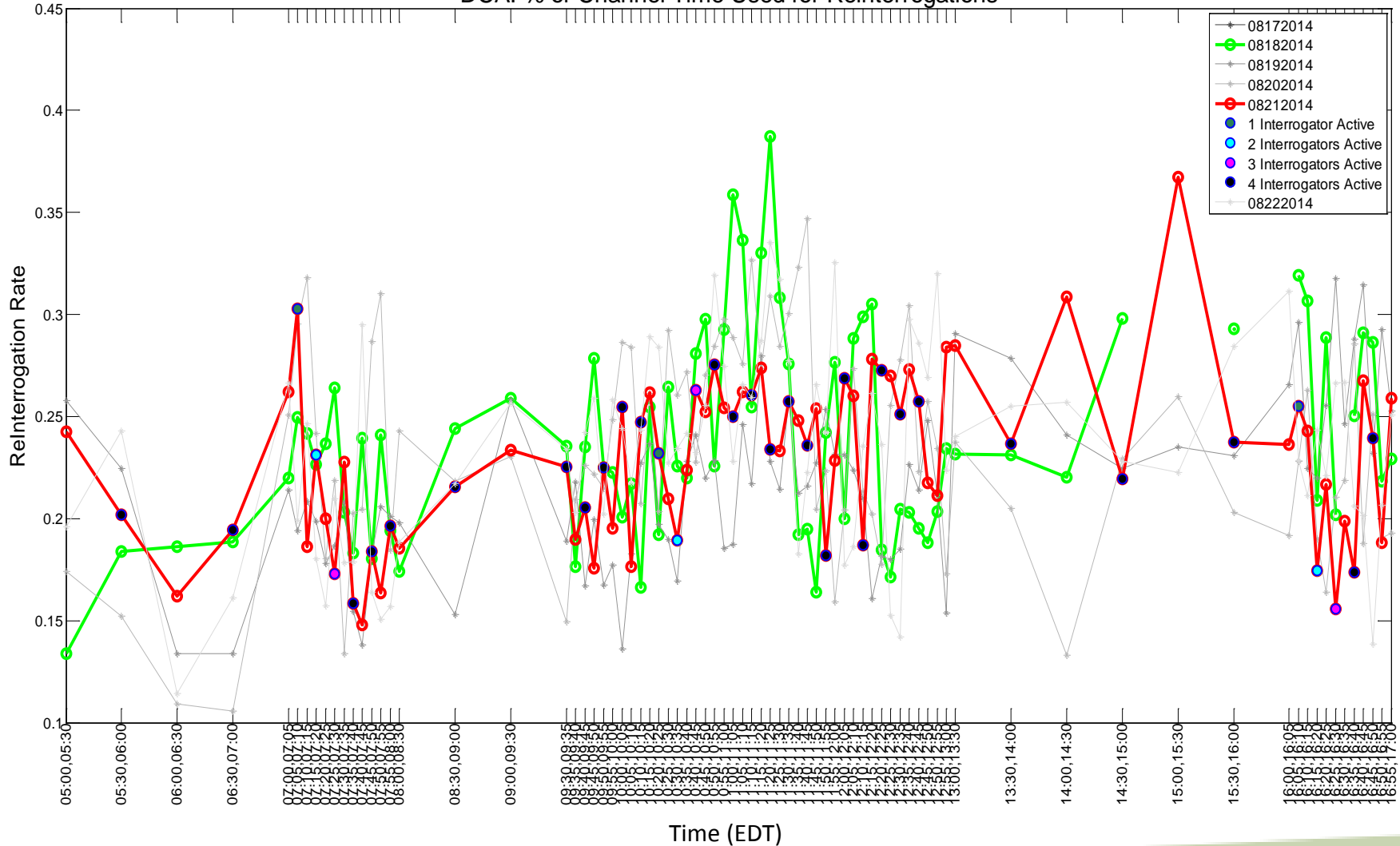


Geographic Filter: None

Target Filter: Targets > 10 NM from SSR

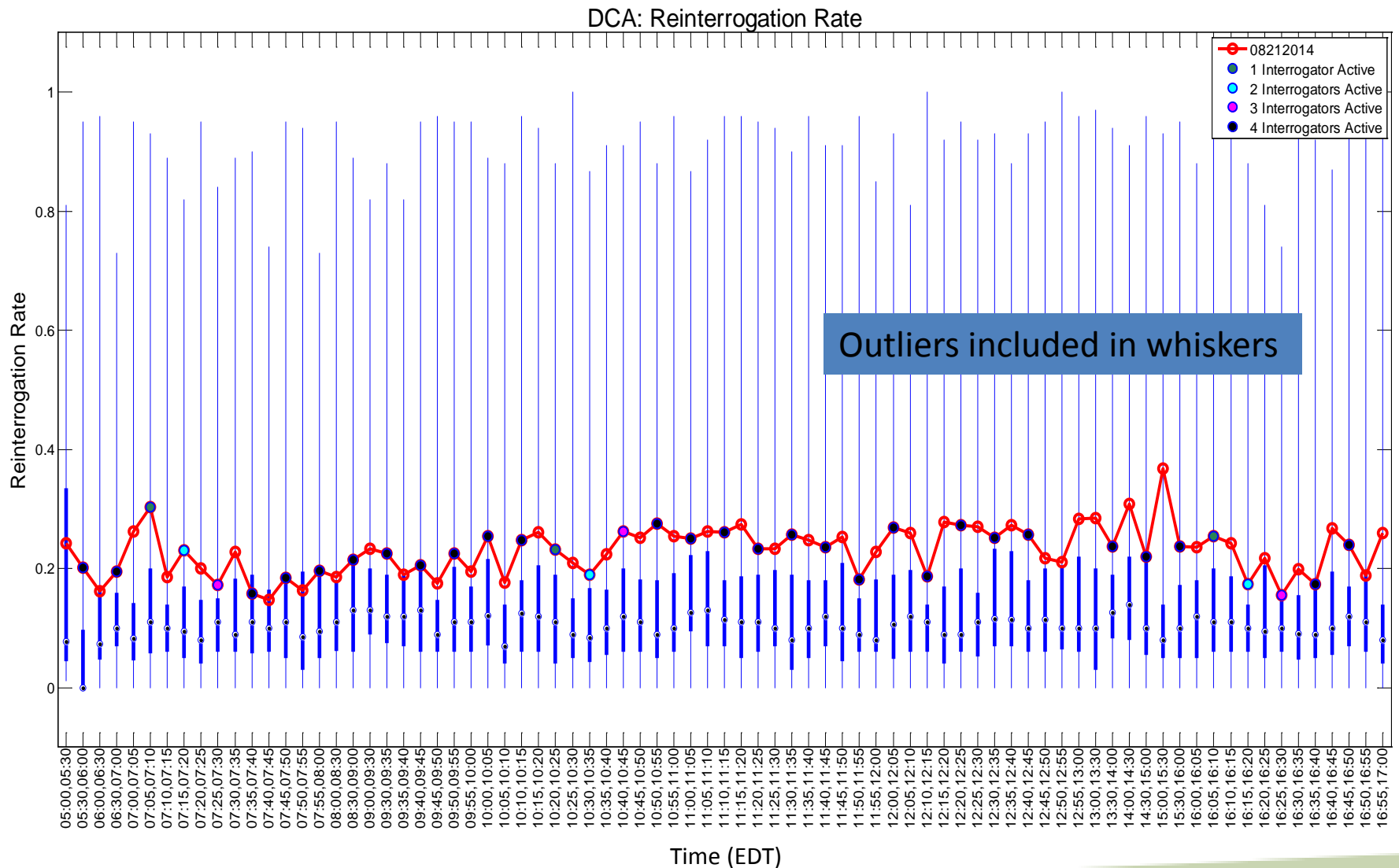
# Reinterrogation Rate – August 21<sup>st</sup>

DCA: % of Channel Time Used for Reinterrogations



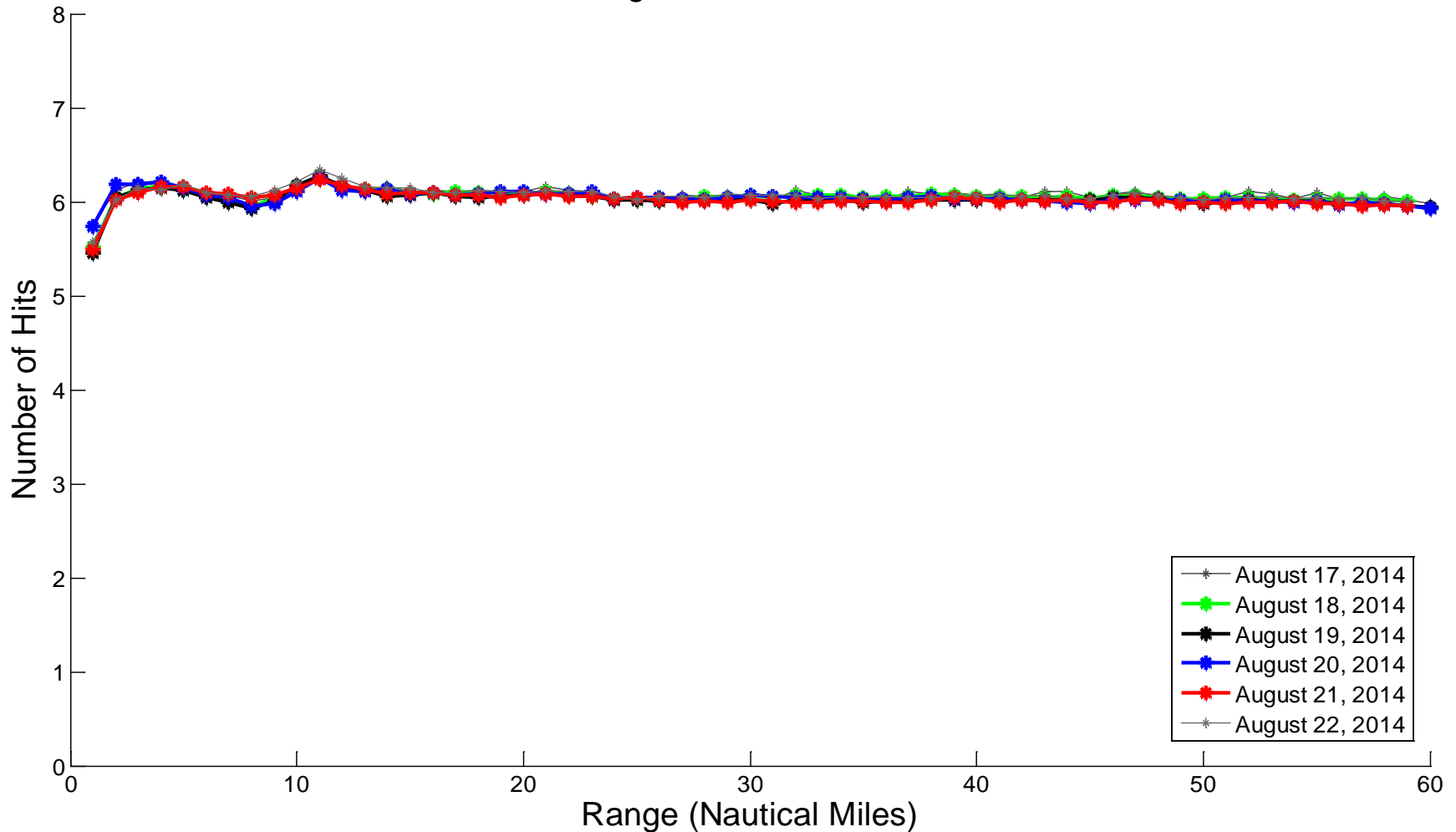
# Reinterrogation Rate – August 21<sup>st</sup>

## Individual Aircraft Distribution



# ATCRBS Number of Hits vs Range – All Days

DCA: Average Number of ATCRBS Hits

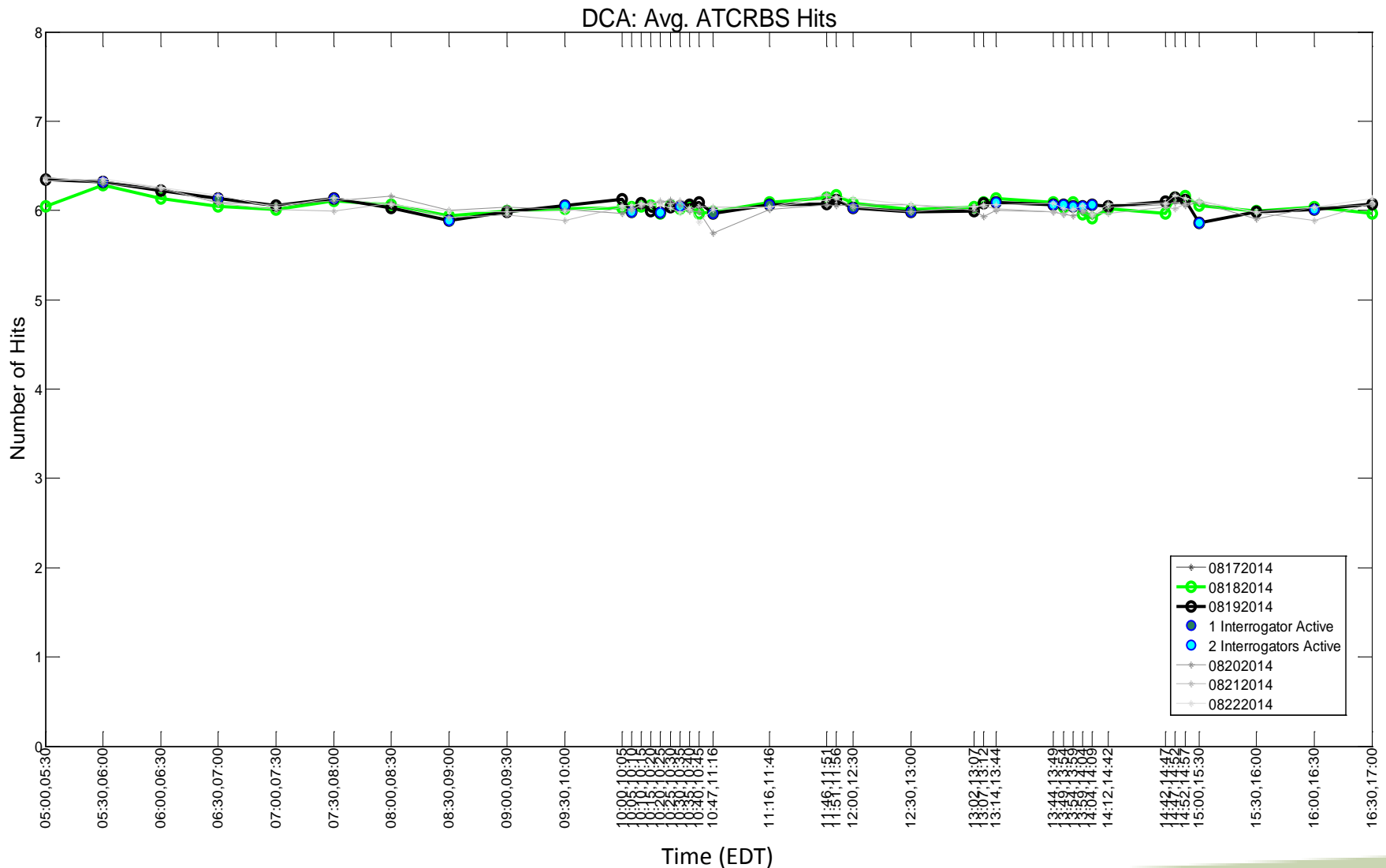


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°



# ATCRBS Number of Hits – August 19<sup>th</sup>



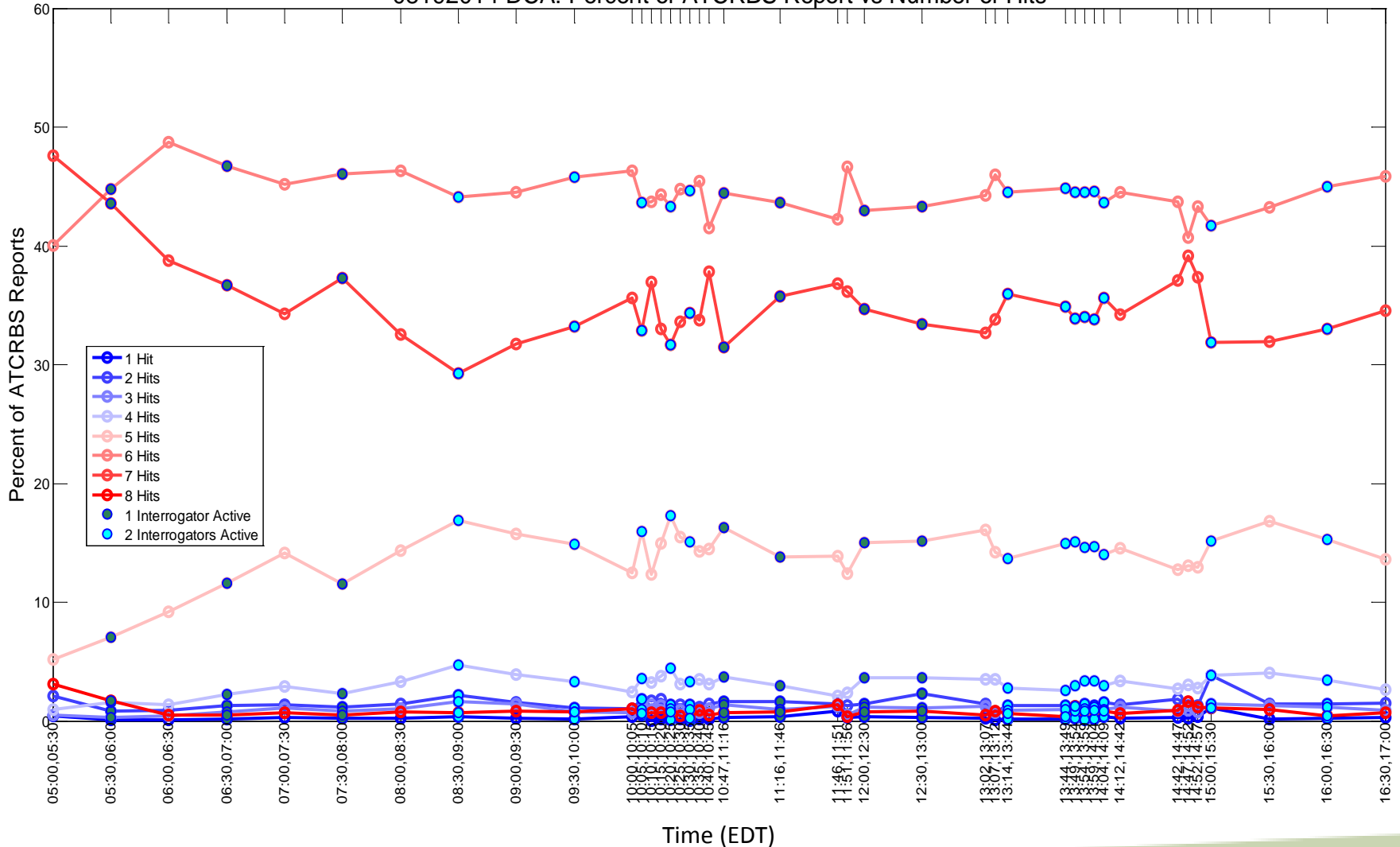
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 19<sup>th</sup>

## Number of Hits Distribution

08192014 DCA: Percent of ATCRBS Report vs Number of Hits

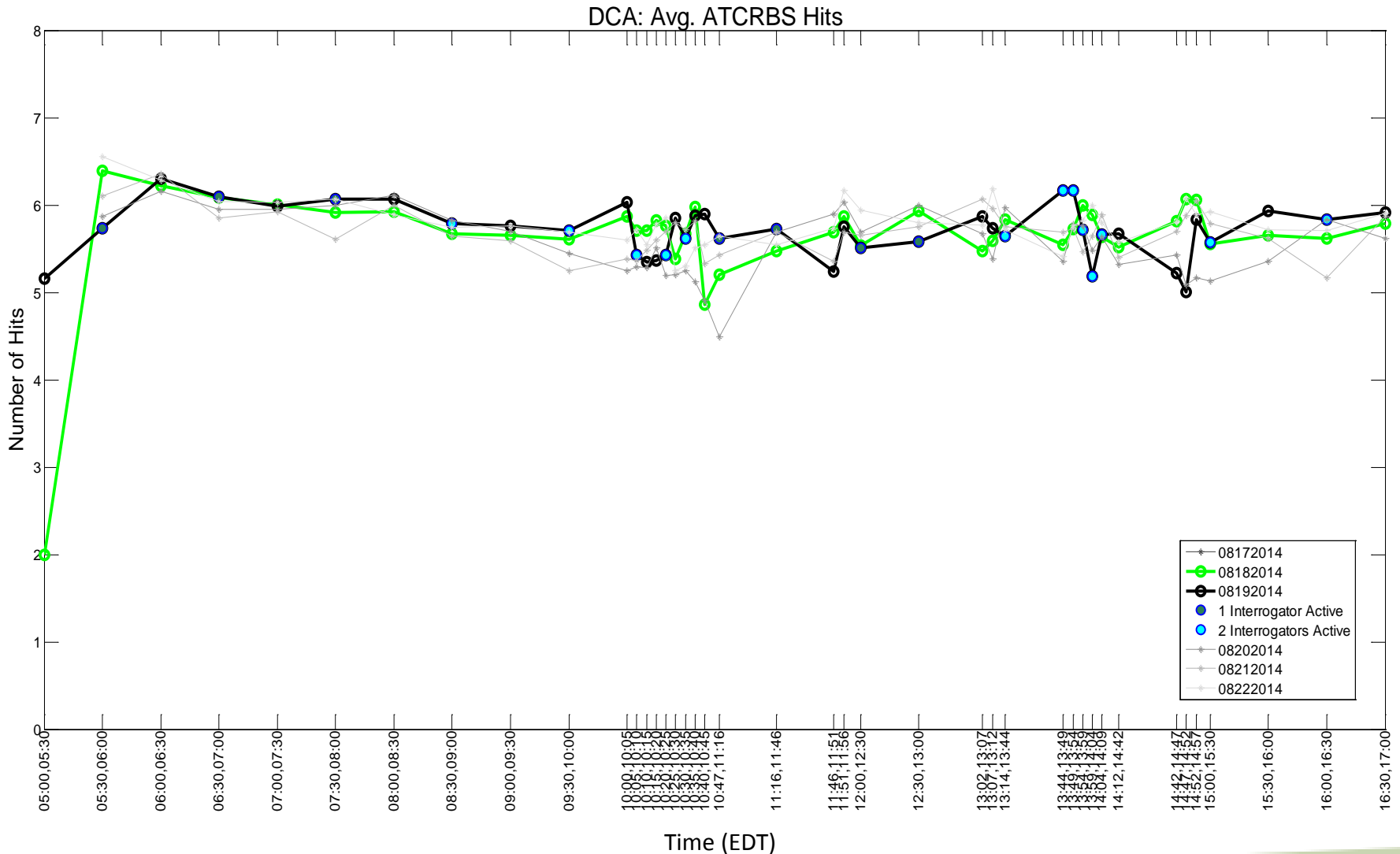


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 19<sup>th</sup>

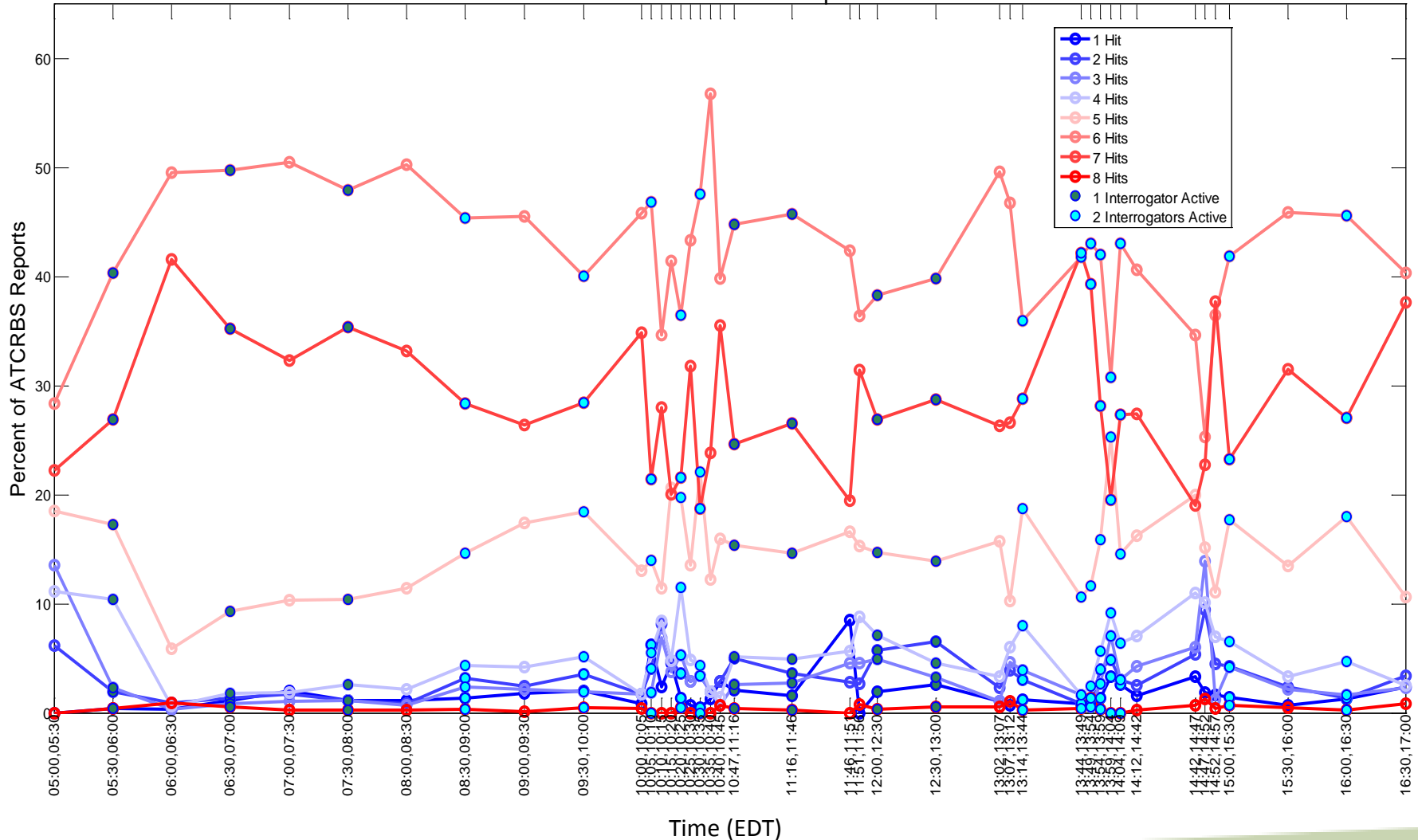
## 20 NM of AN/UPX-41(C) systems



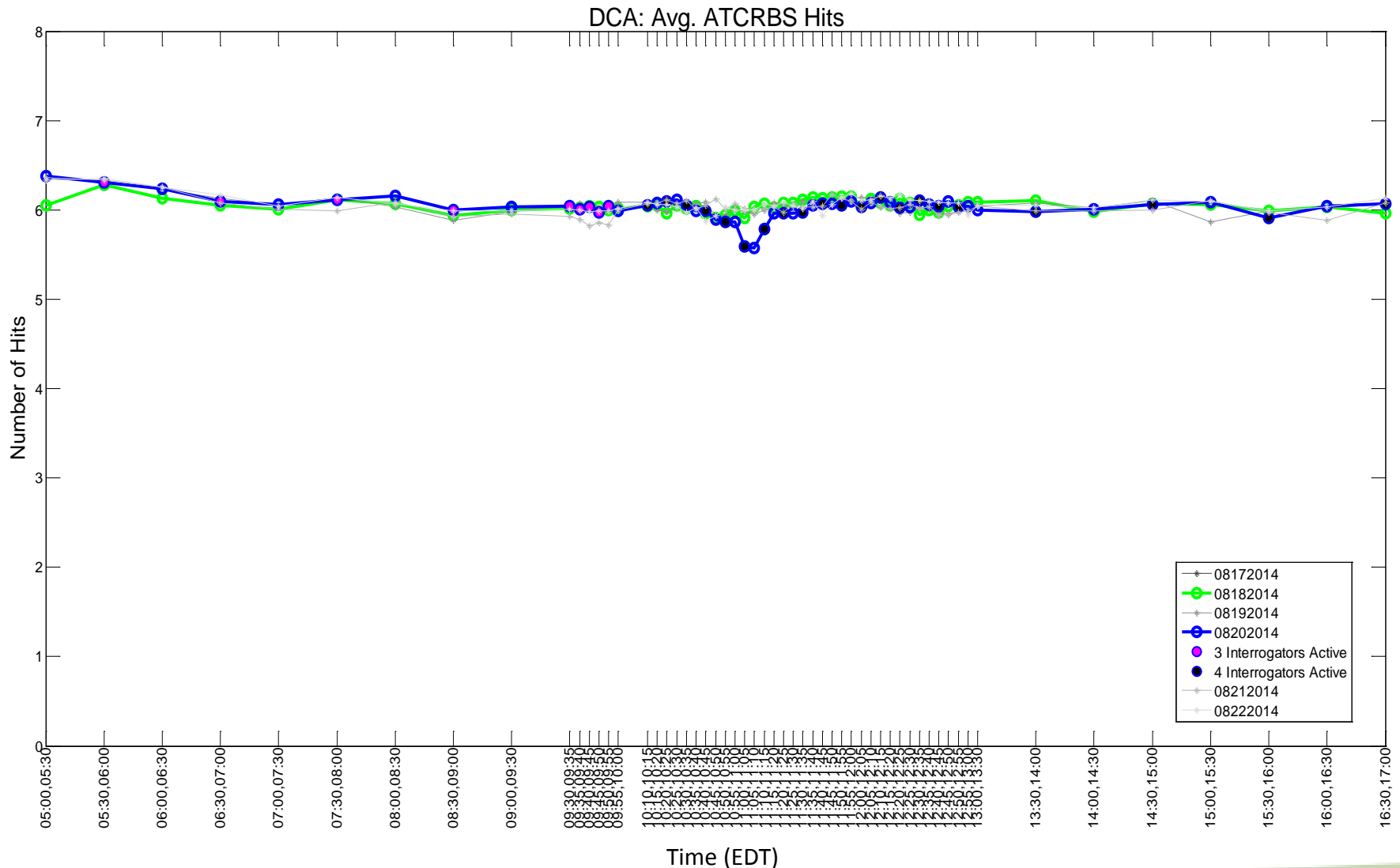
# ATCRBS Number of Hits – August 19<sup>th</sup>

## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution

08192014 DCA: Percent of ATCRBS Report vs Number of Hits



# ATCRBS Number of Hits – August 20<sup>th</sup>



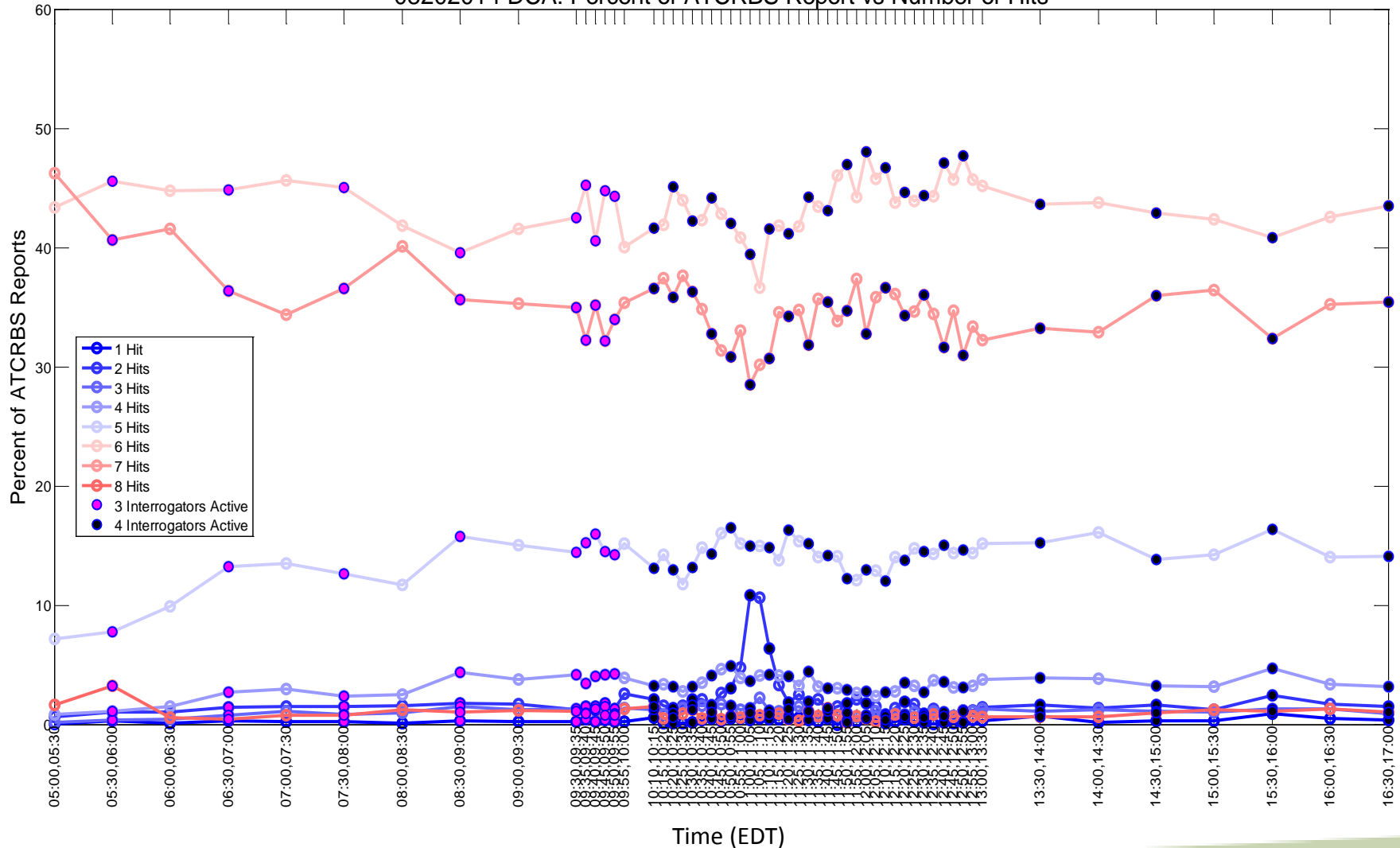
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 20<sup>th</sup>

## Number of Hits Distribution

08202014 DCA: Percent of ATCRBS Report vs Number of Hits

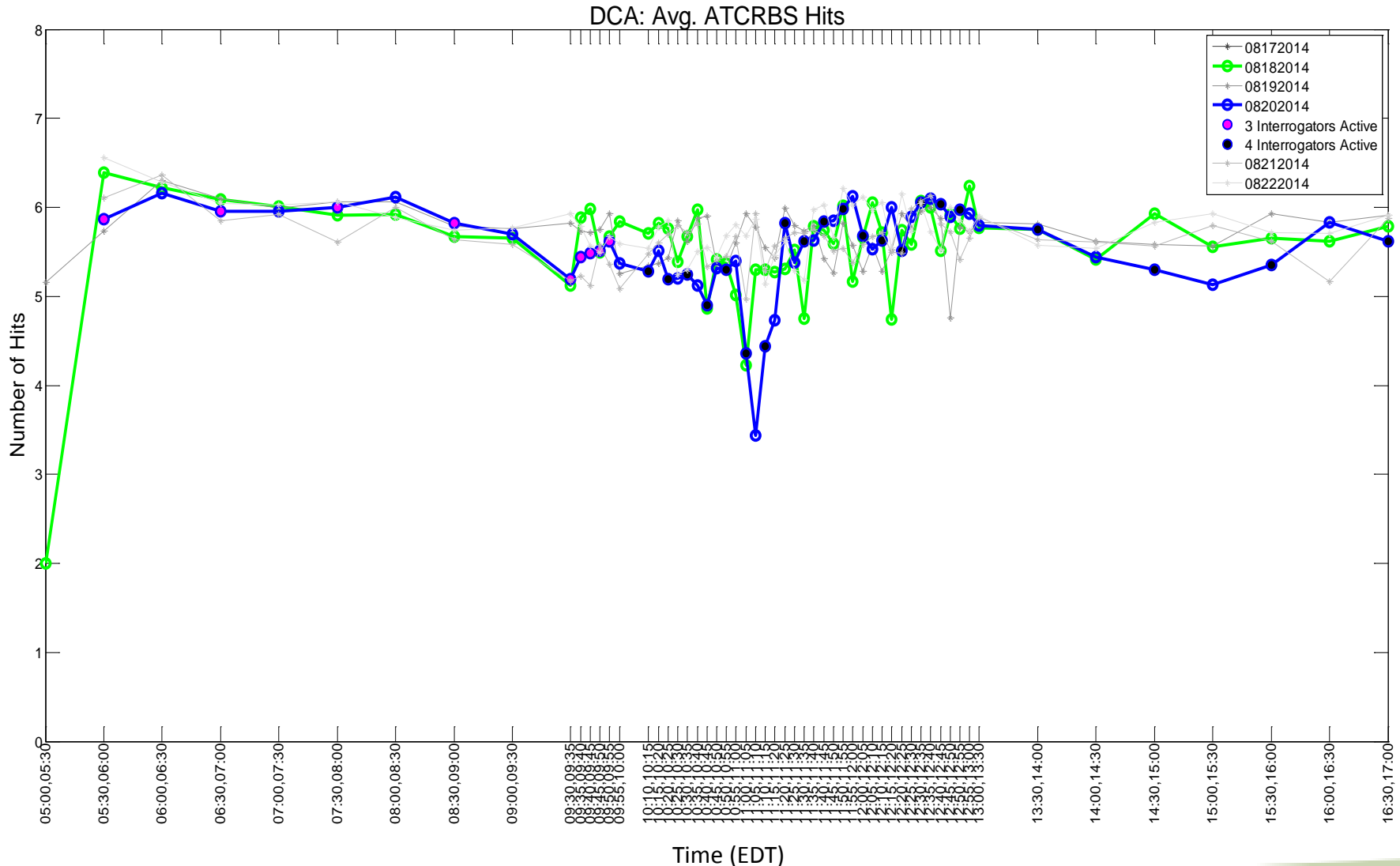


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 20<sup>th</sup>

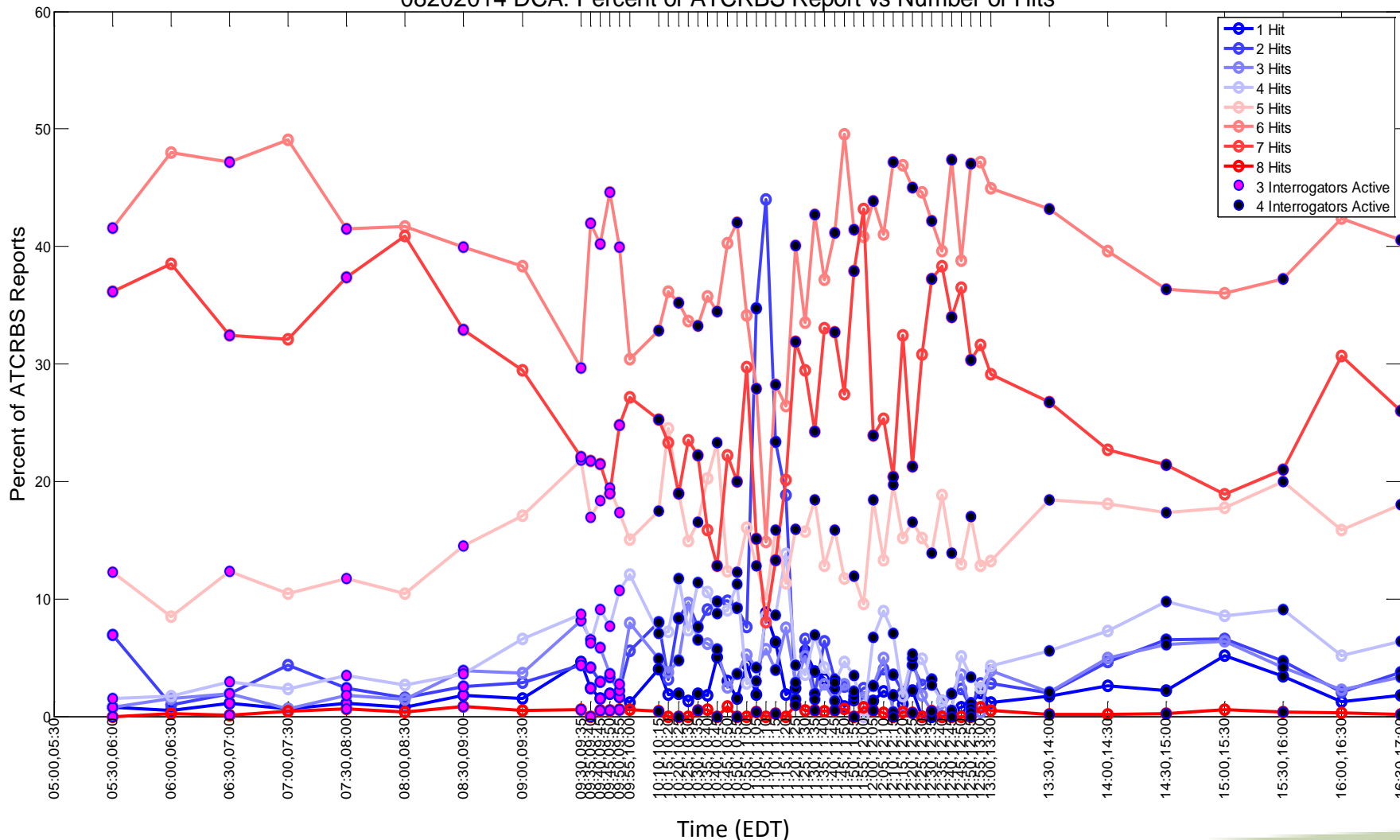
## 20 NM of AN/UPX-41(C) systems



# ATCRBS Number of Hits – August 20<sup>st</sup>

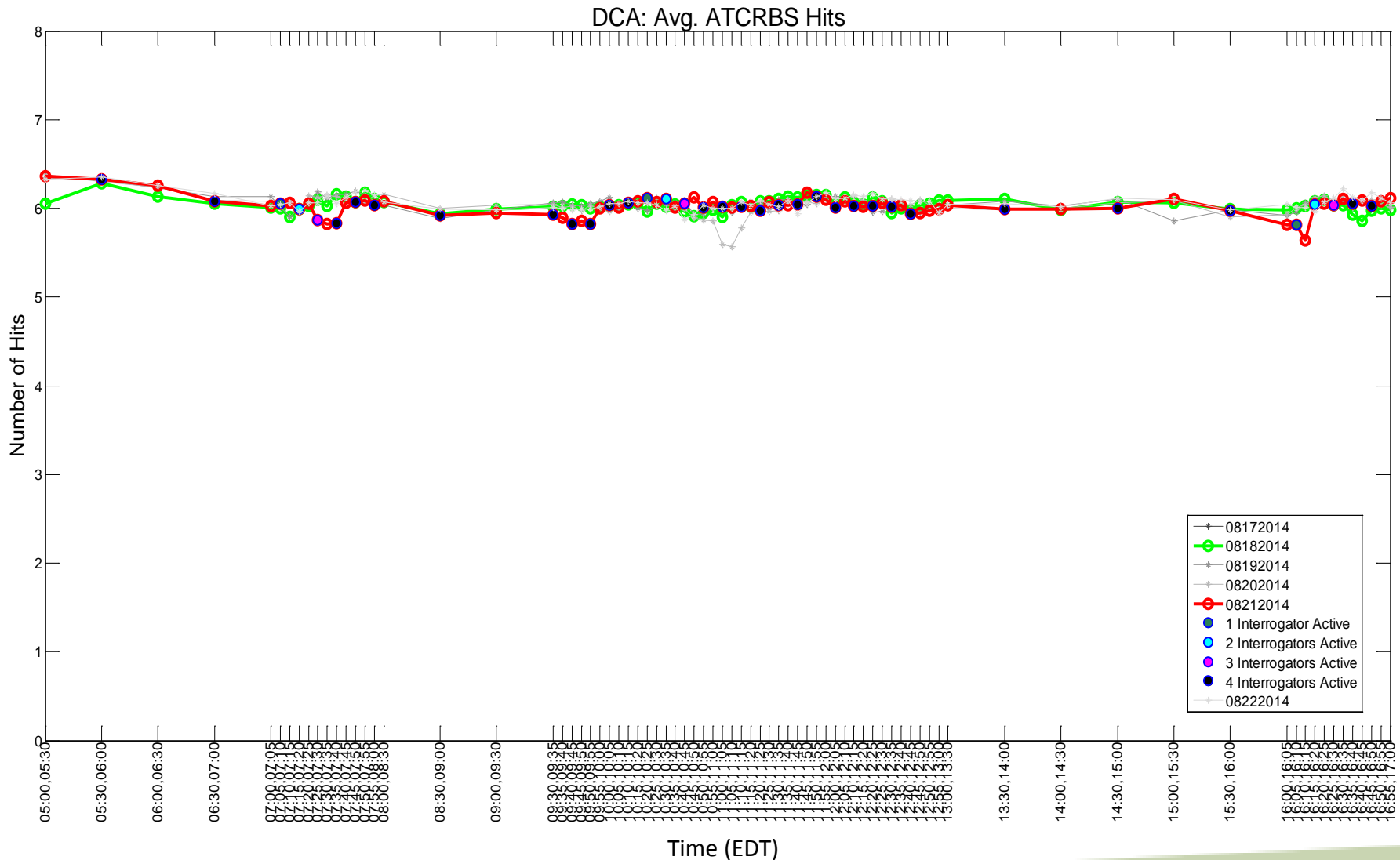
## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution

08202014 DCA: Percent of ATCRBS Report vs Number of Hits





# ATCRBS Number of Hits – August 21<sup>st</sup>



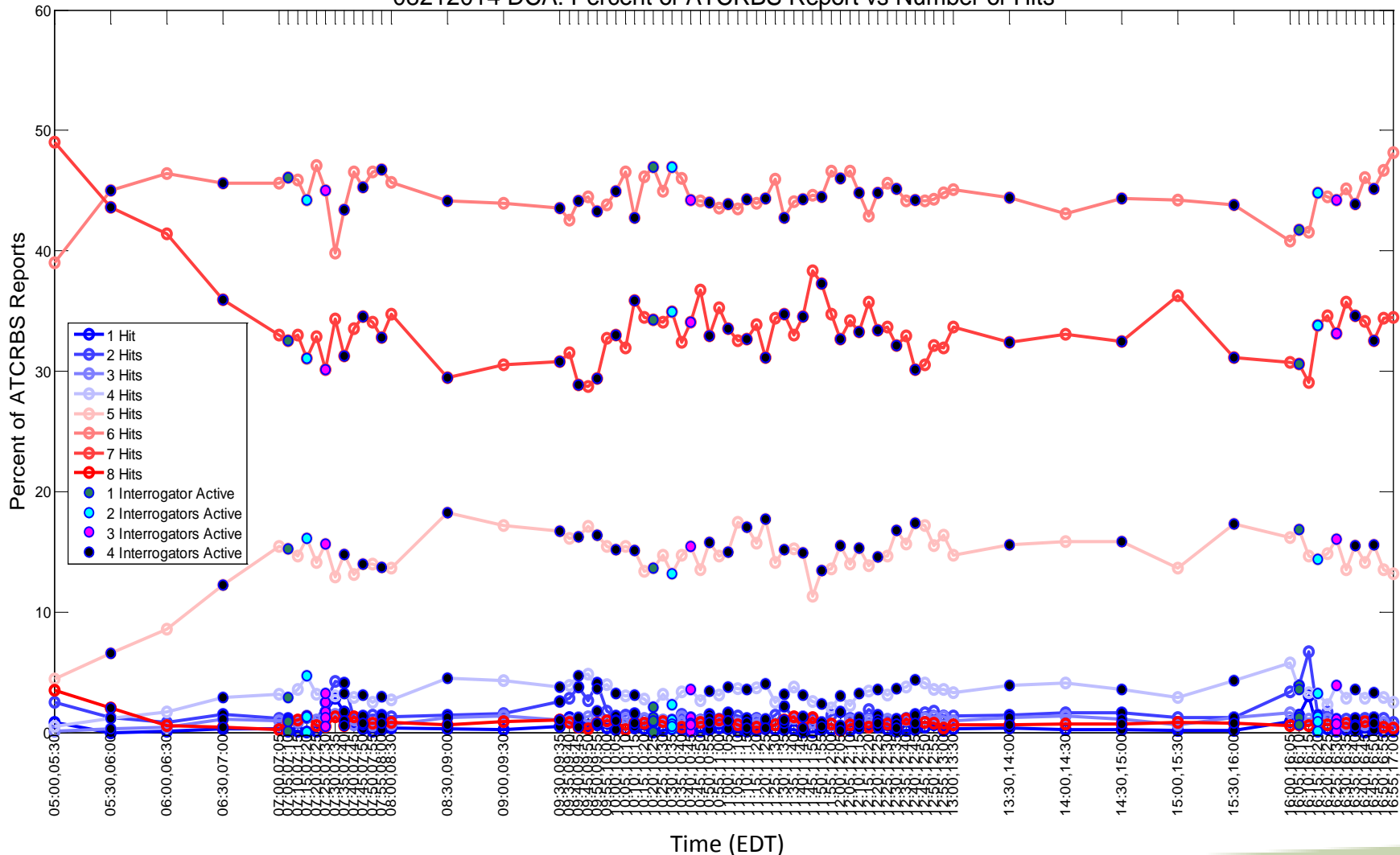
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 21<sup>st</sup>

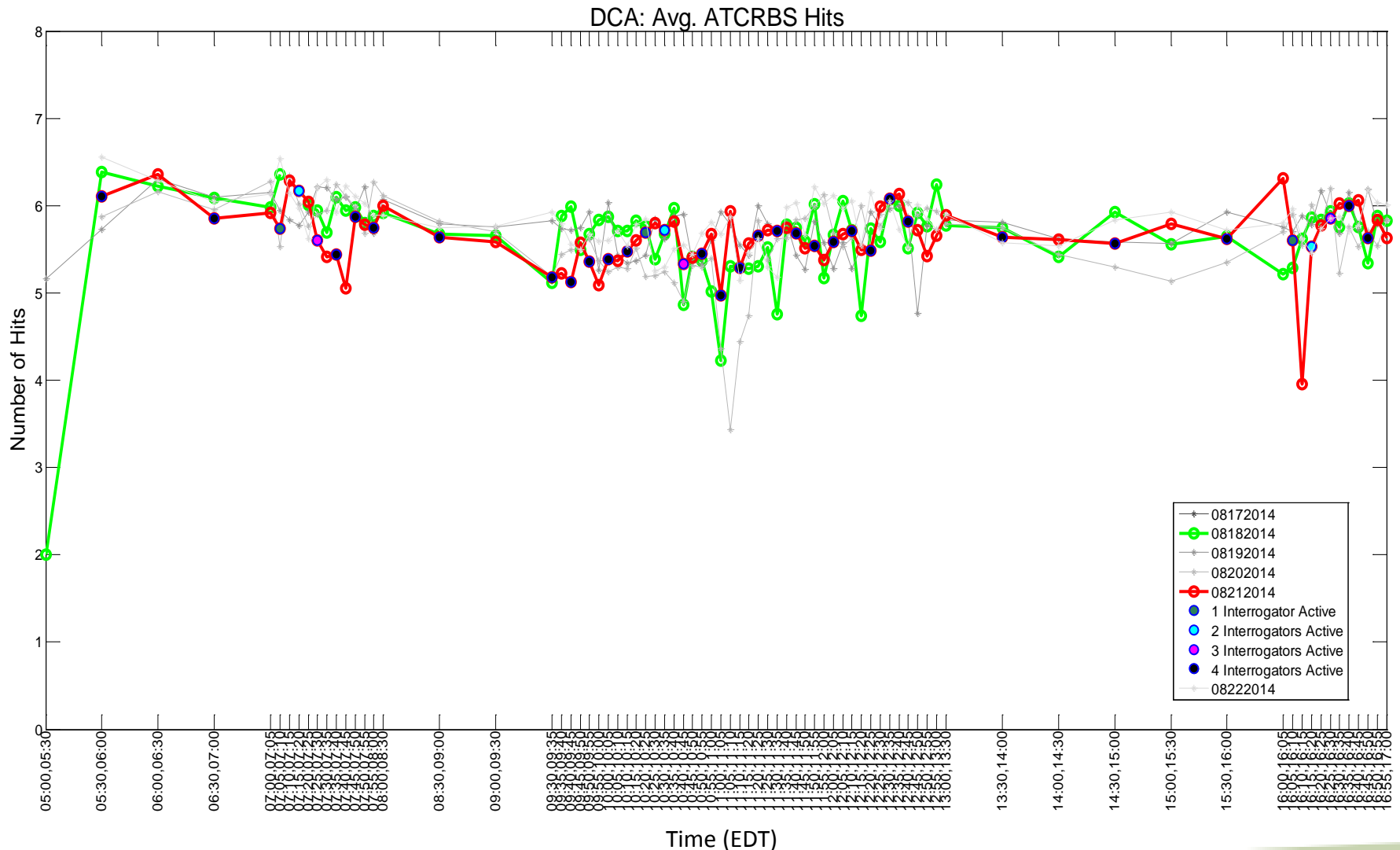
## Number of Hits Distribution

08212014 DCA: Percent of ATCRBS Report vs Number of Hits



# ATCRBS Number of Hits – August 21<sup>st</sup>

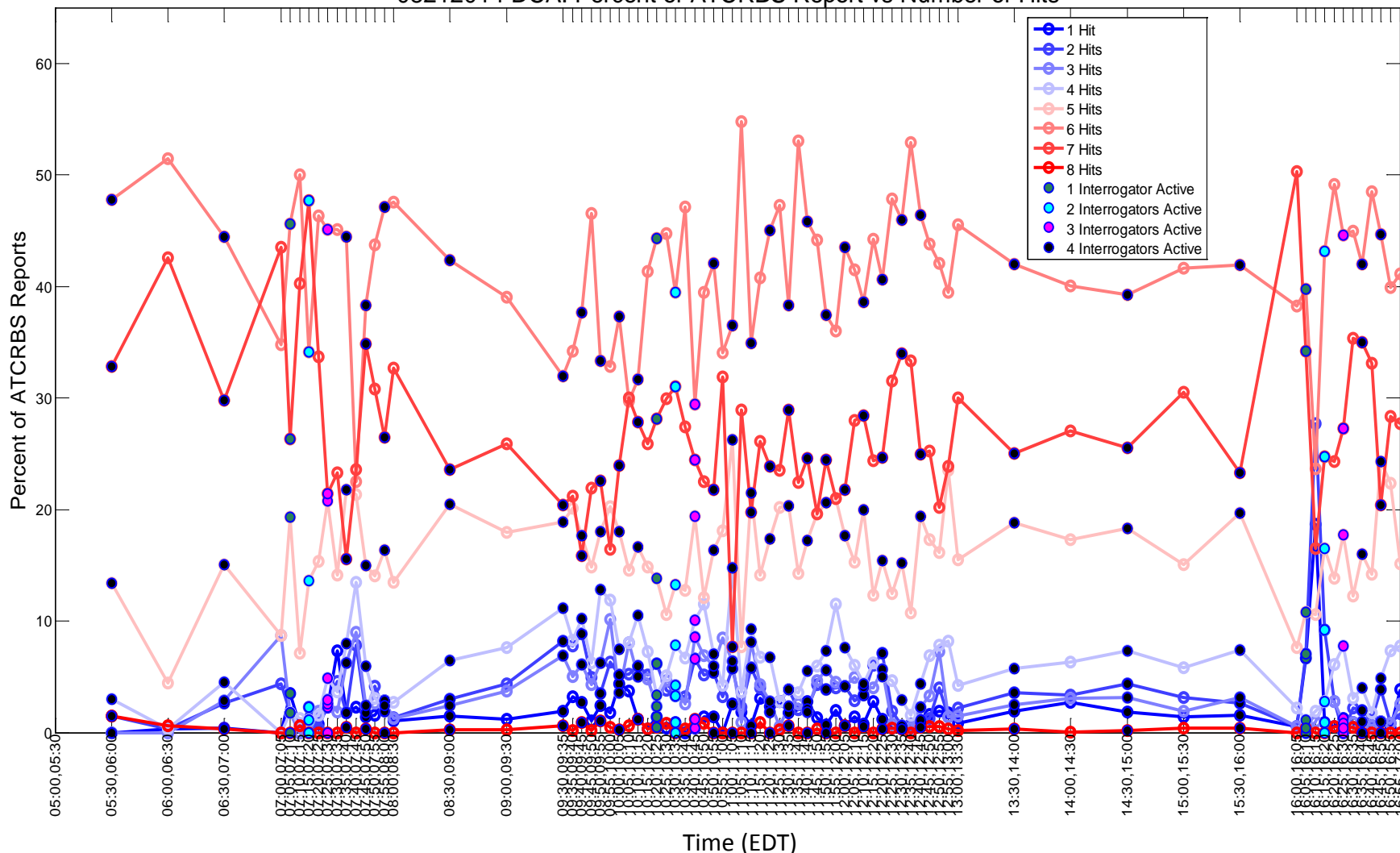
## 20 NM of AN/UPX-41(C) systems



# ATCRBS Number of Hits – August 21<sup>st</sup>

## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution

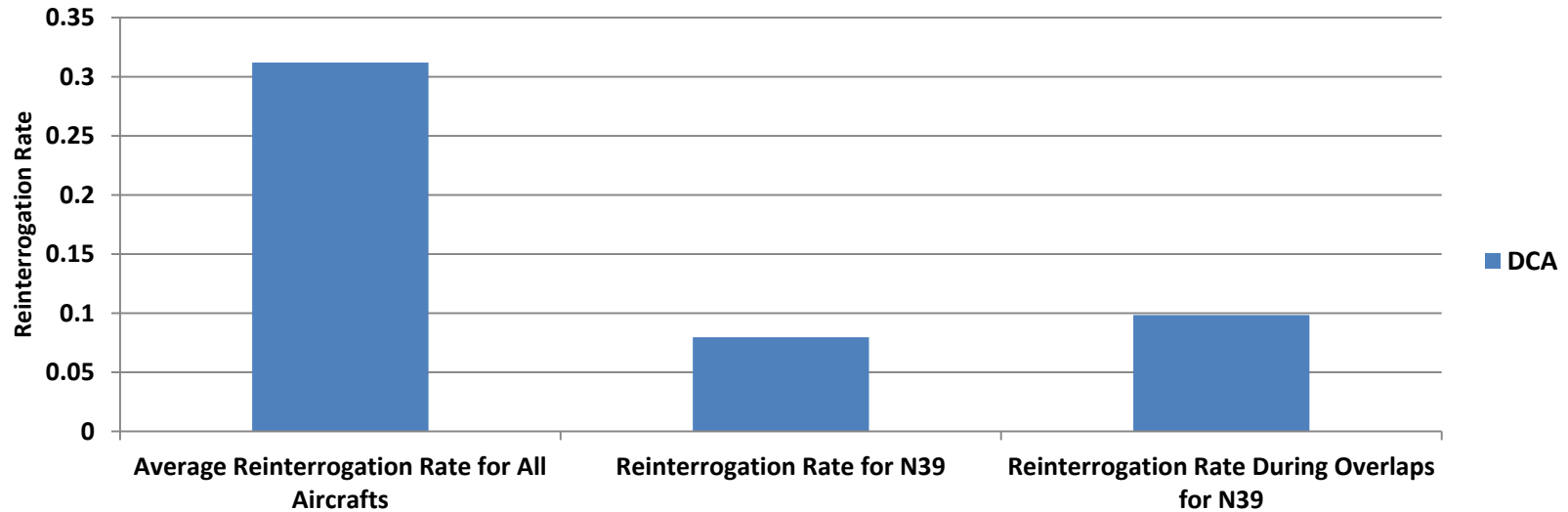
08212014 DCA: Percent of ATCRBS Report vs Number of Hits



# N39 Statistics

# N39 Reinterrogation Rate – August 20<sup>th</sup>

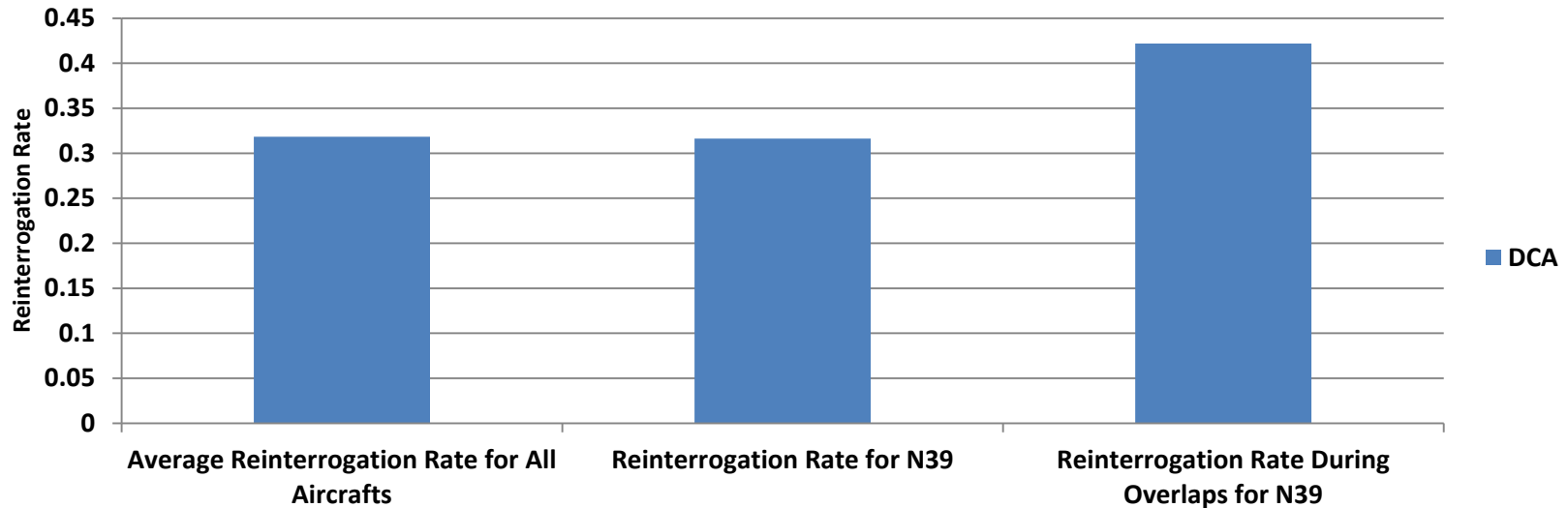
August 20, 2014



- Reinterrogation rate for N39 is lower than average reinterrogation rate for all aircrafts.
- Reinterrogation rate during overlaps of DCA and AN/UPX-41(C) mainbeams is about the same as when there are no overlaps.

# N39 Reinterrogation Rate – August 21<sup>th</sup>

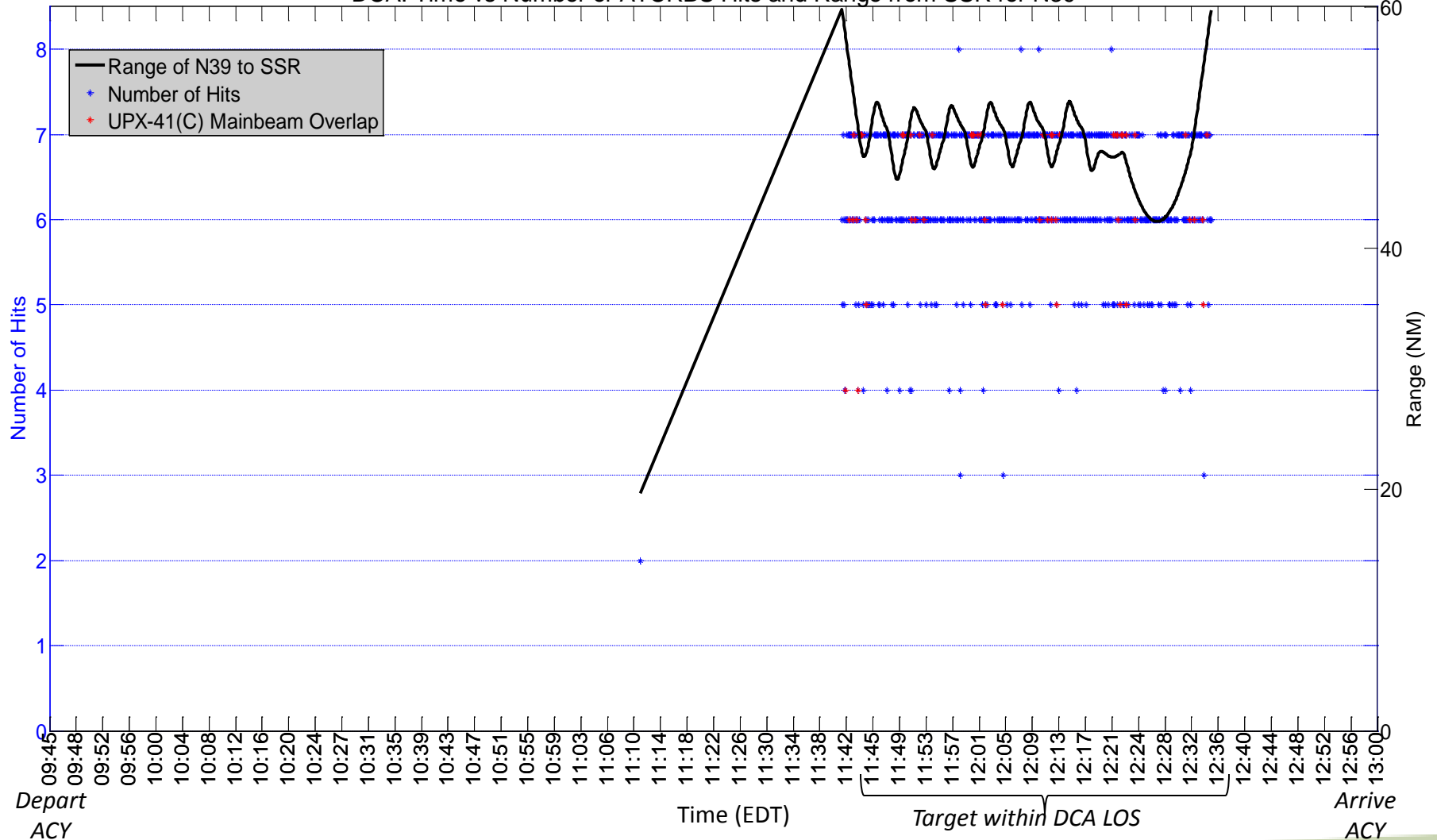
August 21, 2014



- ❑ Reinterrogation rate for N39 is about the same as the average reinterrogation rate for all aircrafts.

# Time vs Range and Number of ATCRBS Hits on N39 – August 20<sup>th</sup>

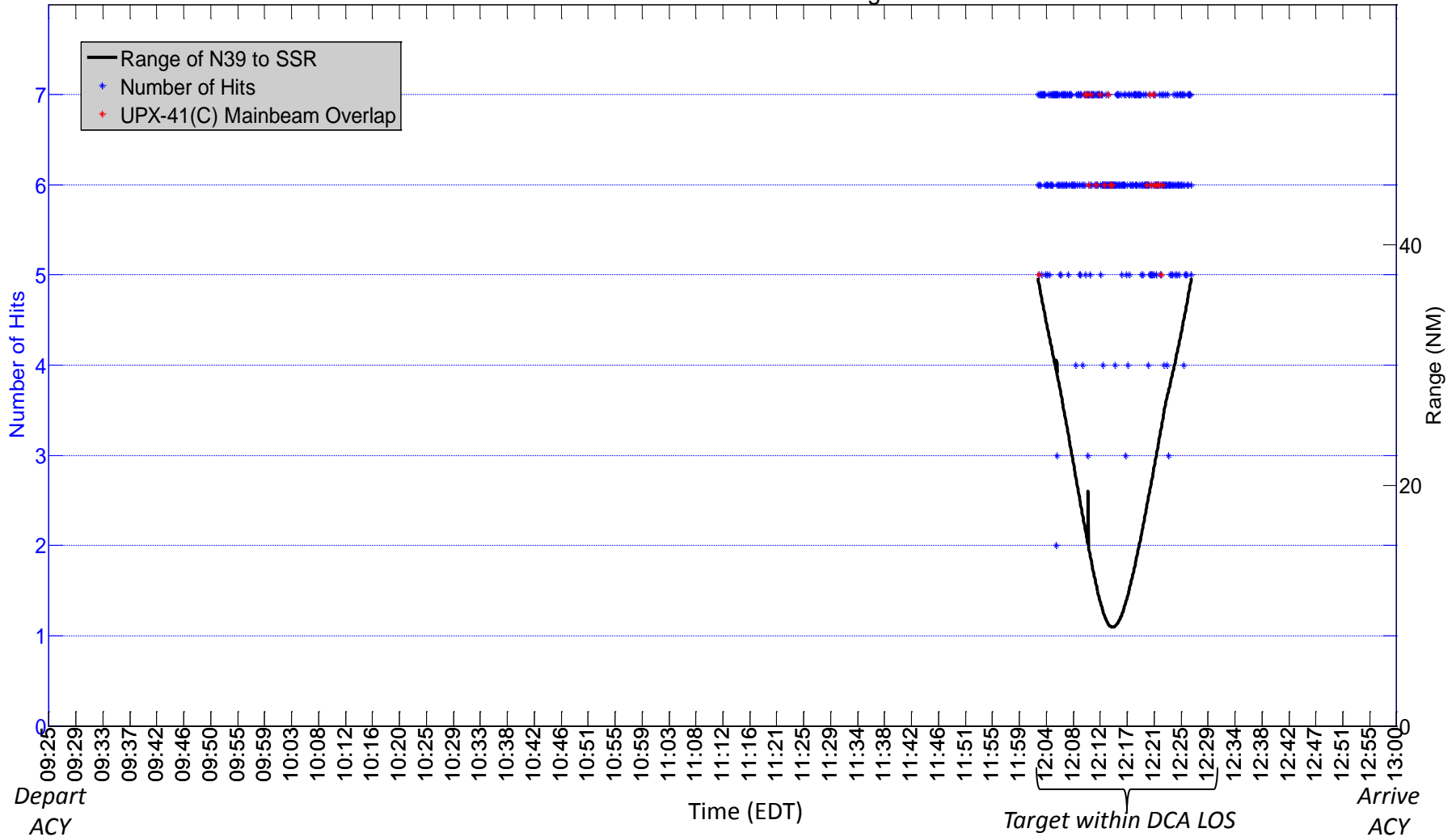
DCA: Time vs Number of ATCRBS Hits and Range from SSR for N39





# Time vs Range and Number of ATCRBS Hits on N39 – August 21<sup>st</sup>

DCA: Time vs Number of ATCRBS Hits and Range from SSR for N39



# Observations and Conclusions

- ❑ Beyond 10 NM, where reinterrogation rates are not artificially high due to tracker predictor performance, changes in target reinterrogation rate average and distribution show no correlation with times when the AN/UPX-41(C) interrogators were active.
- ❑ When reinterrogation rates are compared with days when no AN/UPX-41(C) interrogators were active, the average shows no departure from the normal performance of the Mode S sensor.
- ❑ Similarly, ATCRBS hit count averages and distribution changes show no correlation with AN/UPX-41(C) active periods.
  - The one exception is August 21 when about 80% of the active periods showed a drop in percent of aircraft with hit count equal to six.
  - However, examination of the same day for the other three Mode S sites does not show this trend.

# Observations and Conclusions (cont'd)

- ❑ The Mode S data extraction files are the only ground sensor recorded data at the interrogation and reply level.
  - Degradation will begin here before it flows up to the track level (i.e.  $P_d$ , Conf., Rel.).
  - Hence, this analysis gives the clearest picture of spectrum interference that material affects the SSR surveillance environment.
- ❑ With virtually no observable change in reinterrogation rate and ATCRBS hit count, it is difficult to use this data to predict how more AN/UPX-41(C) interrogators, beyond the Stage 4 certification, would change the surveillance environment.
- ❑ Yet, by virtue of the fact that no change was observed at the interrogation and reply level, the Stage 4 certification restrictions are more than sufficient to protect FAA SSRs and relaxation of those restrictions should be considered to help the Navy meet its operational goals.



# Background

- ❑ The AN/UPX-41(C)\* Stage-4 operational transmit certification for AEGIS-Class ships was signed by NTIA on June 22, 2012 with geographic and platform number restrictions when operating in proximity to the NAS.<sup>†</sup>
- ❑ Additionally, the Stage-4 certification contained a requirement for a joint FAA-Navy test to validate the operational restrictions.
- ❑ The Volpe Center, in conjunction with the Navy, FAA Spectrum, and FAA aeronautical surveillance and collision avoidance systems (ASCAS) SMEs created a test plan to validate the operational restrictions.
- ❑ From August 18-21, 2014 the FAA and Navy conducted the above-mentioned joint test, under the management of the Volpe Center.
- ❑ Since the test, the Volpe Center has analyzed recorded data to look for instances of harmful interference that would affect ASCAS system performance.

\*AN/UPX-41(C) Digital Interrogator System when operated in conjunction with the OE-120 antenna, the AN/UPX-29(V) Identification Friend or Foe (IFF) system, and the AN/UPX-24 software interface Version 2.1.2, controlled by the Cooperative Engagement Capability (CEC), in Naval surface vessels

<sup>†</sup>See SPS-18778\_1 Navy AN-UPX-41 V5.5 St4

# Test Plan Refresher

## □ Baseline week: August 11<sup>th</sup> – 15<sup>th</sup>

- Baseline recording of data from 5 AM – 5 PM
  - No AN/UPX-41(C) systems Active

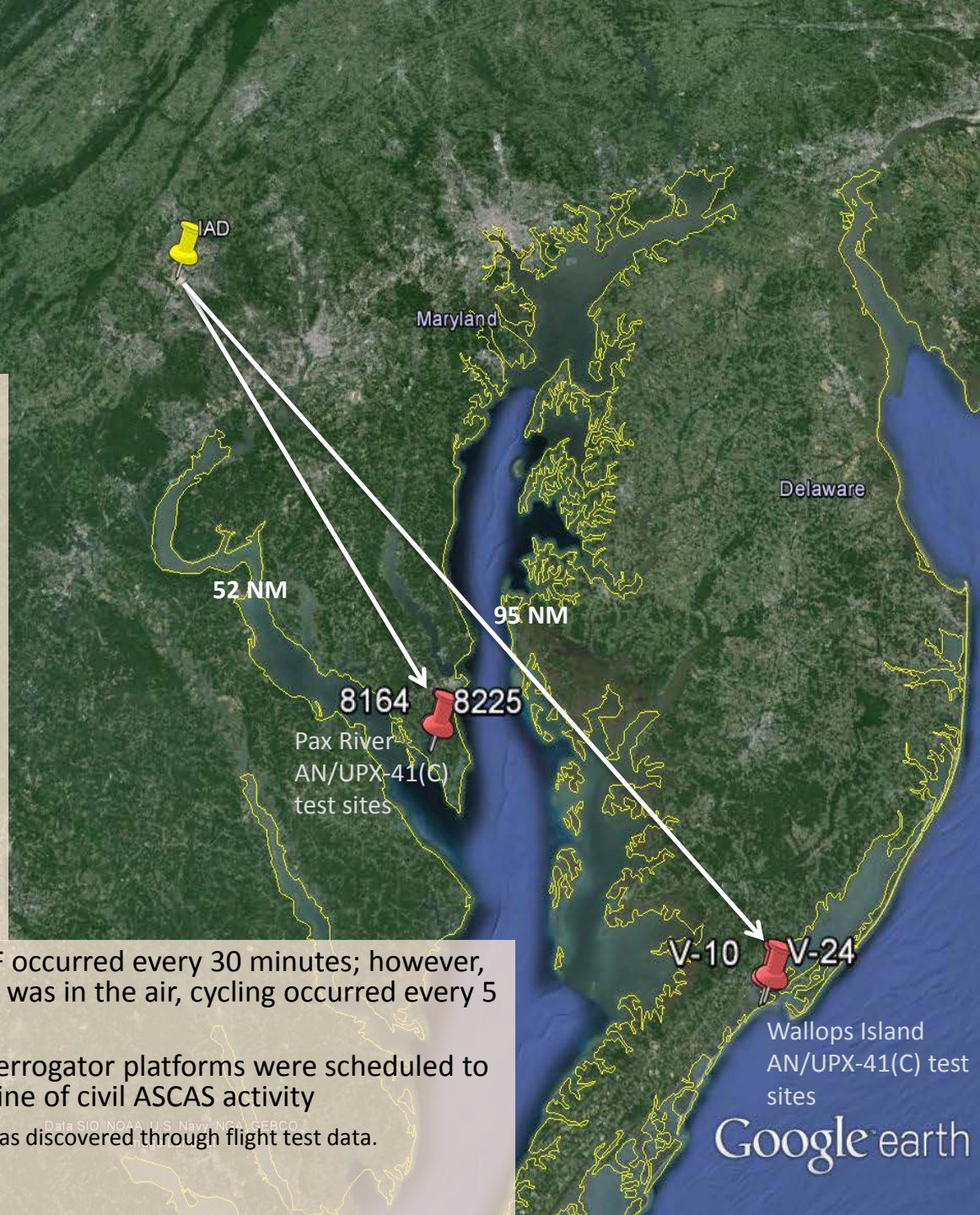
## □ Test week: August 18<sup>th</sup> – 21<sup>st</sup>

- August 18<sup>th</sup> – Baseline recording of data from 5 AM – 5 PM
  - No AN/UPX-41(C) systems Active
- August 19<sup>th</sup> – Record data from 5 AM – 5 PM
  - Cycle 1 and 2 AN/UPX-41(C) systems Active and OFF
- August 20<sup>th</sup> – Record data from 5 AM – 5 PM
  - Cycle 3 and 4 AN/UPX-41(C) systems Active and OFF
- August 21<sup>st</sup> – Record data from 5 AM – 5 PM
  - Cycle 1, 2, 3, and 4 AN/UPX-41(C) systems Active and OFF

- Cycling of AN/UPX-41(C) systems Active/OFF occurred every 30 minutes; however, if N39 (Tech Center signal recording aircraft) was in the air, cycling occurred every 5 minutes

- During the test week, non-essential DoD interrogator platforms were scheduled to be inactive in order to get an accurate baseline of civil ASCAS activity

- This did not occur. Non-test platform radiation was discovered through flight test data.



# Data Recording

- ❑ During the August test, Enroute Common Gateway (ECG) data was recorded at the Tech Center from the IAD site.
- ❑ The Radar Beacon Analysis Tool (RBAT) was used to analyze ECG data to produce statistics for the following list of parameters:
  - Targets per Scan
  - Probability of Detection
  - Identity Reliability
  - Identity Confidence
  - Altitude Reliability
  - Altitude Confidence
  - False Target Percentage
  - 0000 Code Percentage
- ❑ Mode S system version D22020 was used to record data extraction files by Mode S SSR technicians at the SSR Site.
- ❑ Mode S Analysis Tool (MSAT) was used to analyze extraction files to produce statistics for the following list of parameters:
  - FRUIT Rates
  - Interrogation/Reinterrogation Rates
  - ATCRBS Hit count statistics

# Data Analysis

- ❑ Applied time bins that corresponded to the AN/UPX-41(C) Active/OFF periods from test days (August 19<sup>th</sup>-21<sup>st</sup>) to baseline days to produce baseline statistics for all parameters
- ❑ Processed RBAT data through Surveillance Analysis, Scan Summary, and Beacon False Target Summary programs to find parameters of interest for each time bin without geographic or target filters
- ❑ Processed MSAT data through Channel Management Statistics and FRUIT Analysis programs to find parameters of interest for each time bin
  - 1) No geographic or target filters
  - 2) >10 NM filter
- ❑ Produced interrogation, reinterrogation, and hit count statistics for the Tech Center Aircraft (N39) as it flew within the SSRs LOS
  - Focused on possible interference during mainbeam overlap with V10, 8164, and 8225 sites



# Analysis Limitations

- ❑ The theoretical or textbook definition of probability of detection is a function of interrogation/reply round reliability.
- ❑ However, probability of detection in RBAT is the percentage of target updates versus total number of beam dwells over all targets.
- ❑ Therefore, the ability for probability of detection calculated by RBAT to properly represent theoretical probability of detection is minimized as the sample size decreases (either through geographical or time constraints) since it no longer reliably reflects the target population mean.
- ❑ Example: A target population of two where both targets miss one update out of ten scans (approximately 50 seconds) results in a probability of detection of 90%. While this is unacceptable by QARS blip/scan minimums, we have no knowledge of the updates that occurred outside of the given time constraint . If both targets received ten out of ten updates for the previous as well as the next 10 scans, the probability of detection is now 96.7%.

# Mode S Data Extraction Issues

- ❑ Noticed series of messages displayed by MSAT : Interrogation does not match frame table
  - The interrogation type does not match the expected type from the frame table or the time difference is more than 16 USECs
  - 02:34:23.445
  - Frame table not synched with actual periods
  - Try filtering the data starting at a later time or rerun the data
- ❑ After talking with Jim Davis, it was found that these errors occurred when CMS was unable to synchronize the interrogation data with the expected interrogation types from frame table and/or it was not able to maintain synchronization once it was achieved.
  - CMS was unable to synchronize due to interrogation data missing in the beginning of the file. Starting 1-5 seconds later fixed this.
  - CMS was losing sync due to interrogation data missing at a later time in the file.
- ❑ In a single beam dwell, the Mode S sensor records the first 21 interrogations and the rest are thrown away because of data storage space limitations.
- ❑ However, the Mode S sensor does record the number of interrogations past 21 that occurred and stores that amount in a **retry overflow count** field.
- ❑ Originally, MSAT did not count interrogations past 21 because they were not recorded by the Mode S sensor. Now, MSAT has been updated to account for the missing interrogations by considering the retry overflow count as interrogations without replies.
- ❑ Example: if in a beam dwell there are 25 interrogations, the Mode S sensor will record the first 21 and the retry overflow count would be 4.

# Mode S Data Extraction Issues (cont'd)

## All call data for DCA

13:38:17.336	INT	AC	27.58	itime=3cc490	MODE_3A
13:38:17.336	INT	AC	27.64	itime=3d02b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.344	INT	AC	28.19	itime=3ebcf0	MODE_C
13:38:17.344	INT	AC	28.26	itime=3effa0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.352	INT	AC	28.78	itime=409c00	MODE_3A
13:38:17.352	INT	AC	28.85	itime=40dd10	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.359	INT	AC	29.38	itime=427b00	MODE_C
13:38:17.359	INT	AC	29.44	itime=42bb50	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.367	INT	AC	29.99	itime=445890	MODE_3A
13:38:17.367	INT	AC	30.06	itime=4499b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.375	INT	AC	30.59	itime=4639f0	MODE_C
13:38:17.484	INT	AC	39.05	itime=60a300	MODE_C
13:38:17.484	INT	AC	39.11	itime=60e350	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.492	INT	AC	39.62	itime=628090	MODE_3A
13:38:17.492	INT	AC	39.68	itime=62c1b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.500	INT	AC	40.23	itime=6461f0	MODE_C

} Data loss through  
about 8.5°

- ❑ Previous accounts of lost interrogation data at the Mode S sites was accounted for using the retry overflow count that was being reported by the Mode S sensor.
- ❑ However, as the analysis progressed, instances were found where the Mode S site was not reporting loss of data, but we can clearly see there is a loss of data (see highlighted above).
- ❑ The site did not report any missing data, but CMS produced a fatal error due to data not being present and having no record of data being lost.
- ❑ This was not discovered previously due to Probability of Detection changing ever so slightly in the absence of 8 degrees of data for a given time period. This fluctuation of probability of detection could be due to many reasons. (low elevation angle, non-compliant transponder, aircraft turning, etc.)

# Analysis Objective

- ❑ We are attempting to observe distinct patterns of change in the metrics of interest between times when the AN/UPX-41(C) systems are OFF and when they are Active.
- ❑ While geographic and time filters reduces target update sample sizes such that a small sample size itself influences the metric of interest, it is more important to focus on the change from Off to Active since both the Off and Active periods have the same constraints applied.

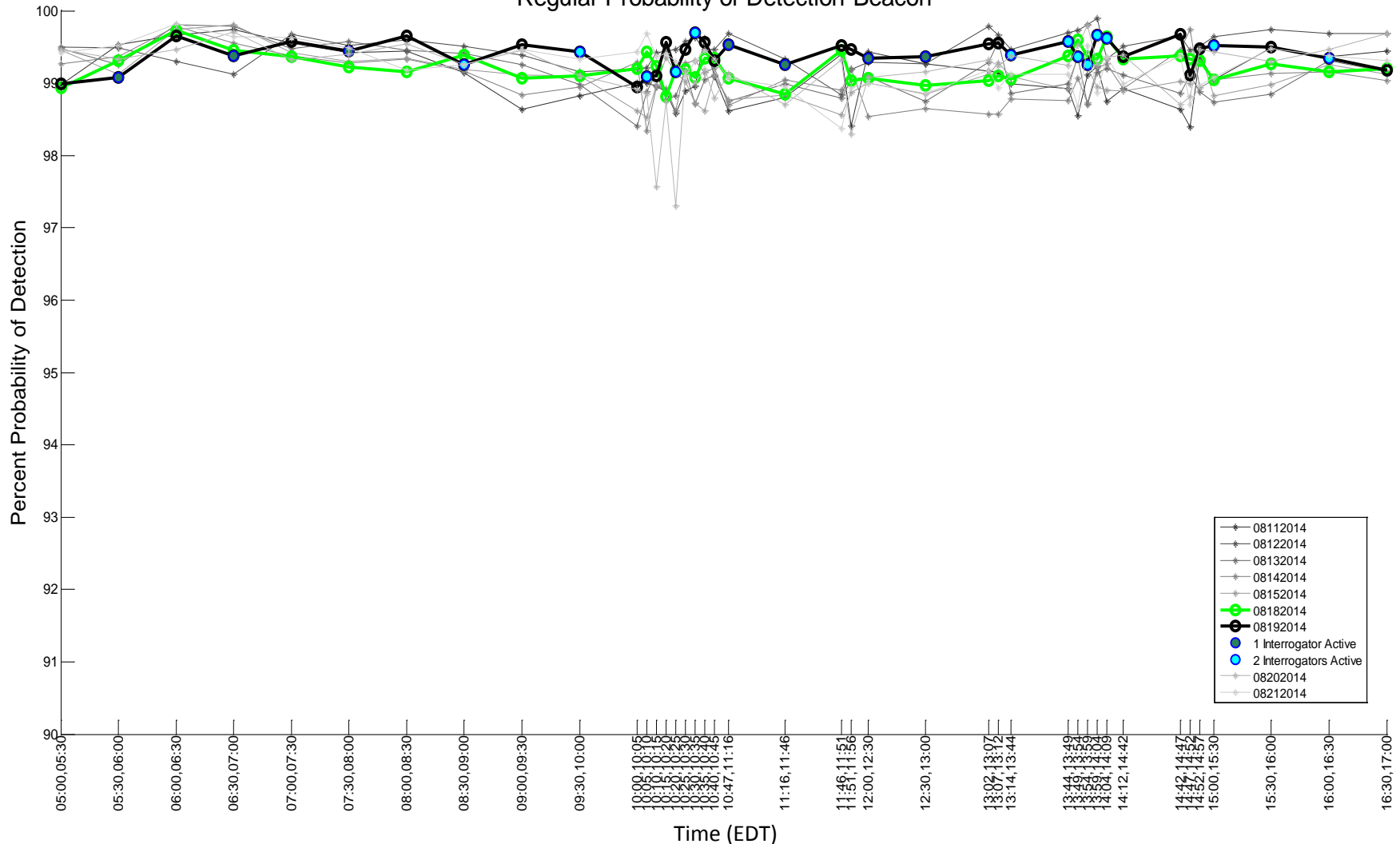
# Plot Guide

- ❑ Plots with multiple days of data utilize the time filters from the Active/Off periods for the date given in the slide's title
- ❑ Plots that use boxplots
  - The edges of the box are the 25<sup>th</sup> and 75<sup>th</sup> percentiles. The maximum whisker length represents approximately 2.7 sigma (99.3%). Points in red are shown as outliers.
    - Exception: Box plots for reinterrogation rate vs time filters have whiskers that reach to the extent of the furthest outlier.
  - For five minute time bins, there are only 65 IAD scans and, if you miss one target update,  $P_d$  will automatically drop to 98.4% (24 out of 25 possible target reports).
  - Horizontal axis 30-min and 5-min time bins are not scaled according to duration.

# Target Metrics with No Filter

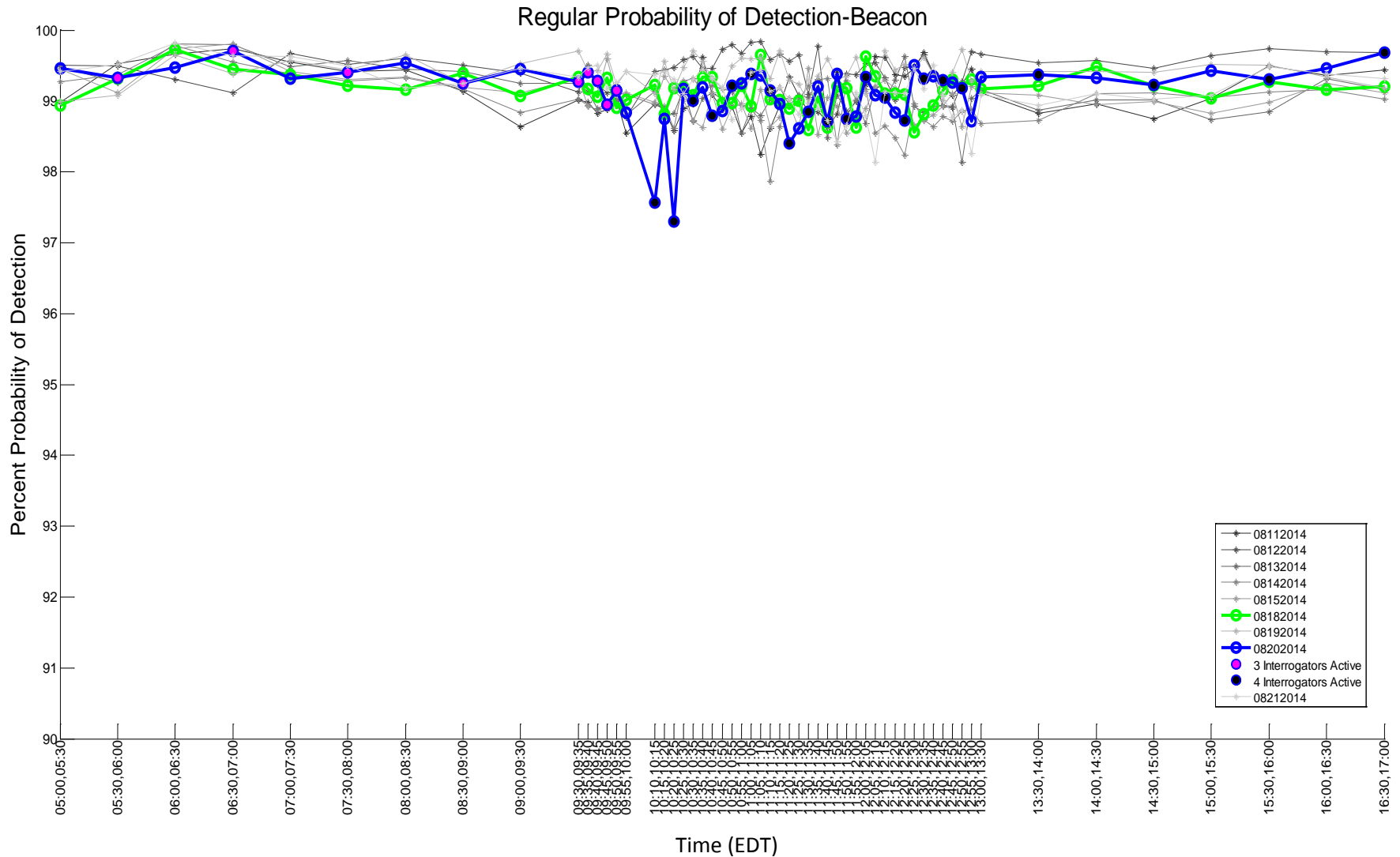
# Probability of Detection – August 19<sup>th</sup>

Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

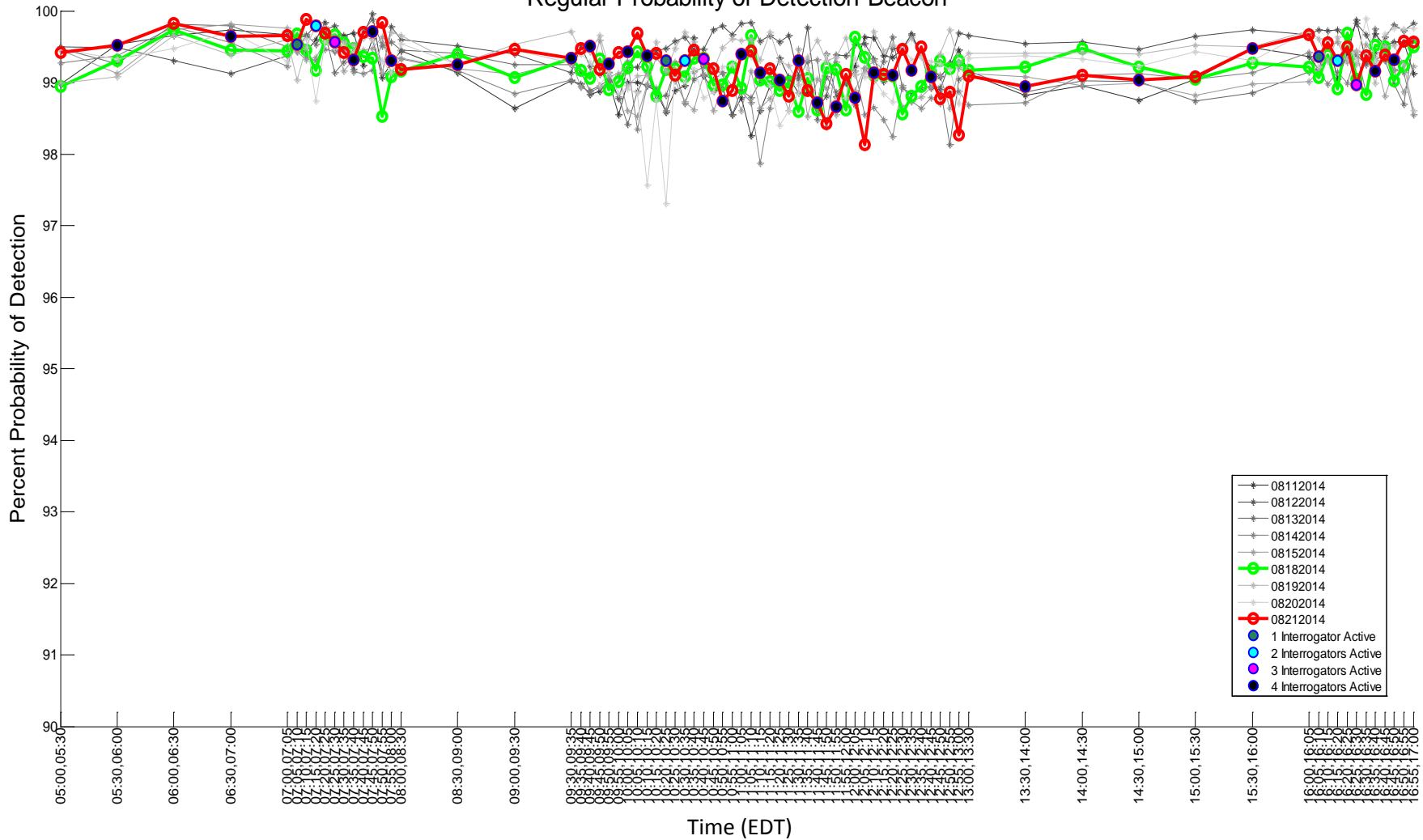


Geographic Filter: None  
Target Filter: None



# Probability of Detection – August 21<sup>st</sup>

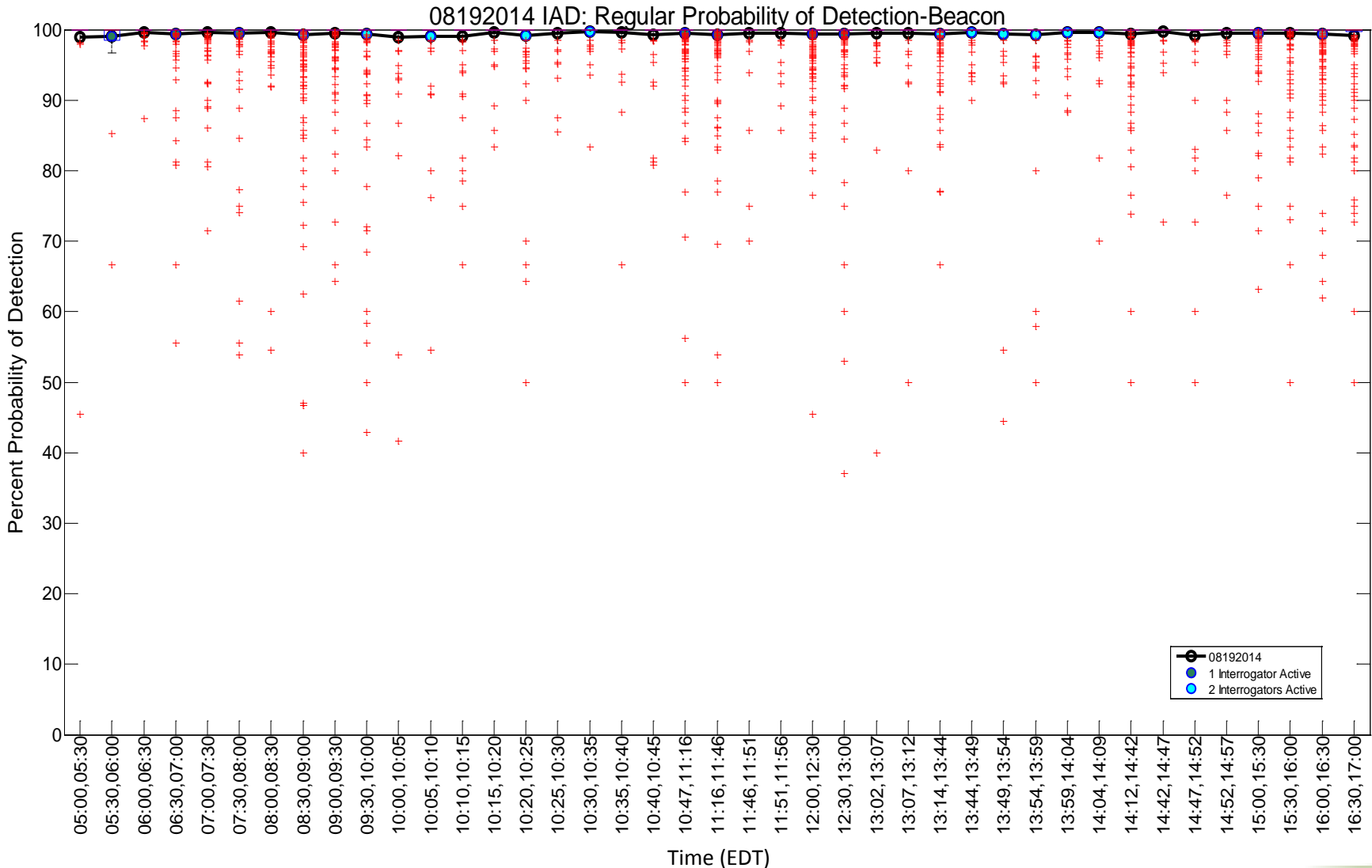
Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

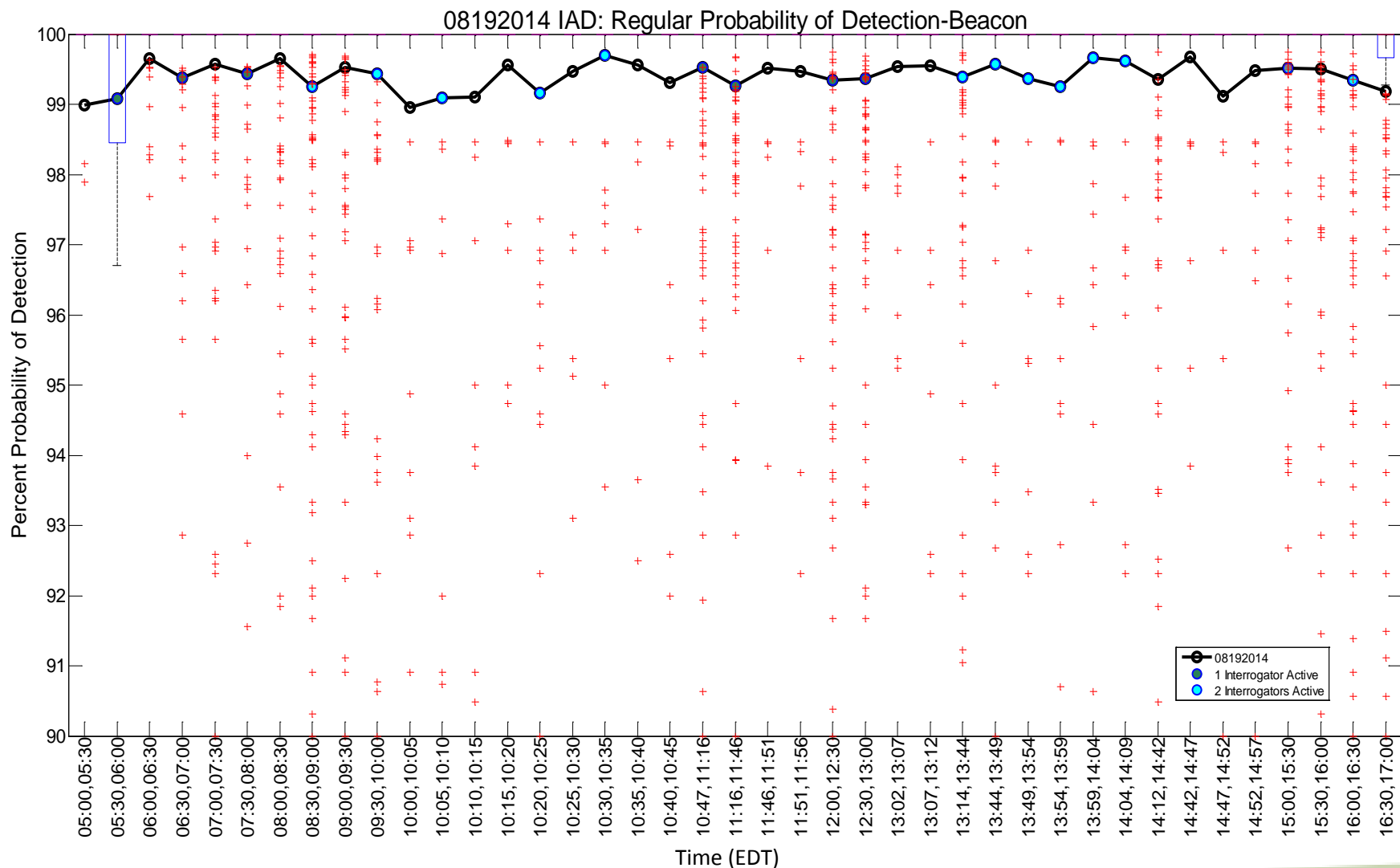
# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution



# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

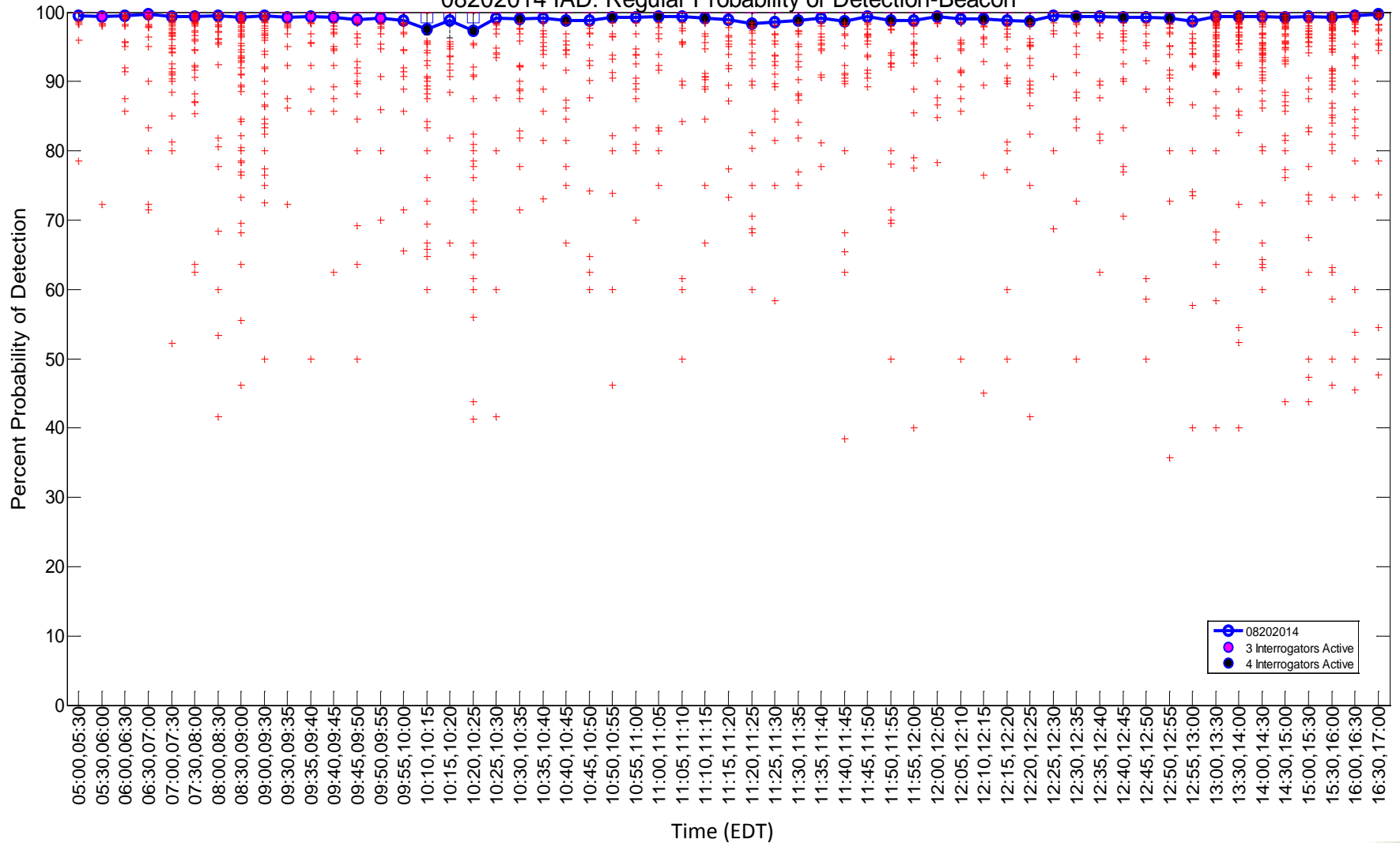


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

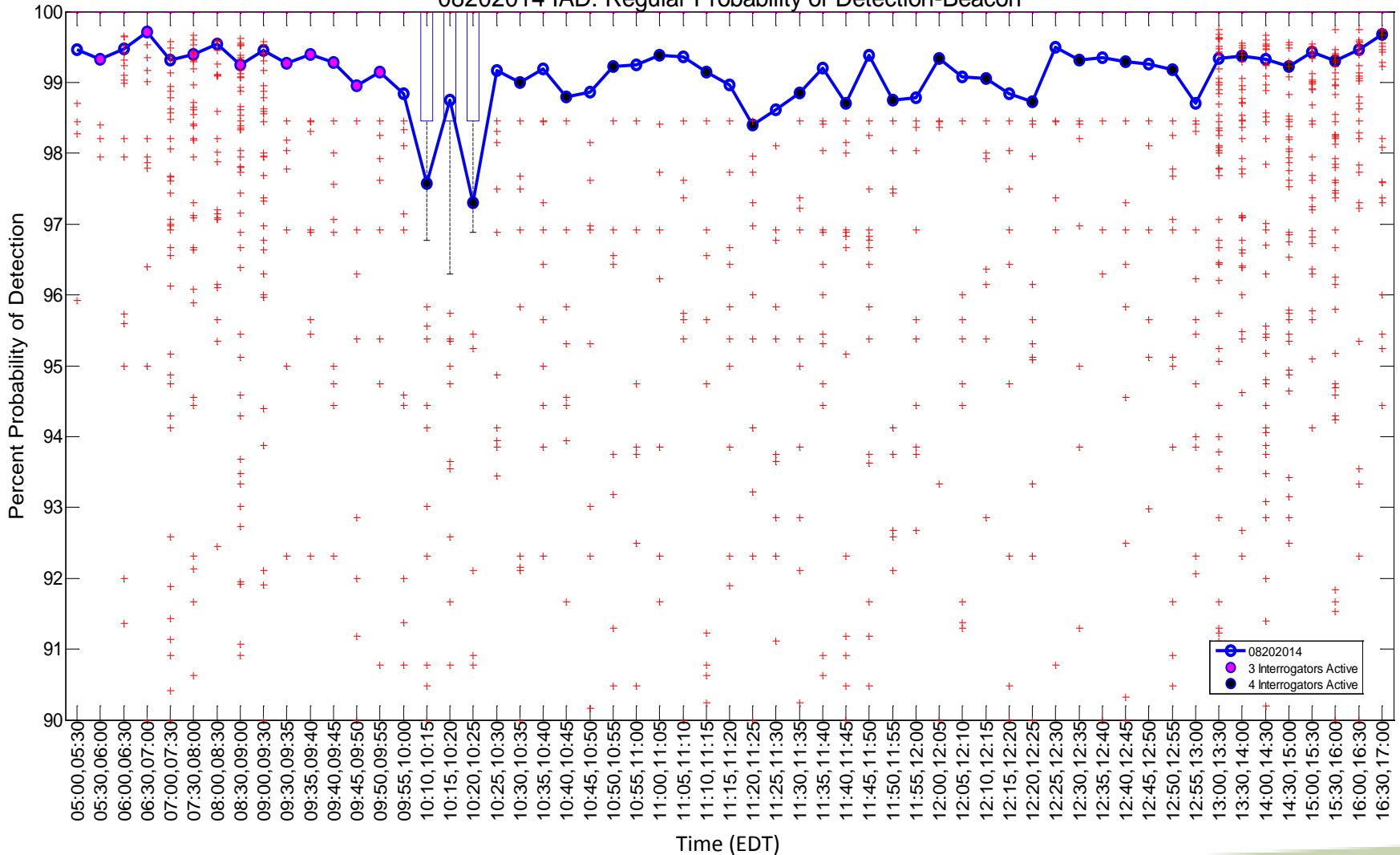
08202014 IAD: Regular Probability of Detection-Beacon



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

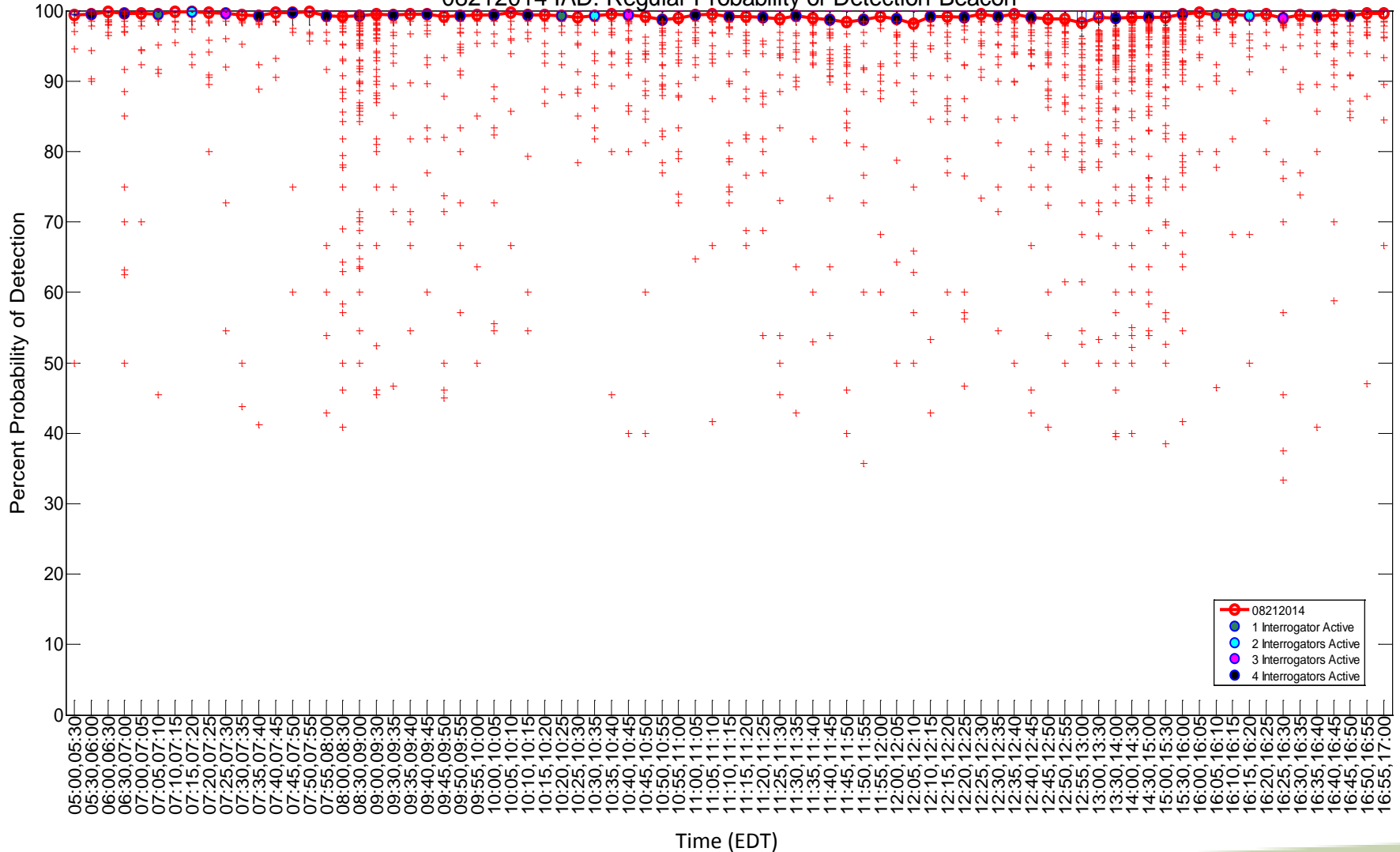
08202014 IAD: Regular Probability of Detection-Beacon



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

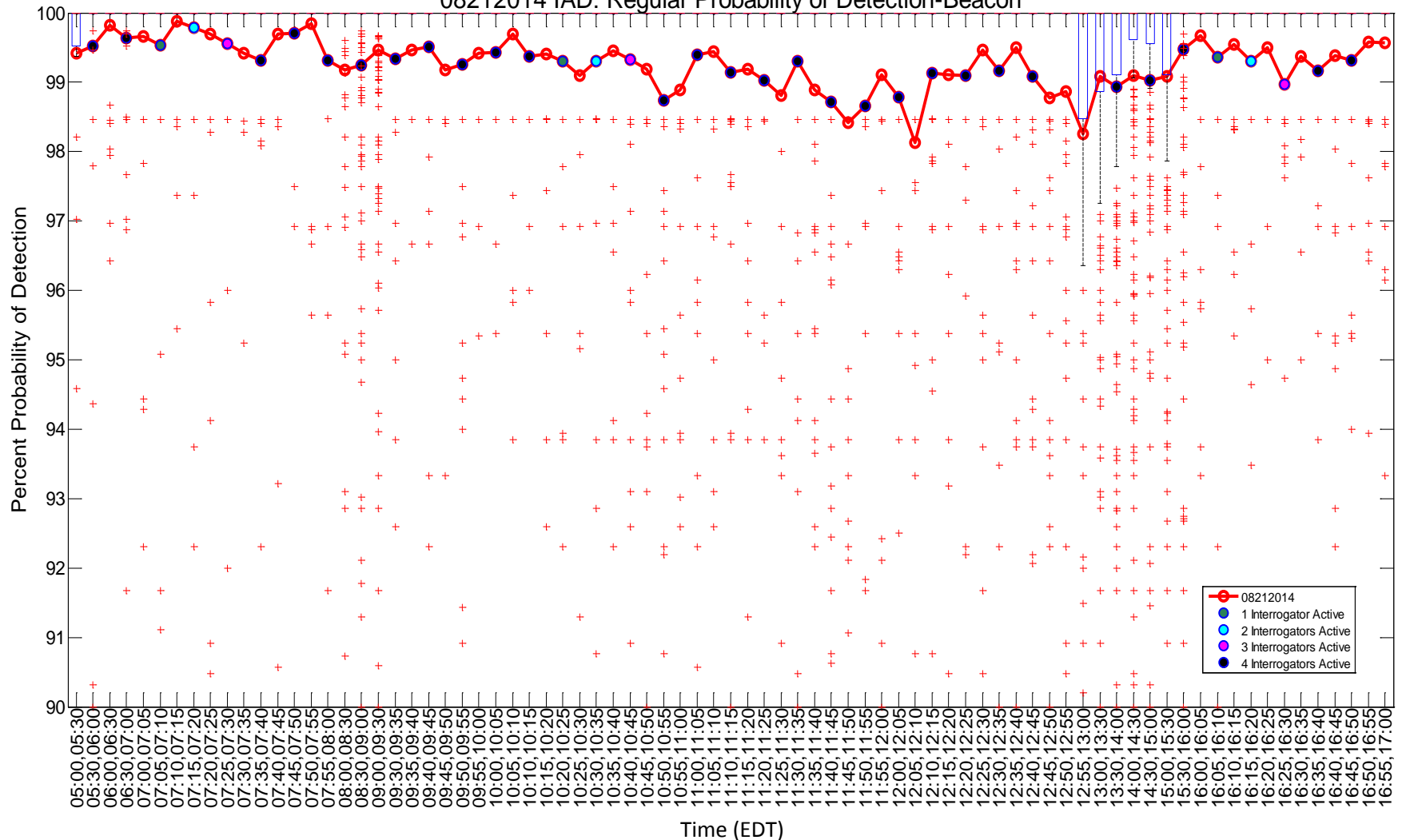
08212014 IAD: Regular Probability of Detection-Beacon



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)

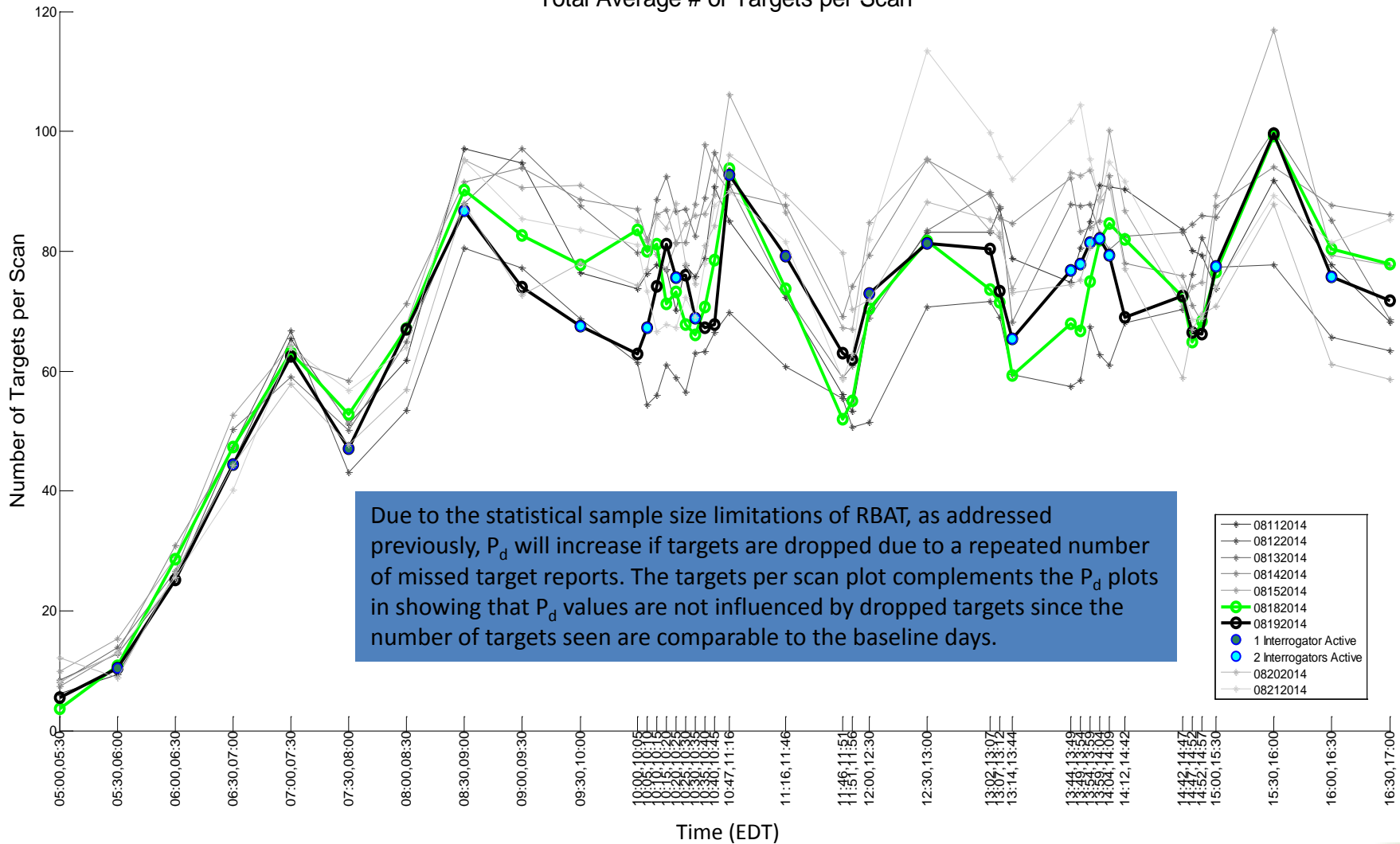
08212014 IAD: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 19<sup>th</sup>

Total Average # of Targets per Scan

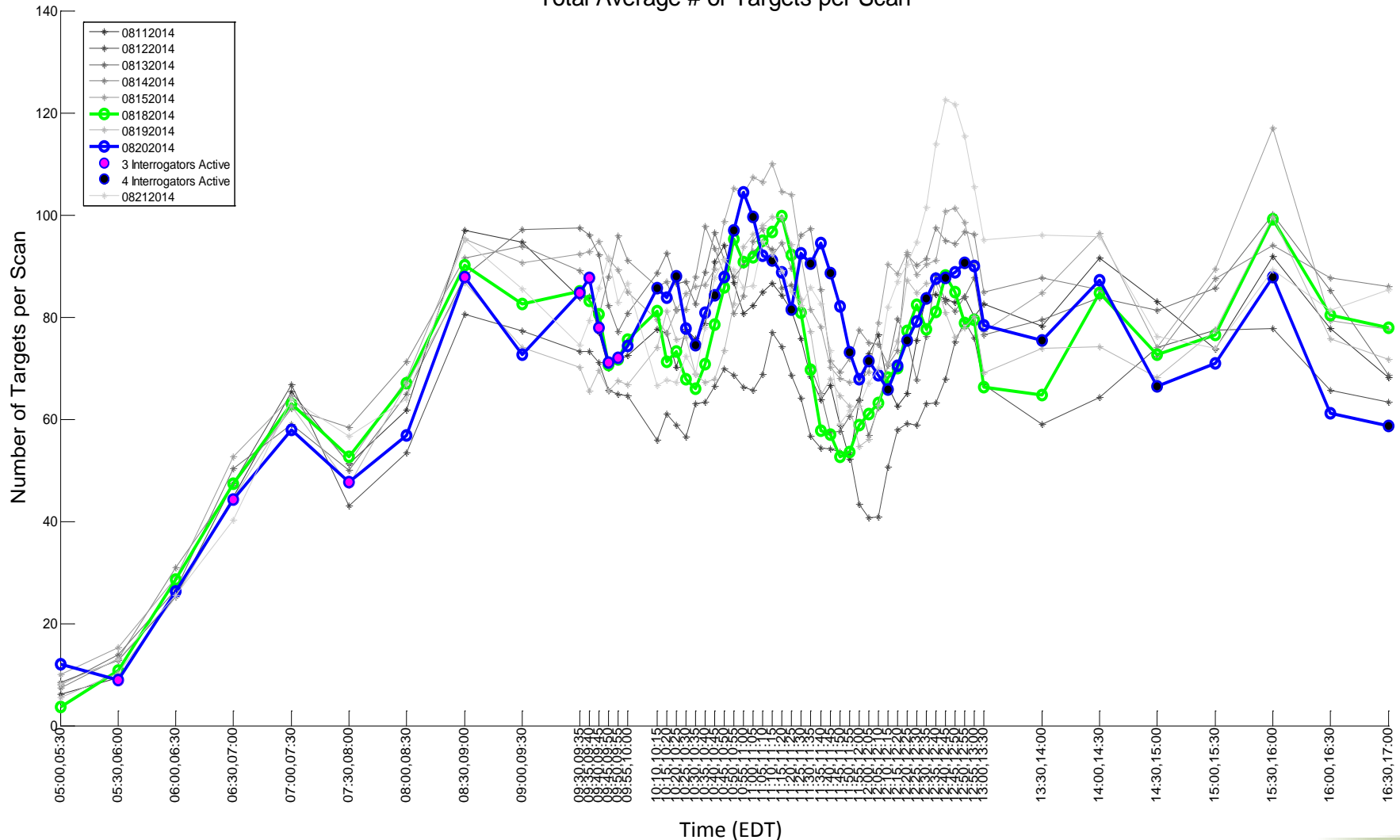


Geographic Filter: None  
Target Filter: None



# Targets per Scan – August 20<sup>th</sup>

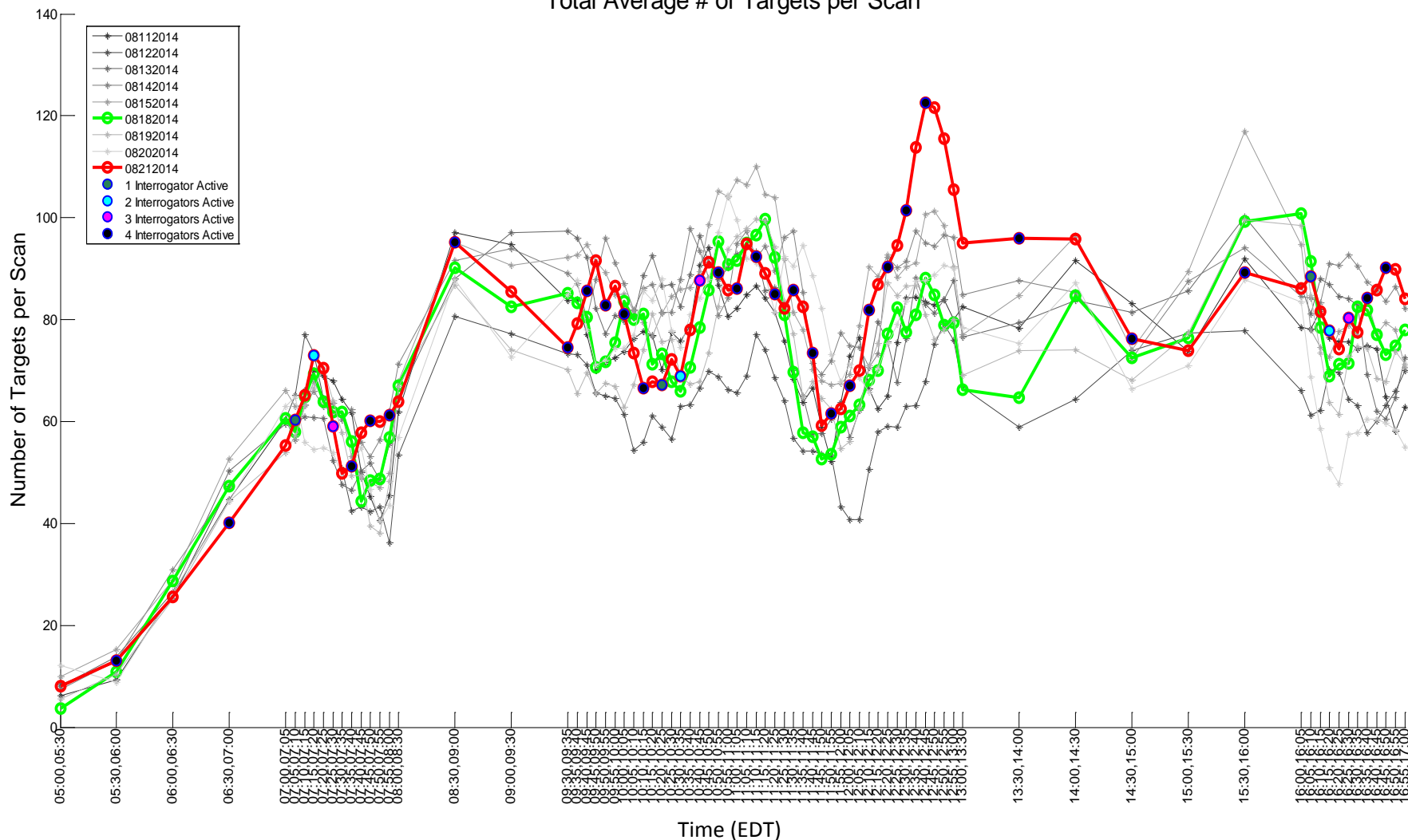
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 21<sup>st</sup>

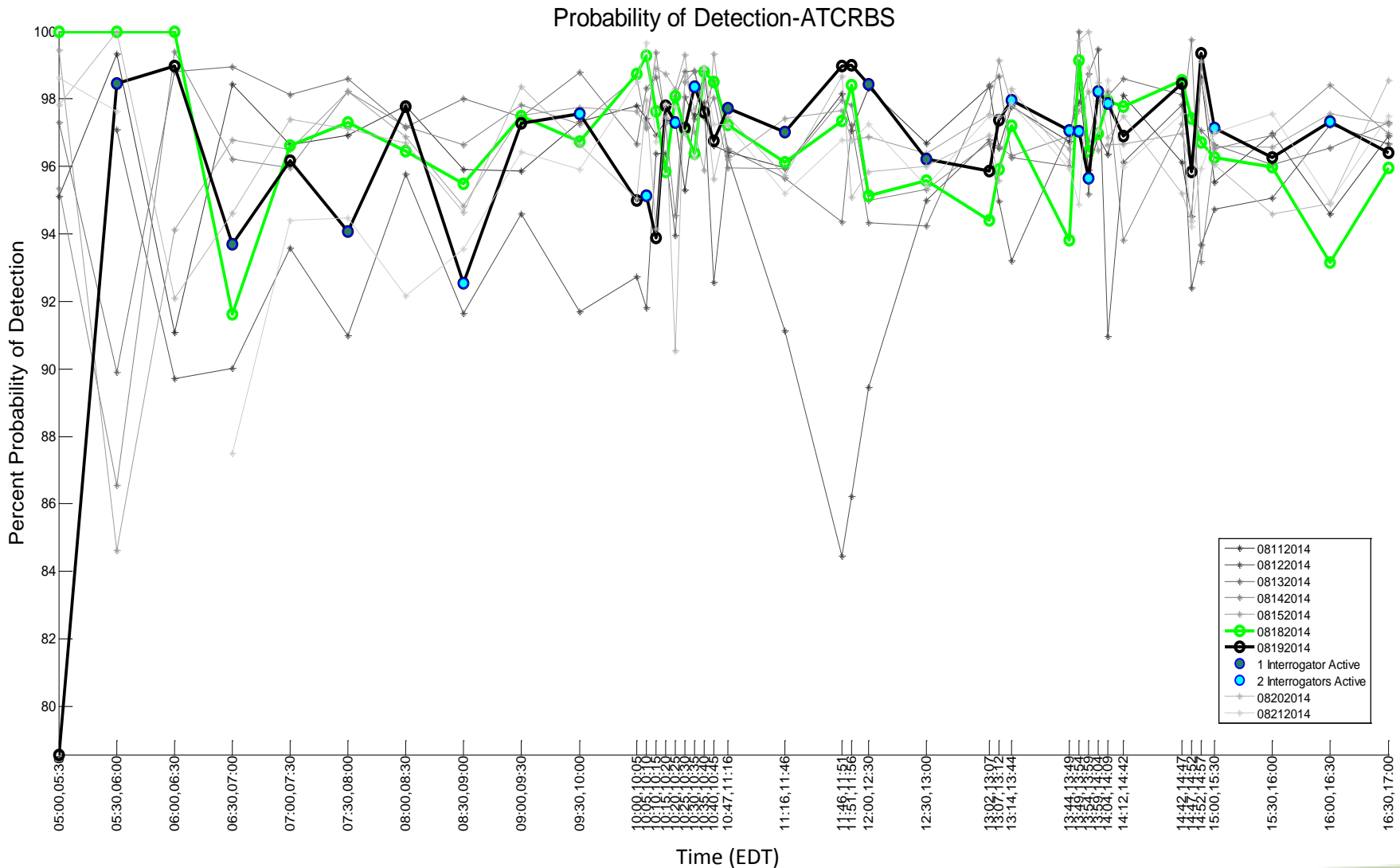
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

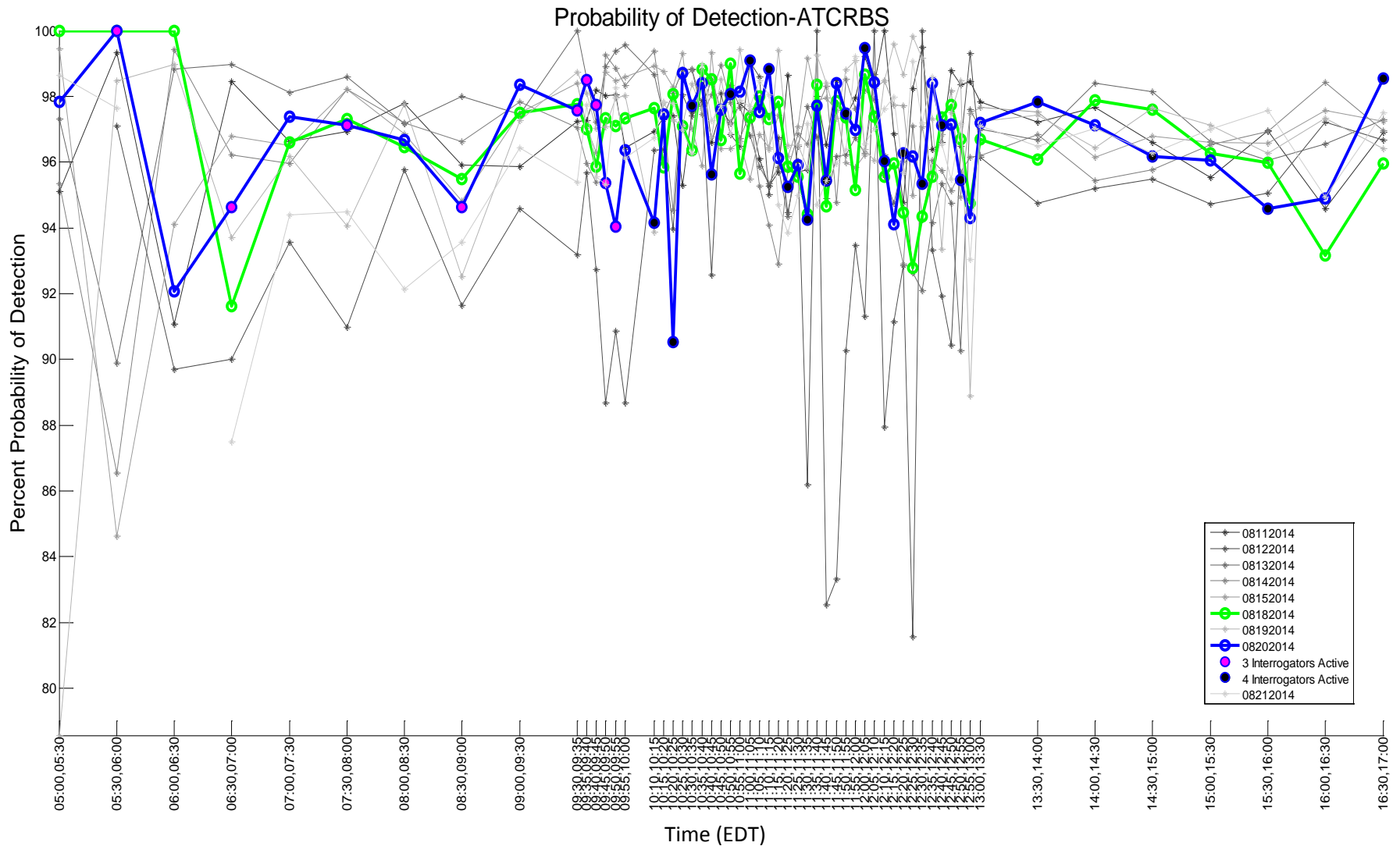
## ATCRBS Targets - Discrete



Geographic Filter: None  
 Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

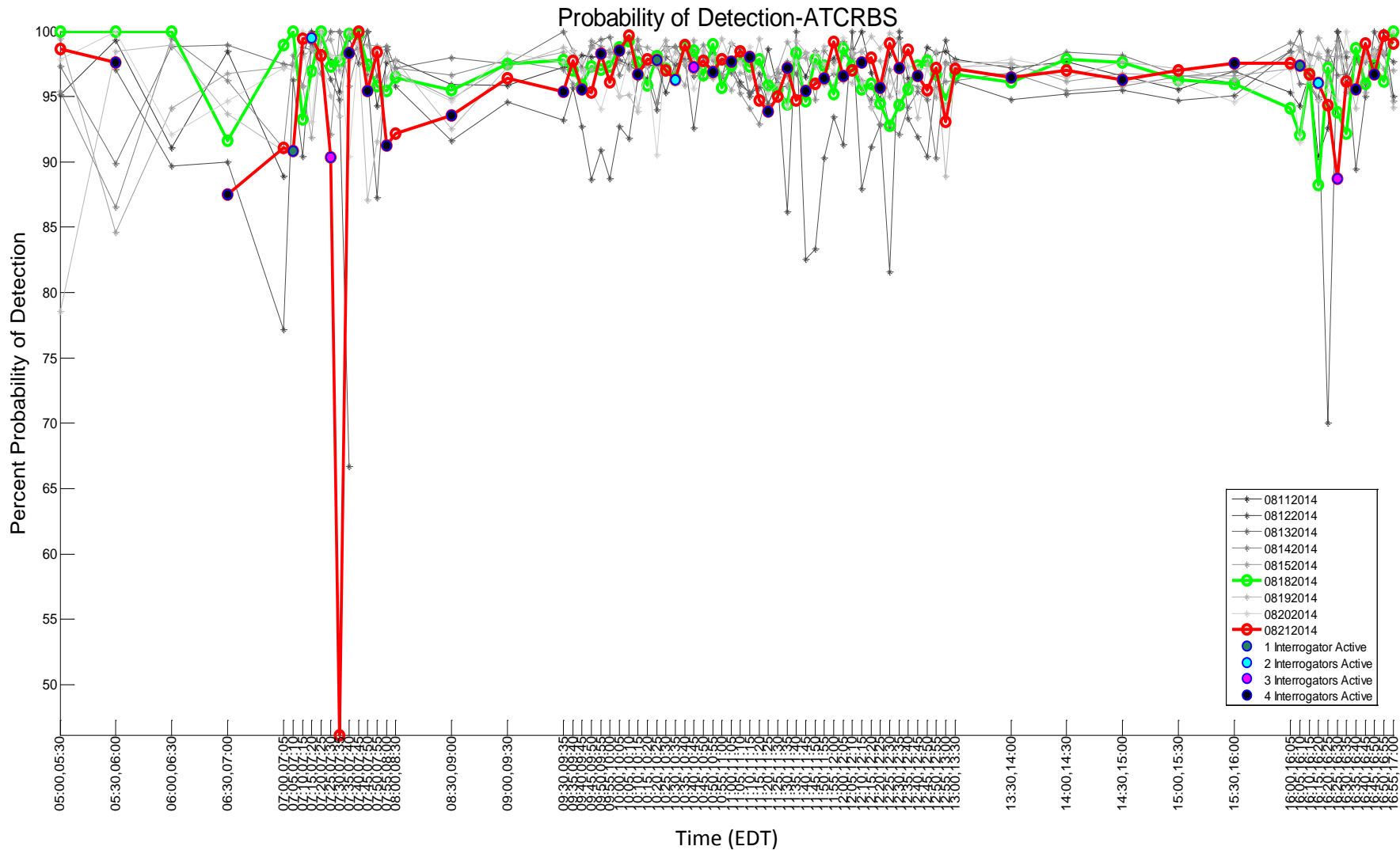
## ATCRBS Targets - Discrete



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

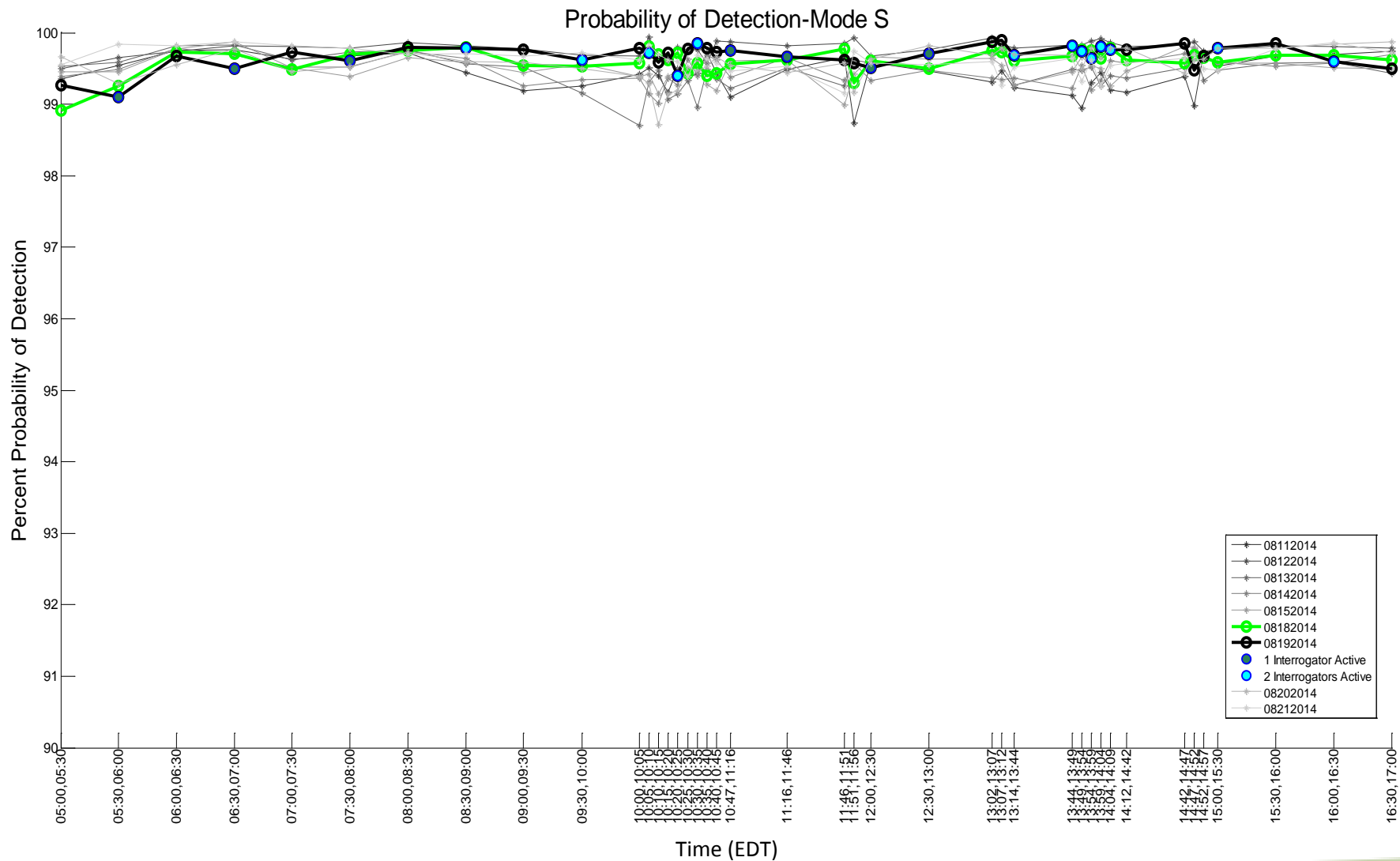
## ATCRBS Targets - Discrete



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

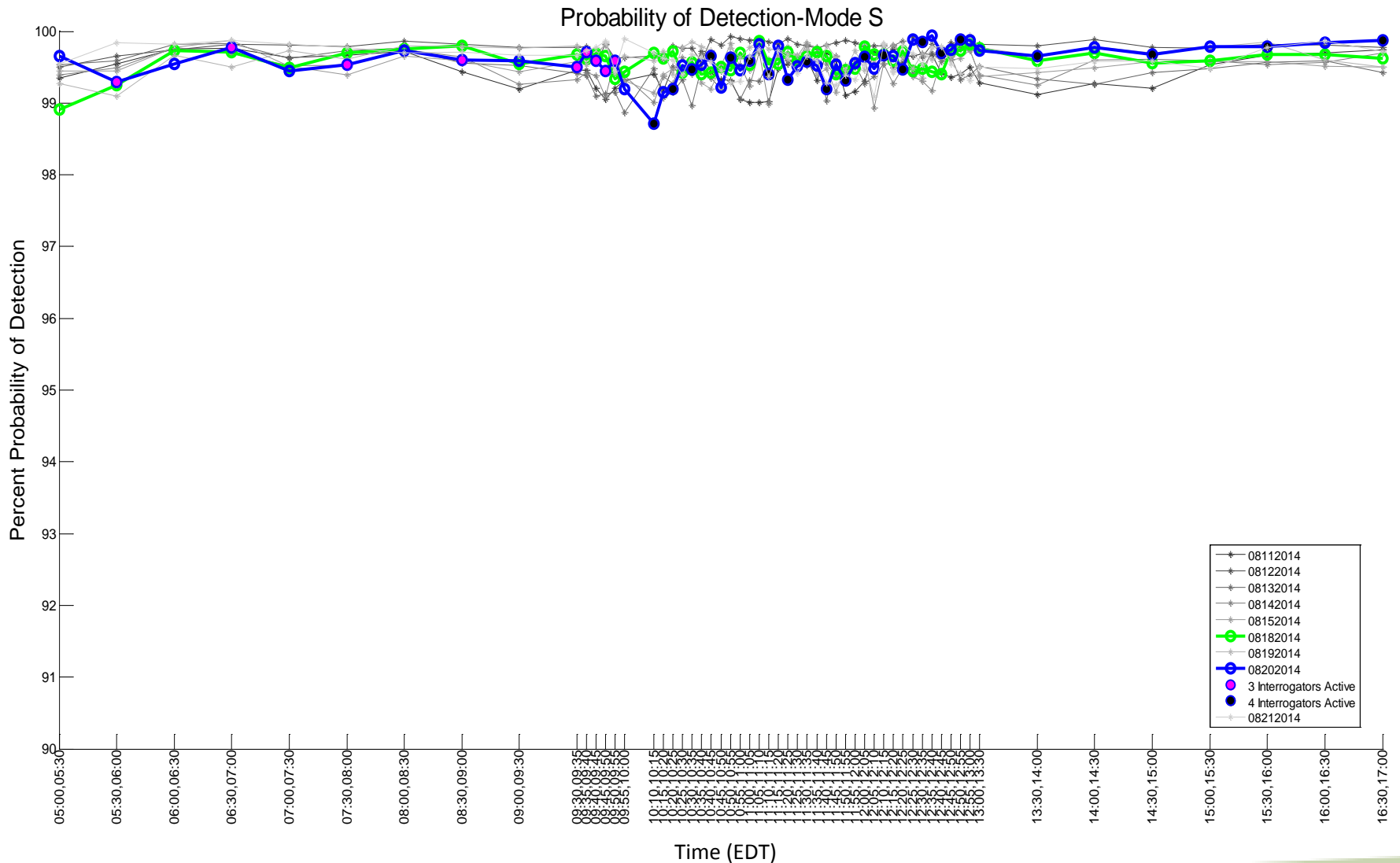
## Mode S Targets



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

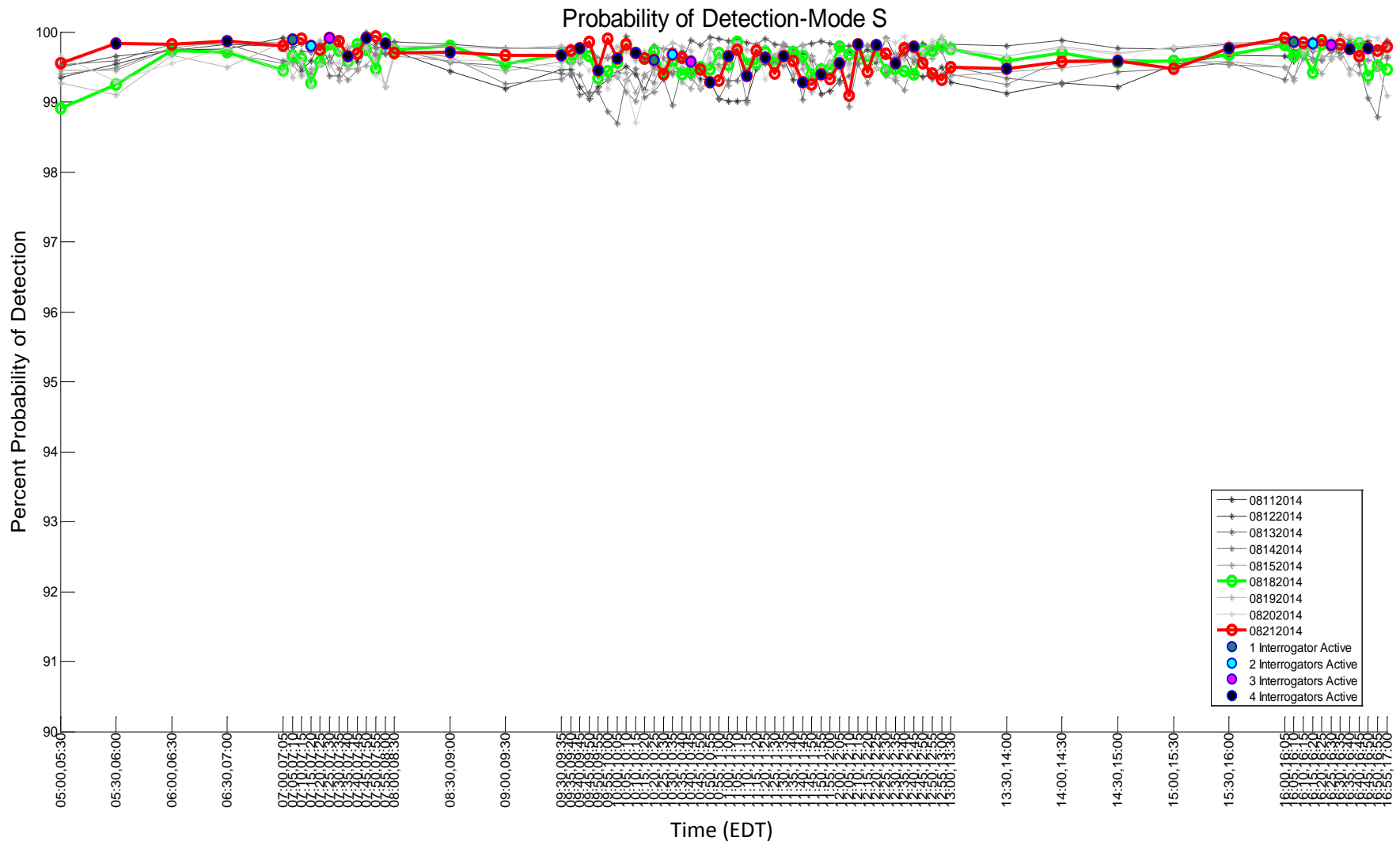
## Mode S Targets



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

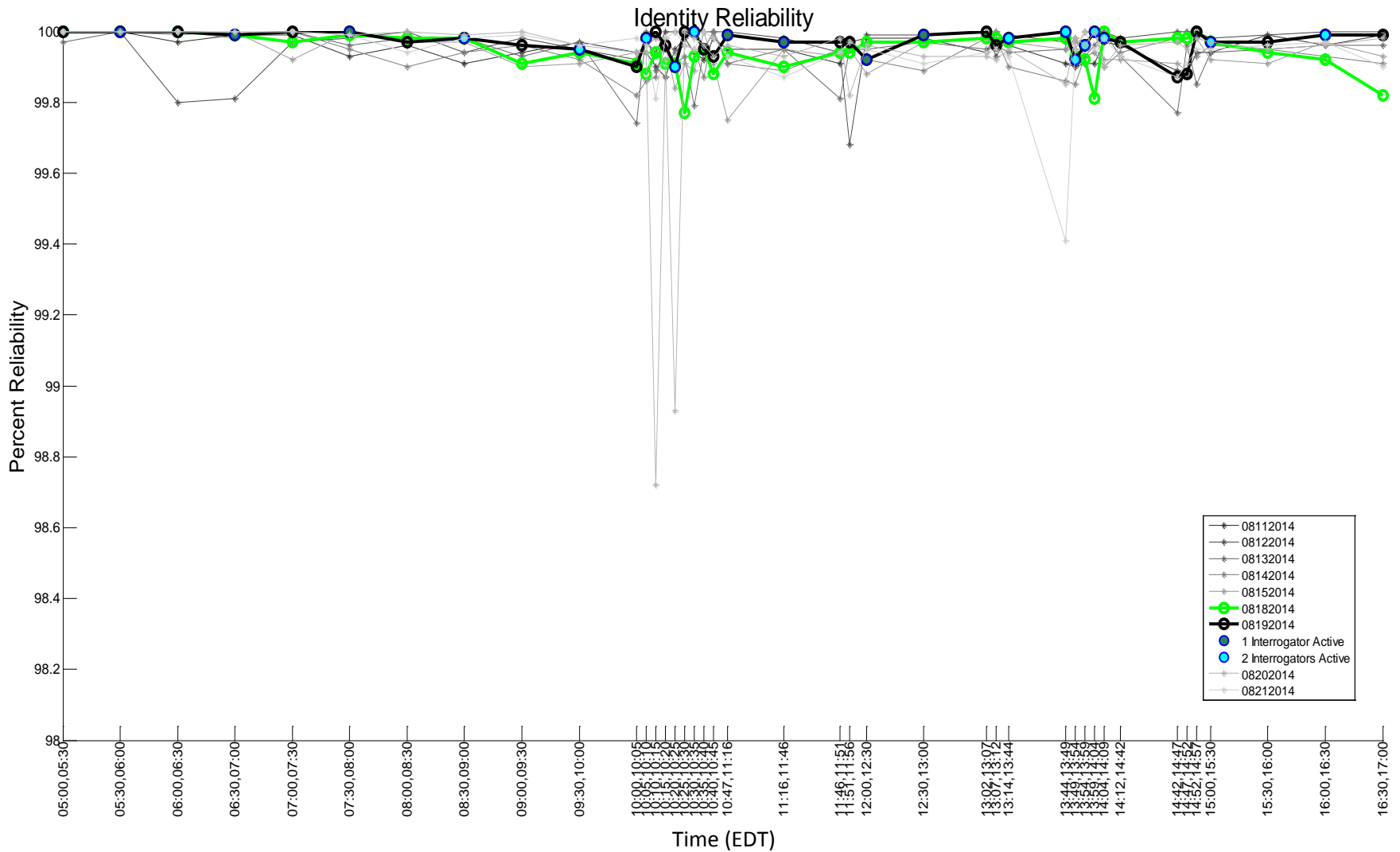
## Mode S Targets



Geographic Filter: None  
Target Filter: None

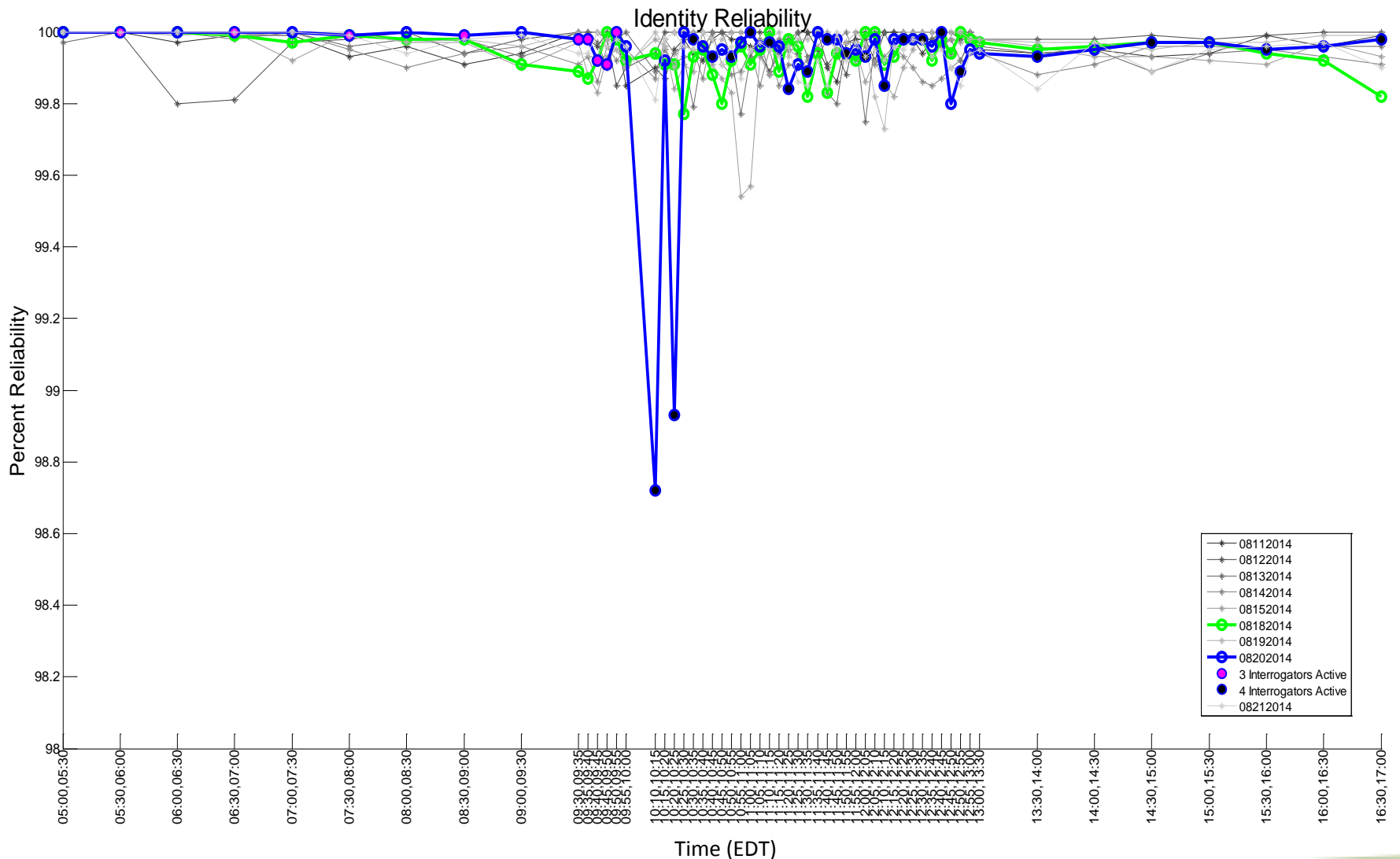


# Identity (3/A) Reliability – August 19th



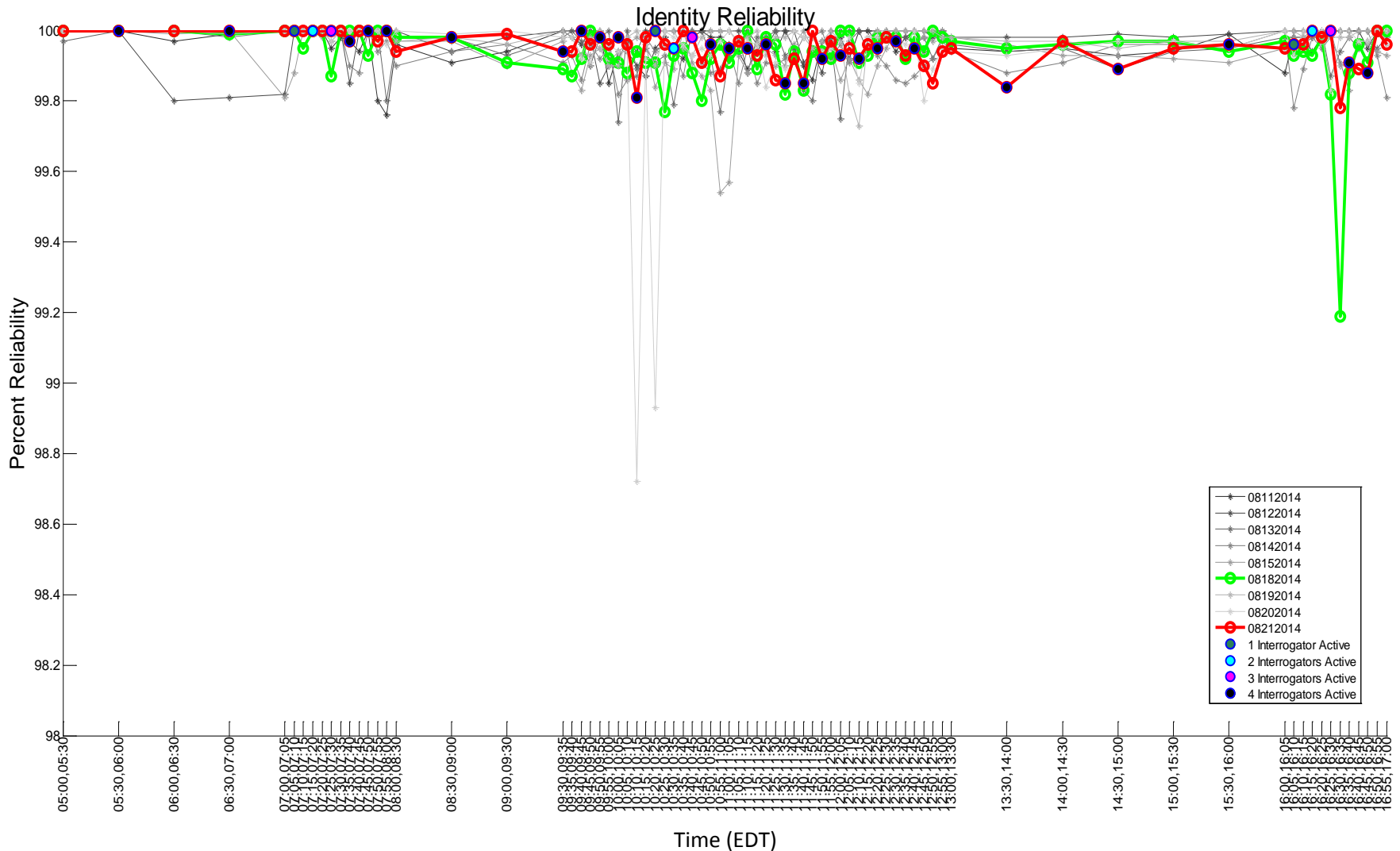
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 20<sup>th</sup>



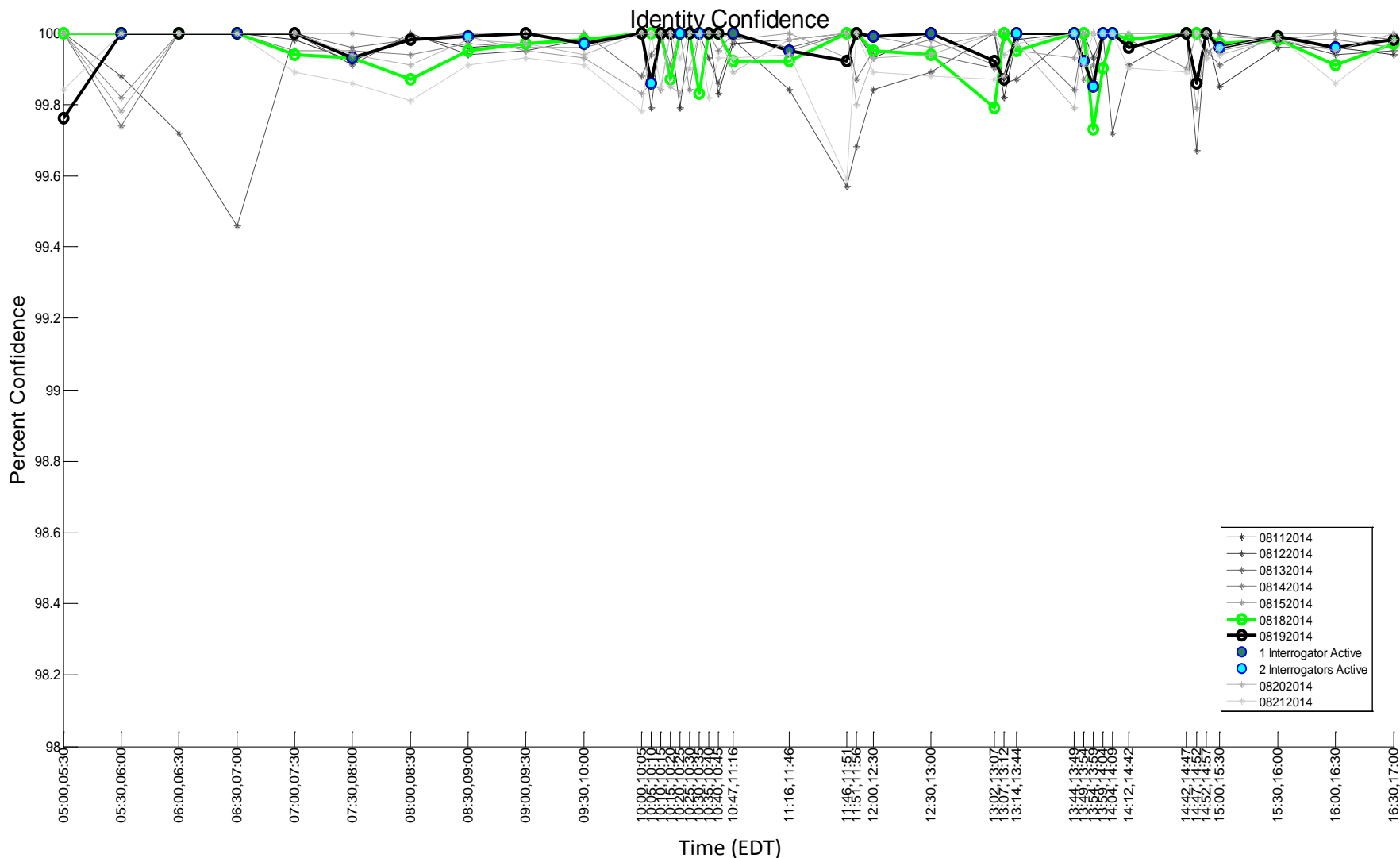
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 21<sup>st</sup>



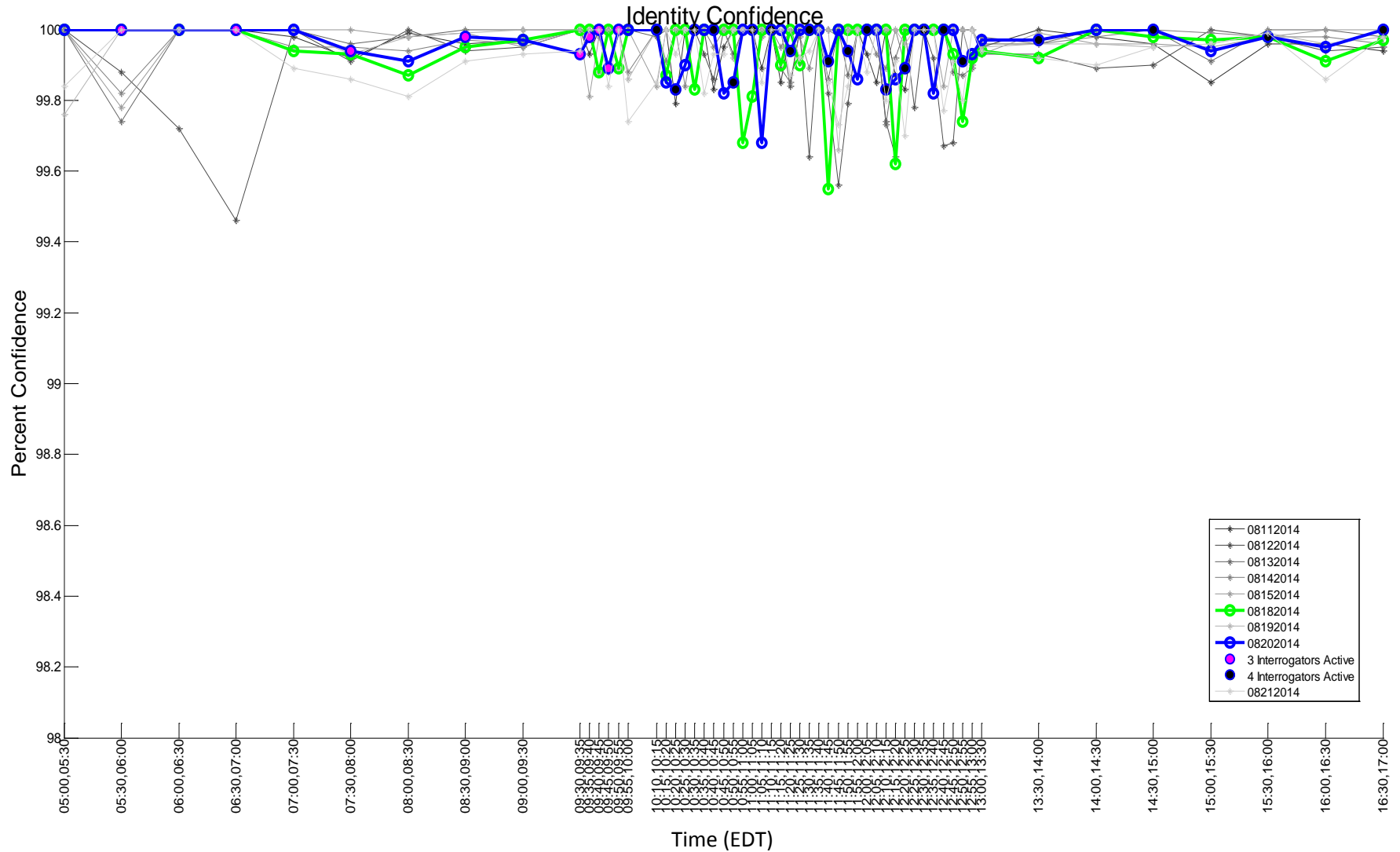
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 19th



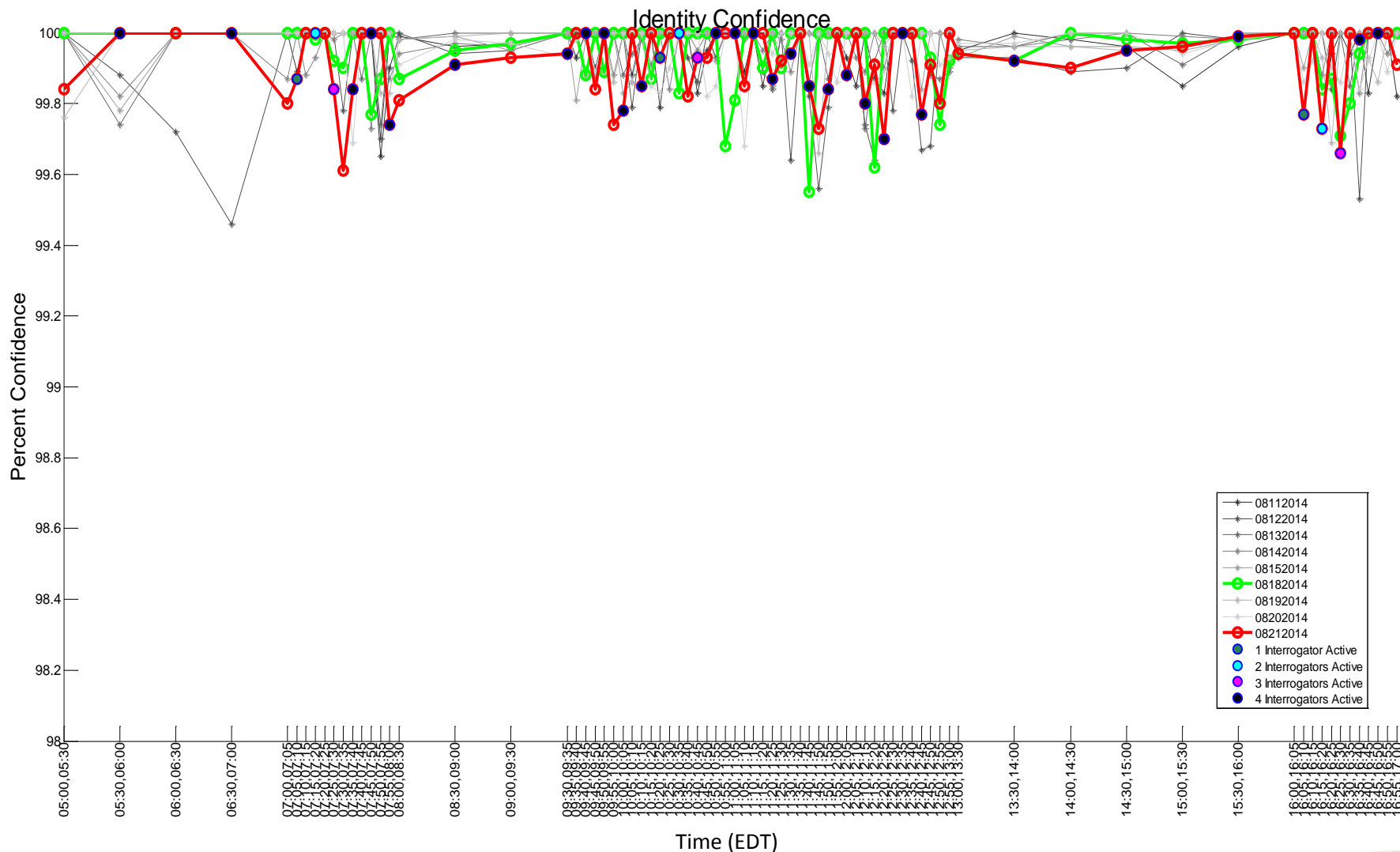
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 20<sup>th</sup>



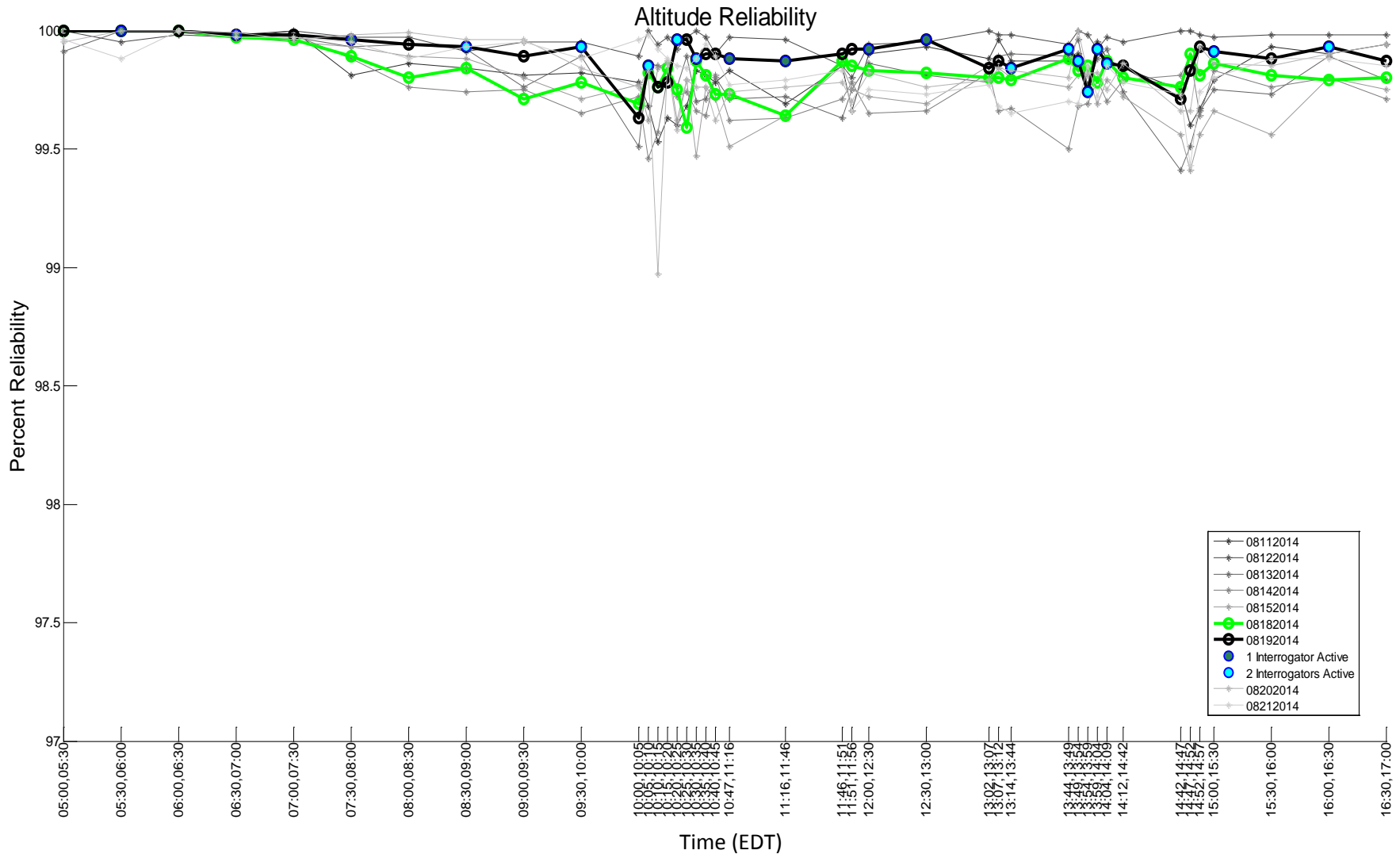
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 21<sup>st</sup>



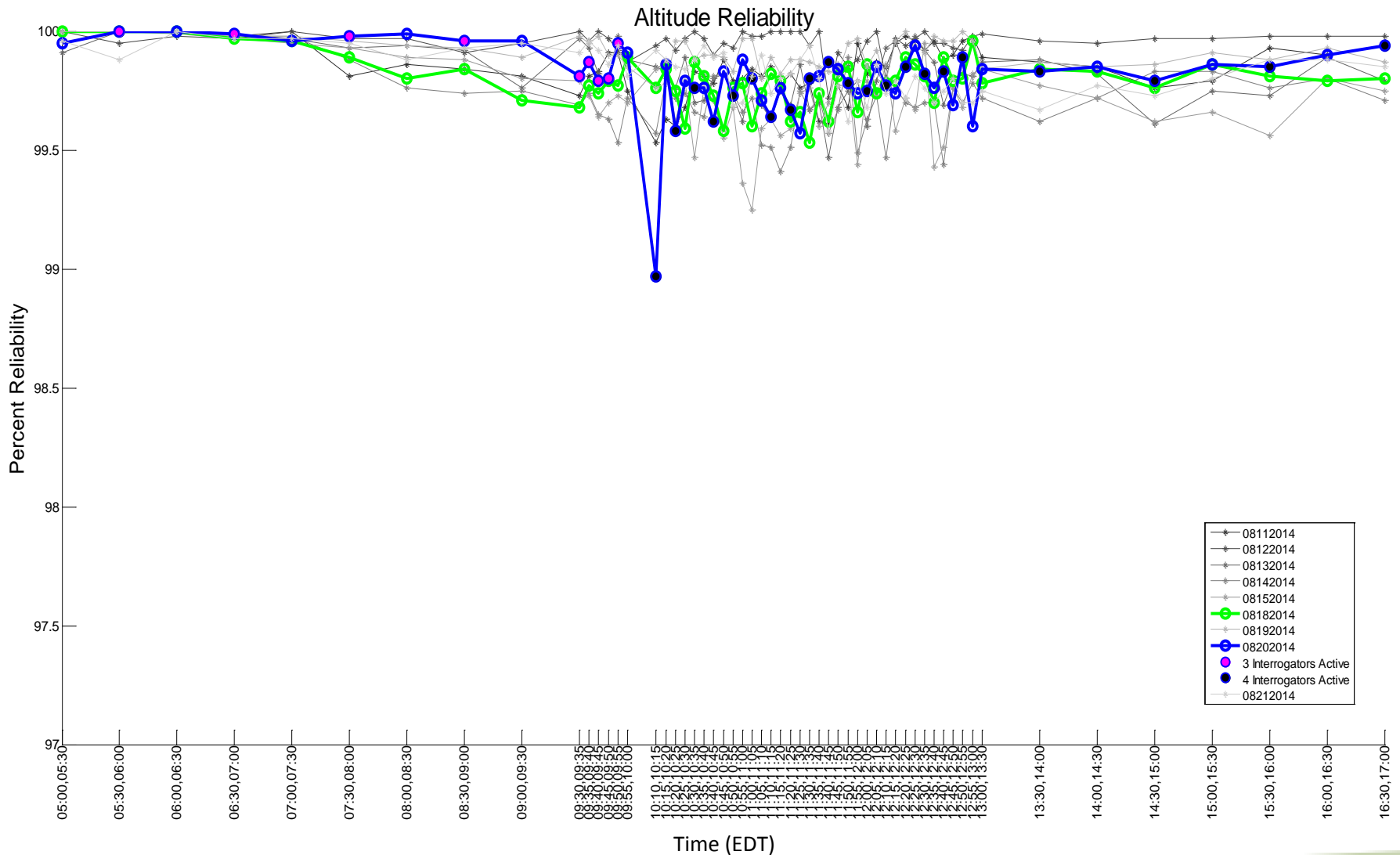
Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 19th



Geographic Filter: None  
Target Filter: None

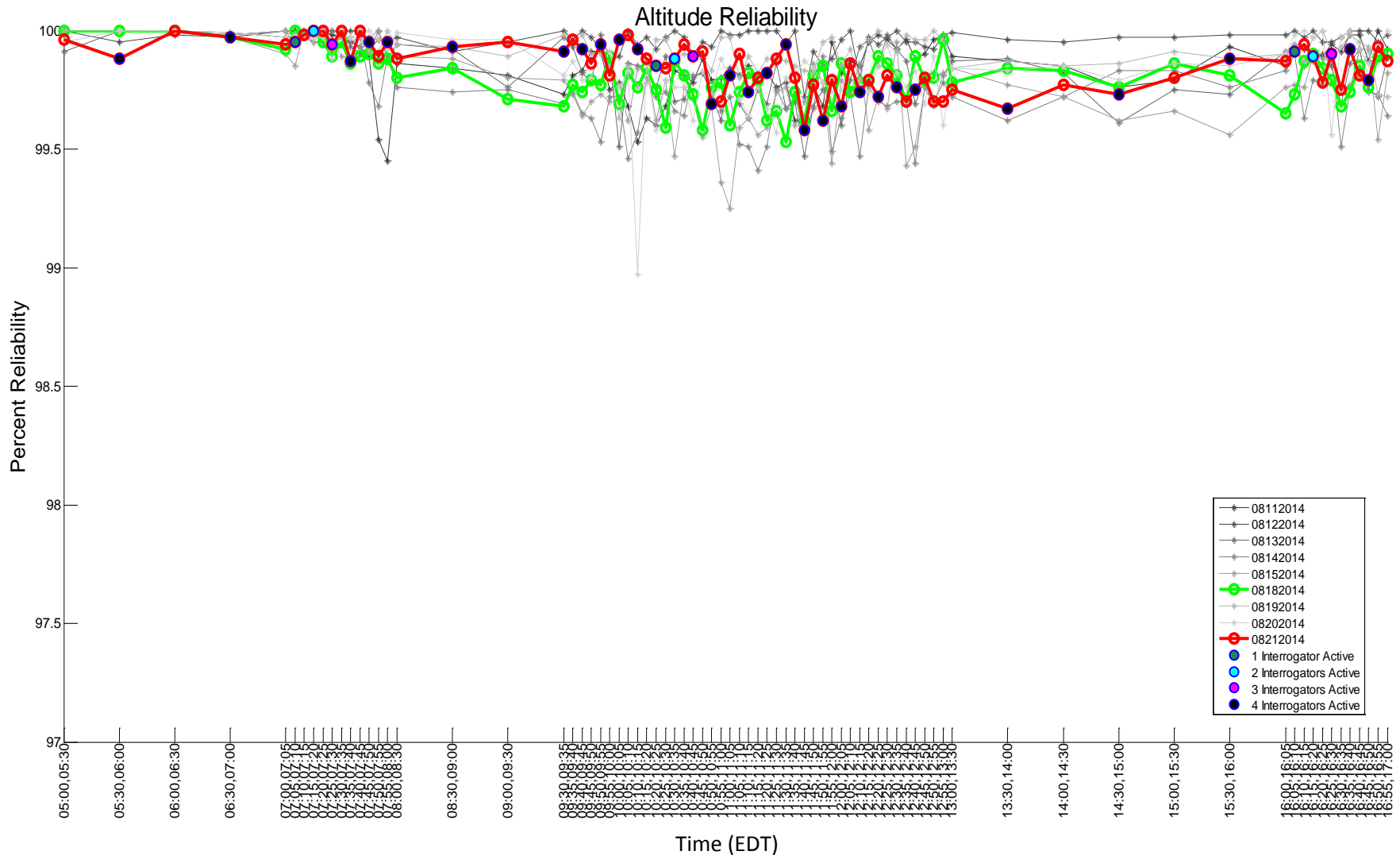
# Altitude (C) Reliability – August 20<sup>th</sup>



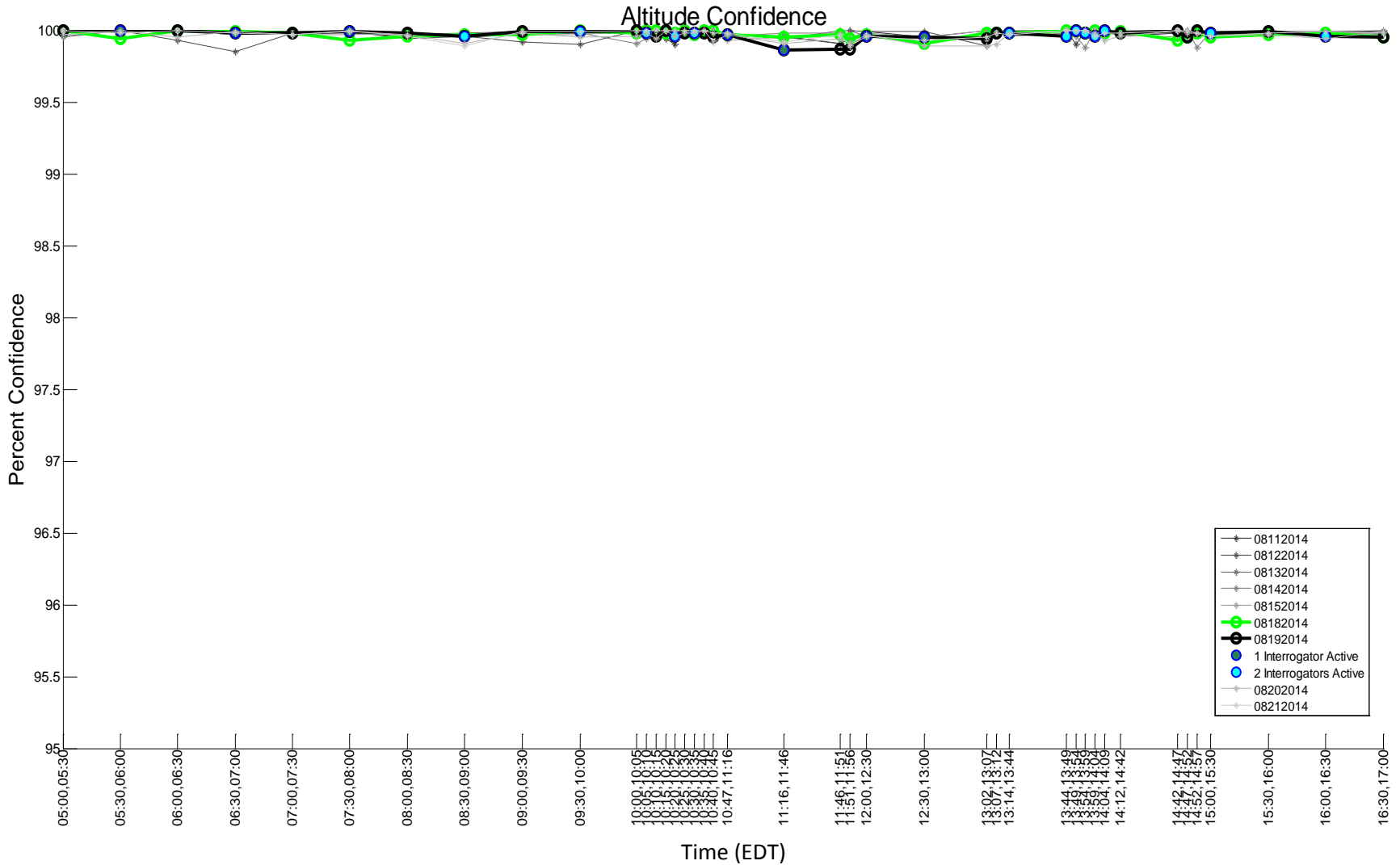
Geographic Filter: None  
Target Filter: None



# Altitude (C) Reliability – August 21<sup>st</sup>

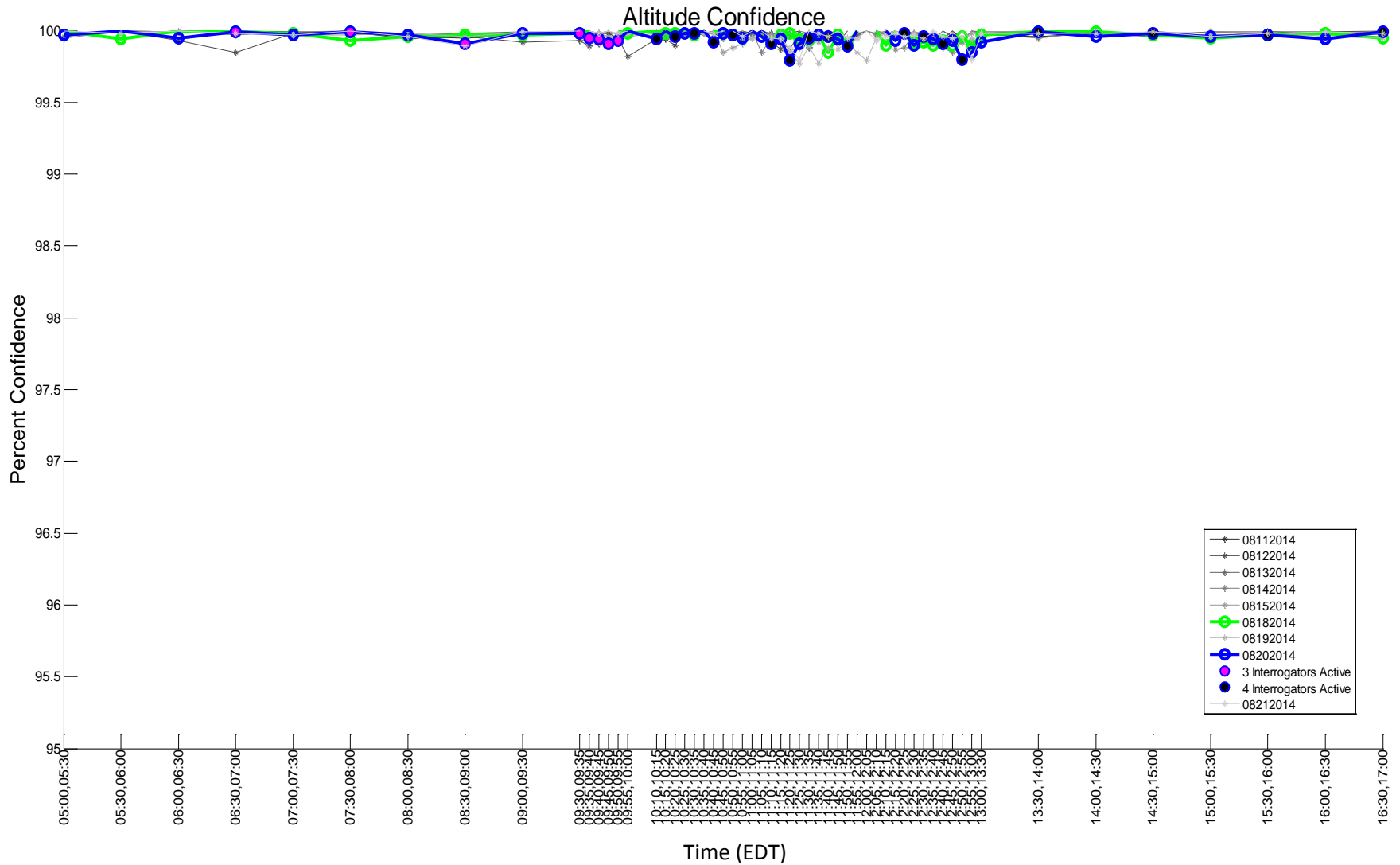


# Altitude (C) Confidence – August 19th



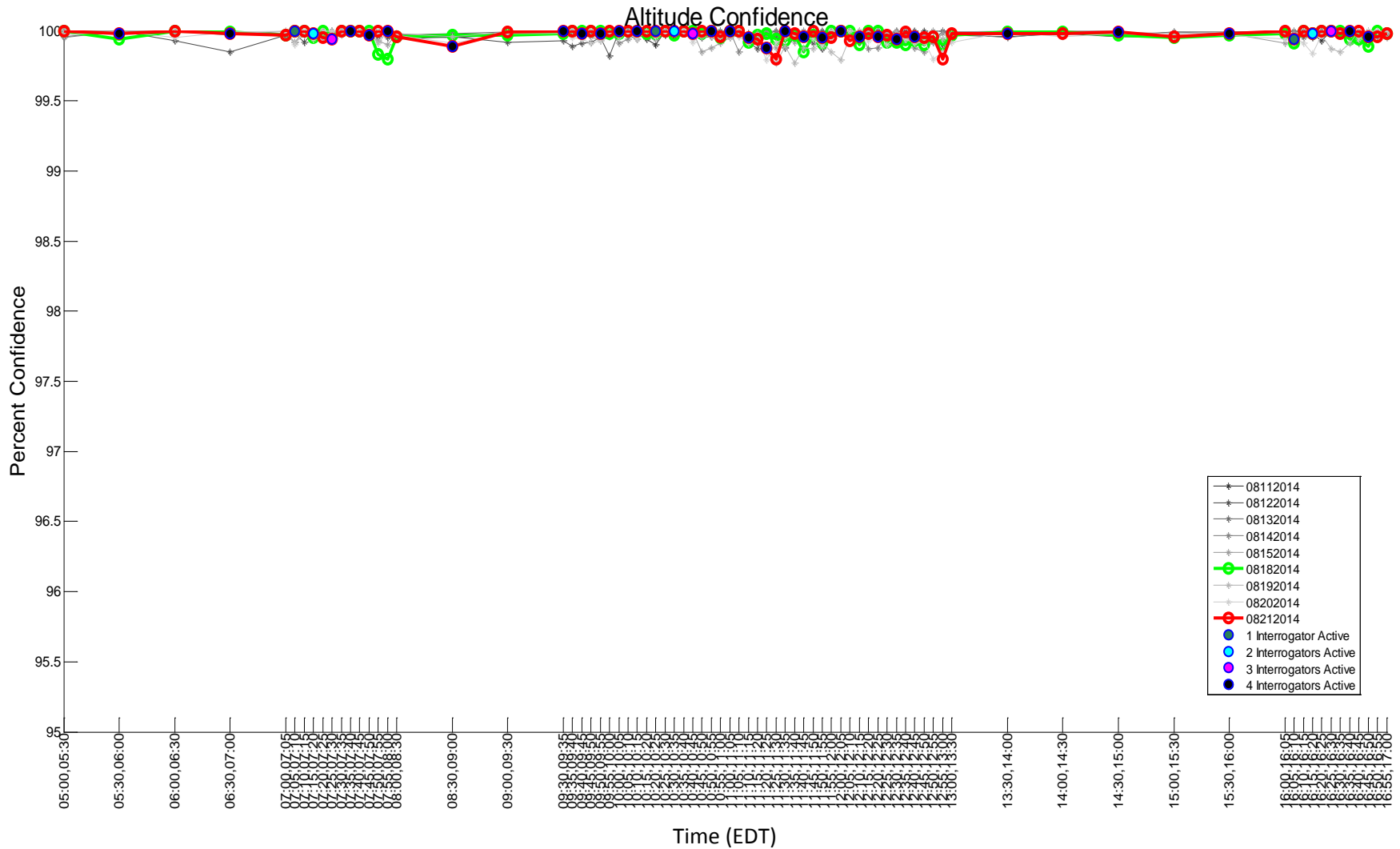
Geographic Filter: None  
Target Filter: None

# Altitude (C) Confidence – August 20<sup>th</sup>



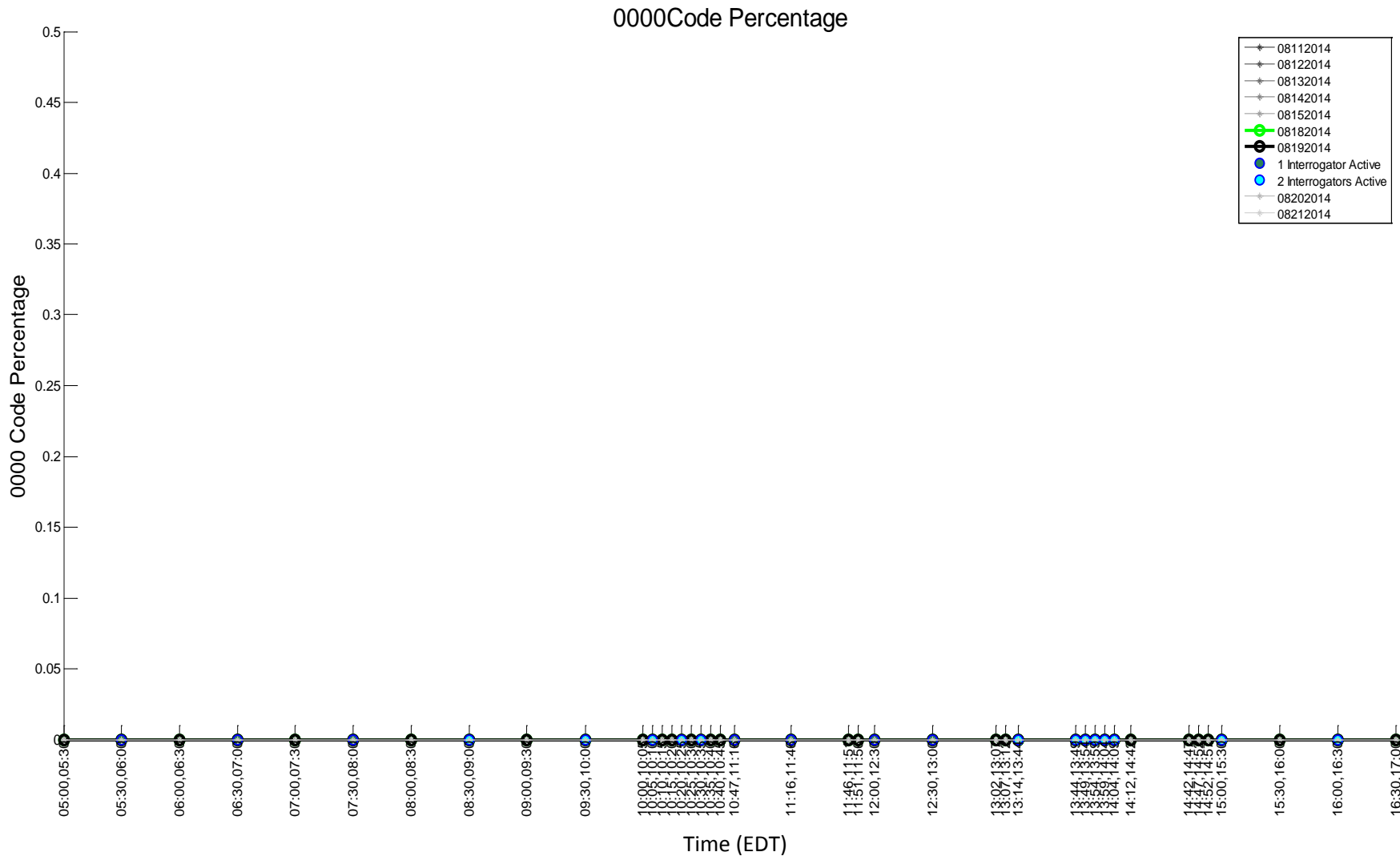
Geographic Filter: None  
Target Filter: None

# Altitude (C) Confidence – August 21<sup>st</sup>



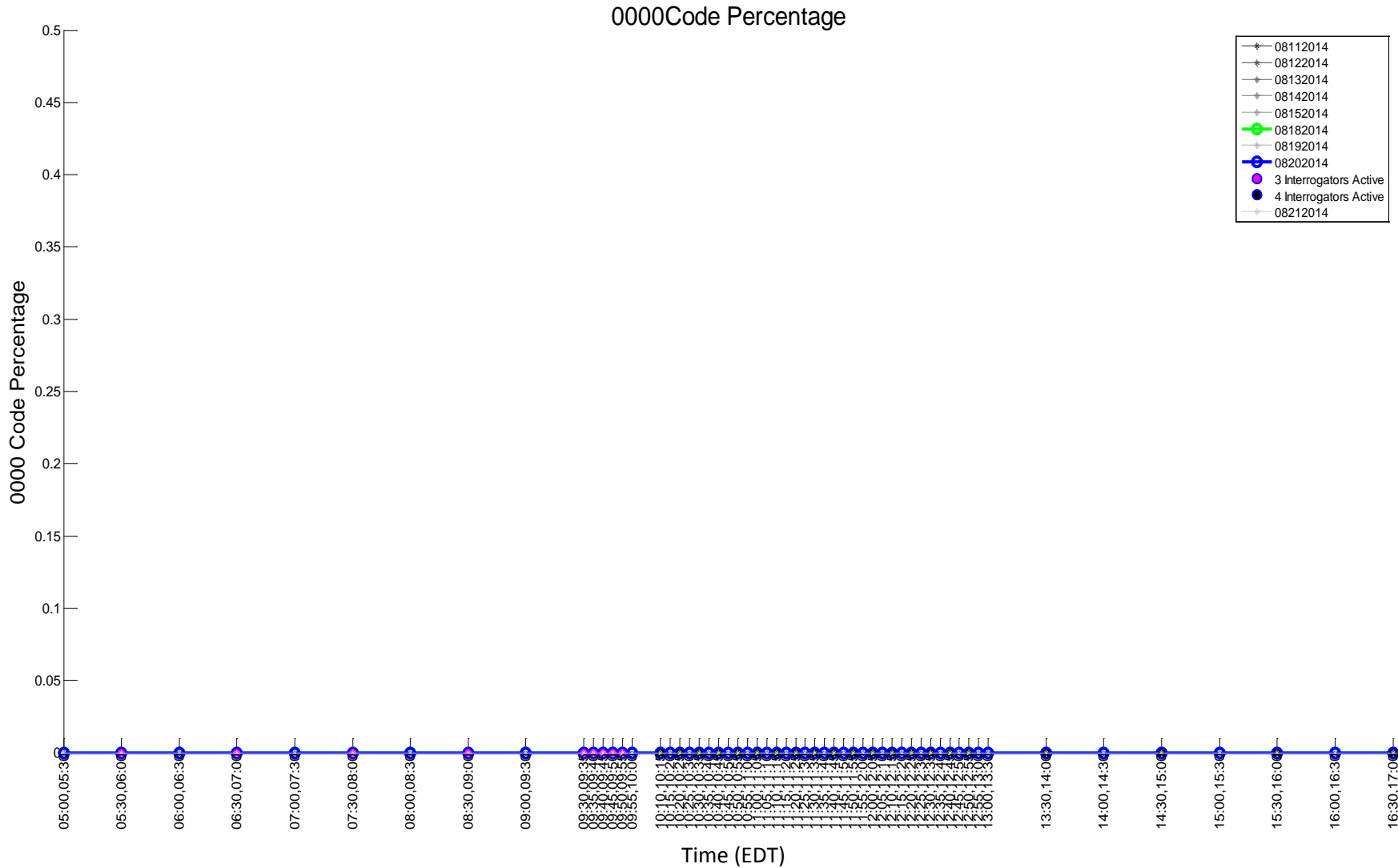
Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 19th



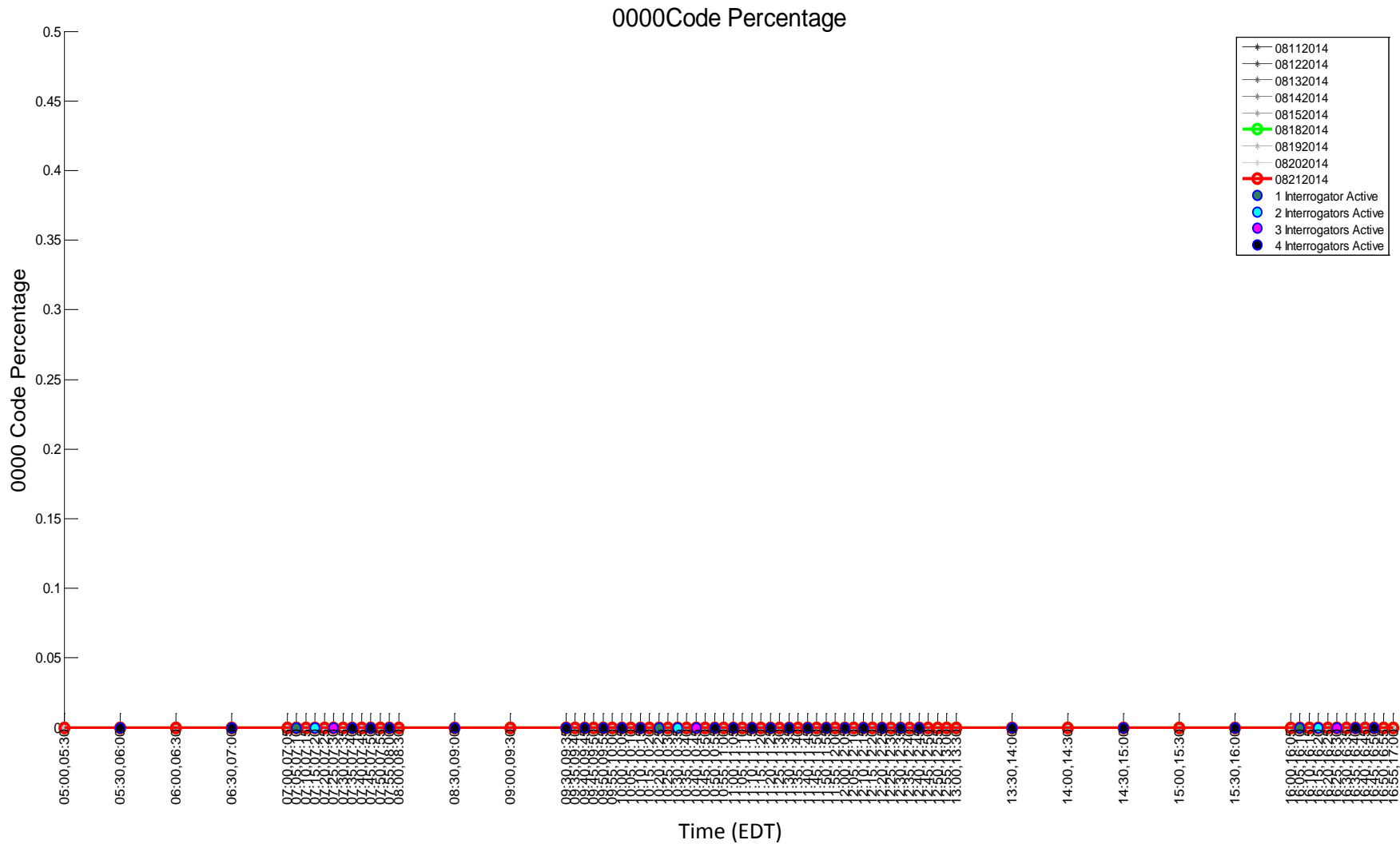
Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 21<sup>st</sup>

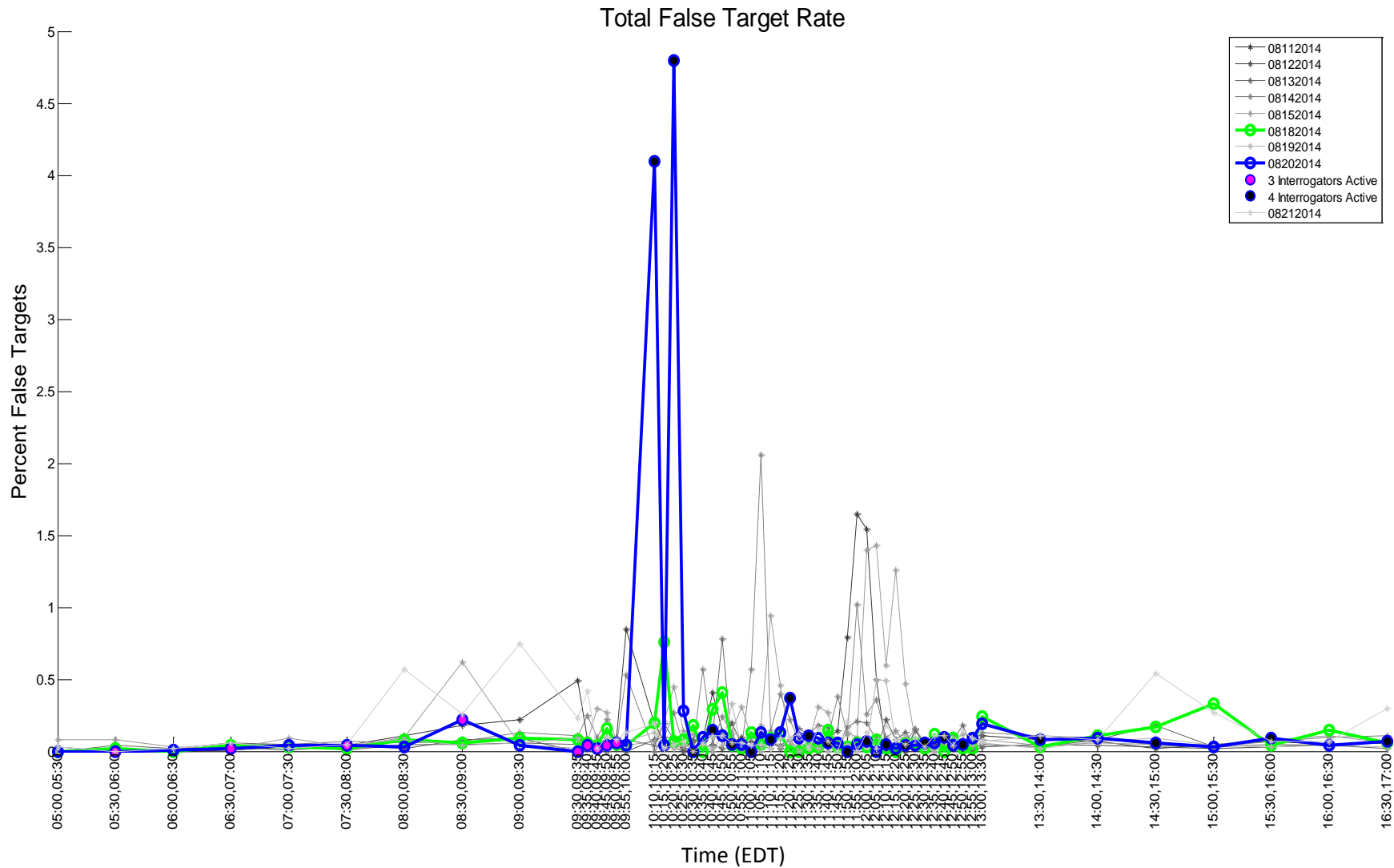


Geographic Filter: None  
Target Filter: None



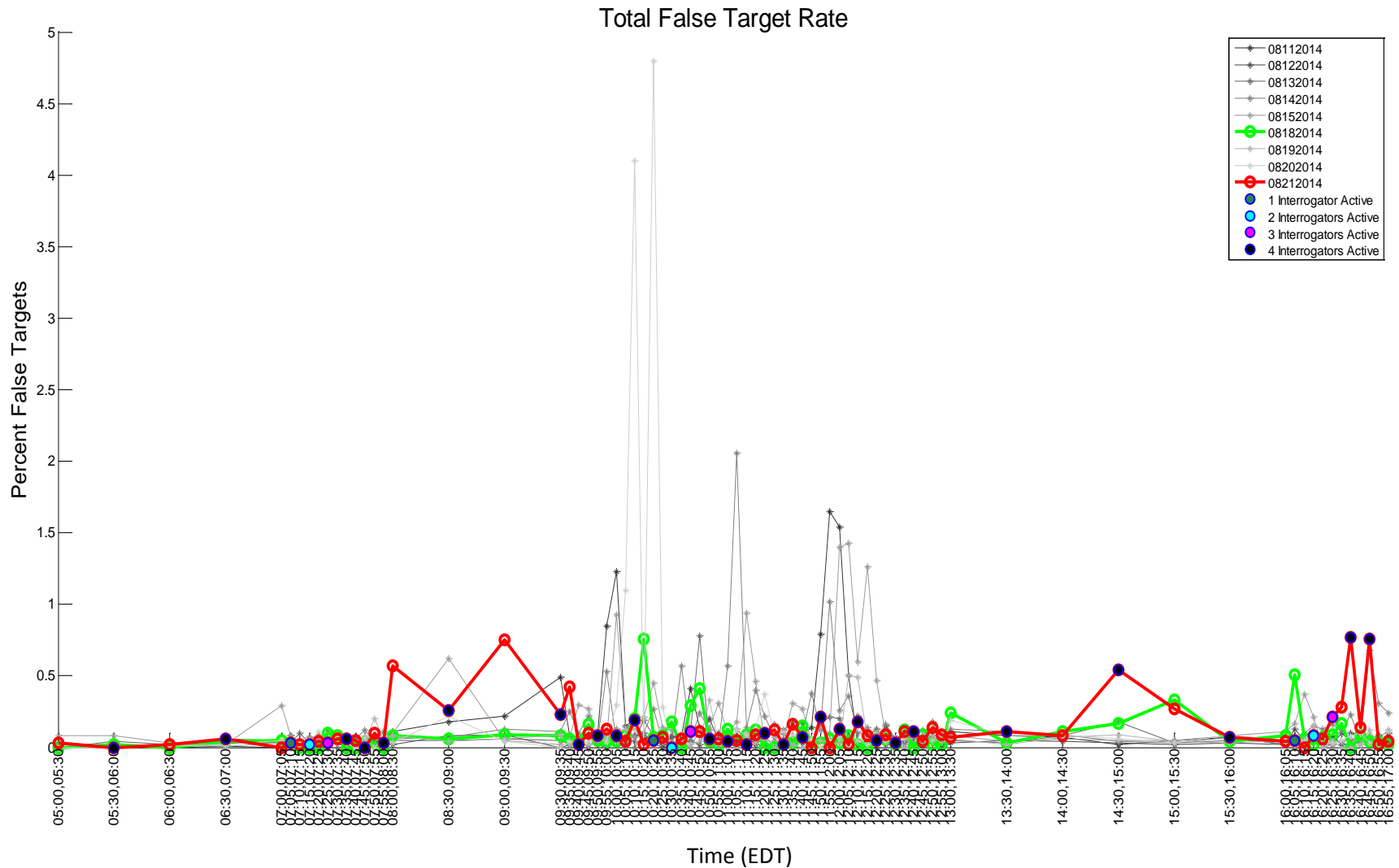


# False Targets – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

# False Targets – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

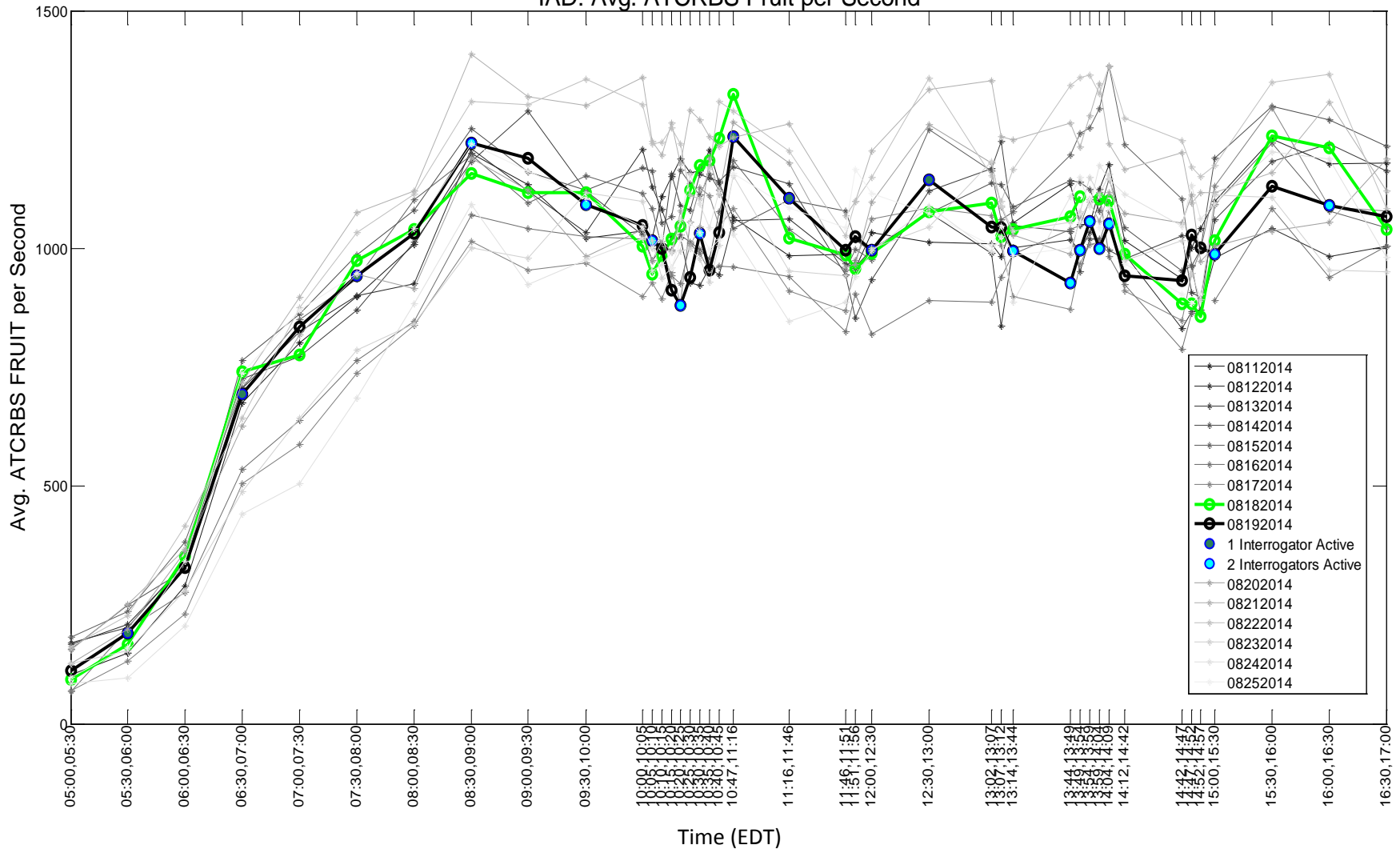
# Observations and Conclusions

- ❑ The Probability of Detection, Identity Reliability and Confidence, Altitude Reliability and Confidence, False Targets, 0000 Codes, and Targets per Scan exhibit no observable adverse trend with respect to periods of radiation by the AN/UPX-41(C) interrogator.
- ❑ During AN/UPX-41(C) interrogator radiation, the variations or volatility of the aforementioned metrics are within the bounds of the variations of the same metrics on non-test days (baseline).
- ❑ In determining possible cases of interference, targets at low elevation angles exhibited relatively low probabilities of detection regardless of Active/OFF period
  - This inherent skew creates many  $P_d$  outliers that mask the ability to notice downward  $P_d$  movement due to interference
  - An analysis excluding low elevation angle targets is available upon request, but the conclusions are no different than the first two bullets of this slide.

# Mode S Extraction Data Analysis

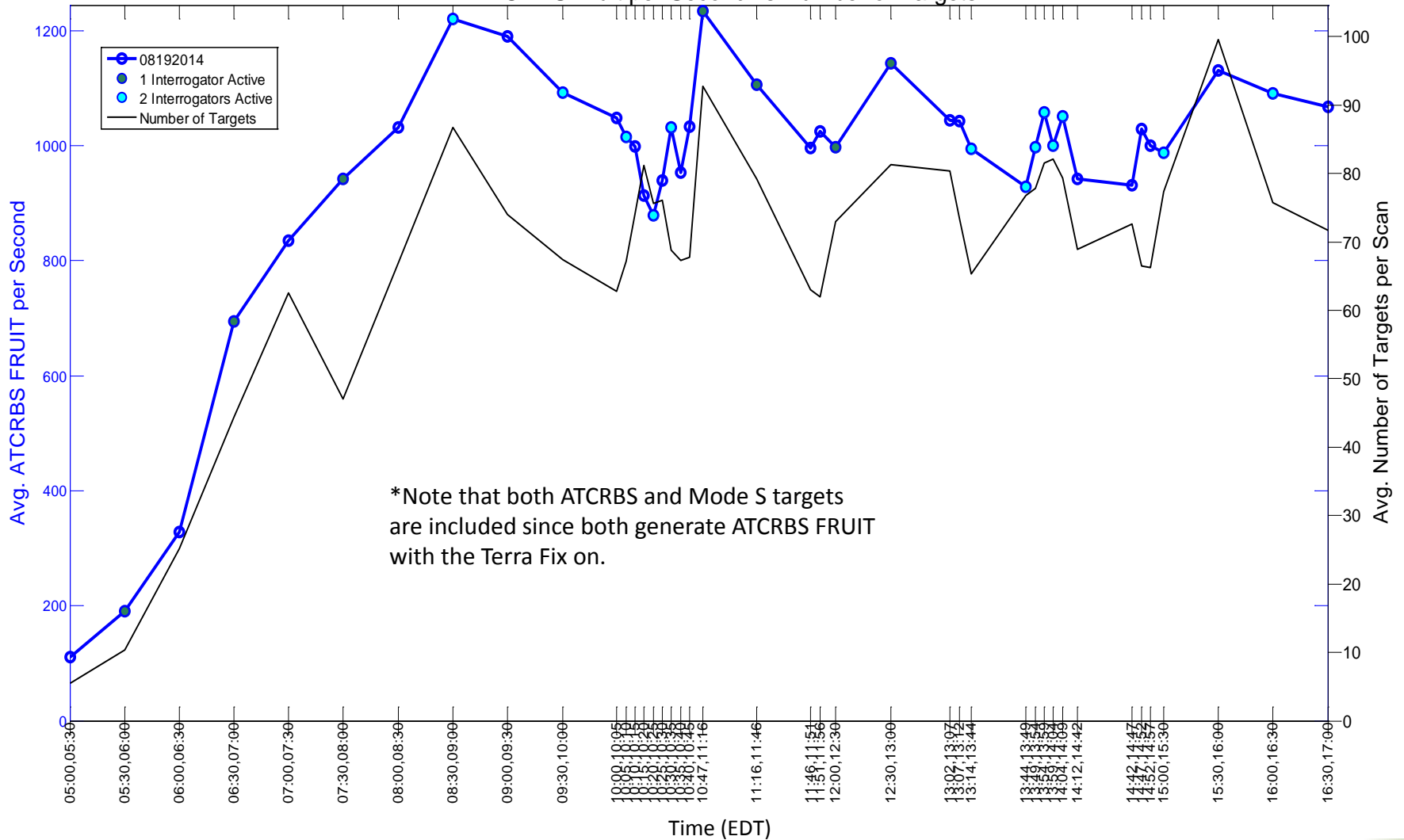
# ATCRBS FRUIT Rate – August 19<sup>th</sup>

IAD: Avg. ATCRBS Fruit per Second



# ATCRBS FRUIT Rate vs # of Targets–August 19<sup>th</sup>

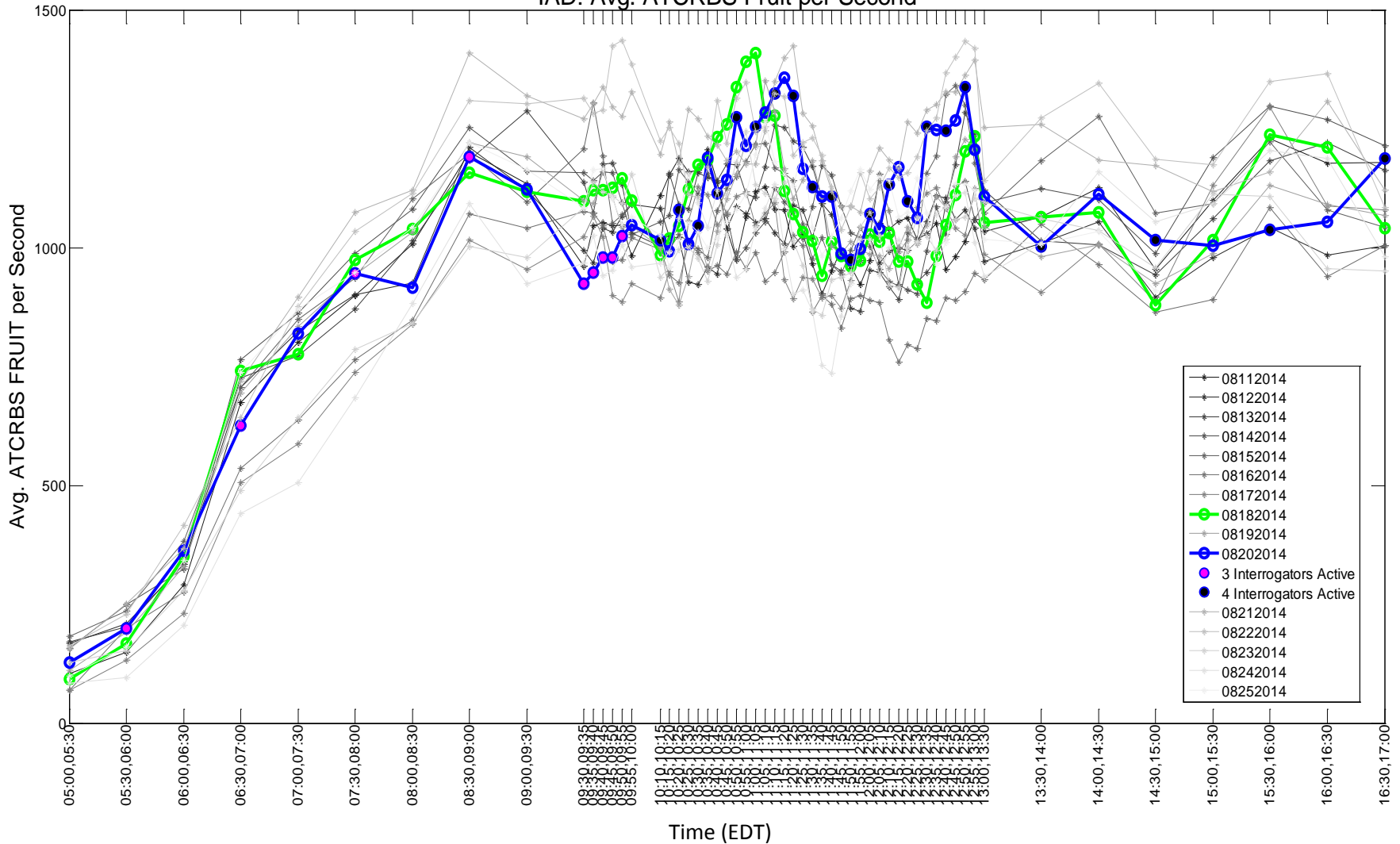
IAD: ATCRBS Fruit per Second vs Number of Targets



\*Note that both ATCRBS and Mode S targets are included since both generate ATCRBS FRUIT with the Terra Fix on.

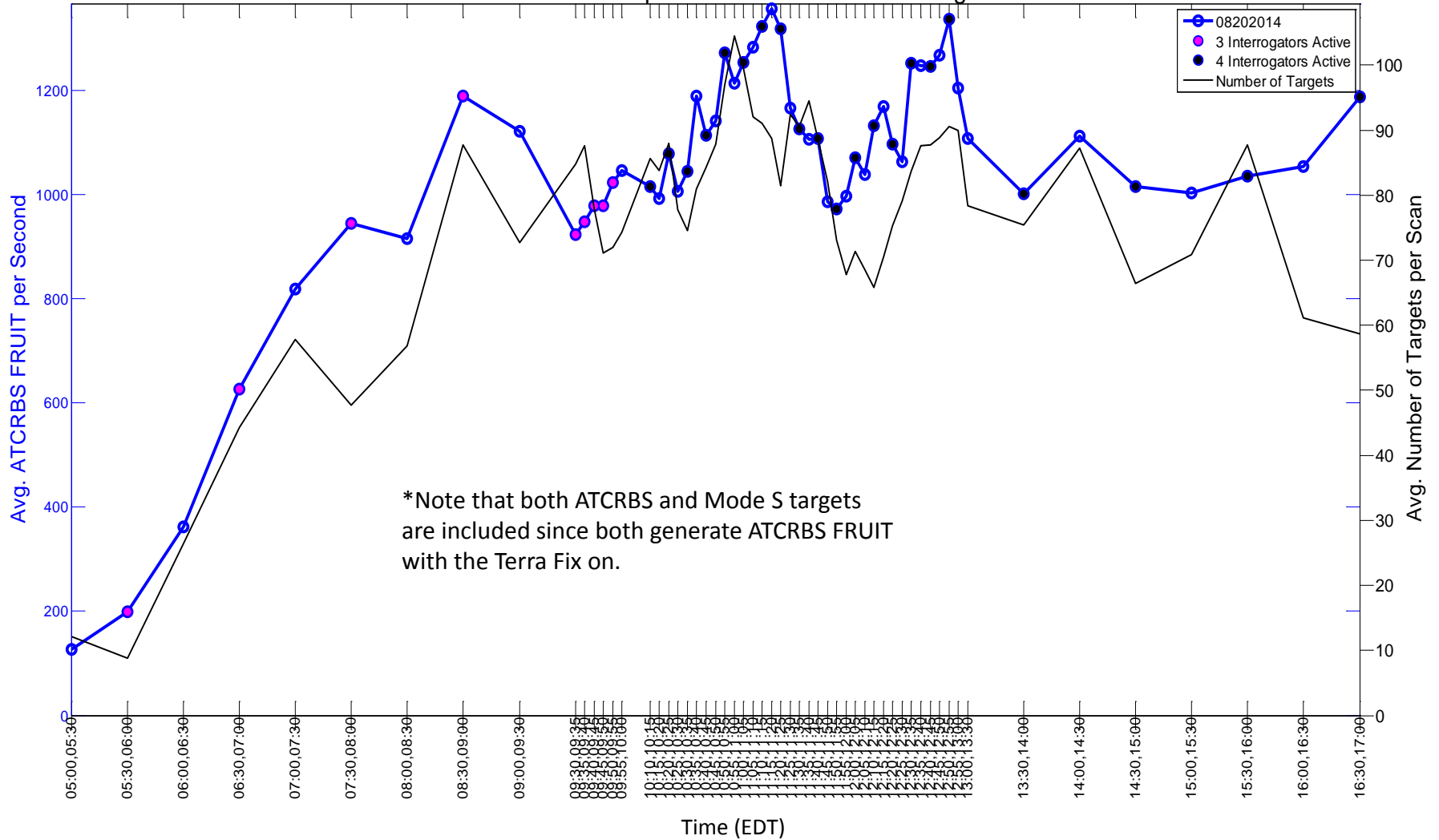
# ATCRBS FRUIT Rate – August 20<sup>th</sup>

IAD: Avg. ATCRBS Fruit per Second



# ATCRBS FRUIT Rate vs # of Targets – August 20<sup>th</sup>

IAD: ATCRBS Fruit per Second vs Number of Targets

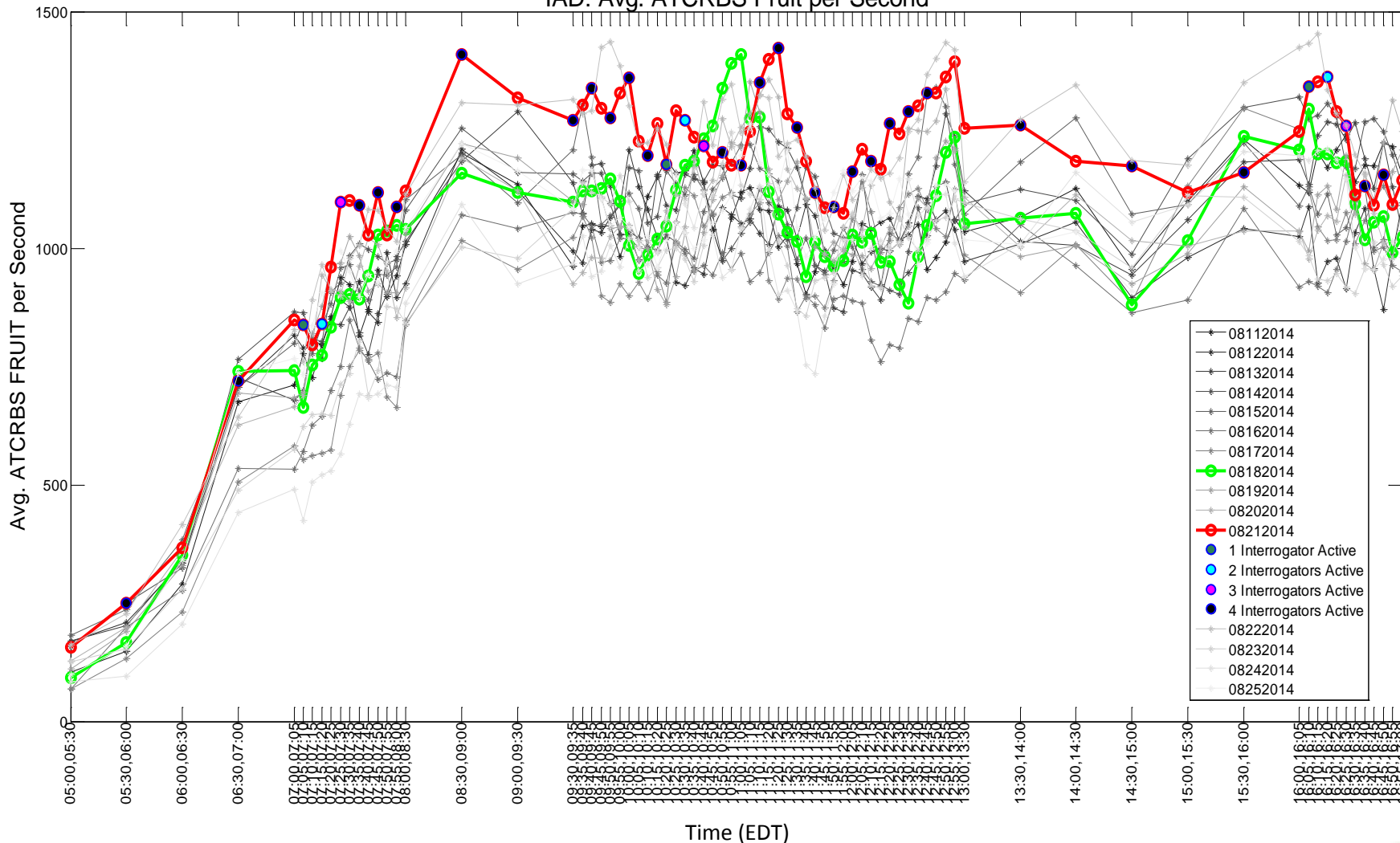


\*Note that both ATCRBS and Mode S targets are included since both generate ATCRBS FRUIT with the Terra Fix on.



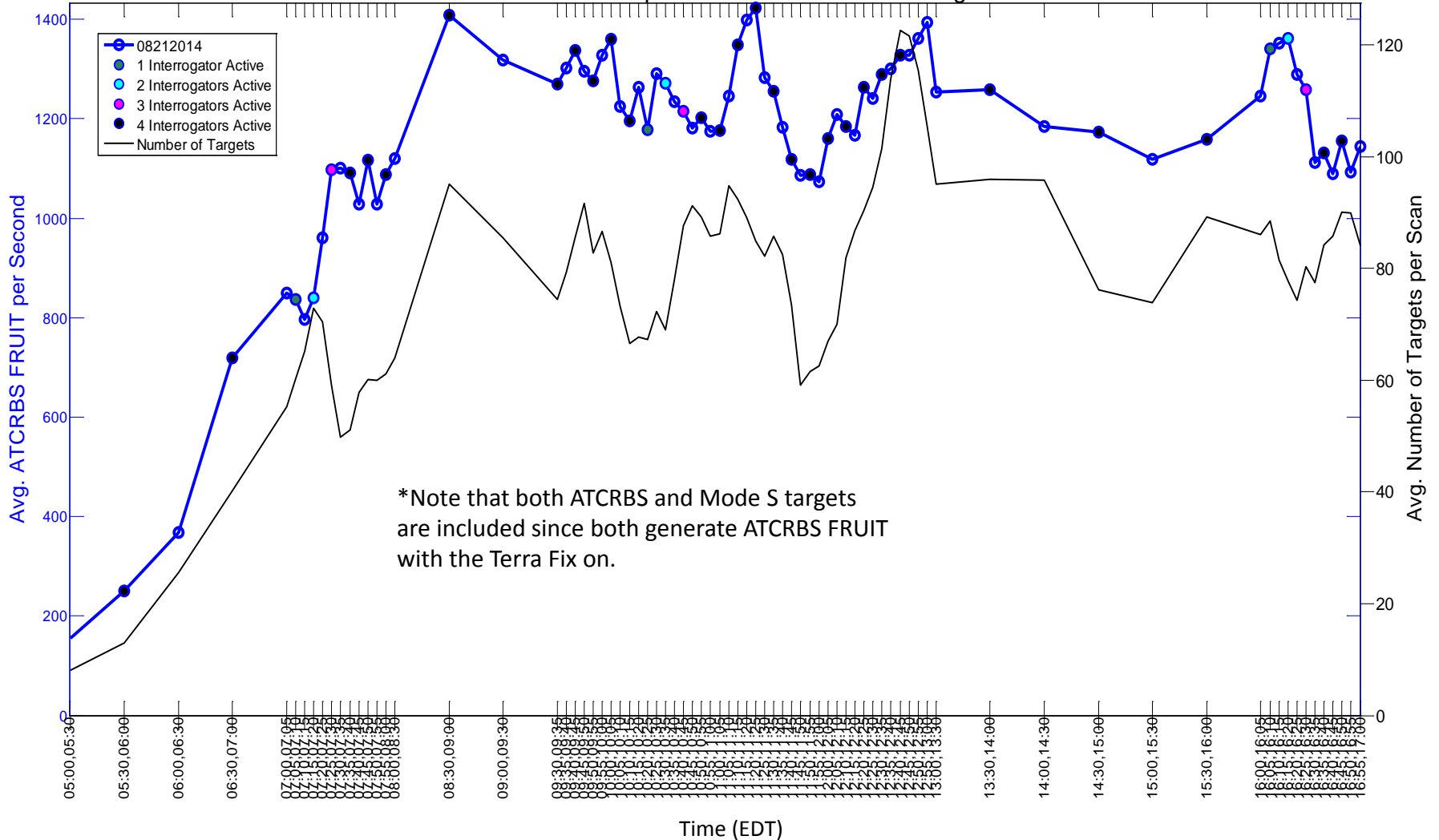
# ATCRBS FRUIT Rate – August 21<sup>st</sup>

IAD: Avg. ATCRBS Fruit per Second



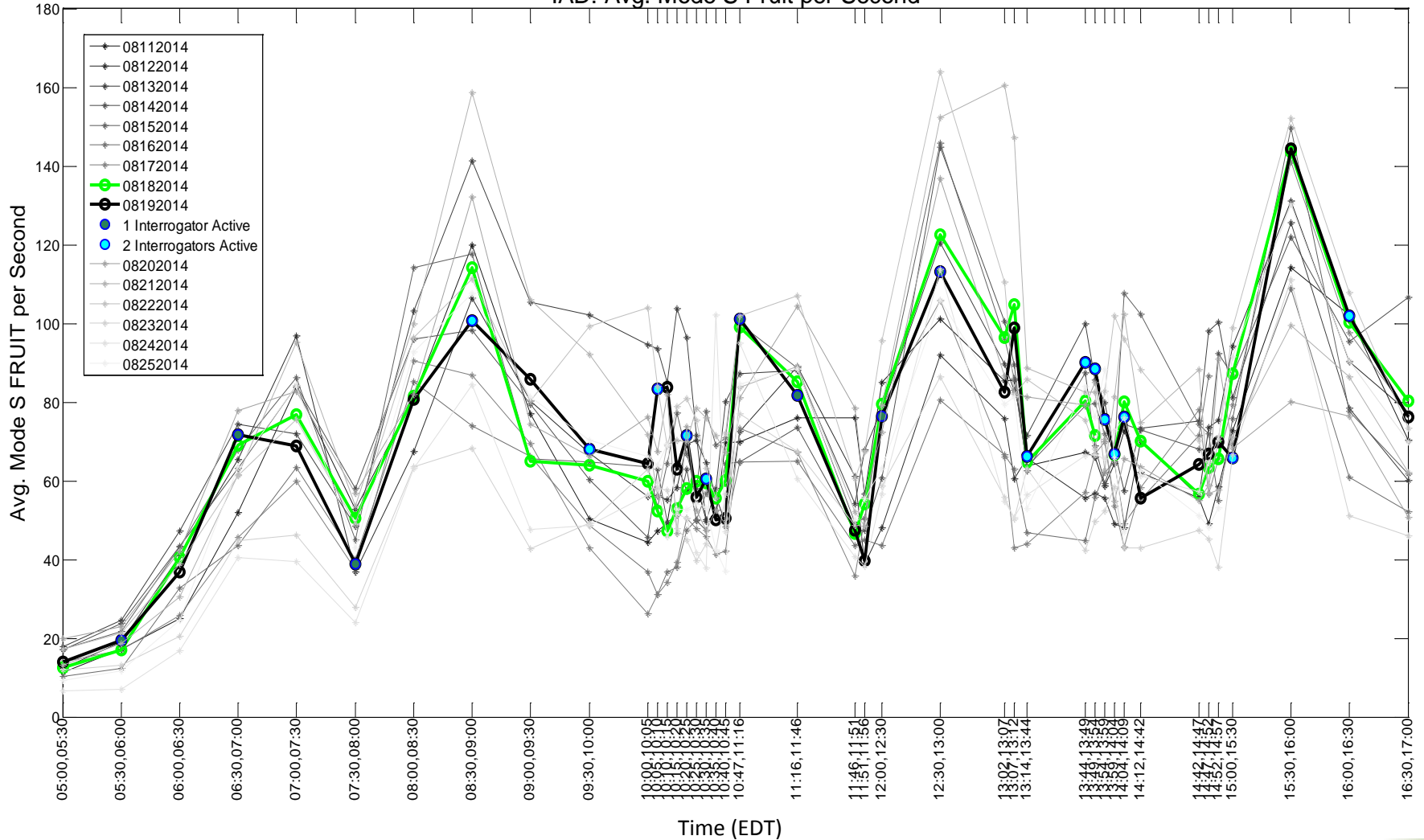
# ATCRBS FRUIT Rate vs # of Targets–August 21<sup>st</sup>

IAD: ATCRBS Fruit per Second vs Number of Targets



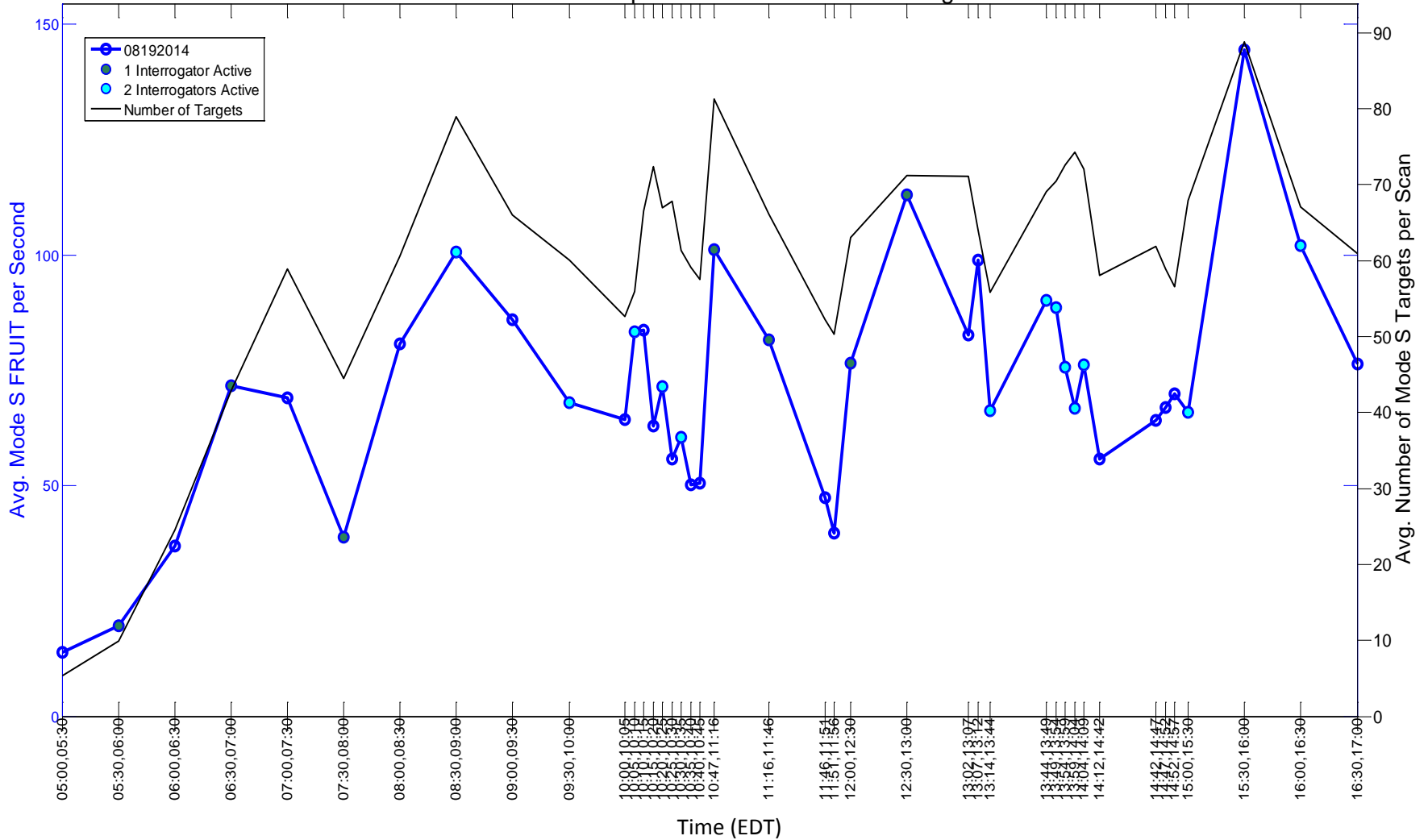
# Mode S FRUIT Rate – August 19<sup>th</sup>

IAD: Avg. Mode S Fruit per Second



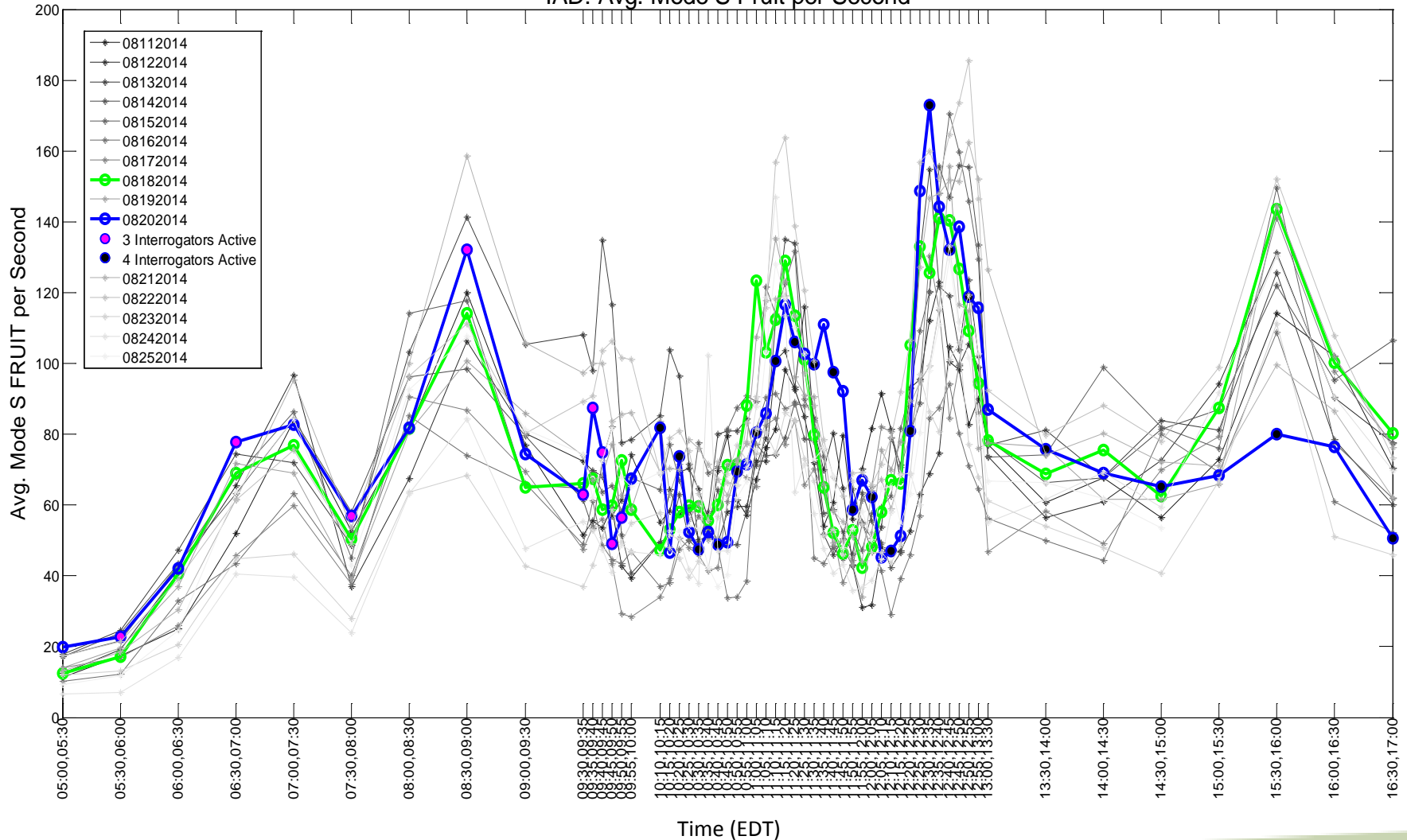
# Mode S FRUIT Rate vs # of Targets–August 19<sup>th</sup>

IAD: Mode S Fruit per Second vs Number of Targets



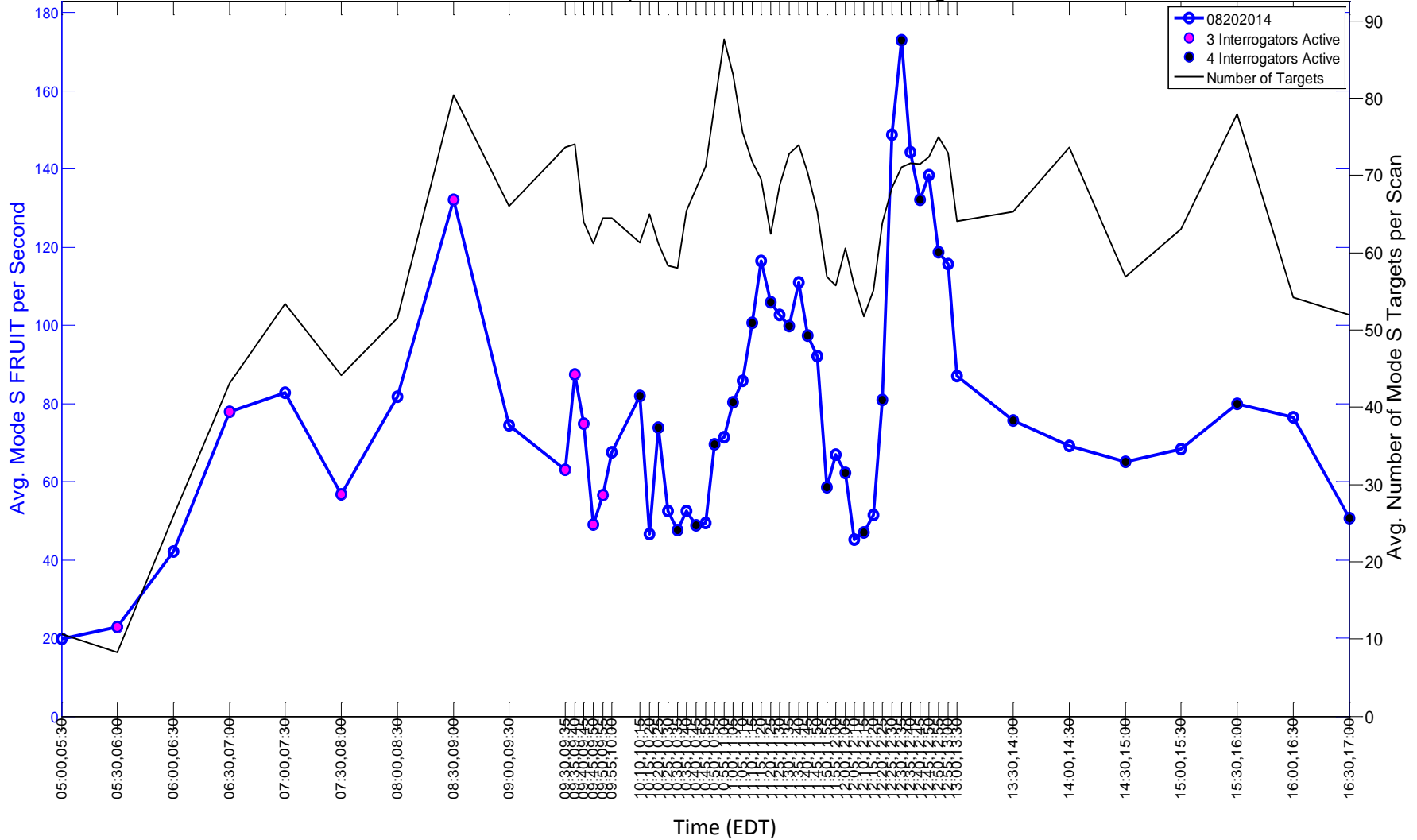
# Mode S FRUIT Rate – August 20<sup>th</sup>

IAD: Avg. Mode S Fruit per Second



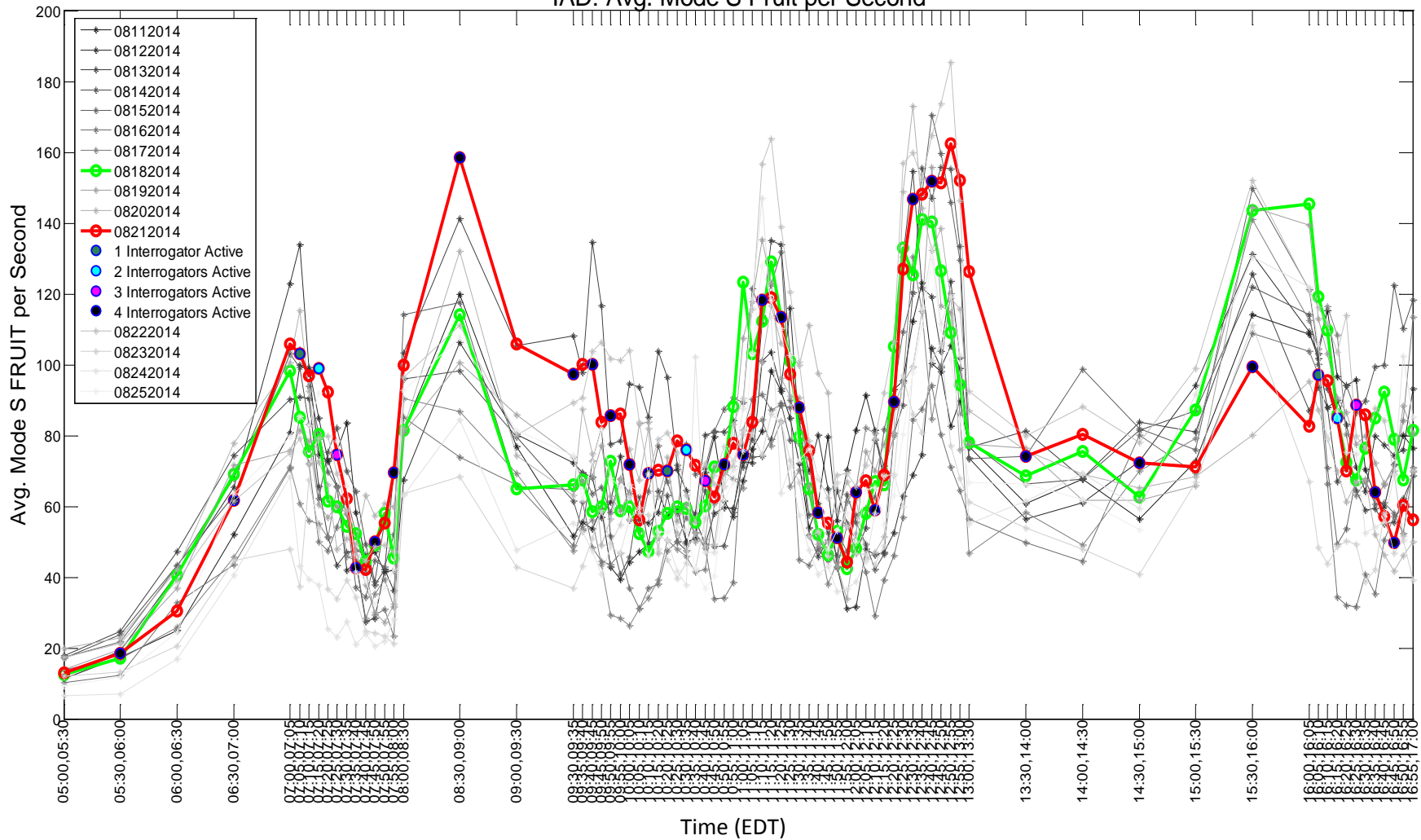
# Mode S FRUIT Rate vs # of Targets–August 20<sup>th</sup>

IAD: Mode S Fruit per Second vs Number of Targets



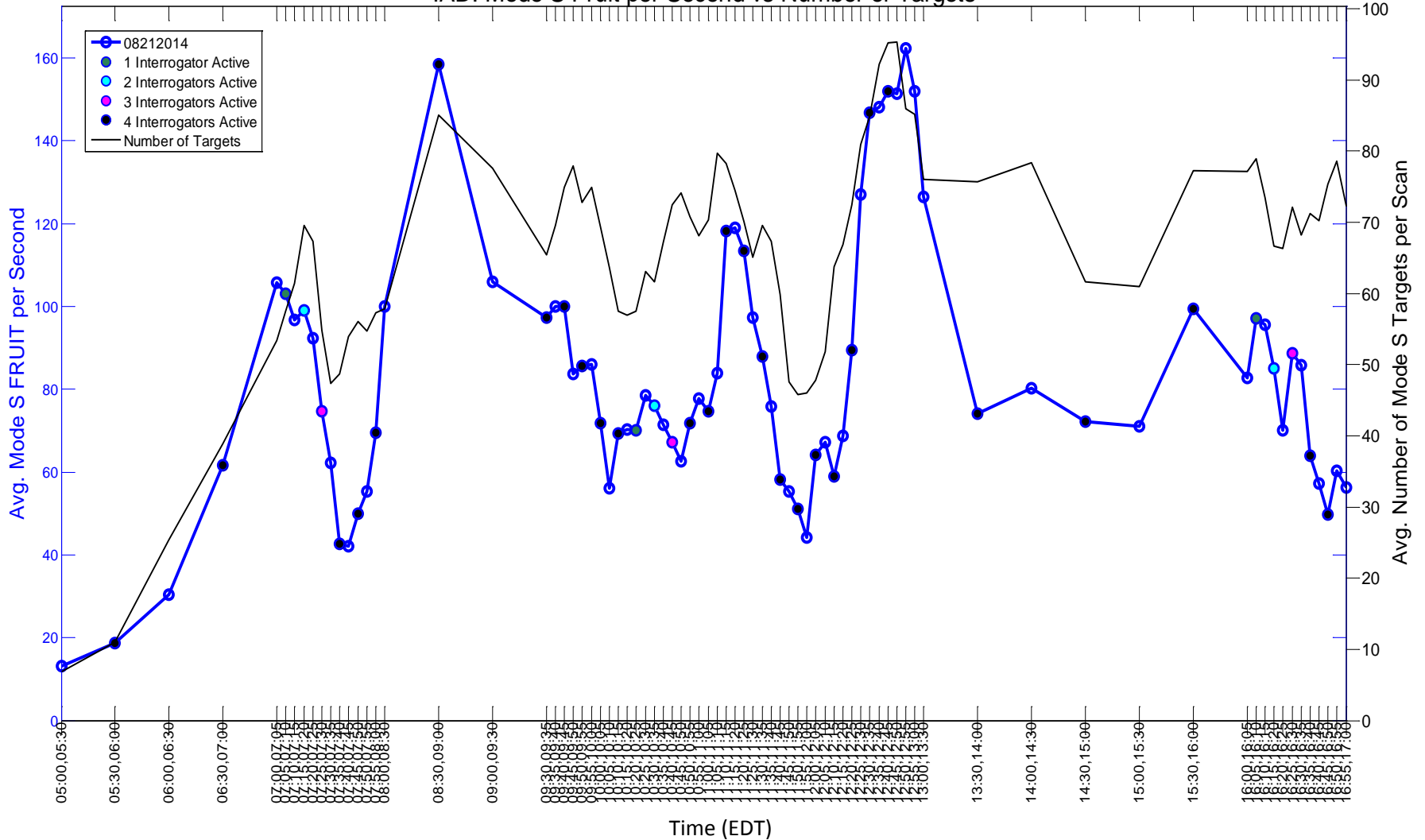
# Mode S FRUIT Rate – August 21<sup>st</sup>

IAD: Avg. Mode S Fruit per Second



# Mode S FRUIT Rate vs # of Targets—August 21<sup>st</sup>

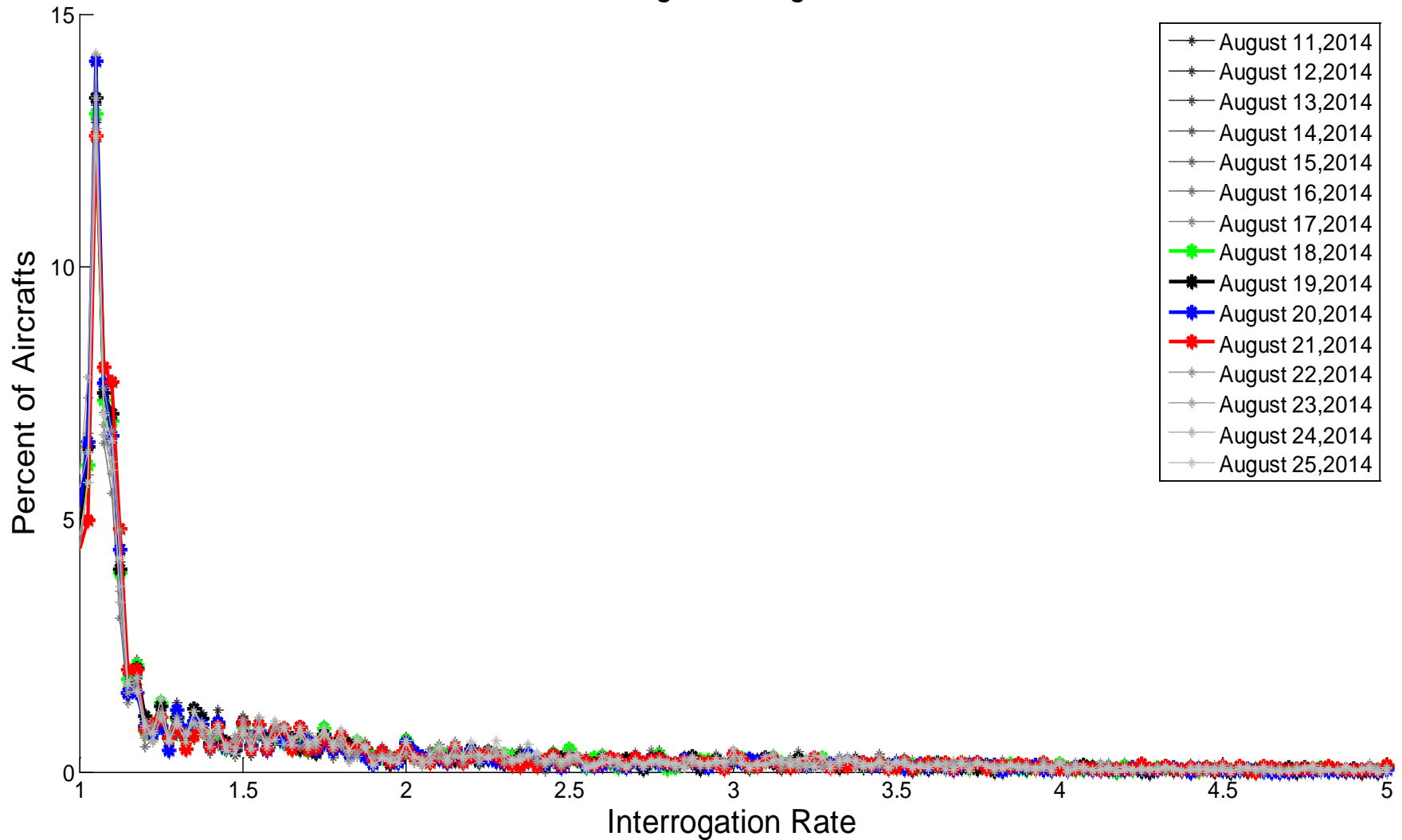
IAD: Mode S Fruit per Second vs Number of Targets





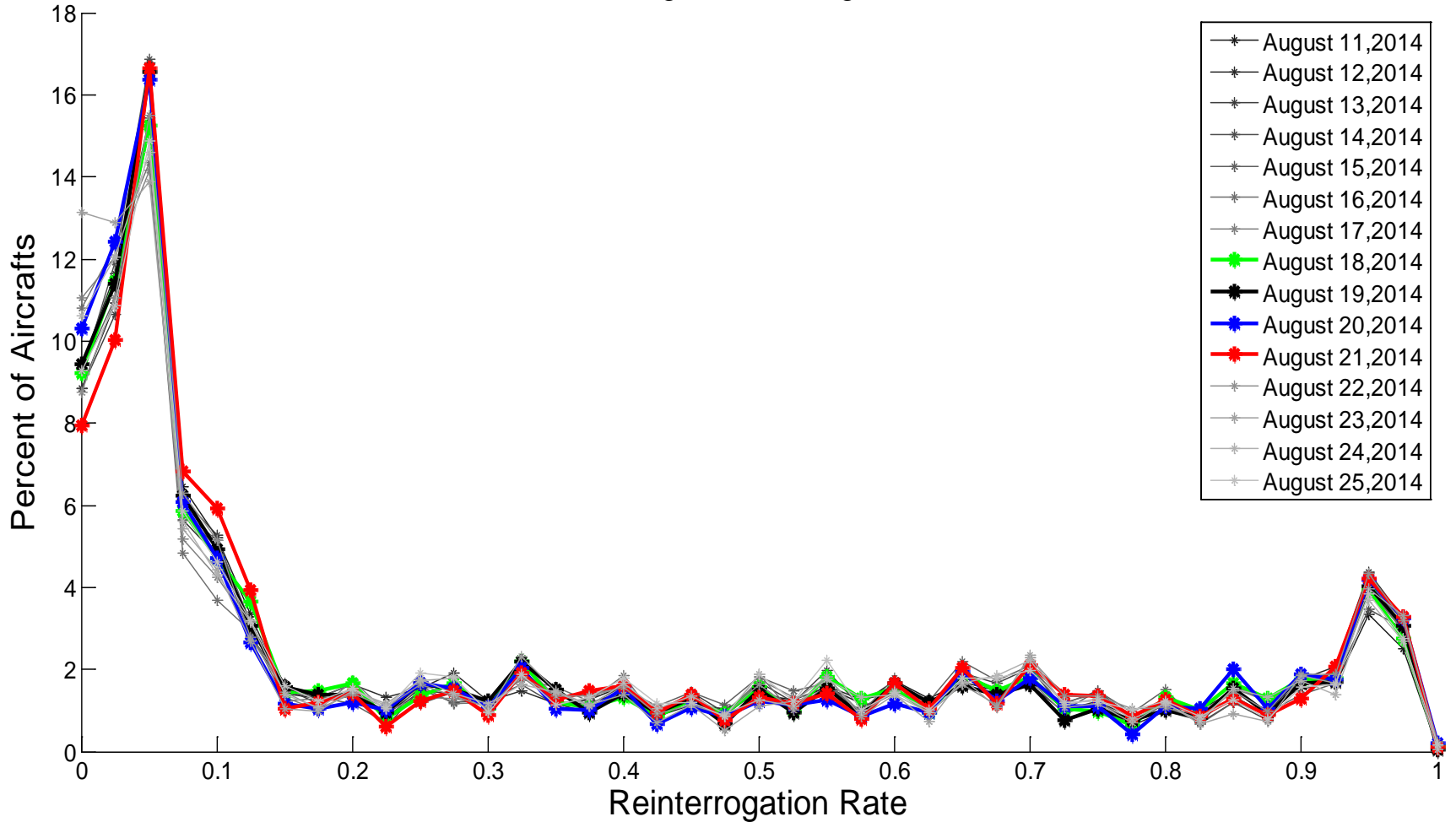
# Interrogation Rate – All Days

IAD:Average Interrogation Rate



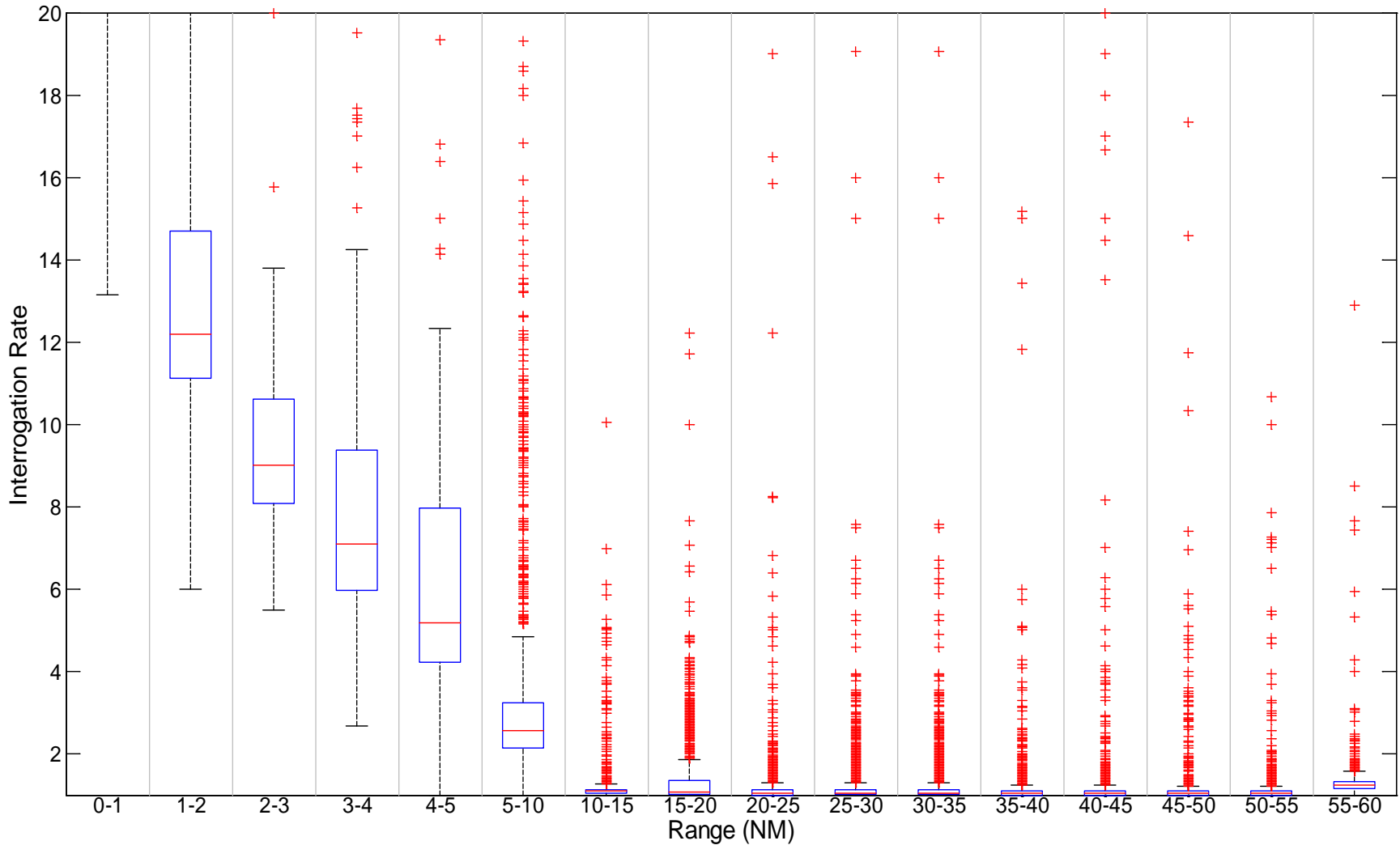
# Reinterrogation Rate – All Days

IAD:Average Reinterrogation Rate



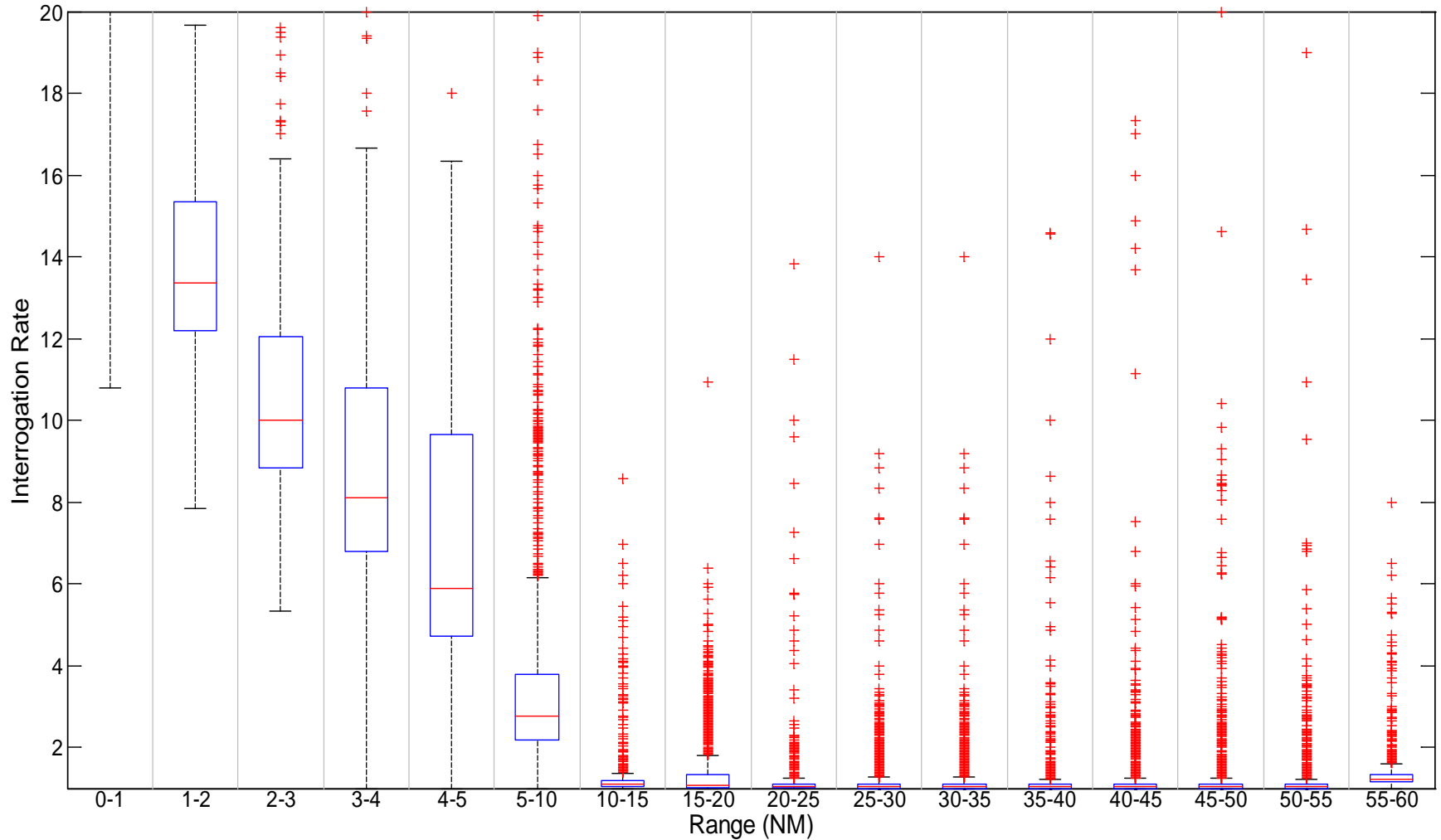
# Interrogation Rate vs Range – August 19<sup>th</sup>

Site: IAD



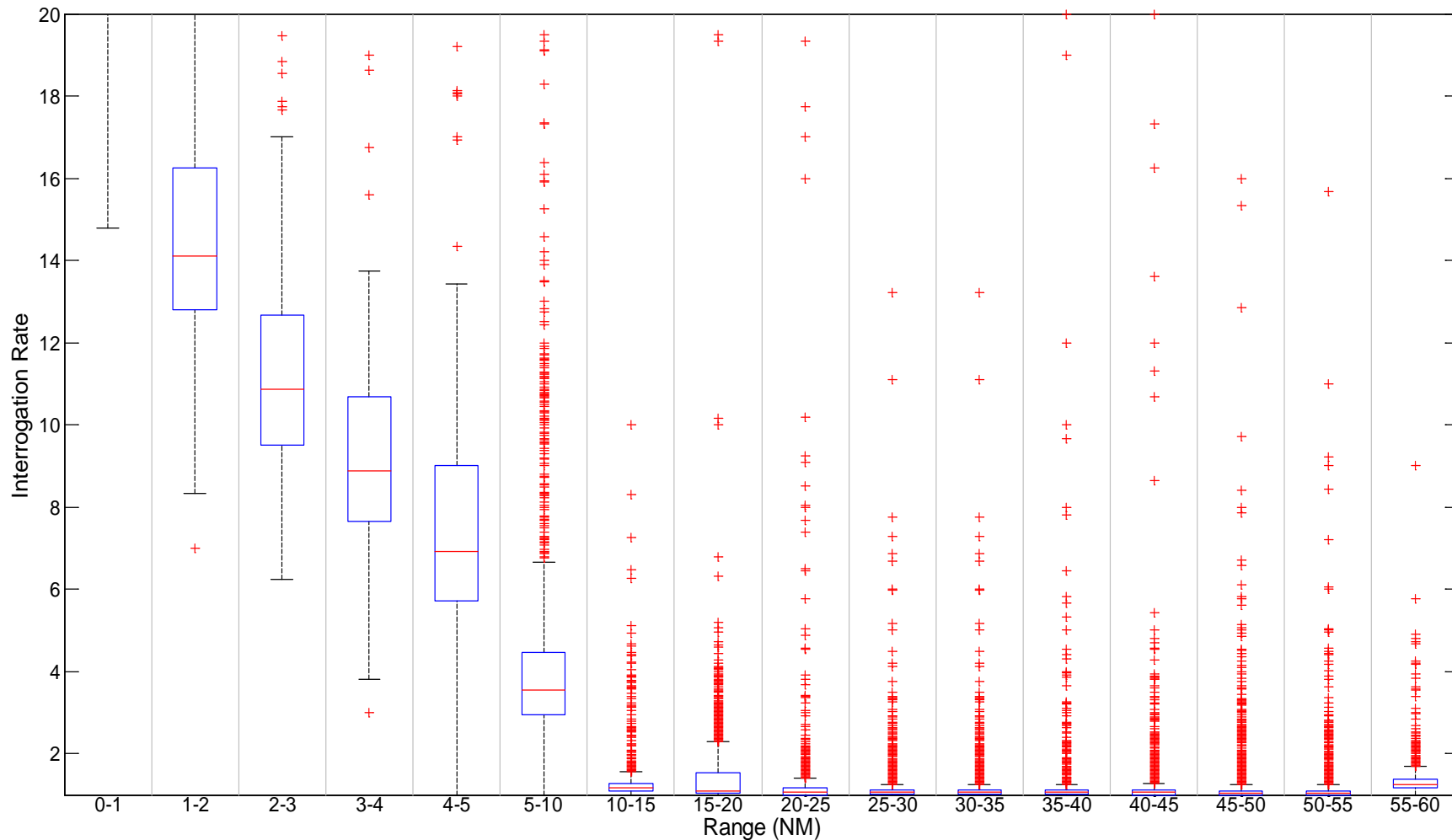
# Interrogation Rate vs Range – August 20<sup>th</sup>

Site: IAD



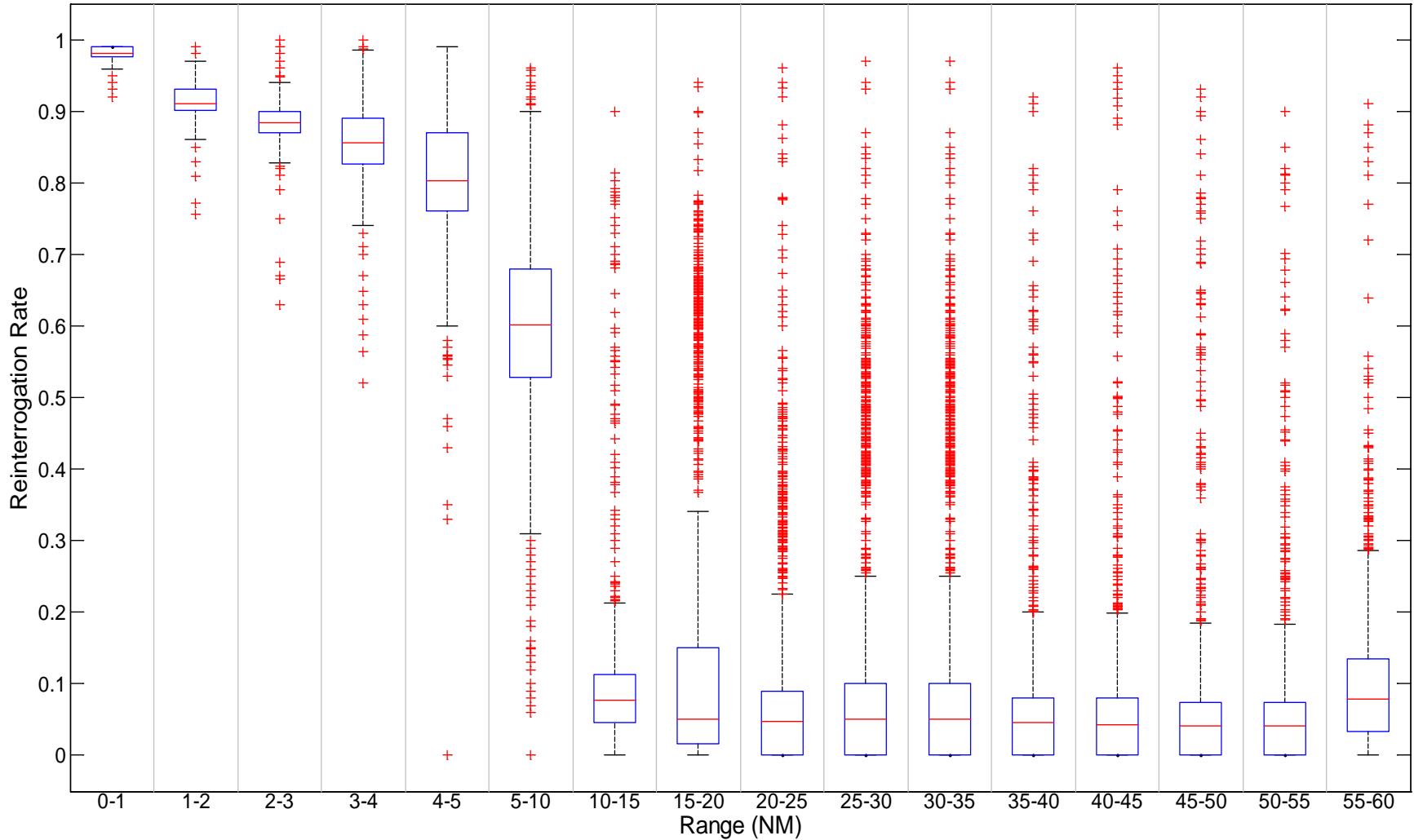
# Interrogation Rate vs Range – August 21<sup>st</sup>

Site: IAD



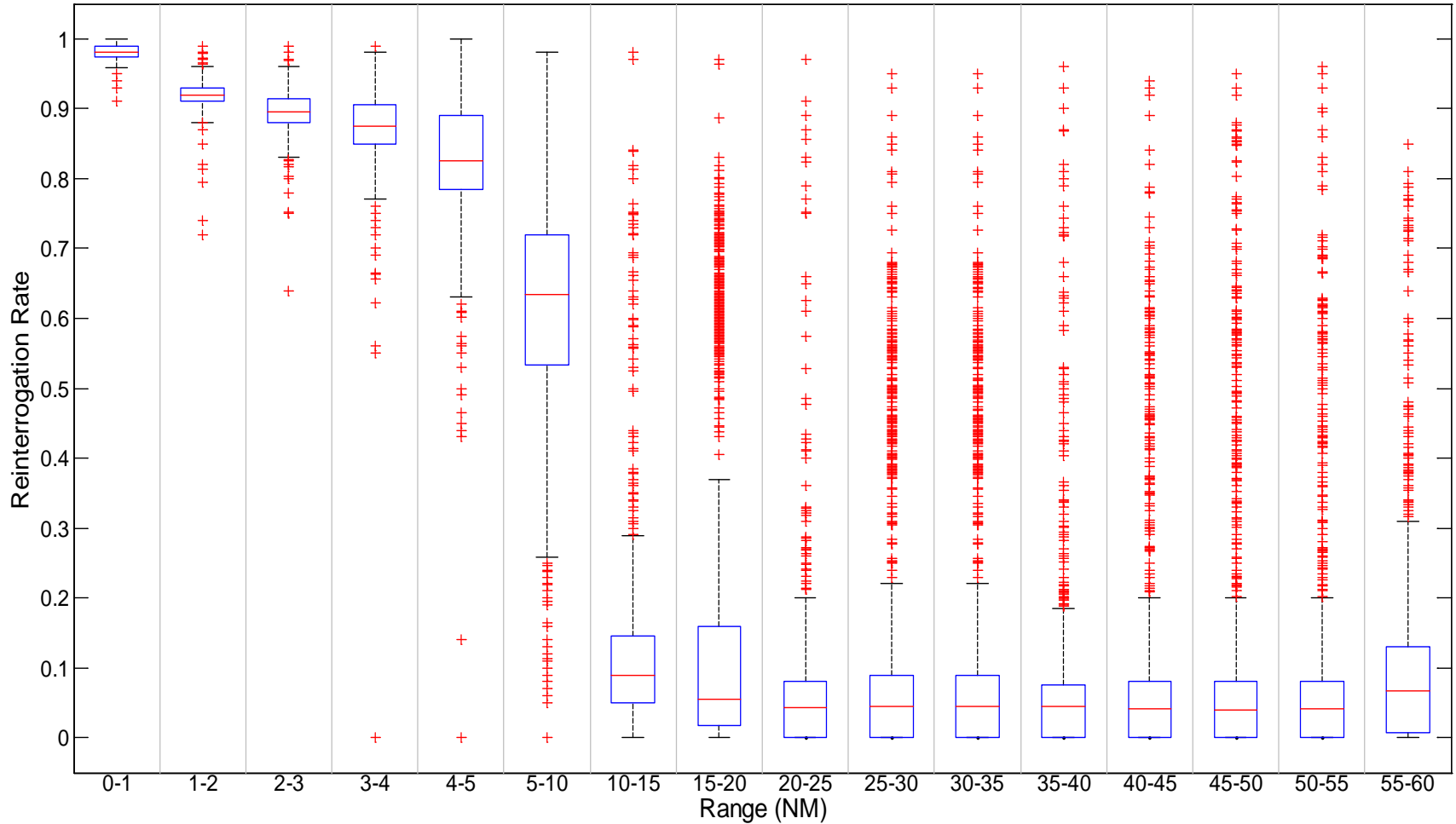
# Reinterrogation Rate vs Range – August 19<sup>th</sup>

Site: IAD



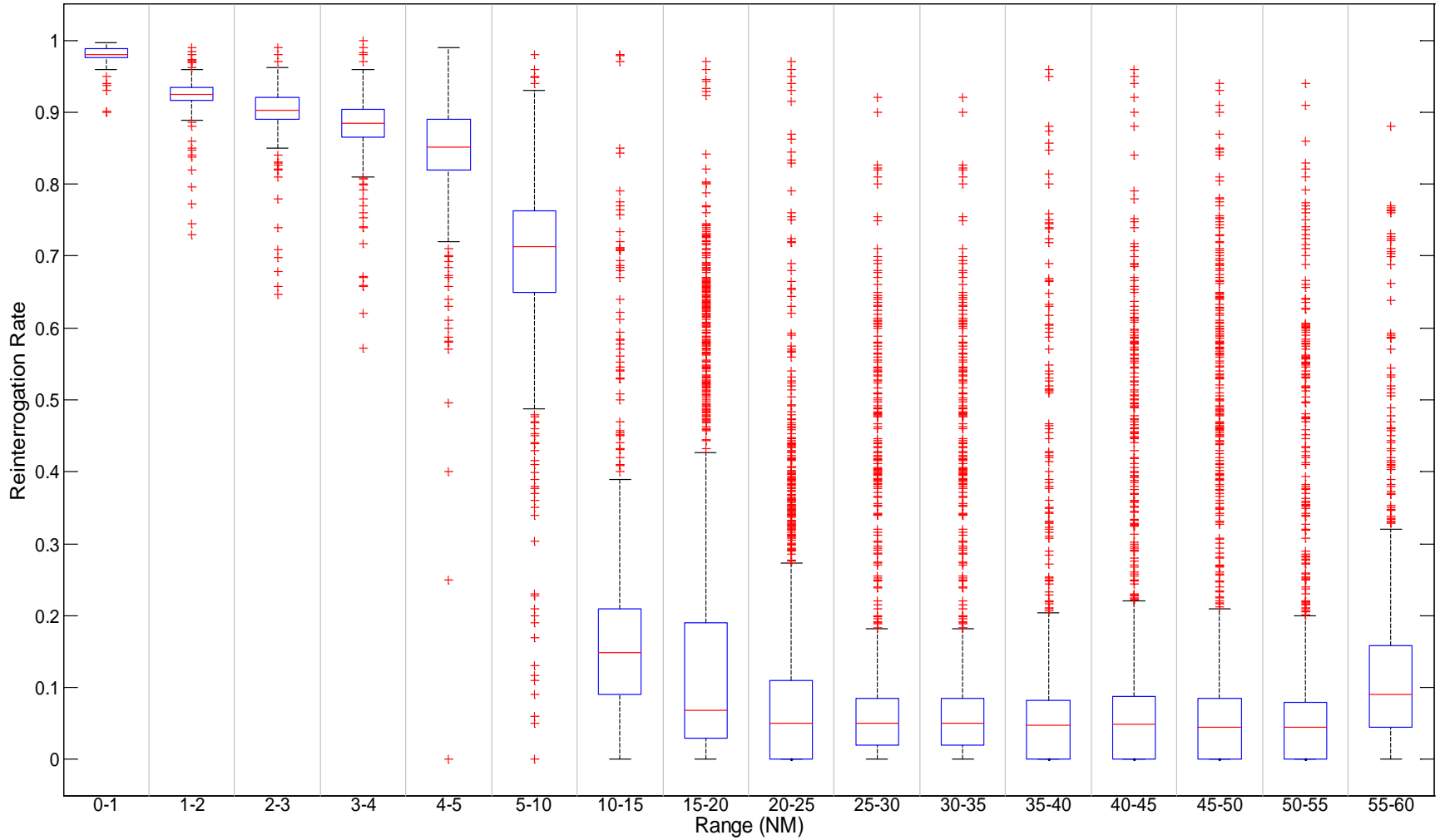
# Reinterrogation Rate vs Range – August 20<sup>th</sup>

Site: IAD



# Reinterrogation Rate vs Range – August 21<sup>st</sup>

Site: IAD





# Observations and Conclusions

## ❑ FRUIT Analysis

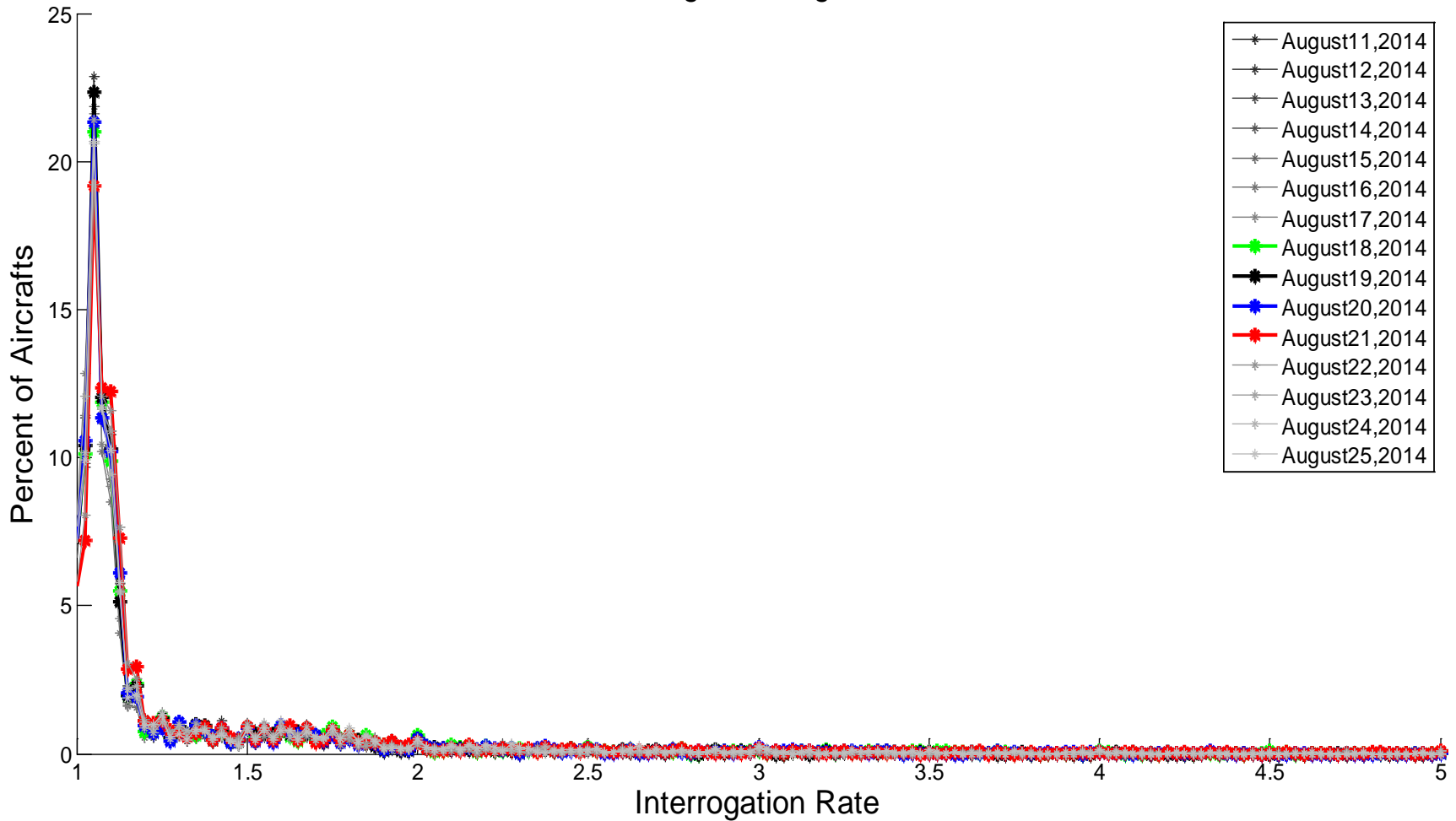
- ATCRBS FRUIT rates do not always increase when AN/UPX-41(C) interrogators are Active. This means the AN/UPX-41(C) FRUIT impact, for the Stage 4 configuration, generates less ATCRBS FRUIT than the normal daily fluctuations of ATCRBS FRUIT due to changes in traffic densities. This is also confirmed by the generally high correlation between traffic count and ATCRBS FRUIT rate movements.
- AN/UPX-41(C) interrogators should have produced no extra Mode S FRUIT and the plots confirm this.

## ❑ Channel Management Statistics

- Targets within 10 NM showed consistently high interrogation/reinterrogation rates
  - This phenomenon is due to the unpredictability of roll call target azimuths at close ranges. The Mode S roll call scheduler starts interrogations many degrees before the tracker's predicted azimuth to ensure that unknown changes in speed and heading will not limit the ability of the Mode S system to get an update on the target.
  - So while the reinterrogation rate is high within 10 NM, it is not due to transponder occupancy or receiver garble.
  - To notice any possible change in interrogation/reinterrogation rates between Active/OFF periods, targets within 10 NM of SSR site were excluded in the next section of analysis.

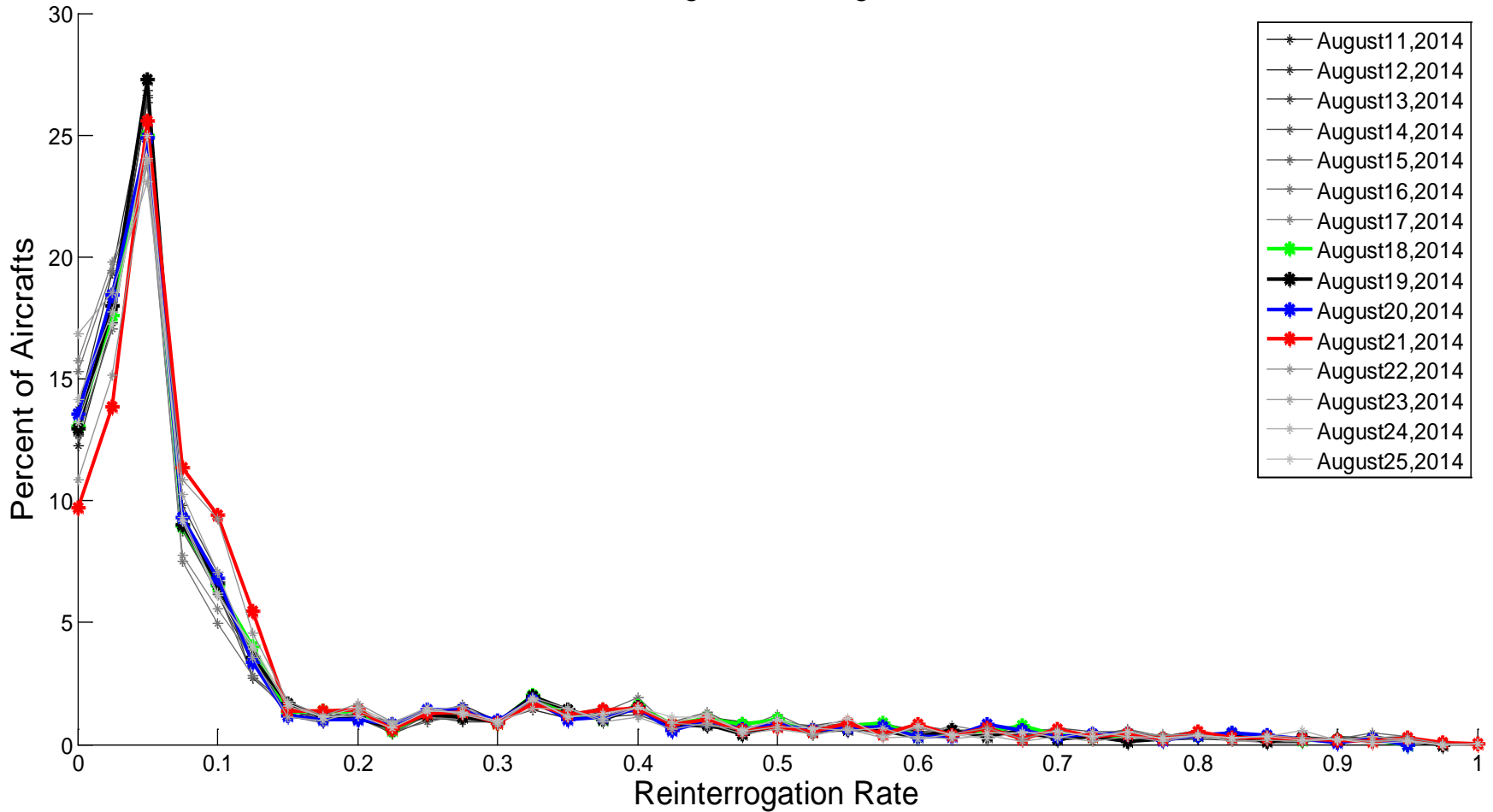
# Interrogation Rate – All Days

IAD:Average Interrogation Rate



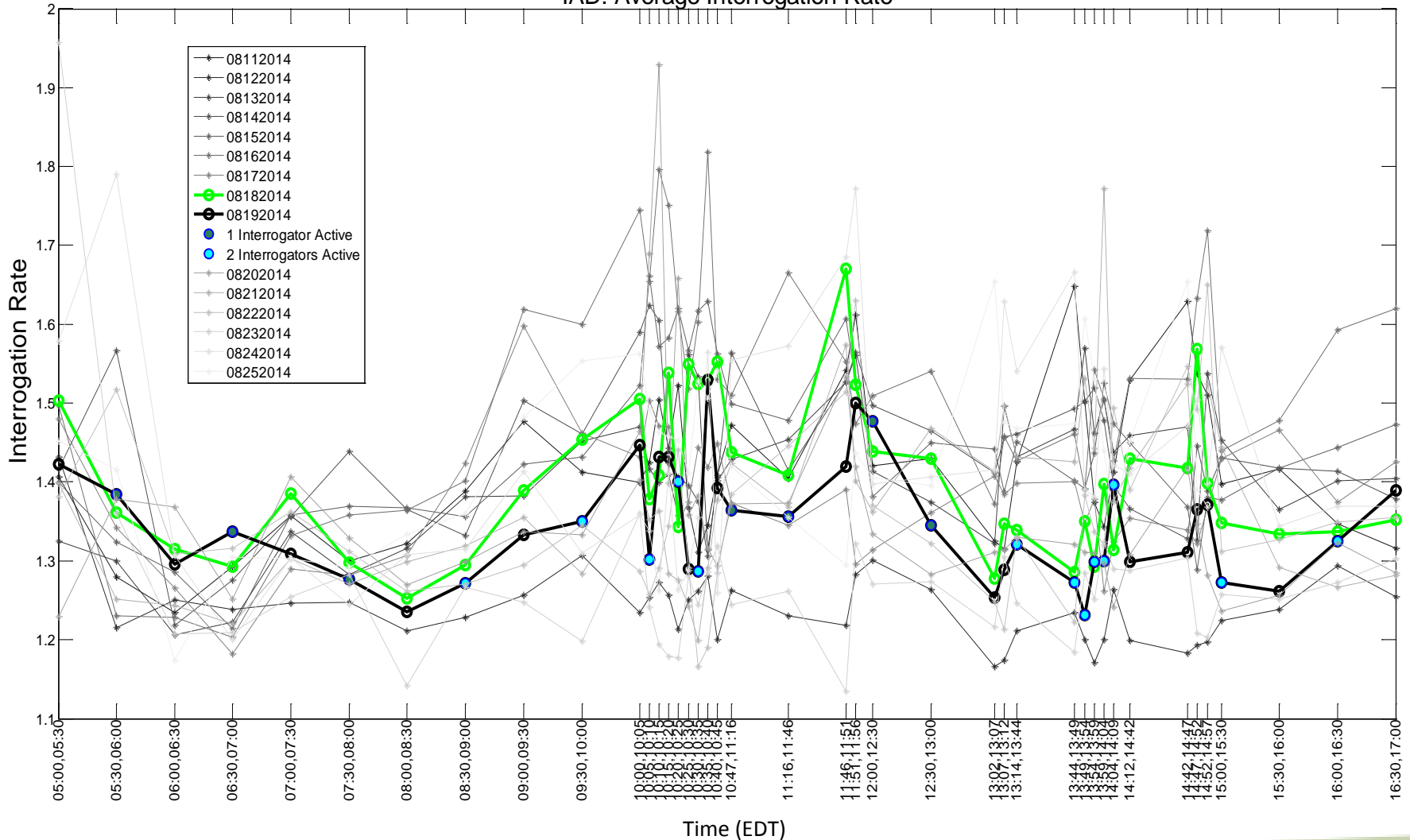
# Reinterrogation Rate – All Days

IAD:Average Reinterrogation Rate



# Interrogation Rate – August 19<sup>th</sup>

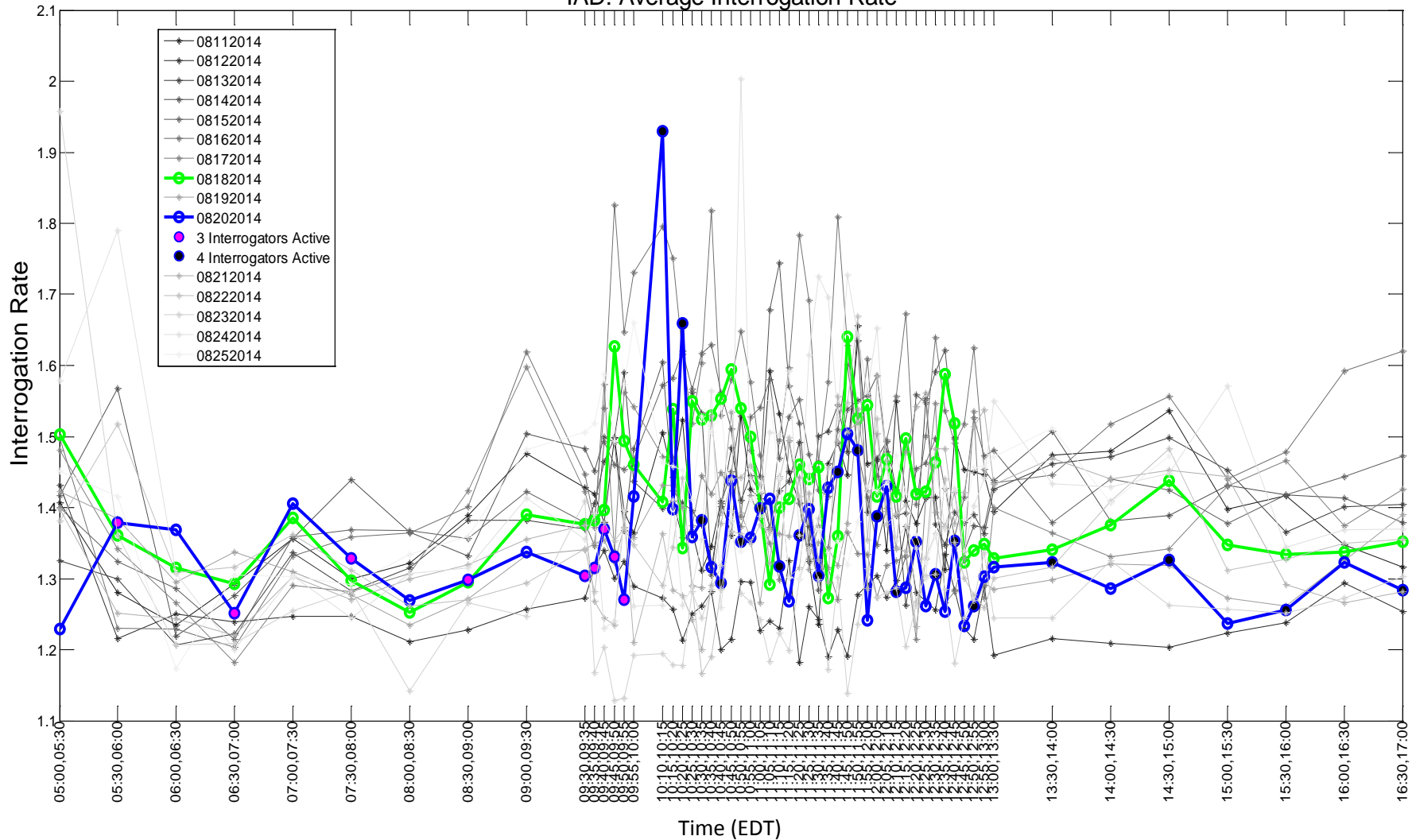
IAD: Average Interrogation Rate



Geographic Filter: None  
Target Filter: Targets > 10 NM from SSR

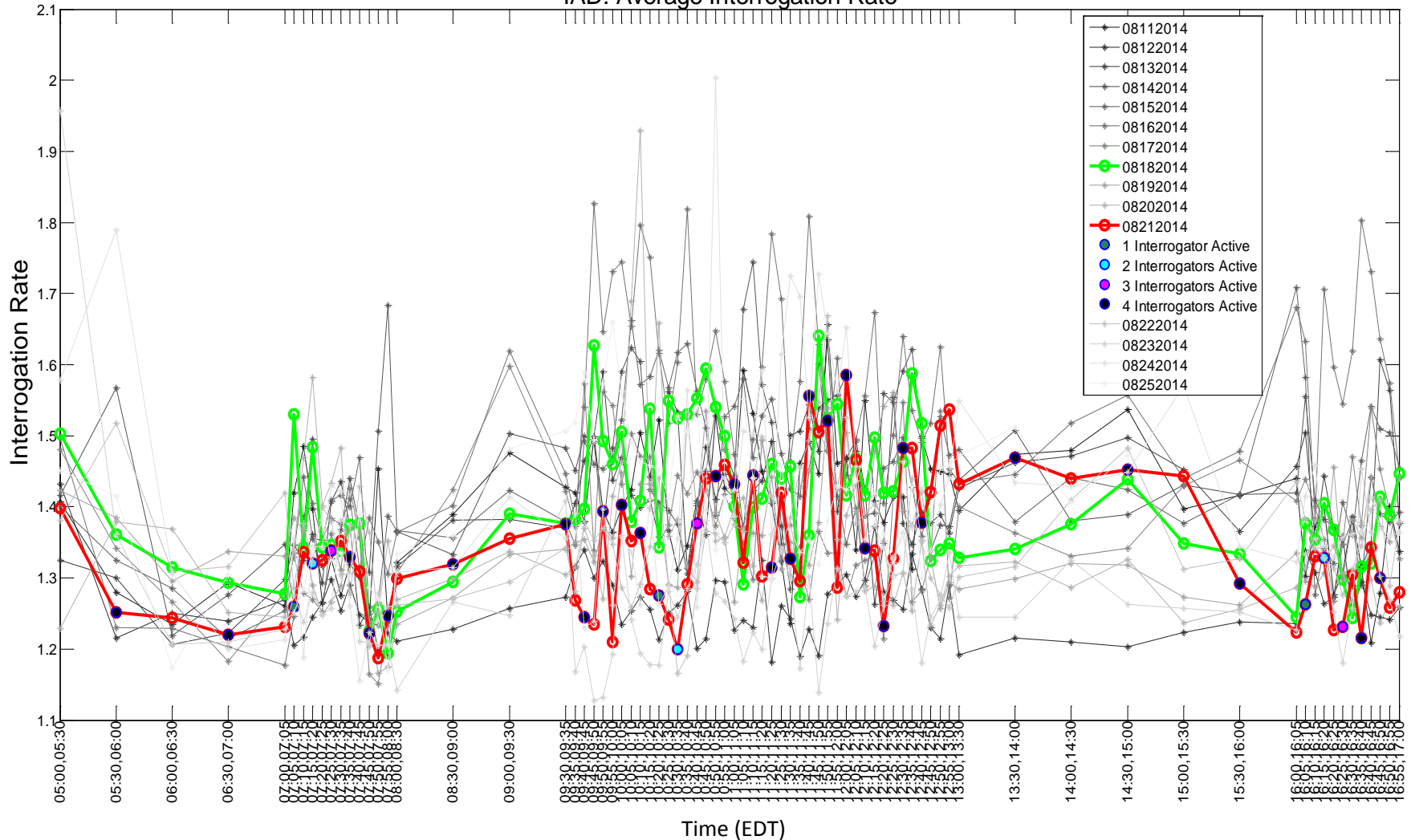
# Interrogation Rate – August 20<sup>th</sup>

IAD: Average Interrogation Rate



# Interrogation Rate – August 21<sup>st</sup>

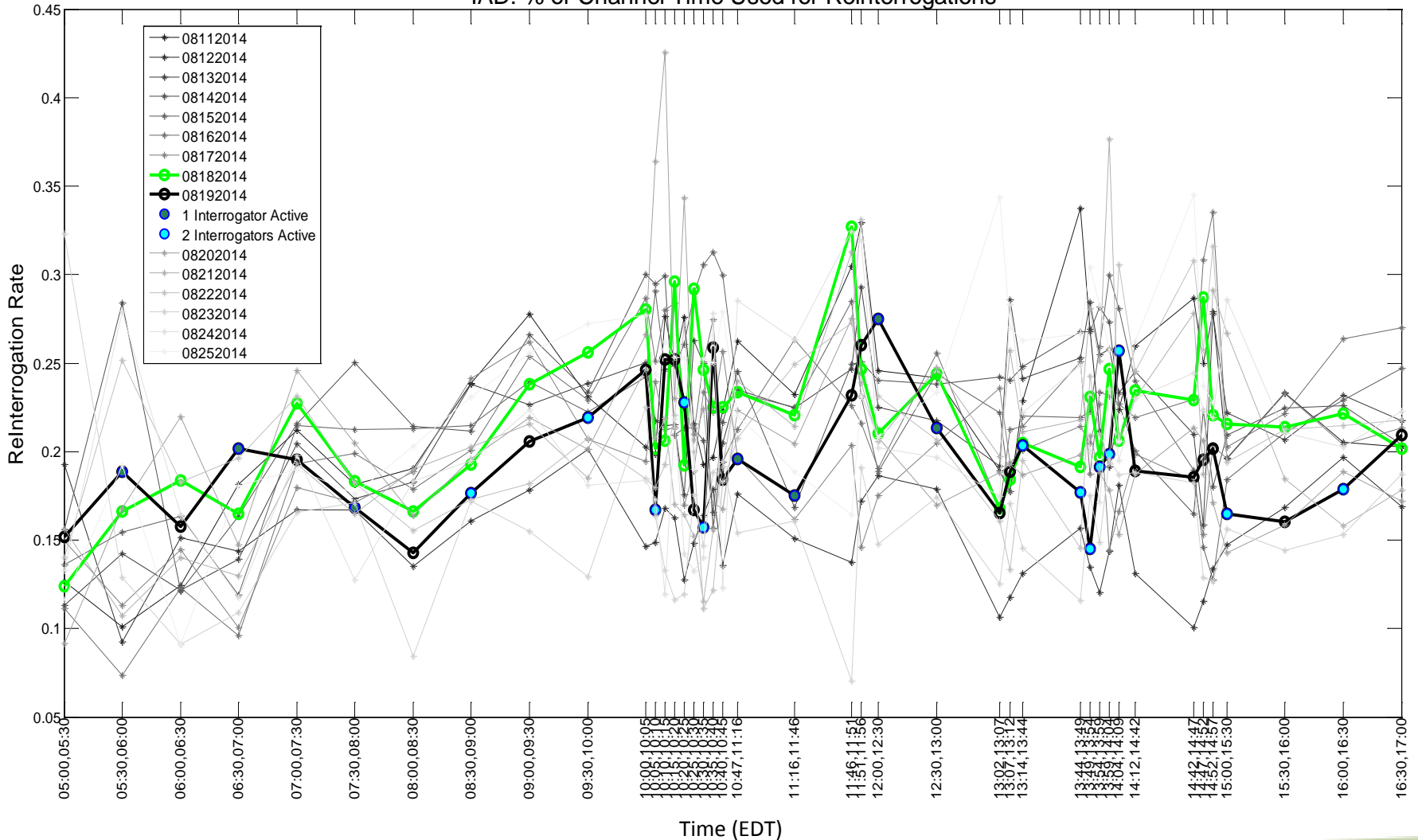
IAD: Average Interrogation Rate



Geographic Filter: None  
Target Filter: Targets > 10 NM from SSR

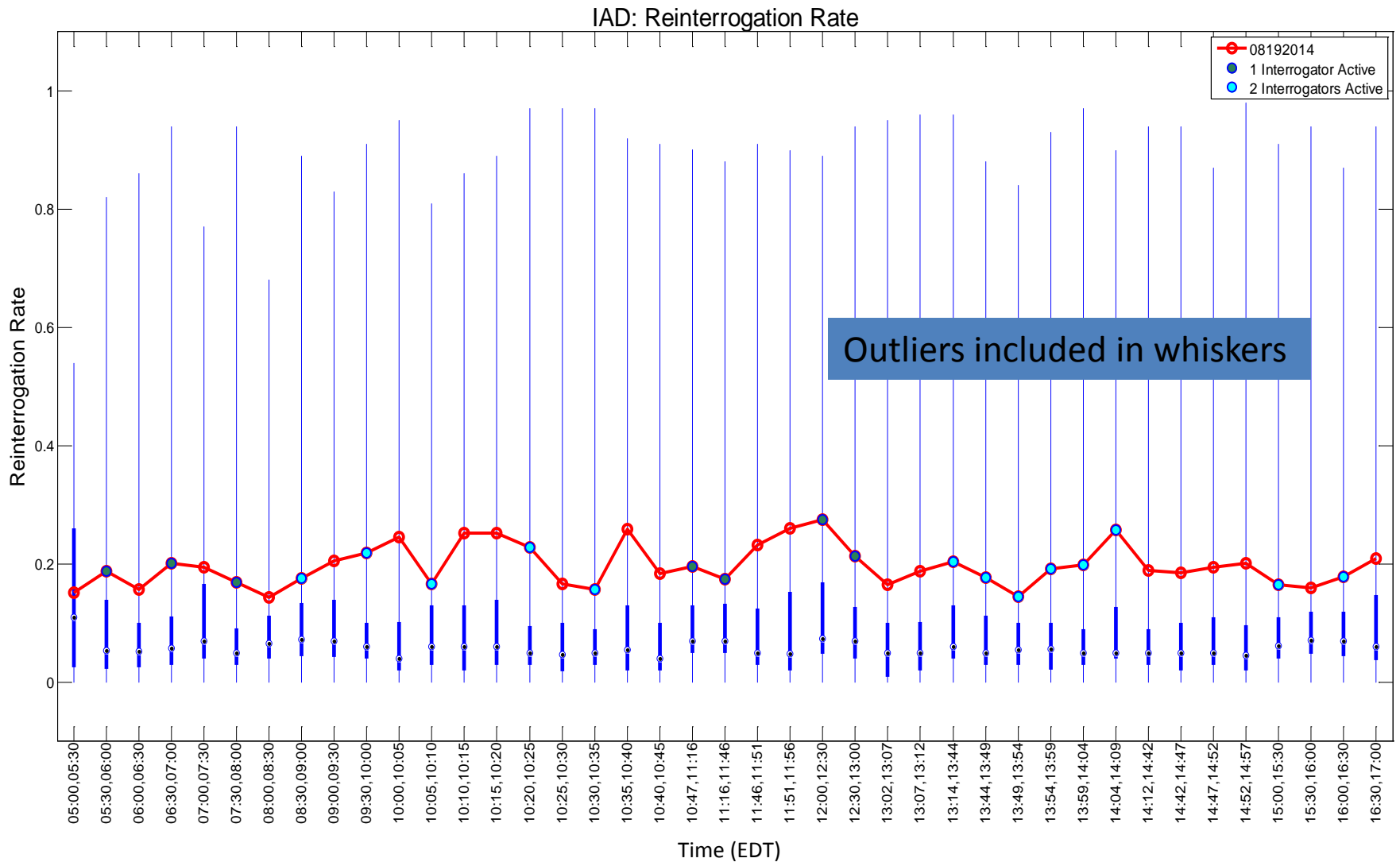
# Reinterrogation Rate – August 19<sup>th</sup>

IAD: % of Channel Time Used for Reinterrogations



# Reinterrogation Rate – August 19<sup>th</sup>

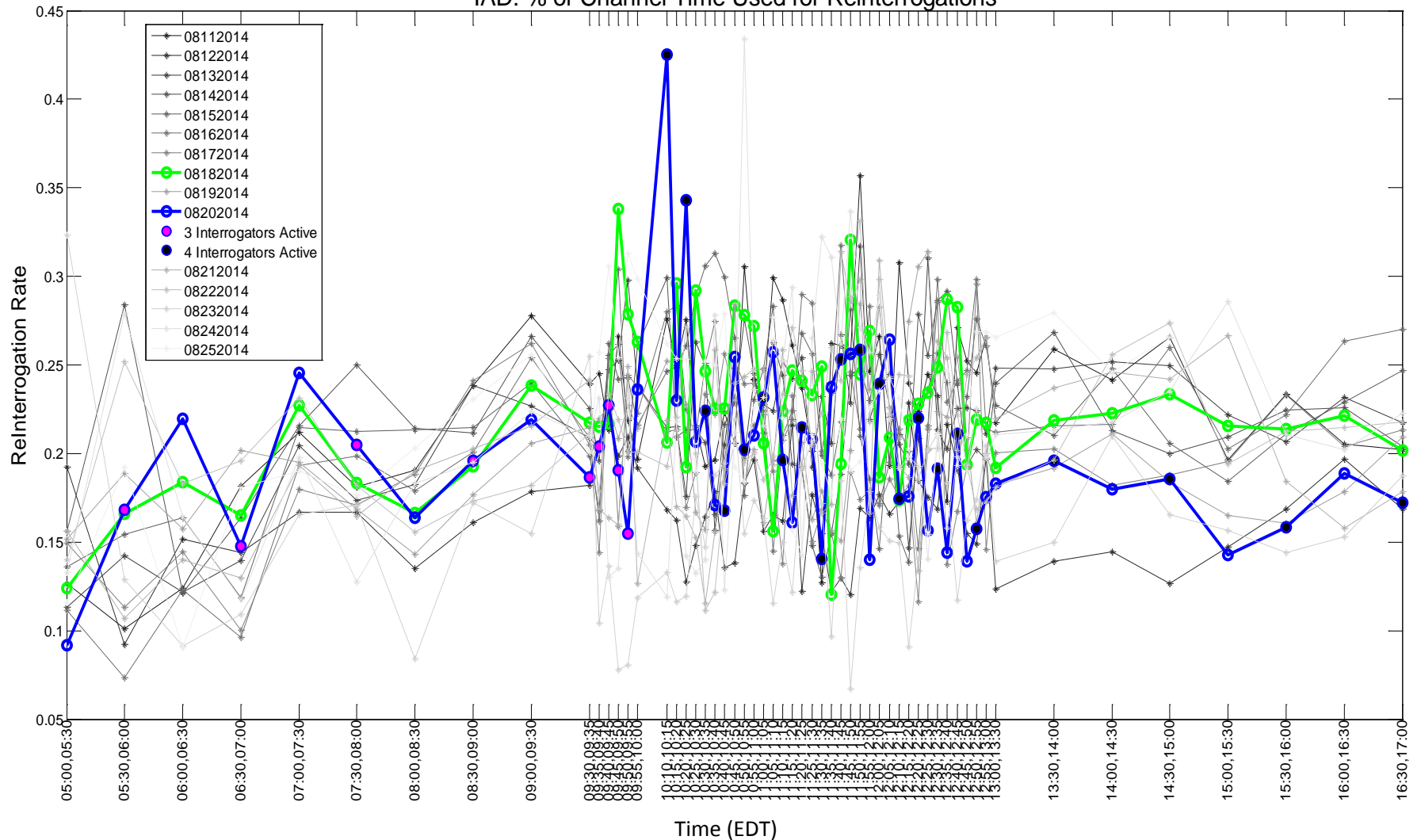
## Individual Aircraft Distribution





# Reinterrogation Rate – August 20<sup>th</sup>

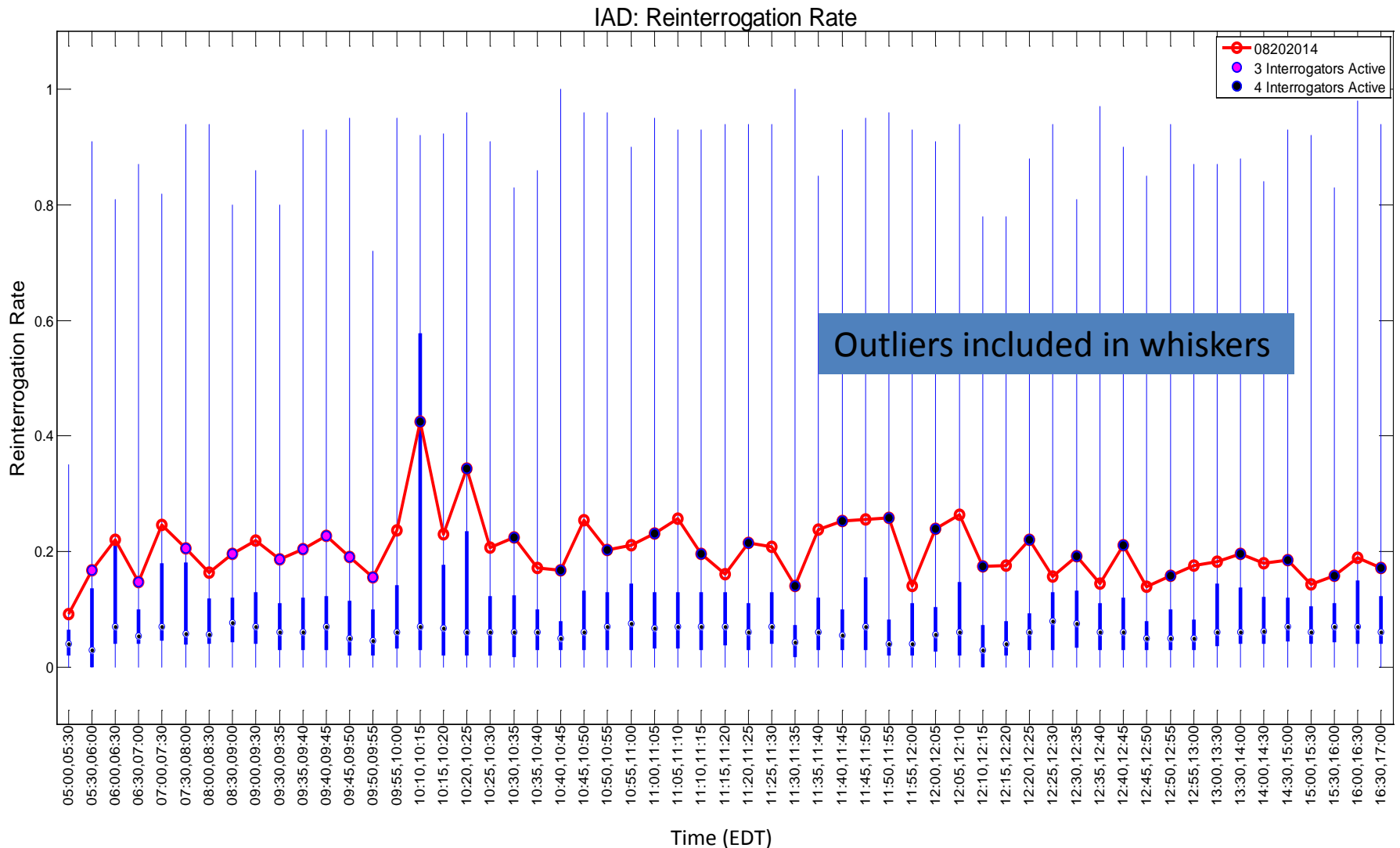
IAD: % of Channel Time Used for Reinterrogations



Geographic Filter: None  
Target Filter: Targets > 10 NM from SSR

# Reinterrogation Rate – August 20<sup>th</sup>

## Individual Aircraft Distribution

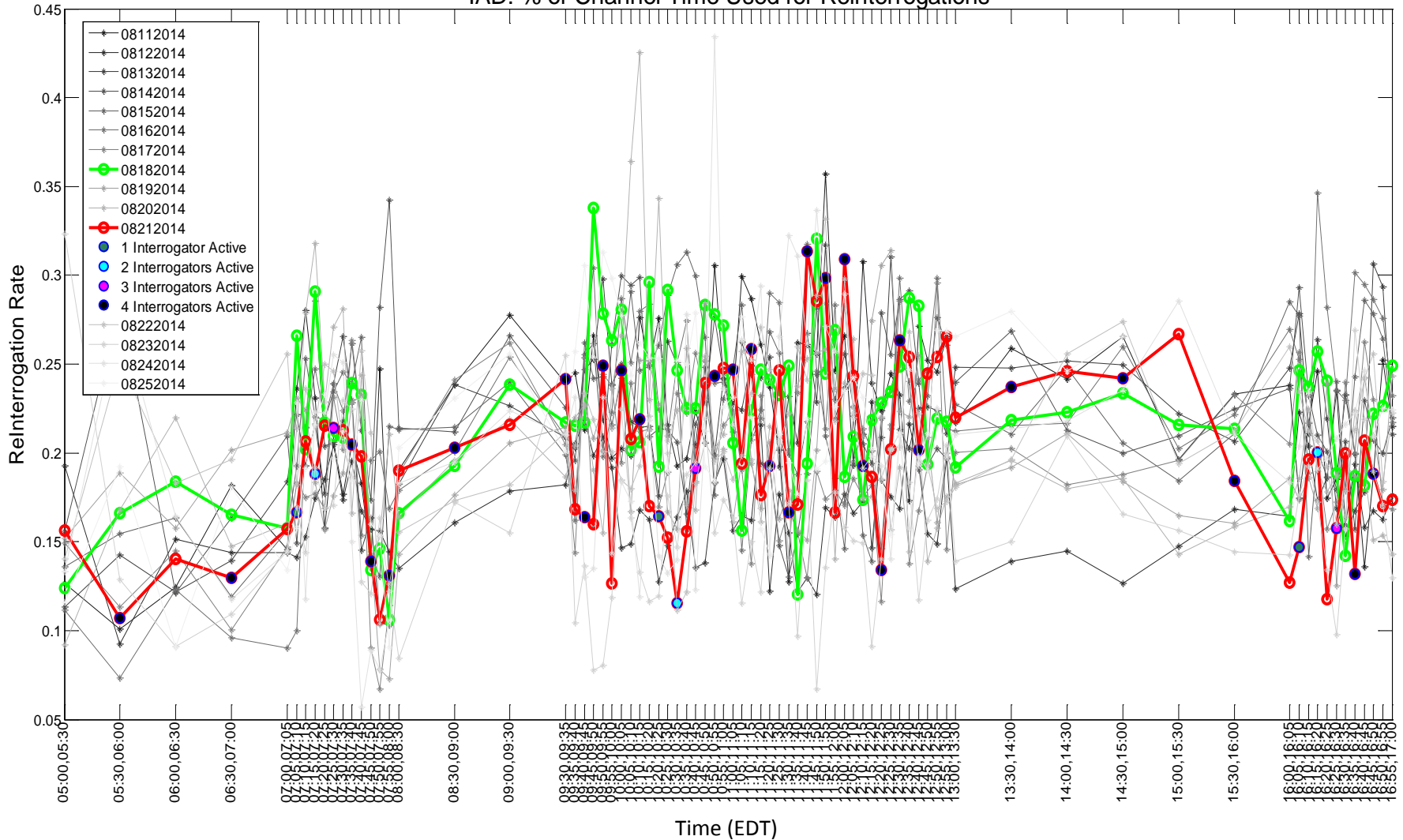


Geographic Filter: None

Target Filter: Targets > 10 NM from SSR

# Reinterrogation Rate – August 21<sup>st</sup>

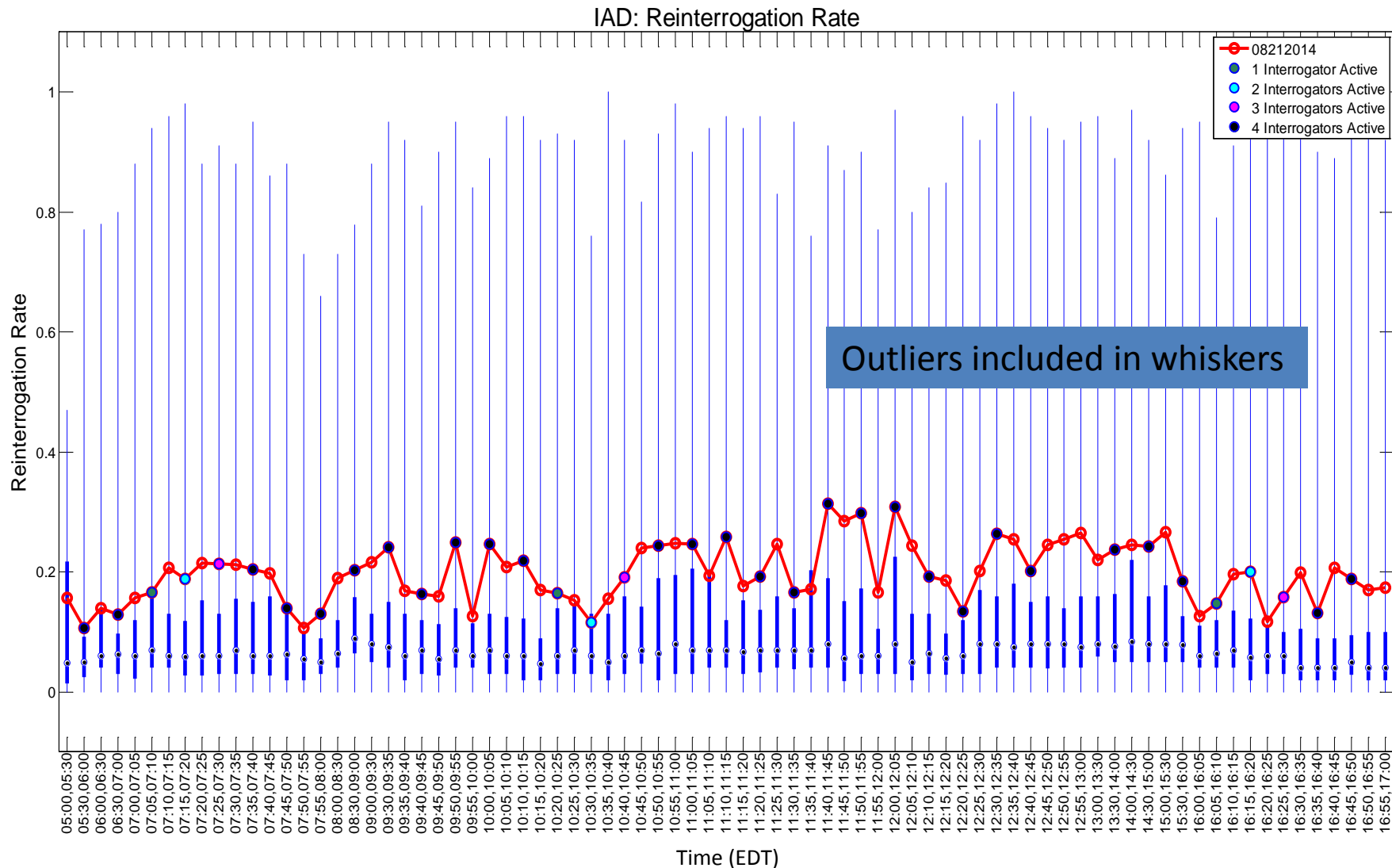
IAD: % of Channel Time Used for Reinterrogations



Geographic Filter: None  
Target Filter: Targets > 10 NM from SSR

# Reinterrogation Rate – August 21<sup>st</sup>

## Individual Aircraft Distribution

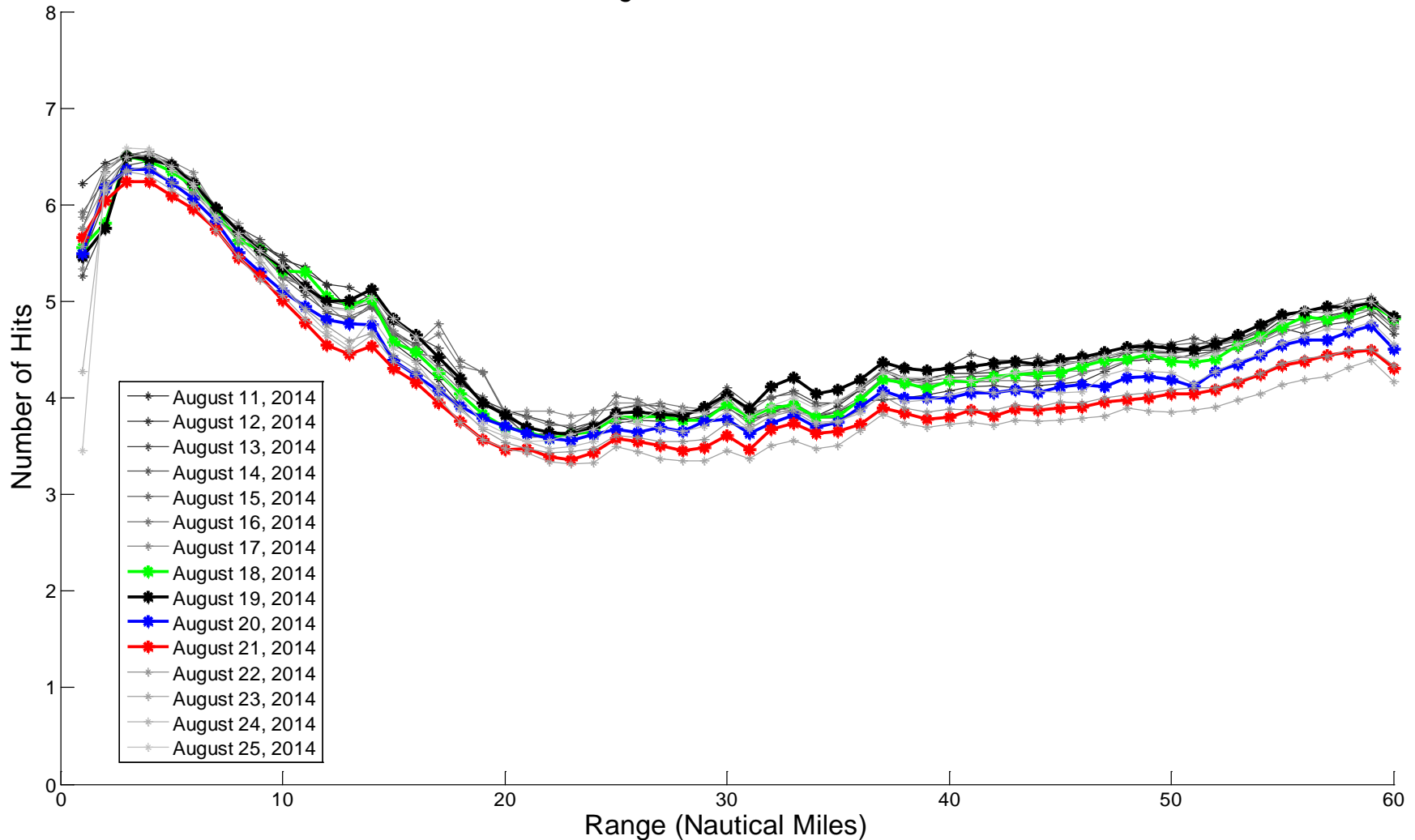


Geographic Filter: None

Target Filter: Targets > 10 NM from SSR

# ATCRBS Number of Hits vs Range – All Days

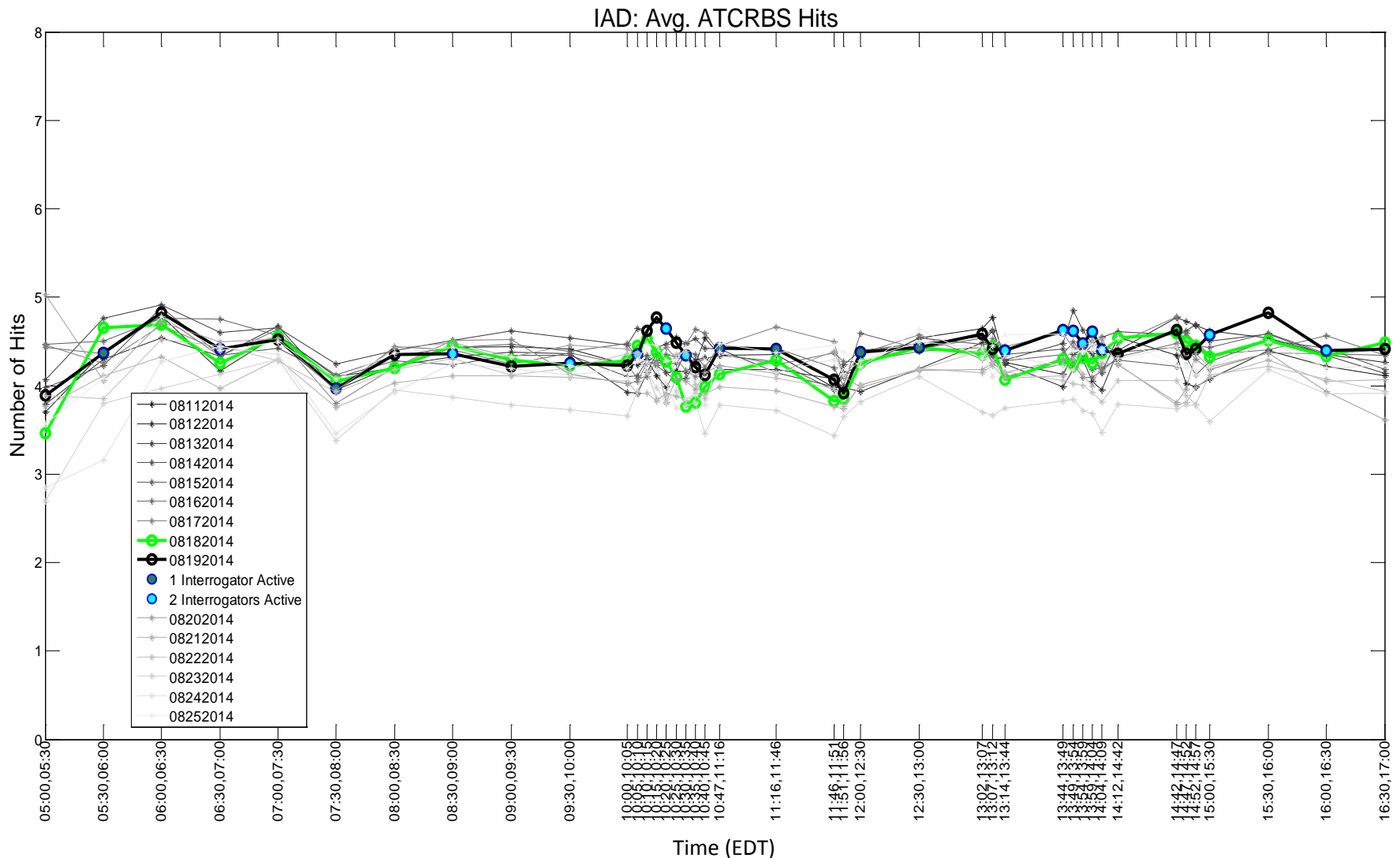
IAD: Average Number of ATCRBS Hits



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 19<sup>th</sup>

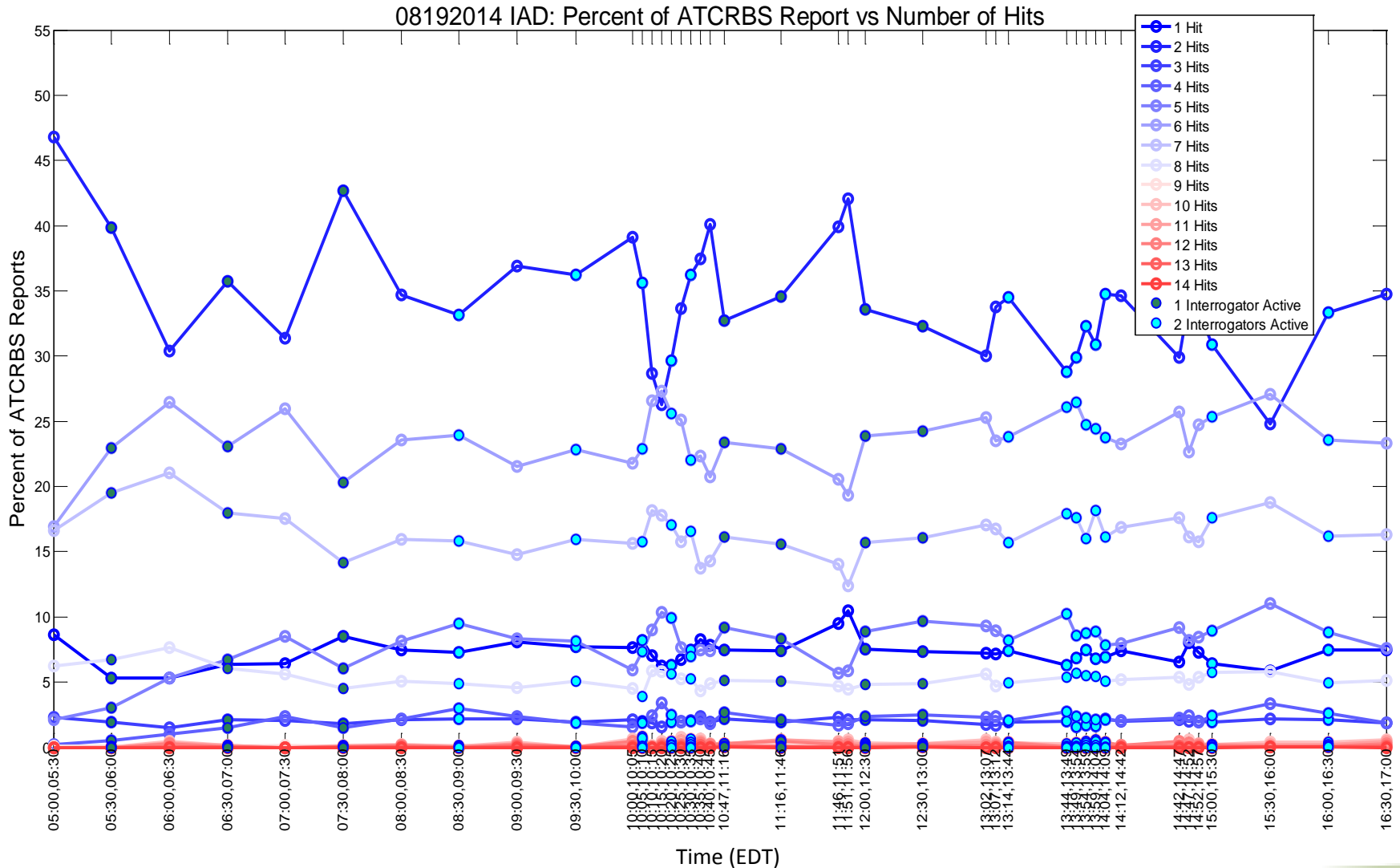


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 19<sup>th</sup>

## Number of Hits Distribution

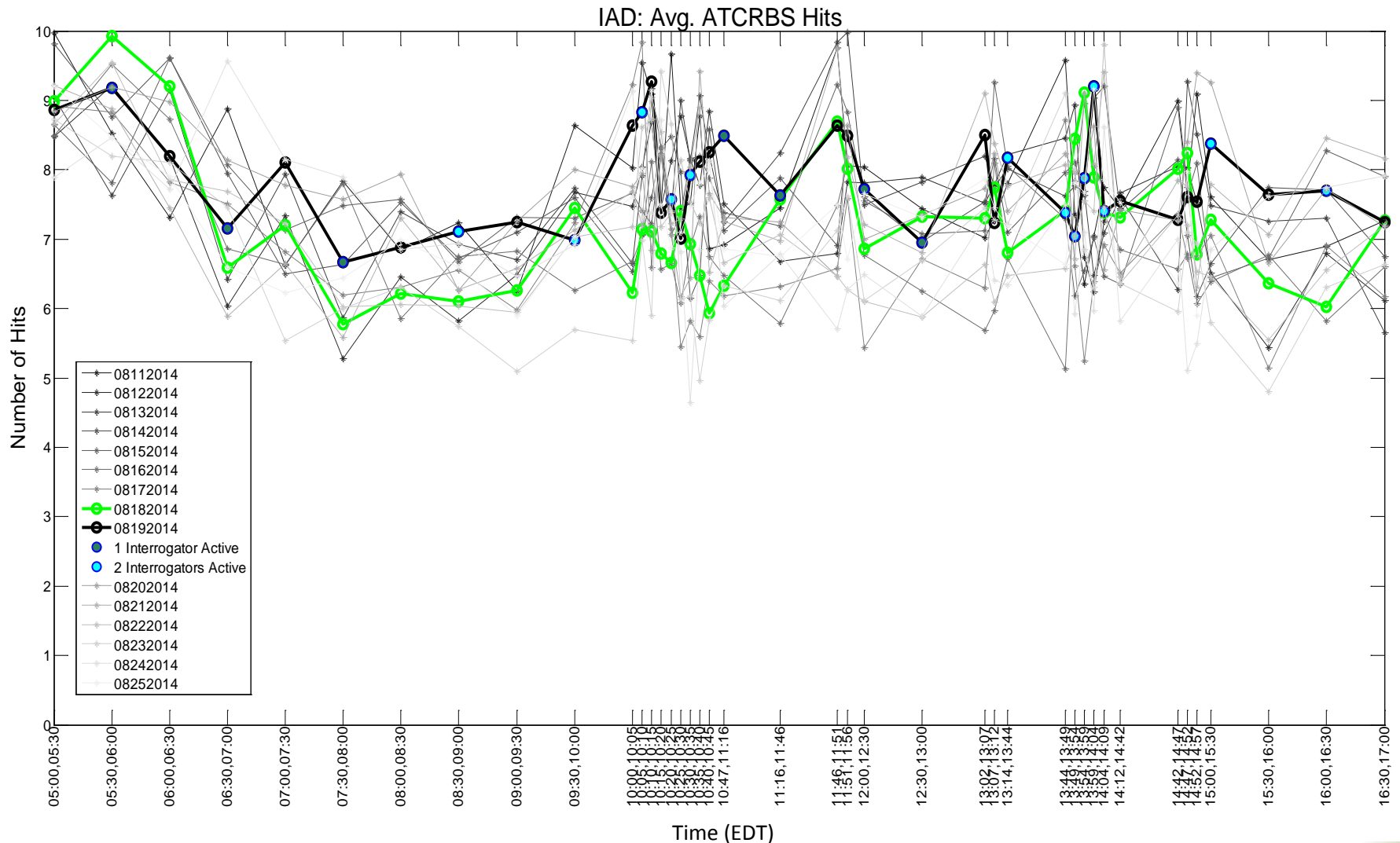


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 19<sup>th</sup>

## 20 NM of AN/UPX-41(C) systems

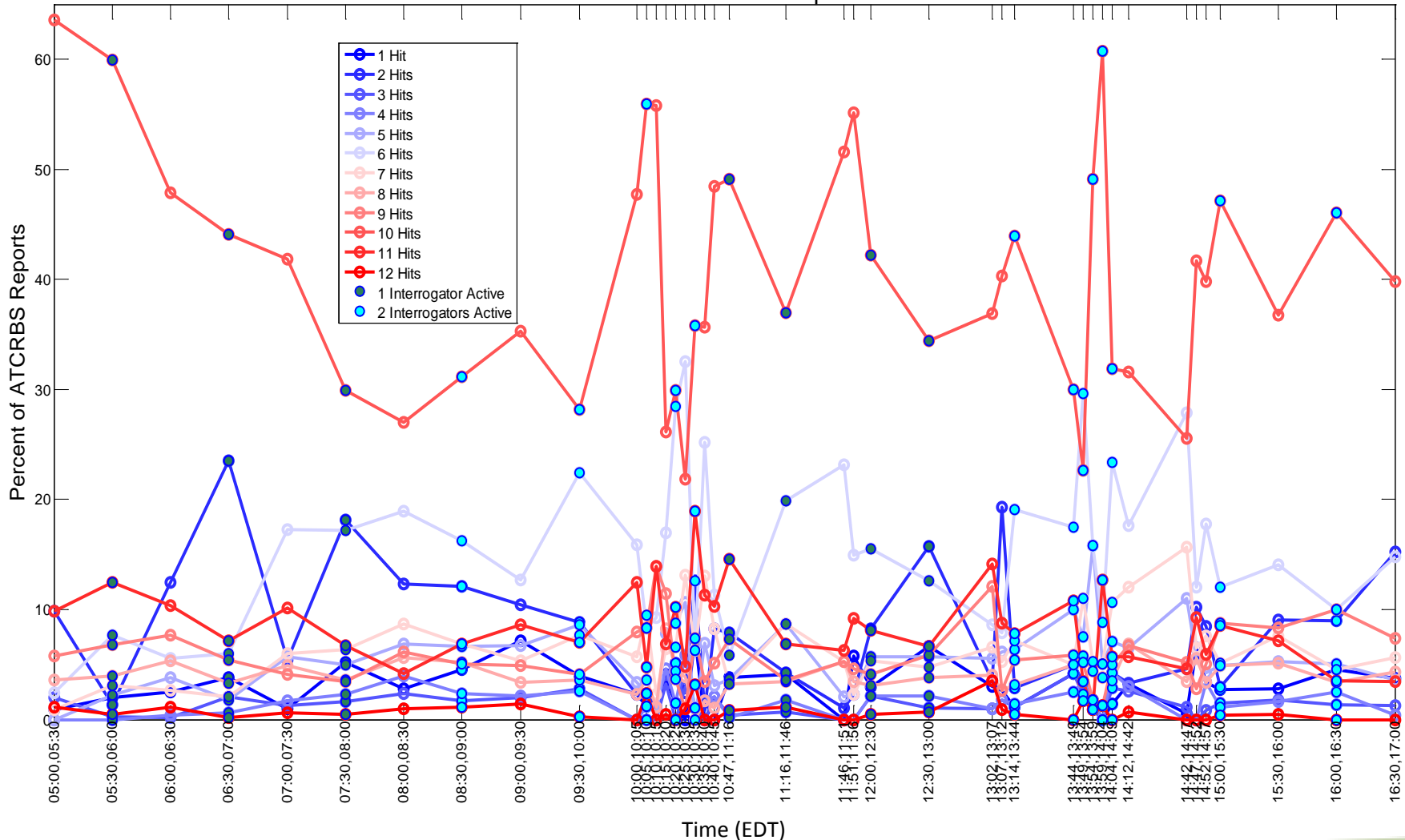




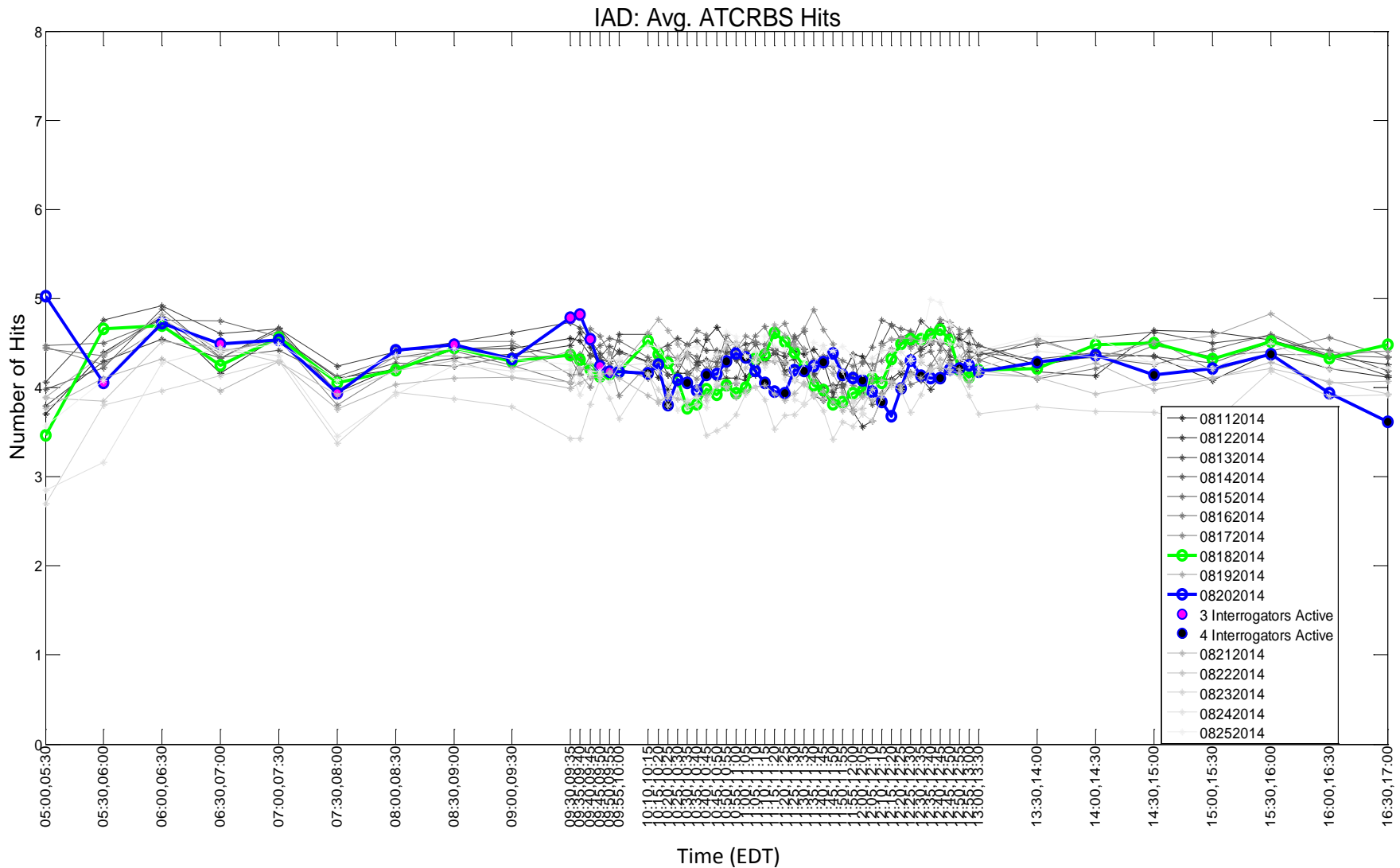
# ATCRBS Number of Hits – August 19<sup>th</sup>

## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution

08192014 IAD: Percent of ATCRBS Report vs Number of Hits



# ATCRBS Number of Hits – August 20<sup>th</sup>



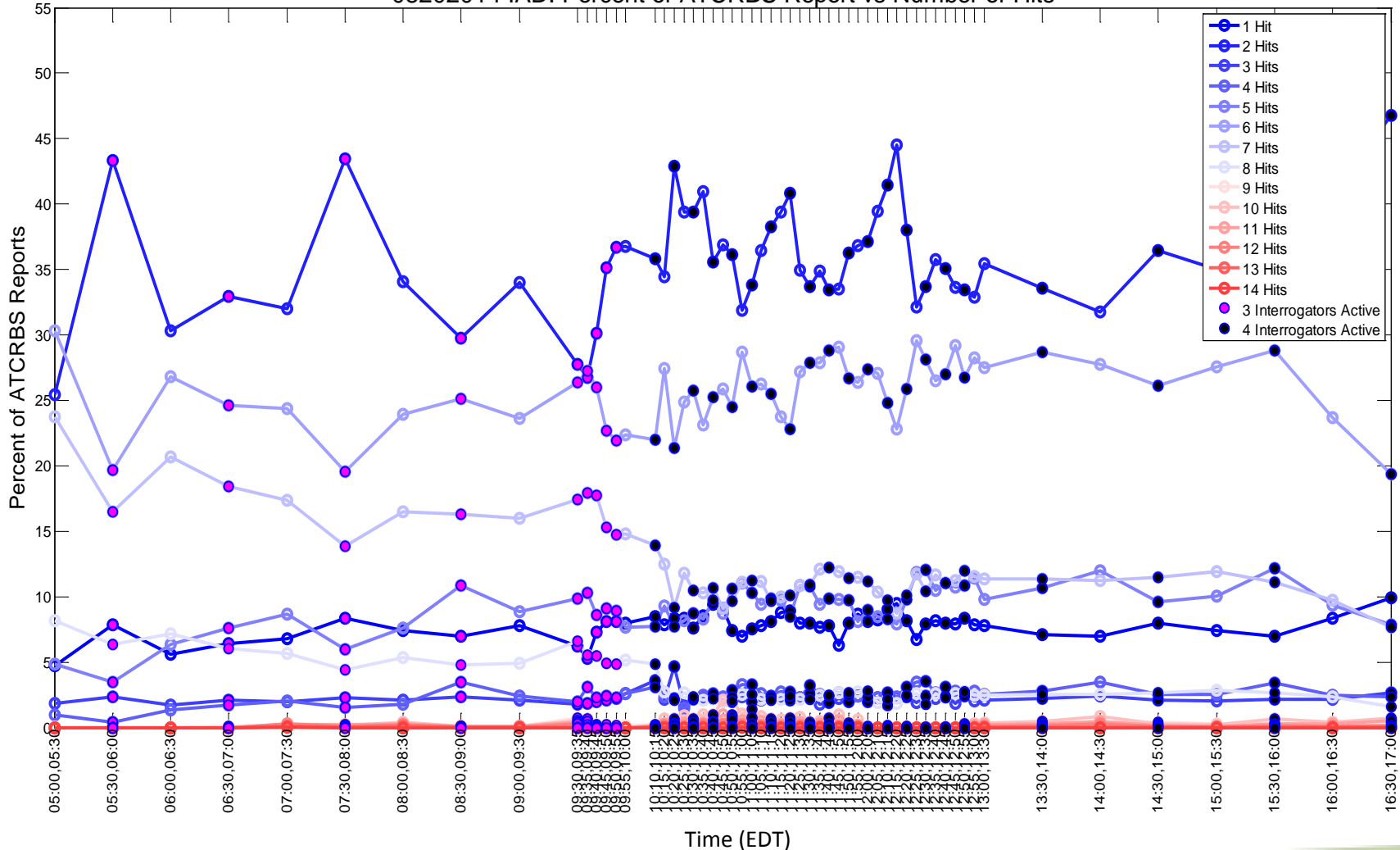
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 20<sup>th</sup>

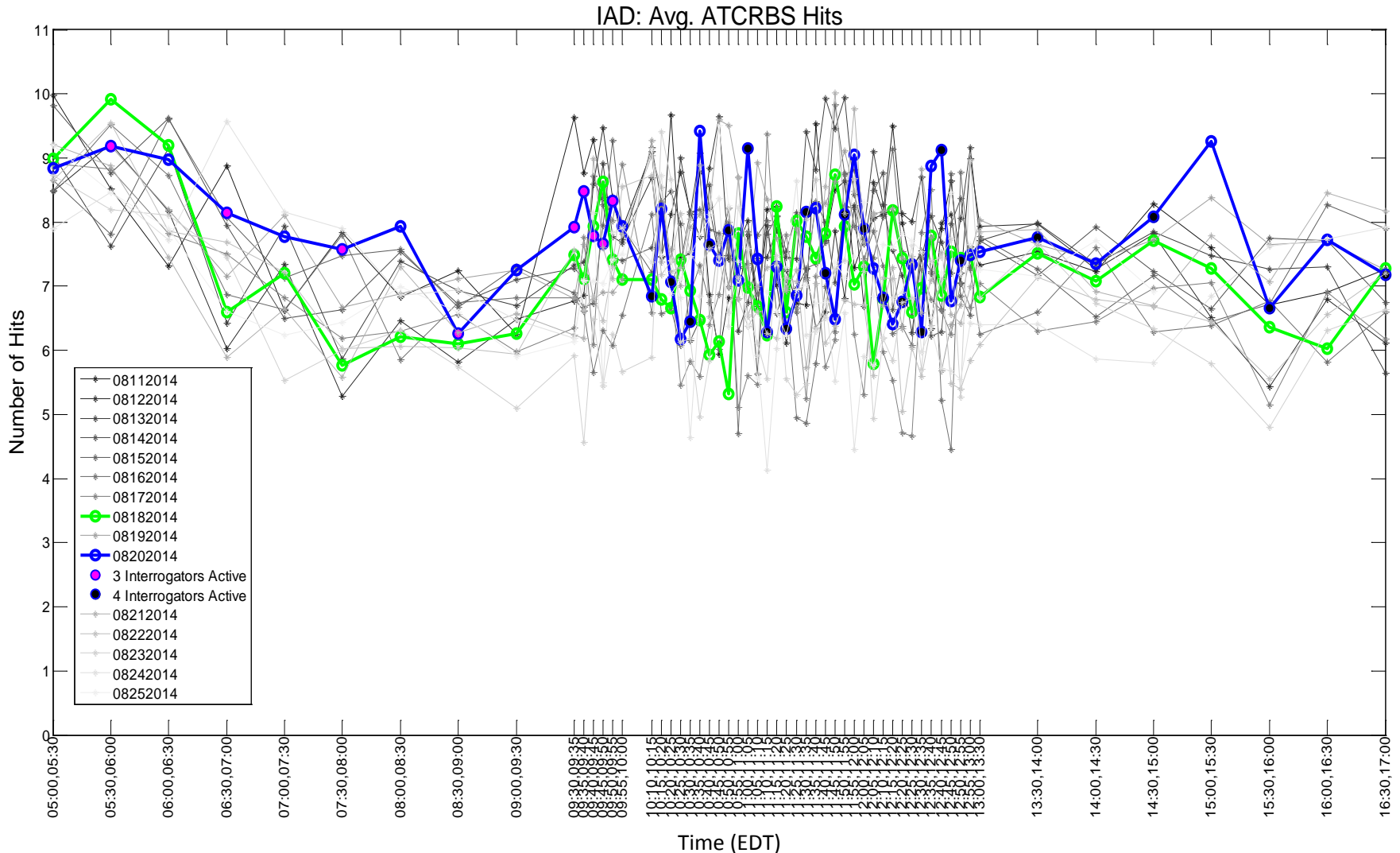
## Number of Hits Distribution

08202014 IAD: Percent of ATCRBS Report vs Number of Hits



# ATCRBS Number of Hits – August 20<sup>th</sup>

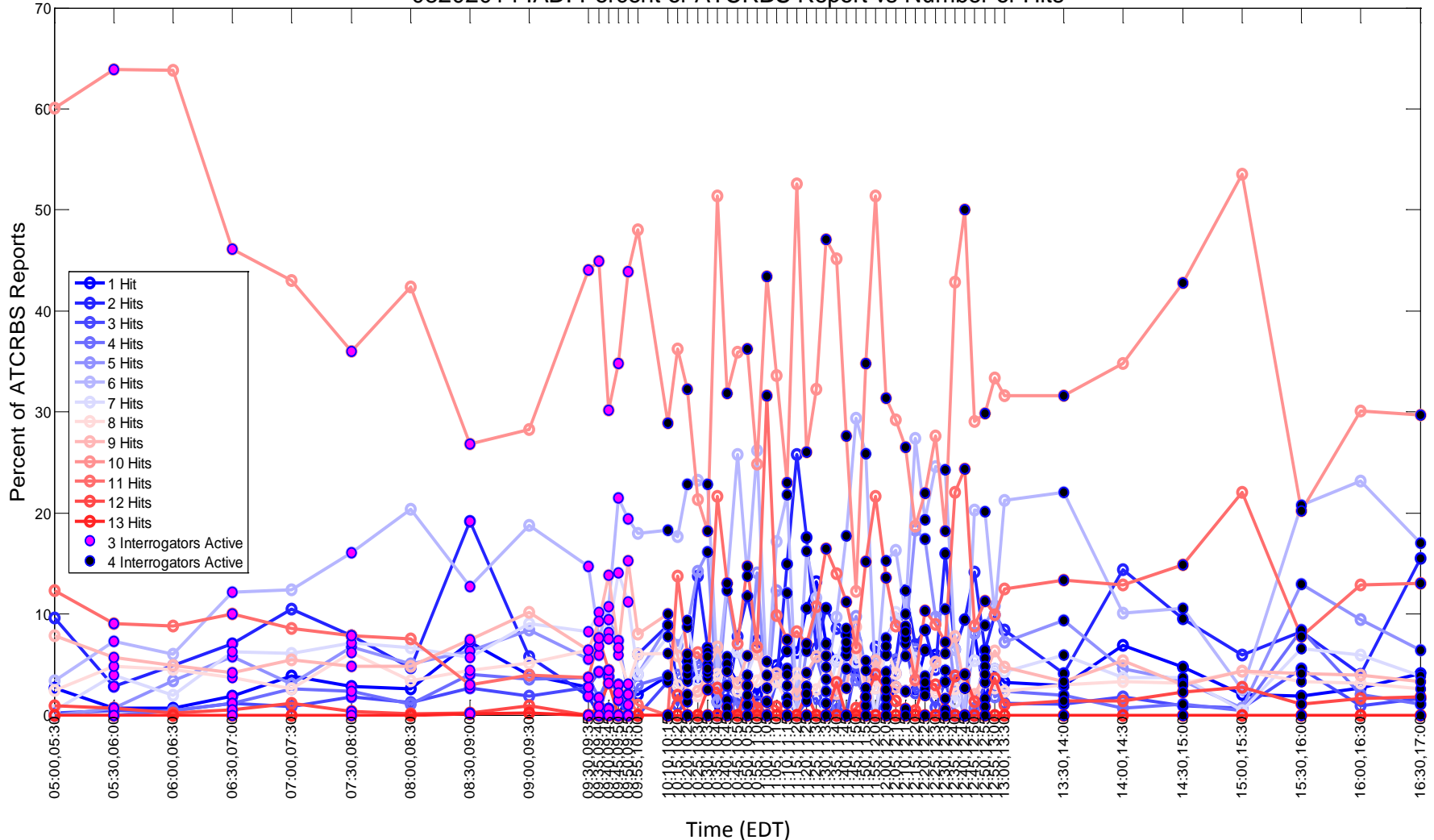
## 20 NM of AN/UPX-41(C) systems



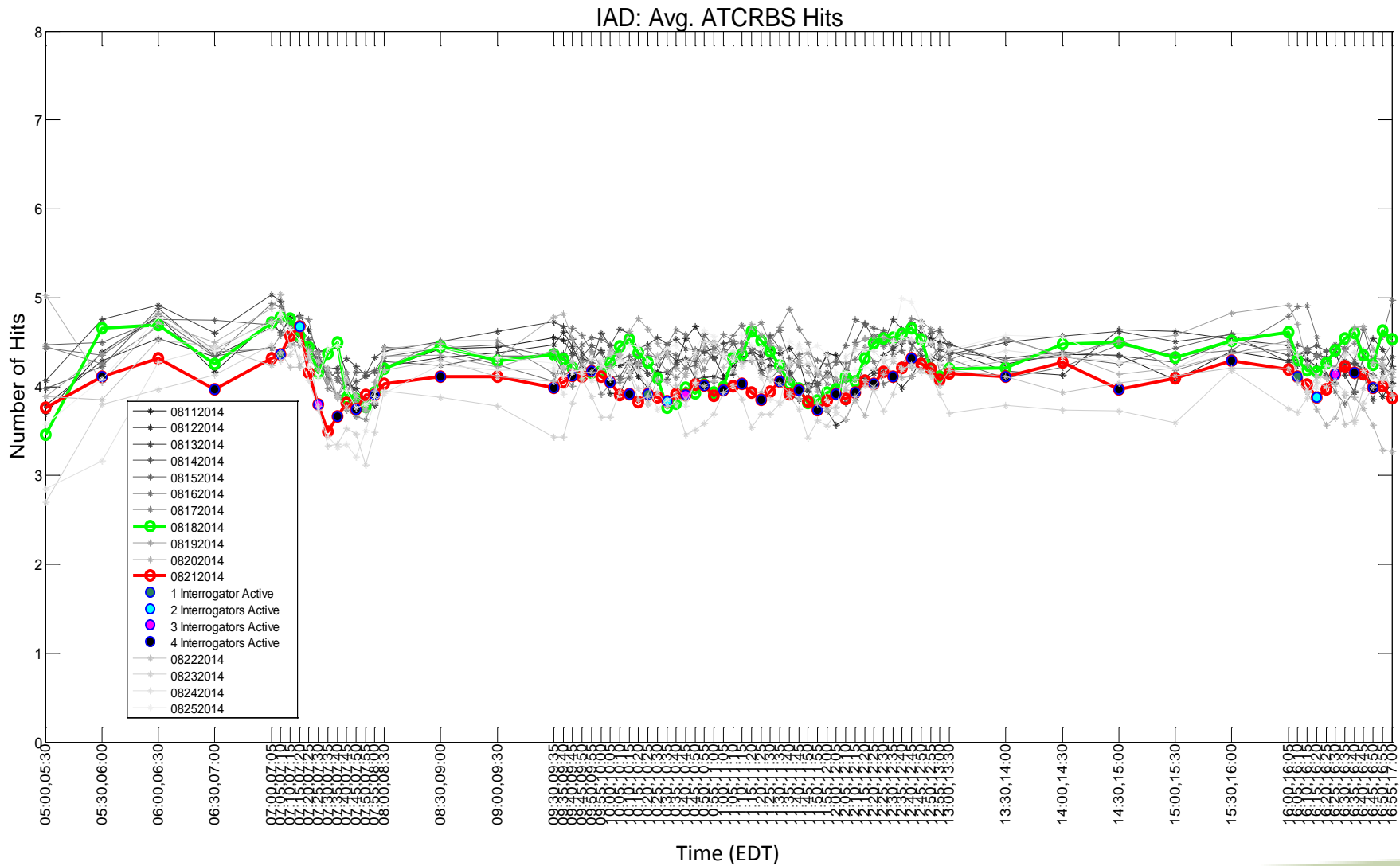
# ATCRBS Number of Hits – August 20<sup>th</sup>

## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution

08202014 IAD: Percent of ATCRBS Report vs Number of Hits



# ATCRBS Number of Hits – August 21<sup>st</sup>

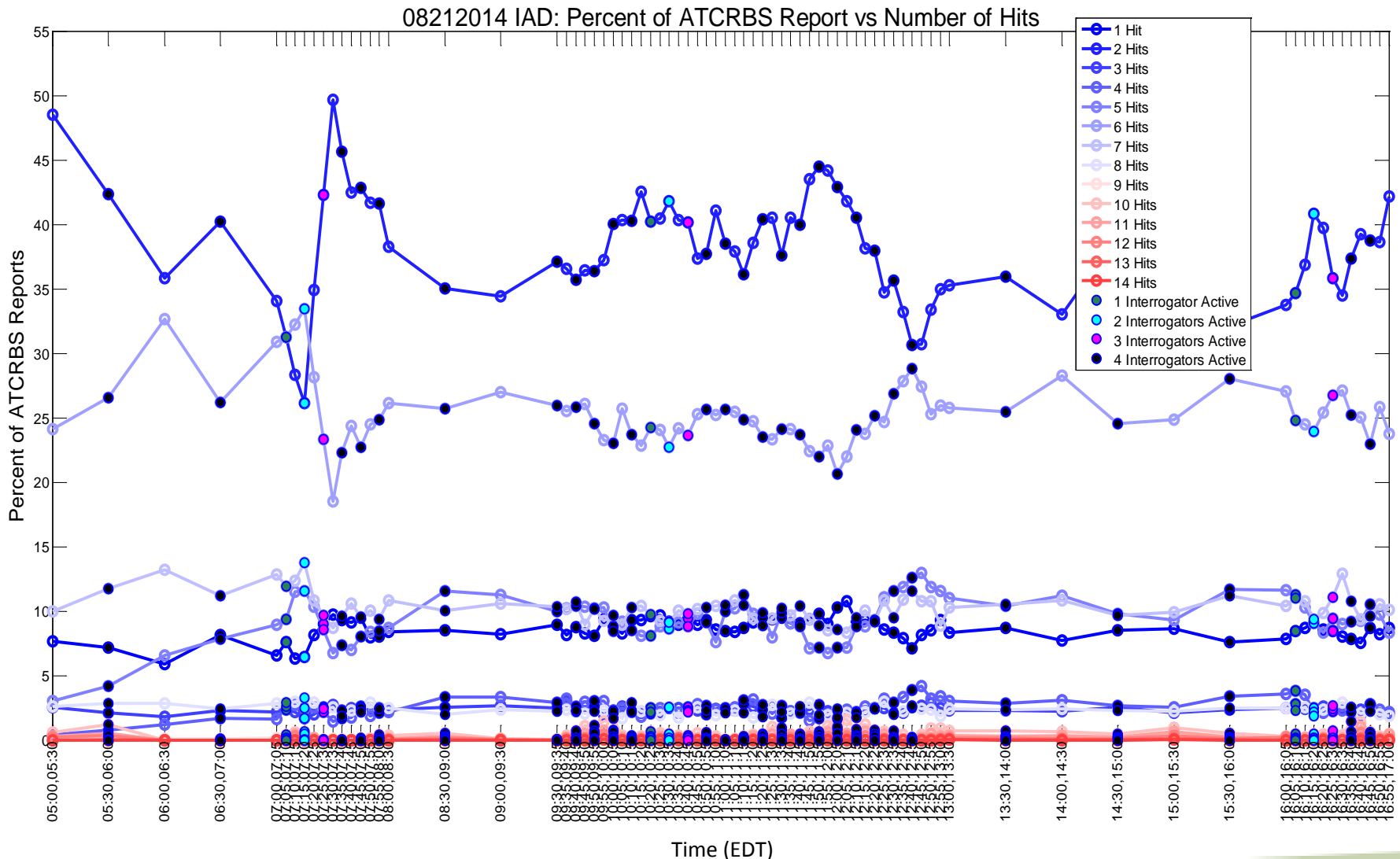


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 21<sup>st</sup>

## Number of Hits Distribution

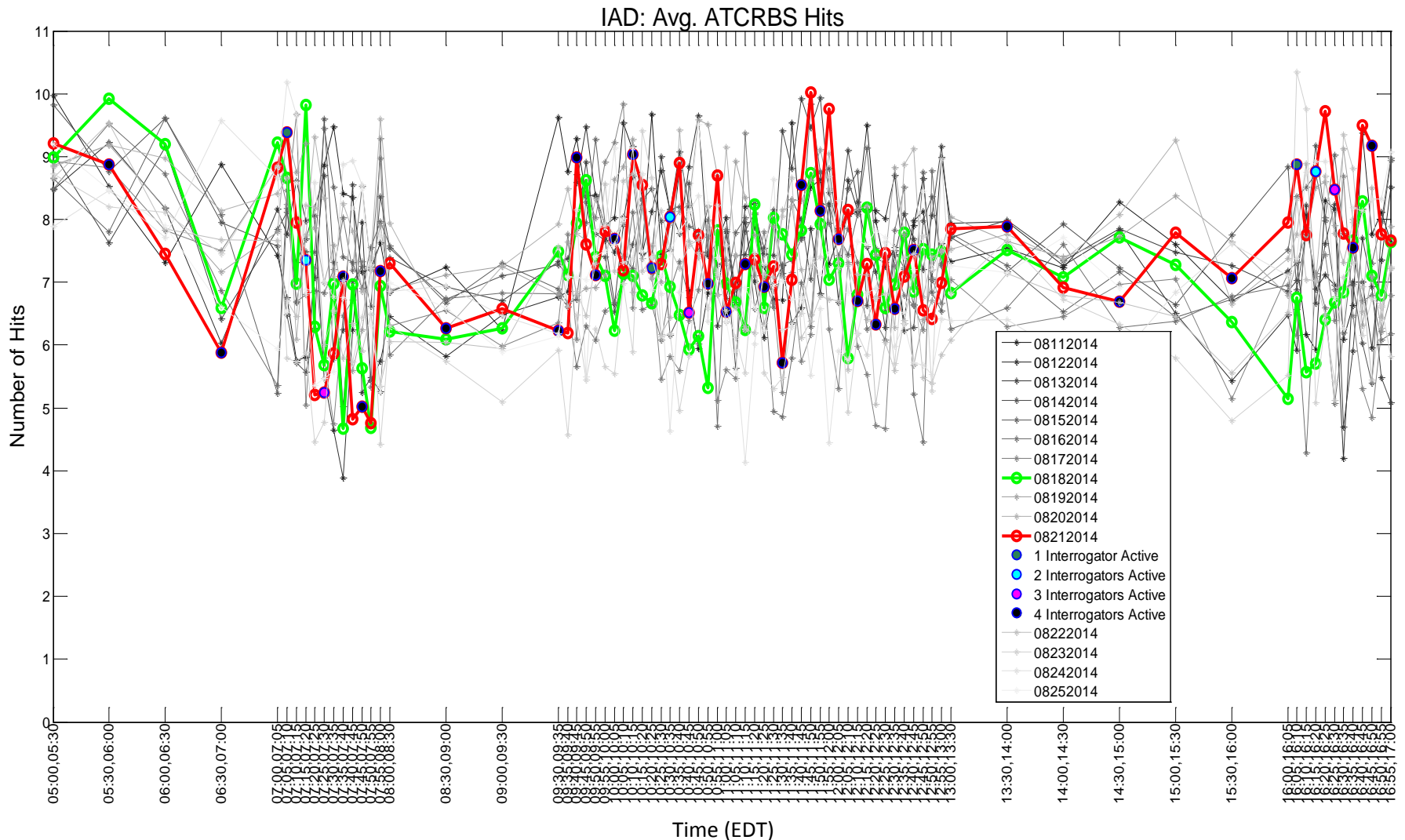


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 21<sup>st</sup>

## 20 NM of AN/UPX-41(C) systems

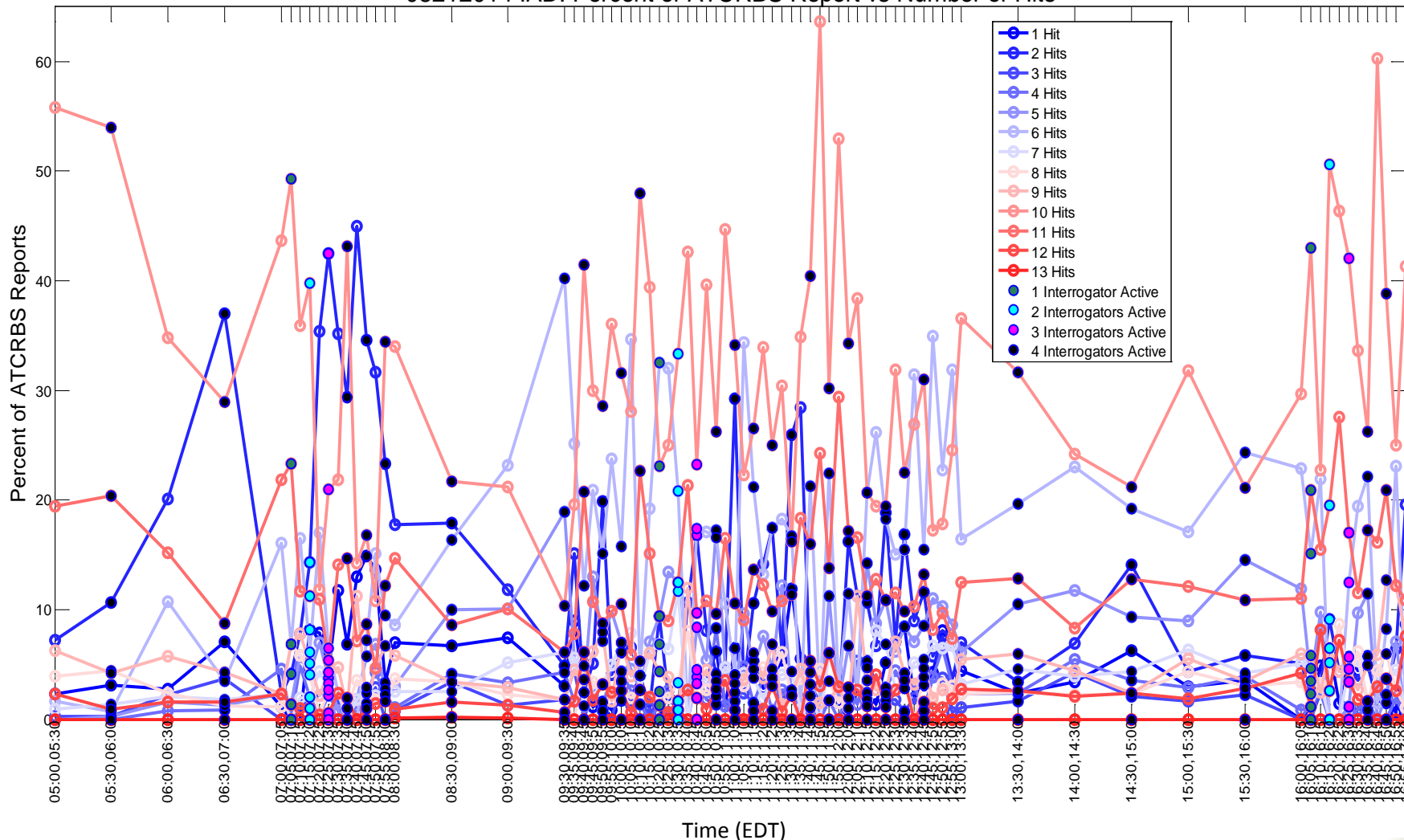




# ATCRBS Number of Hits – August 21<sup>st</sup>

## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution

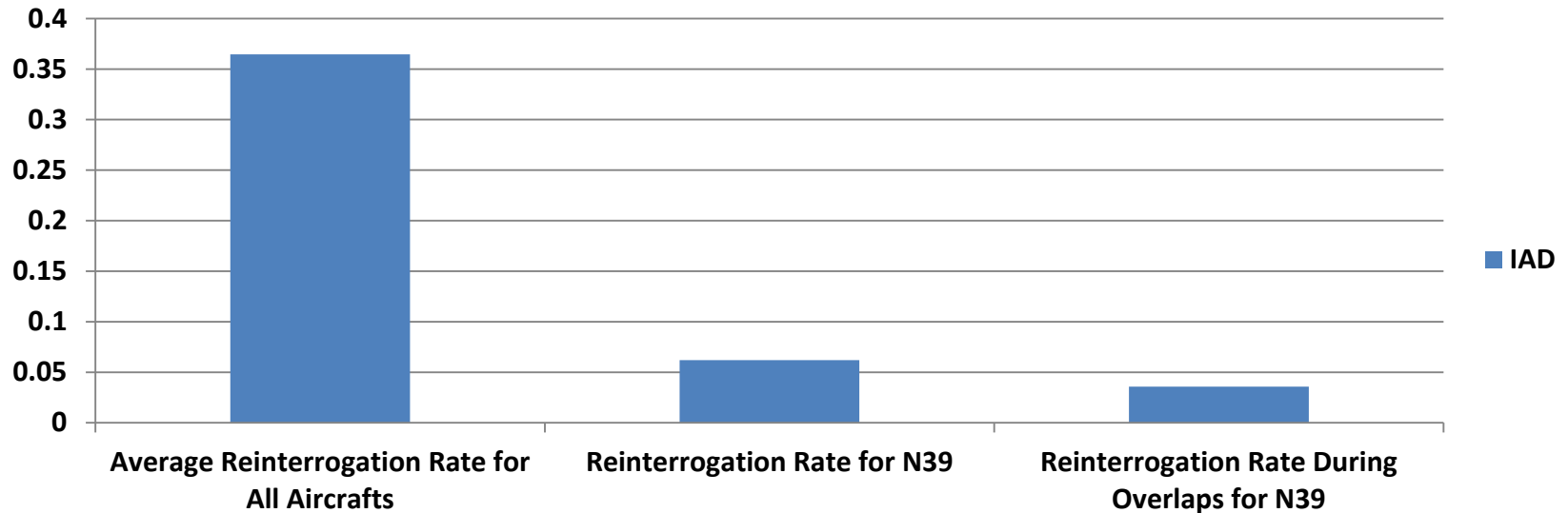
08212014 IAD: Percent of ATCRBS Report vs Number of Hits



# N39 Statistics

# N39 Reinterrogation Rate – August 20<sup>th</sup>

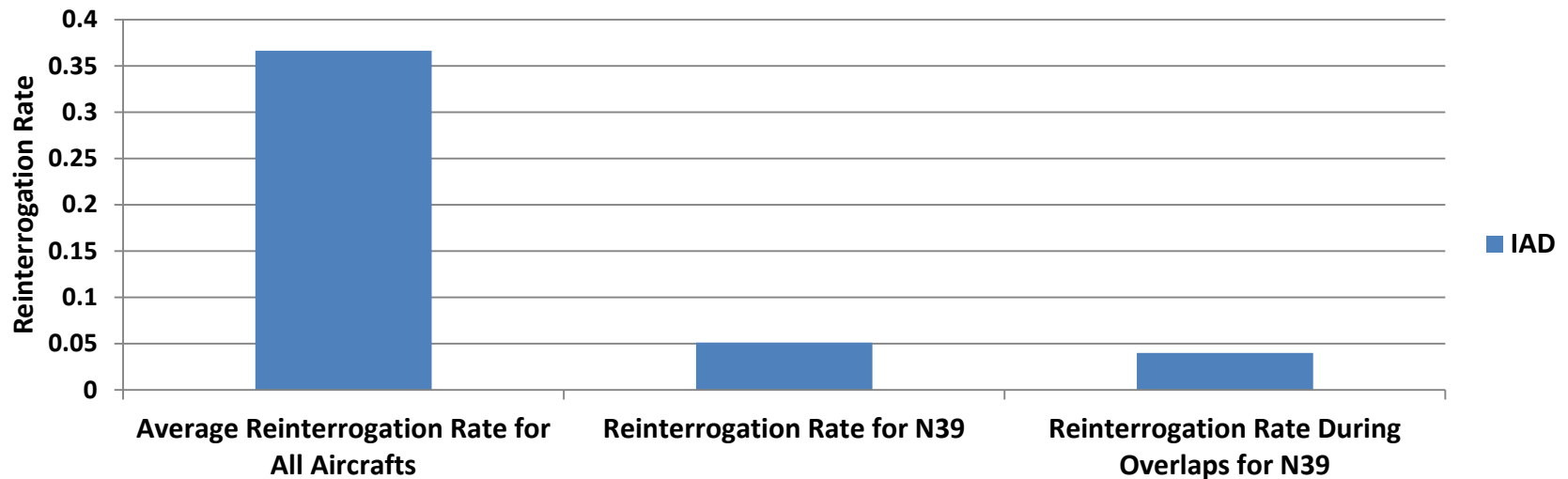
August 20, 2014



- Reinterrogation rate for N39 is lower than average reinterrogation rate for all aircrafts.
- Reinterrogation rate during overlaps of IAD and AN/UPX-41(C) mainbeams is about the same as when there are no overlaps.

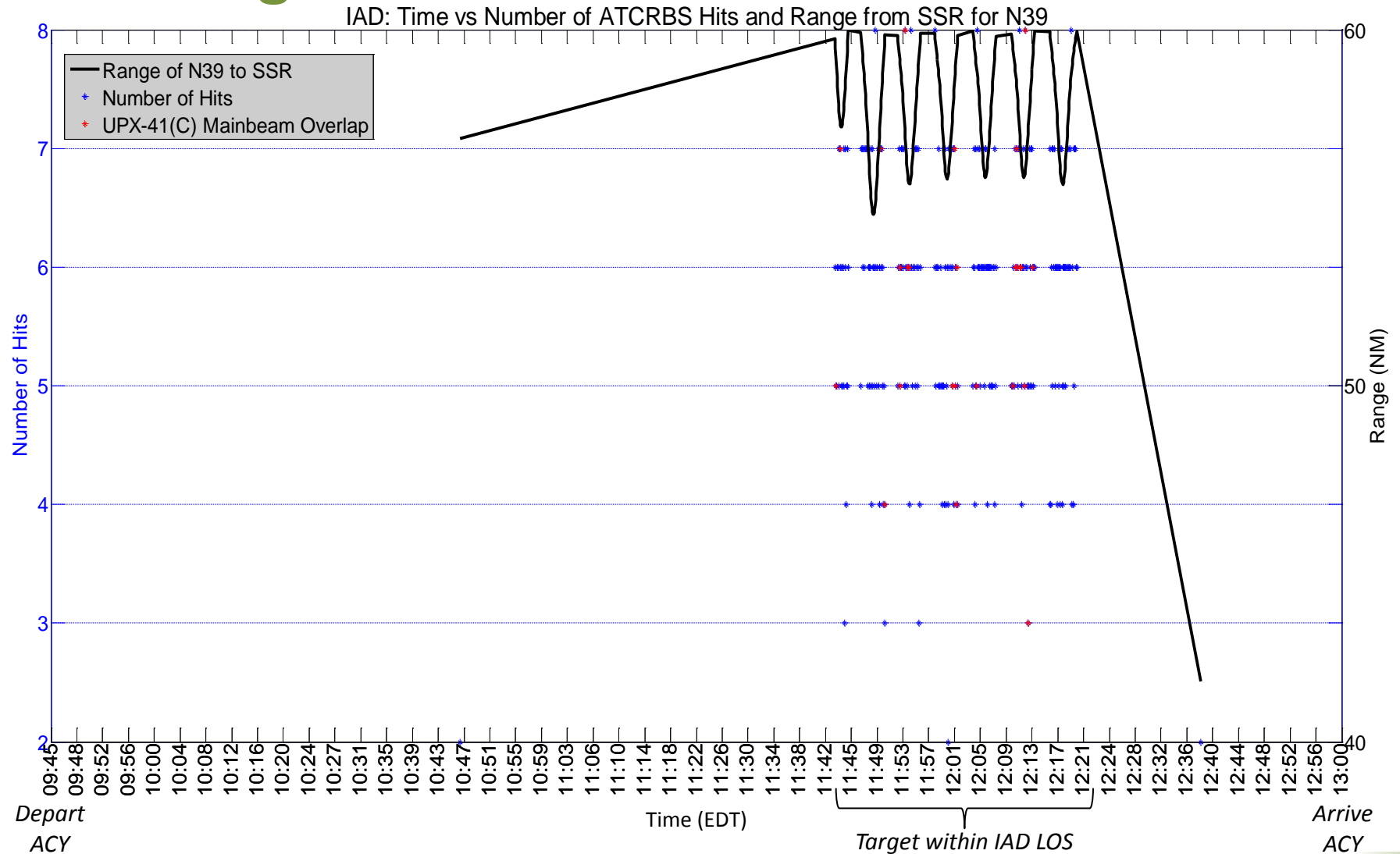
# N39 Reinterrogation Rate – August 21<sup>th</sup>

August 21, 2014



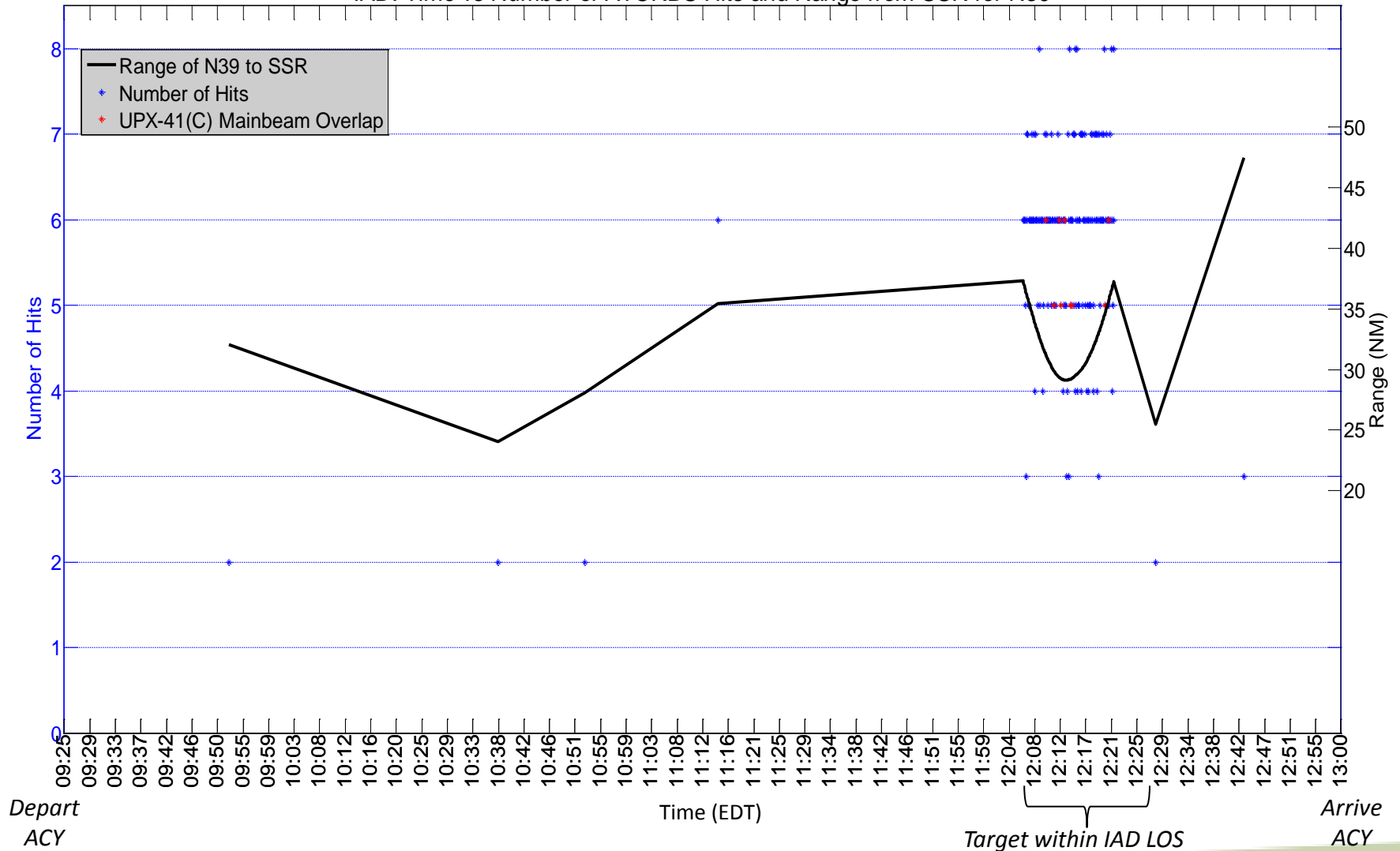
- Reinterrogation Rate for N39 is lower than average reinterrogation rate for all aircrafts.
- Reinterrogation rate for N39 during mainbeam overlaps is about the same as when they are no overlaps.

# Time vs Range and Number of ATCRBS Hits on N39 – August 20<sup>th</sup>



# Time vs Range and Number of ATCRBS Hits on N39 – August 21<sup>st</sup>

IAD: Time vs Number of ATCRBS Hits and Range from SSR for N39



# Observations and Conclusions

- ❑ Beyond 10 NM, where reinterrogation rates are not artificially high due to tracker predictor performance, changes in target reinterrogation rate average and distribution show no correlation with times when the AN/UPX-41(C) interrogators were active.
- ❑ When reinterrogation rates are compared with days when no AN/UPX-41(C) interrogators were active, the average shows no departure from the normal performance of the Mode S sensor.
- ❑ Similarly, ATCRBS hit count averages and distribution changes show no correlation with AN/UPX-41(C) active periods.
  - The one exception is August 21 when about 80% of the active periods showed a drop in percent of aircraft with hit count equal to six.
  - However, examination of the same day for the other three Mode S sites does not show this trend.

# Observations and Conclusions (cont'd)

- ❑ The Mode S data extraction files are the only ground sensor recorded data at the interrogation and reply level.
  - Degradation will begin here before it flows up to the track level (i.e.  $P_d$ , Conf., Rel.).
  - Hence, this analysis gives the clearest picture of spectrum interference that material affects the SSR surveillance environment.
- ❑ With virtually no observable change in reinterrogation rate and ATCRBS hit count, it is difficult to use this data to predict how more AN/UPX-41(C) interrogators, beyond the Stage 4 certification, would change the surveillance environment.
- ❑ Yet, by virtue of the fact that no change was observed at the interrogation and reply level, the Stage 4 certification restrictions are more than sufficient to protect FAA SSRs and relaxation of those restrictions should be considered to help the Navy meet its operational goals.





# Background

- ❑ The AN/UPX-41(C)\* Stage-4 operational transmit certification for AEGIS-Class ships was signed by NTIA on June 22, 2012 with geographic and platform number restrictions when operating in proximity to the NAS.<sup>†</sup>
- ❑ Additionally, the Stage-4 certification contained a requirement for a joint FAA-Navy test to validate the operational restrictions.
- ❑ The Volpe Center, in conjunction with the Navy, FAA Spectrum, and FAA aeronautical surveillance and collision avoidance systems (ASCAS) SMEs created a test plan to validate the operational restrictions.
- ❑ From August 18-21, 2014 the FAA and Navy conducted the above-mentioned joint test, under the management of the Volpe Center.
- ❑ Since the test, the Volpe Center has analyzed recorded data to look for instances of harmful interference that would affect ASCAS system performance.

\*AN/UPX-41(C) Digital Interrogator System when operated in conjunction with the OE-120 antenna, the AN/UPX-29(V) Identification Friend or Foe (IFF) system, and the AN/UPX-24 software interface Version 2.1.2, controlled by the Cooperative Engagement Capability (CEC), in Naval surface vessels

<sup>†</sup>See SPS-18778\_1 Navy AN-UPX-41 V5.5 St4

# Test Plan Refresher

## □ Baseline week: August 11<sup>th</sup> – 15<sup>th</sup>

- Baseline recording of data from 5 AM – 5 PM
  - No AN/UPX-41(C) systems Active

## □ Test week: August 18<sup>th</sup> – 21<sup>st</sup>

- August 18<sup>th</sup> – Baseline recording of data from 5 AM – 5 PM
  - No AN/UPX-41(C) systems Active
- August 19<sup>th</sup> – Record data from 5 AM – 5 PM
  - Cycle 1 and 2 AN/UPX-41(C) systems Active and OFF
- August 20<sup>th</sup> – Record data from 5 AM – 5 PM
  - Cycle 3 and 4 AN/UPX-41(C) systems Active and OFF
- August 21<sup>st</sup> – Record data from 5 AM – 5 PM
  - Cycle 1, 2, 3, and 4 AN/UPX-41(C) systems Active and OFF

## □ Cycling of AN/UPX-41(C) systems Active/OFF occurred every 30 minutes; however, if N39 (Tech Center signal recording aircraft) was in the air, cycling occurred every 5 minutes

## □ During the test week, non-essential DoD interrogator platforms were scheduled to be inactive in order to get an accurate baseline of civil ASCAS activity

- This did not occur. Non-test platform radiation was discovered through flight test data.



Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Image Landsat

Google earth

# Data Recording

- ❑ During the August test, Enroute Common Gateway (ECG) data was recorded at the Tech Center from the ORF site.
- ❑ The Radar Beacon Analysis Tool (RBAT) was used to analyze ECG data to produce statistics for the following list of parameters:
  - Targets per Scan
  - Probability of Detection
  - Identity Reliability
  - Identity Confidence
  - Altitude Reliability
  - Altitude Confidence
  - False Target Percentage
  - 0000 Code Percentage
- ❑ Mode S system version D22020 was used to record data extraction files by Mode S SSR technicians at the SSR Site.
- ❑ Mode S Analysis Tool (MSAT) was used to analyze extraction files to produce statistics for the following list of parameters:
  - FRUIT Rates
  - Interrogation/Reinterrogation Rates
  - ATCRBS Hit count statistics

# Data Analysis

- ❑ Applied time bins that corresponded to the AN/UPX-41(C) Active/OFF periods from test days (August 19<sup>th</sup>-21<sup>st</sup>) to baseline days to produce baseline statistics for all parameters
- ❑ Processed RBAT data through Surveillance Analysis, Scan Summary, and Beacon False Target Summary programs to find parameters of interest for each time bin without geographic or target filters
- ❑ Processed MSAT data through Channel Management Statistics and FRUIT Analysis programs to find parameters of interest for each time bin
  - 1) No geographic or target filters
  - 2) >10 NM filter
- ❑ Produced interrogation, reinterrogation, and hit count statistics for the Tech Center Aircraft (N39) as it flew within the SSRs LOS
  - Focused on possible interference during mainbeam overlap with V10, 8164, and 8225 sites

# Analysis Limitations

- ❑ The theoretical or textbook definition of probability of detection is a function of interrogation/reply round reliability.
- ❑ However, probability of detection in RBAT is the percentage of target updates versus total number of beam dwells over all targets.
- ❑ Therefore, the ability for probability of detection calculated by RBAT to properly represent theoretical probability of detection is minimized as the sample size decreases (either through geographical or time constraints) since it no longer reliably reflects the target population mean.
- ❑ Example: A target population of two where both targets miss one update out of ten scans (approximately 50 seconds) results in a probability of detection of 90%. While this is unacceptable by QARS blip/scan minimums, we have no knowledge of the updates that occurred outside of the given time constraint . If both targets received ten out of ten updates for the previous as well as the next 10 scans, the probability of detection is now 96.7%.

# Mode S Data Extraction Issues

- ❑ Noticed series of messages displayed by MSAT : Interrogation does not match frame table
  - The interrogation type does not match the expected type from the frame table or the time difference is more than 16 USECs
  - 02:34:23.445
  - Frame table not synched with actual periods
  - Try filtering the data starting at a later time or rerun the data
- ❑ After talking with Jim Davis, it was found that these errors occurred when CMS was unable to synchronize the interrogation data with the expected interrogation types from frame table and/or it was not able to maintain synchronization once it was achieved.
  - CMS was unable to synchronize due to interrogation data missing in the beginning of the file. Starting 1-5 seconds later fixed this.
  - CMS was losing sync due to interrogation data missing at a later time in the file.
- ❑ In a single beam dwell, the Mode S sensor records the first 21 interrogations and the rest are thrown away because of data storage space limitations.
- ❑ However, the Mode S sensor does record the number of interrogations past 21 that occurred and stores that amount in a **retry overflow count** field.
- ❑ Originally, MSAT did not count interrogations past 21 because they were not recorded by the Mode S sensor. Now, MSAT has been updated to account for the missing interrogations by considering the retry overflow count as interrogations without replies.
- ❑ Example: if in a beam dwell there are 25 interrogations, the Mode S sensor will record the first 21 and the retry overflow count would be 4.

# Mode S Data Extraction Issues (cont'd)

All call data for DCA

13:38:17.336	INT	AC	27.58	itime=3cc490	MODE_3A
13:38:17.336	INT	AC	27.64	itime=3d02b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.344	INT	AC	28.19	itime=3ebcf0	MODE_C
13:38:17.344	INT	AC	28.26	itime=3effa0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.352	INT	AC	28.78	itime=409c00	MODE_3A
13:38:17.352	INT	AC	28.85	itime=40dd10	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.359	INT	AC	29.38	itime=427b00	MODE_C
13:38:17.359	INT	AC	29.44	itime=42bb50	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.359	INT	AC	29.99	itime=445890	MODE_3A
13:38:17.367	INT	AC	30.06	itime=4499b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.375	INT	AC	30.59	itime=4639f0	MODE_C
13:38:17.484	INT	AC	39.05	itime=60a300	MODE_C
13:38:17.484	INT	AC	39.11	itime=60e350	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.492	INT	AC	39.62	itime=628090	MODE_3A
13:38:17.492	INT	AC	39.68	itime=62c1b0	MODE_S_SHORT_ROLL_CALL/ALL_CALL
13:38:17.500	INT	AC	40.23	itime=6461f0	MODE_C

Data loss through  
about 8.5°

- ❑ Previous accounts of lost interrogation data at the Mode S sites was accounted for using the retry overflow count that was being reported by the Mode S sensor.
- ❑ However, as the analysis progressed, instances were found where the Mode S site was not reporting loss of data, but we can clearly see there is a loss of data (see highlighted above).
- ❑ The site did not report any missing data, but CMS produced a fatal error due to data not being present and having no record of data being lost.
- ❑ This was not discovered previously due to Probability of Detection changing ever so slightly in the absence of 8 degrees of data for a given time period. This fluctuation of probability of detection could be due to many reasons. (low elevation angle, non-compliant transponder, aircraft turning, etc.)



# Analysis Objective

- ❑ We are attempting to observe distinct patterns of change in the metrics of interest between times when the AN/UPX-41(C) systems are OFF and when they are Active.
- ❑ While geographic and time filters reduces target update sample sizes such that a small sample size itself influences the metric of interest, it is more important to focus on the change from Off to Active since both the Off and Active periods have the same constraints applied.

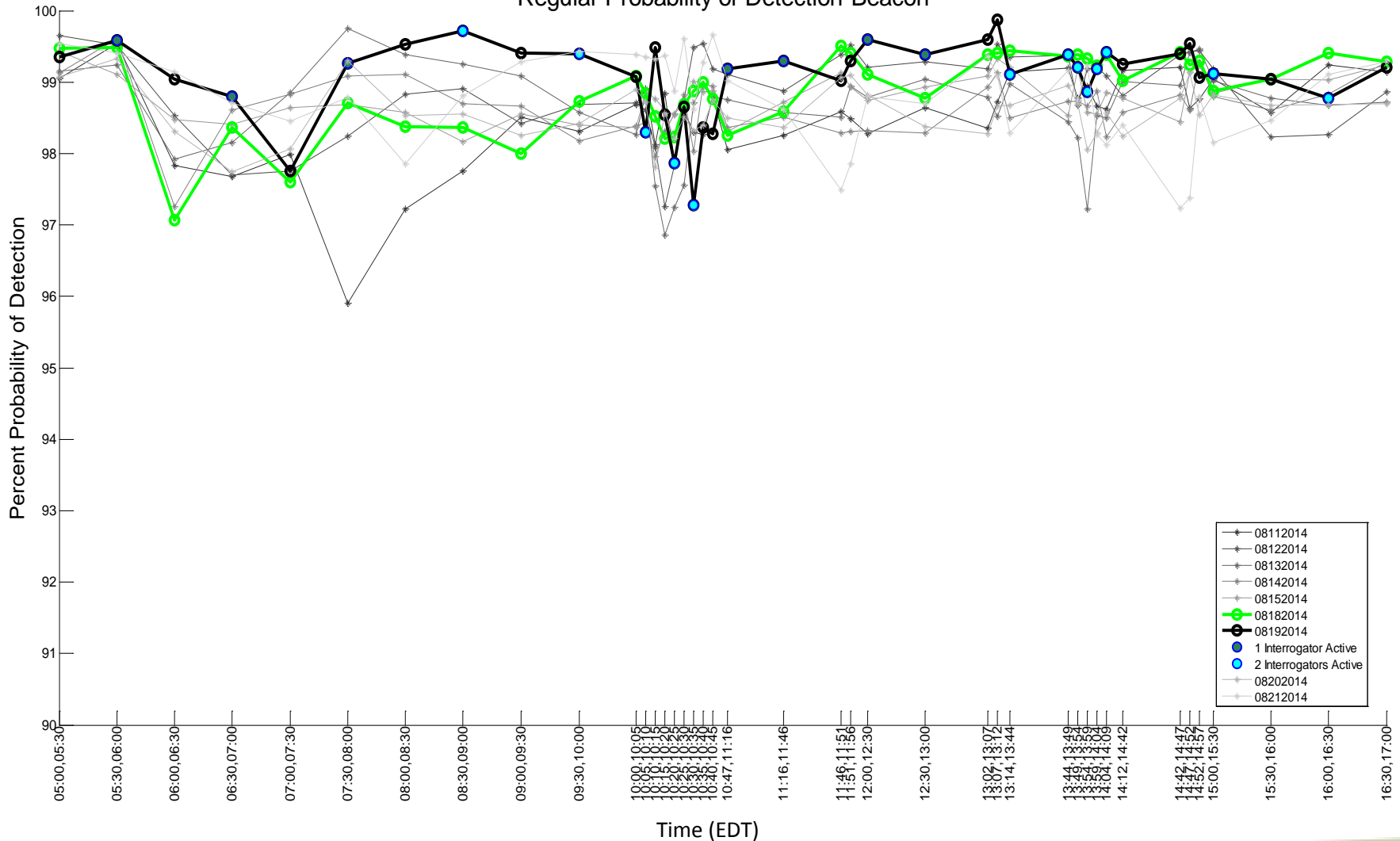
# Plot Guide

- ❑ Plots with multiple days of data utilize the time filters from the Active/Off periods for the date given in the slide's title
- ❑ Plots that use boxplots
  - The edges of the box are the 25<sup>th</sup> and 75<sup>th</sup> percentiles. The maximum whisker length represents approximately 2.7 sigma (99.3%). Points in red are shown as outliers.
    - Exception: Box plots for reinterrogation rate vs time filters have whiskers that reach to the extent of the furthest outlier.
  - For five minute time bins, there are only 65 ORF scans and, if you miss one target update,  $P_d$  will automatically drop to 98.4% (24 out of 25 possible target reports).
  - Horizontal axis 30-min and 5-min time bins are not scaled according to duration.

# Target Metrics with No Filter

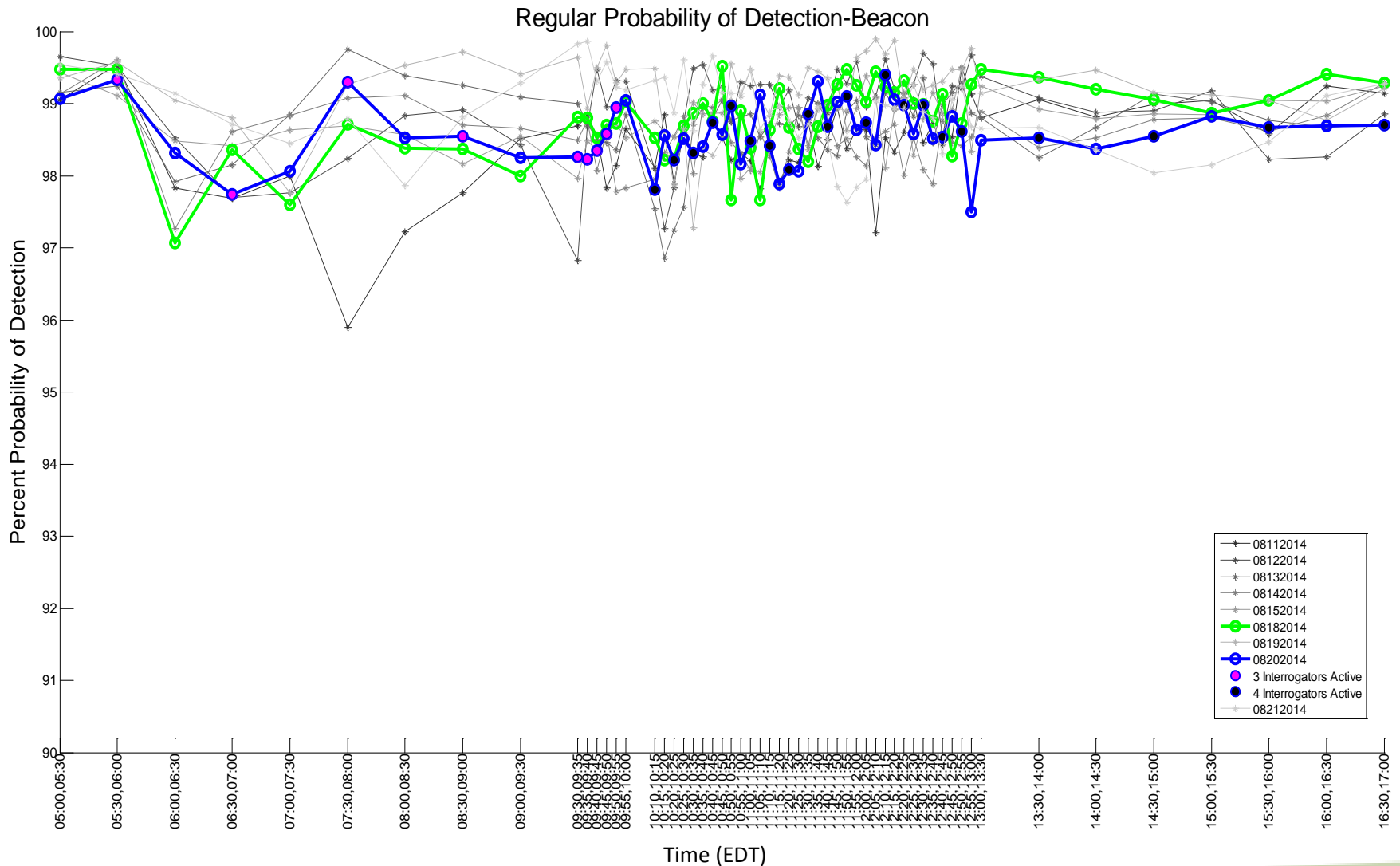
# Probability of Detection – August 19<sup>th</sup>

Regular Probability of Detection-Beacon



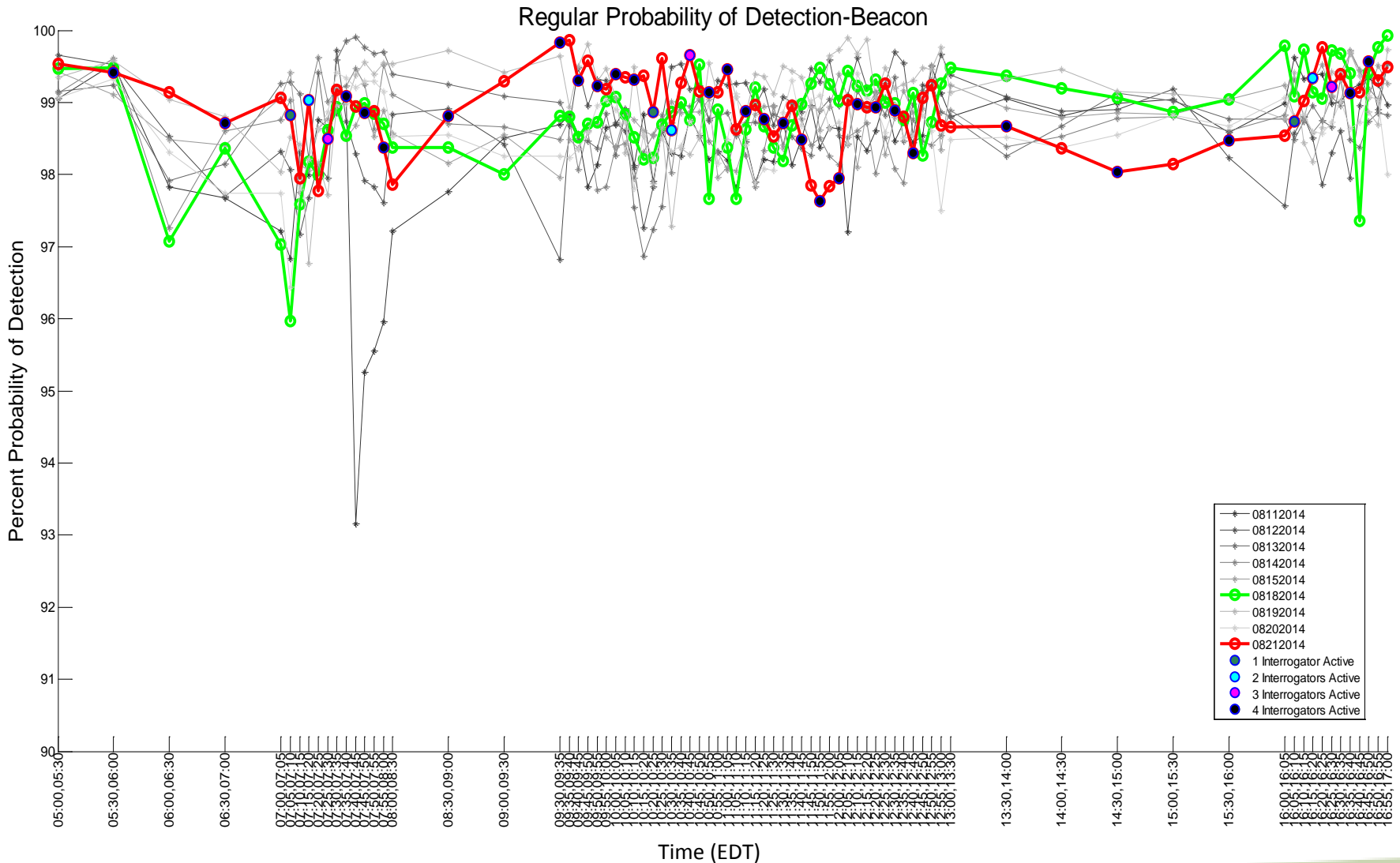
Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

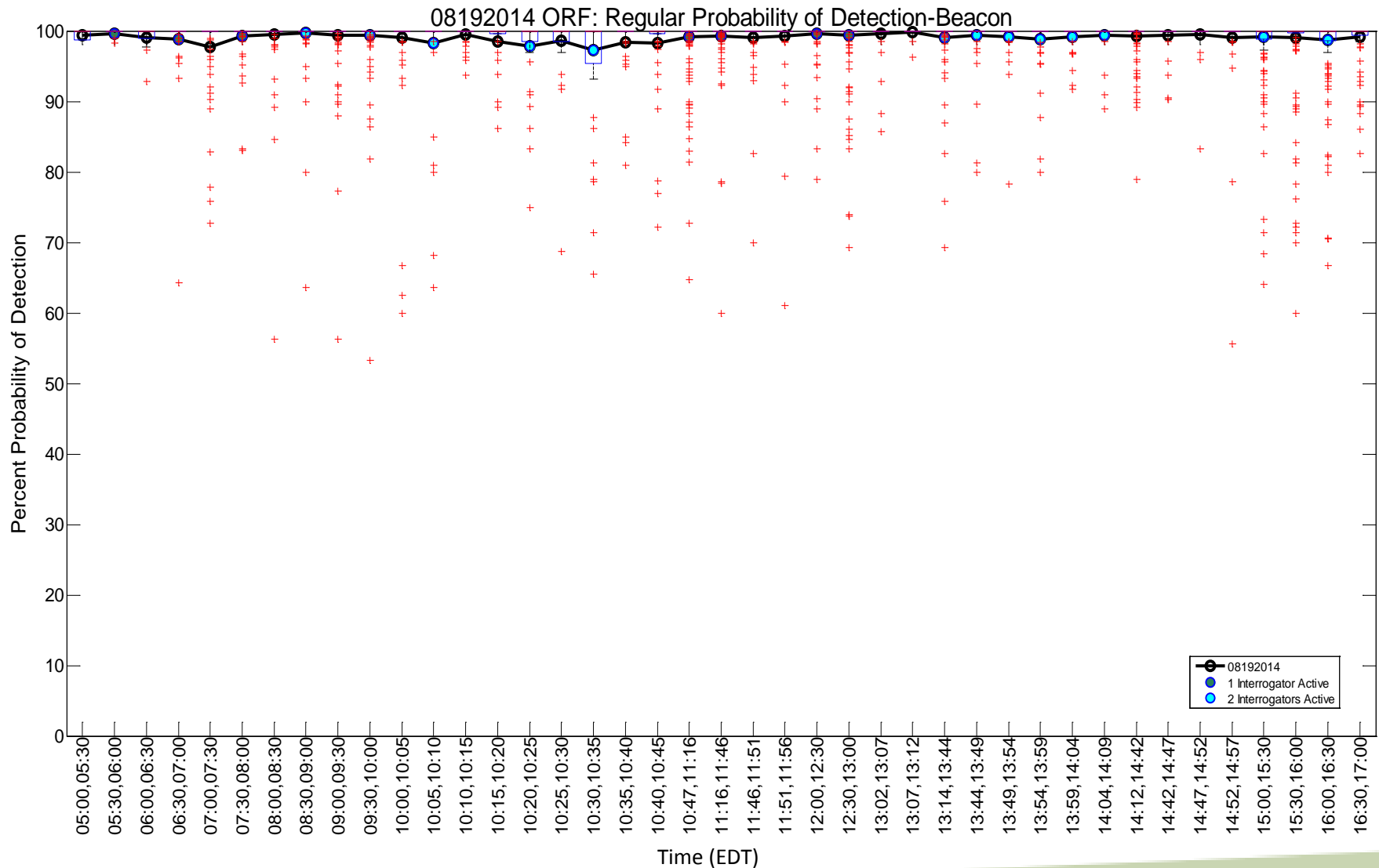
# Probability of Detection – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

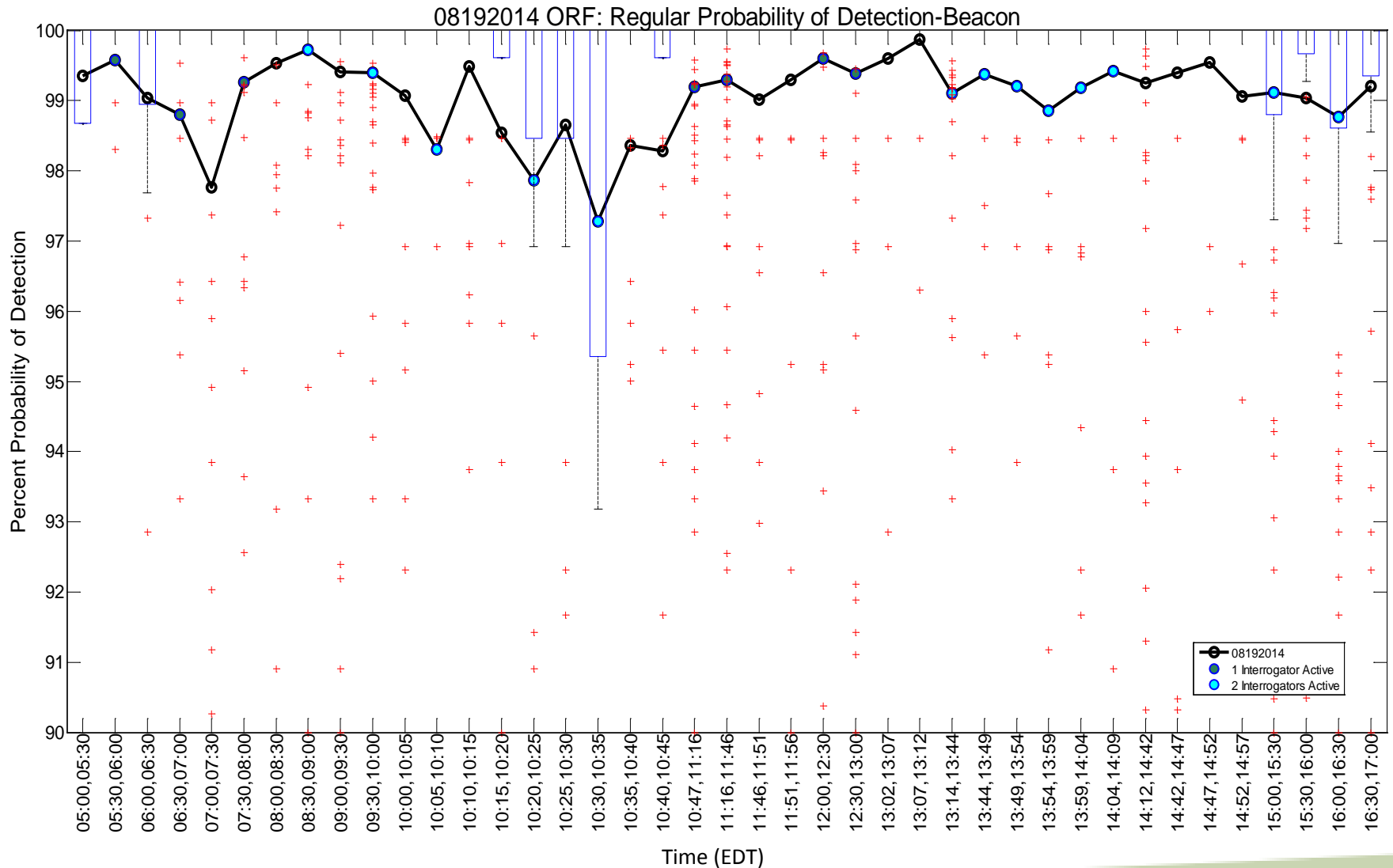
## Individual Aircraft Distribution



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)



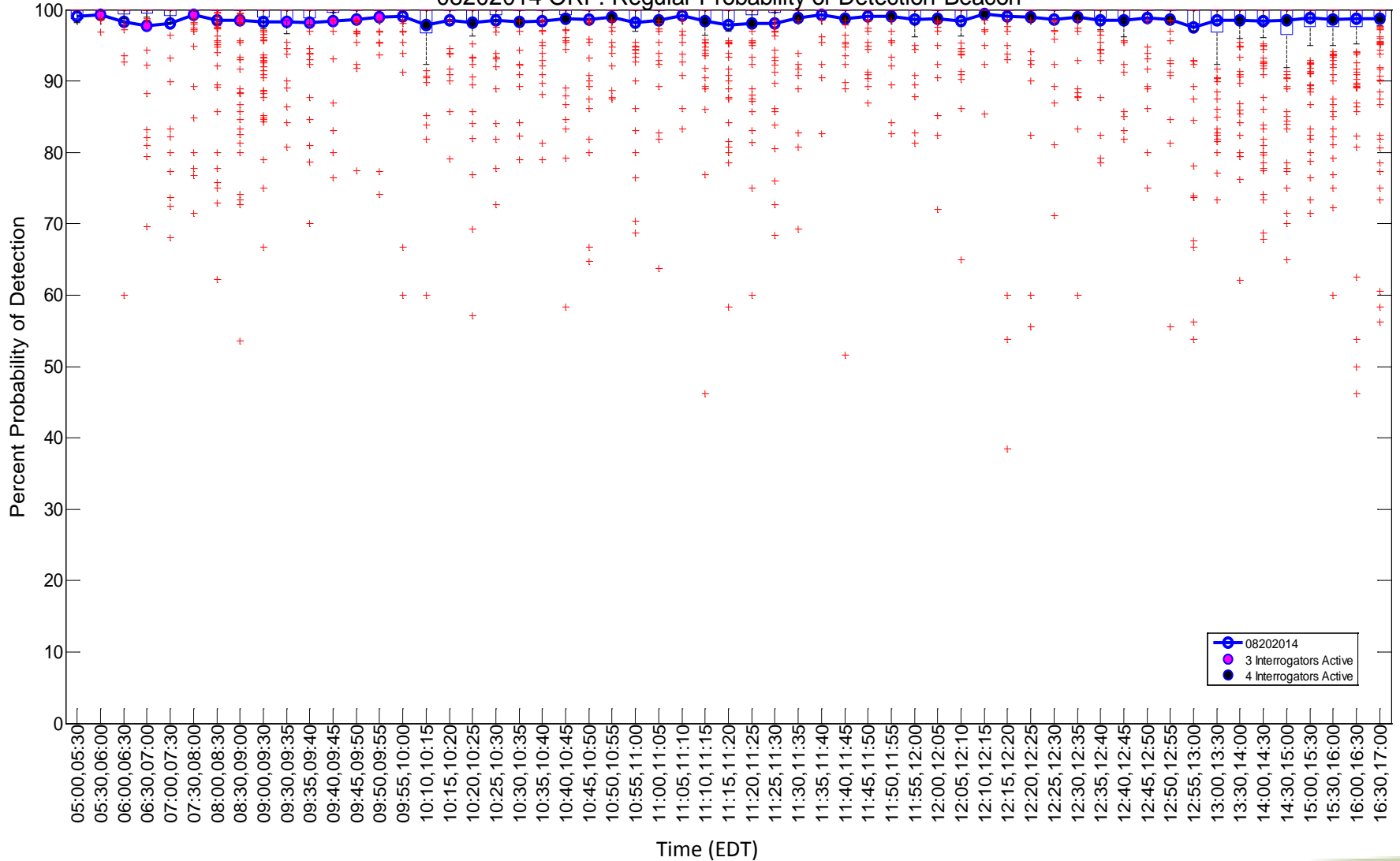
Geographic Filter: None  
Target Filter: None



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

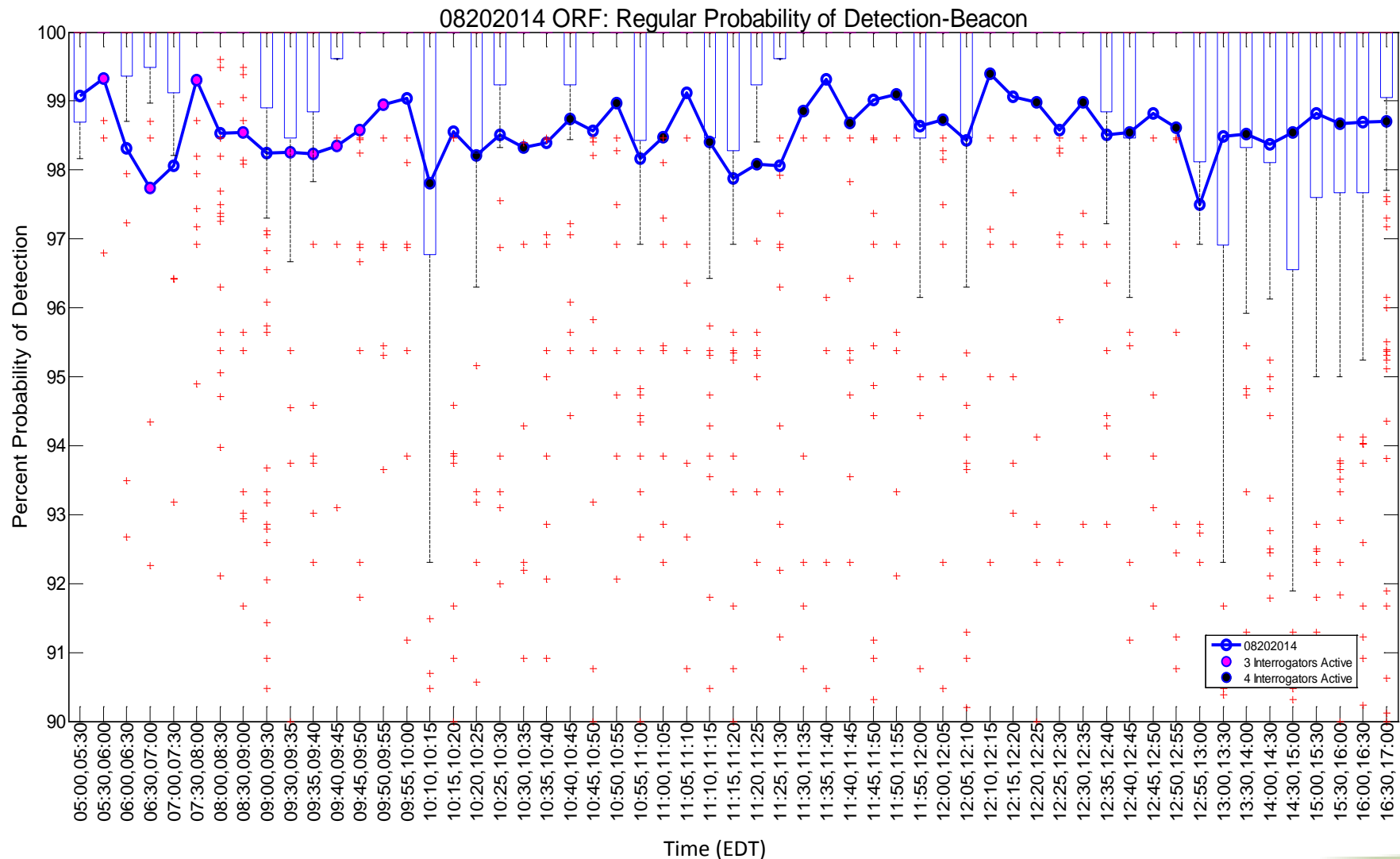
08202014 ORF: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

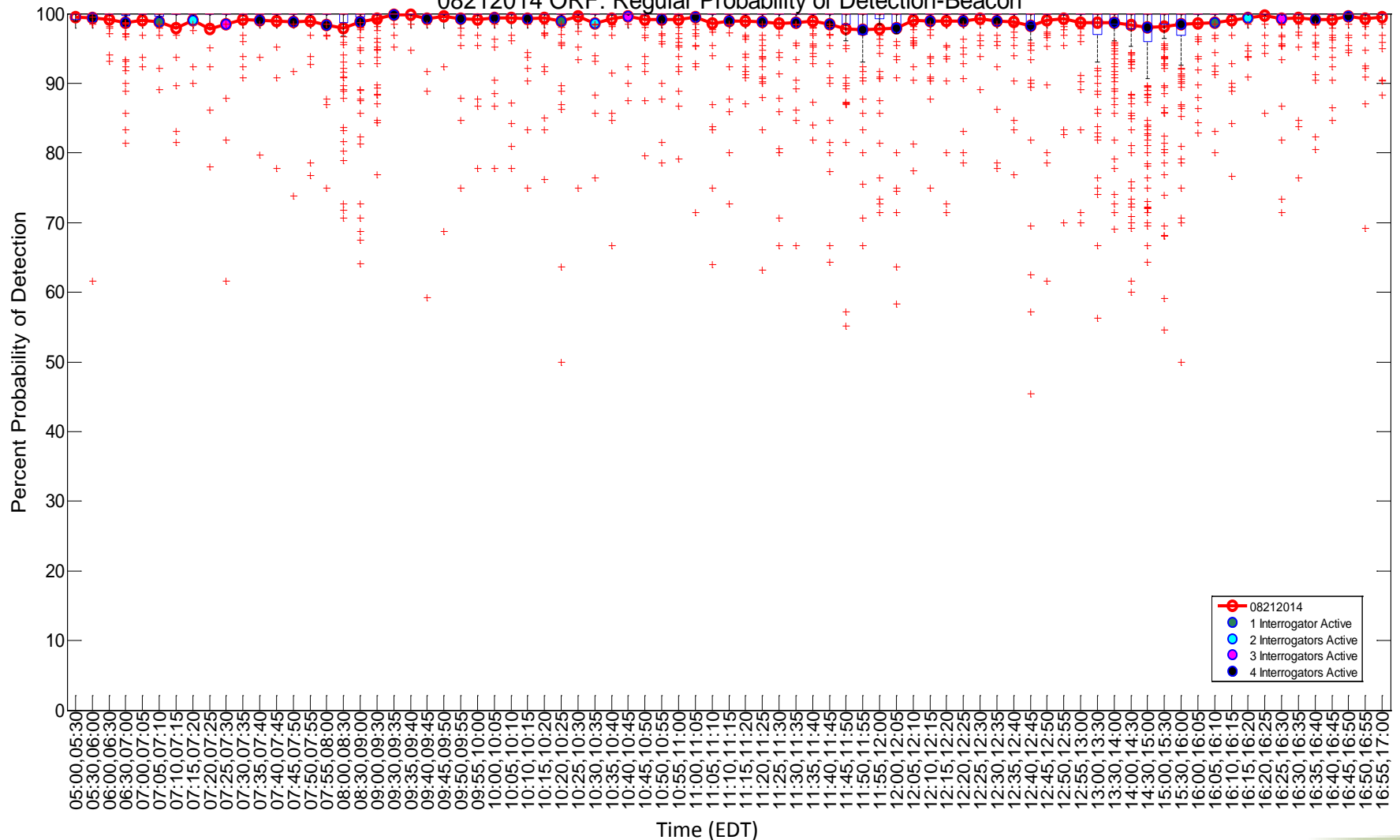


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

08212014 ORF: Regular Probability of Detection-Beacon

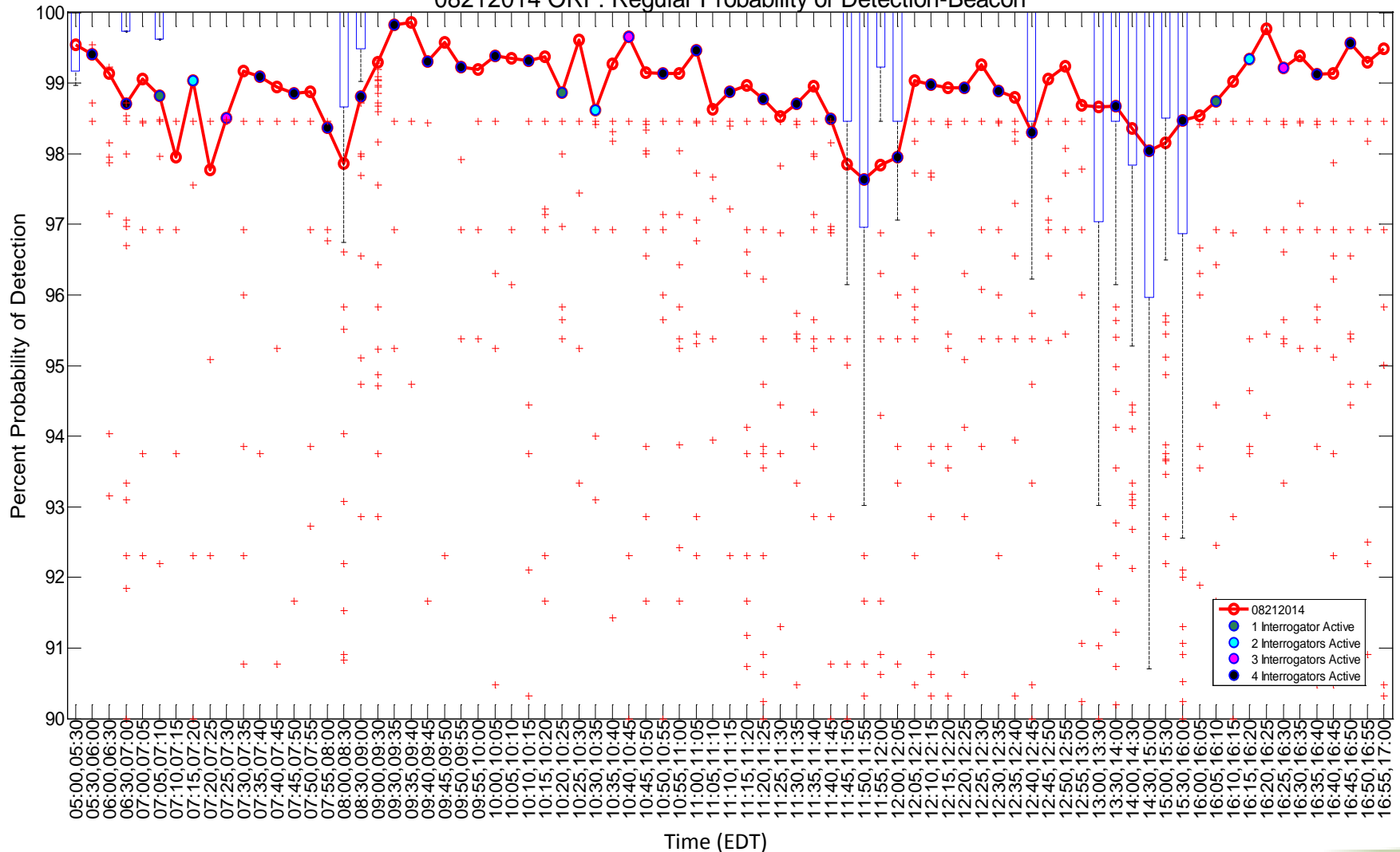


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

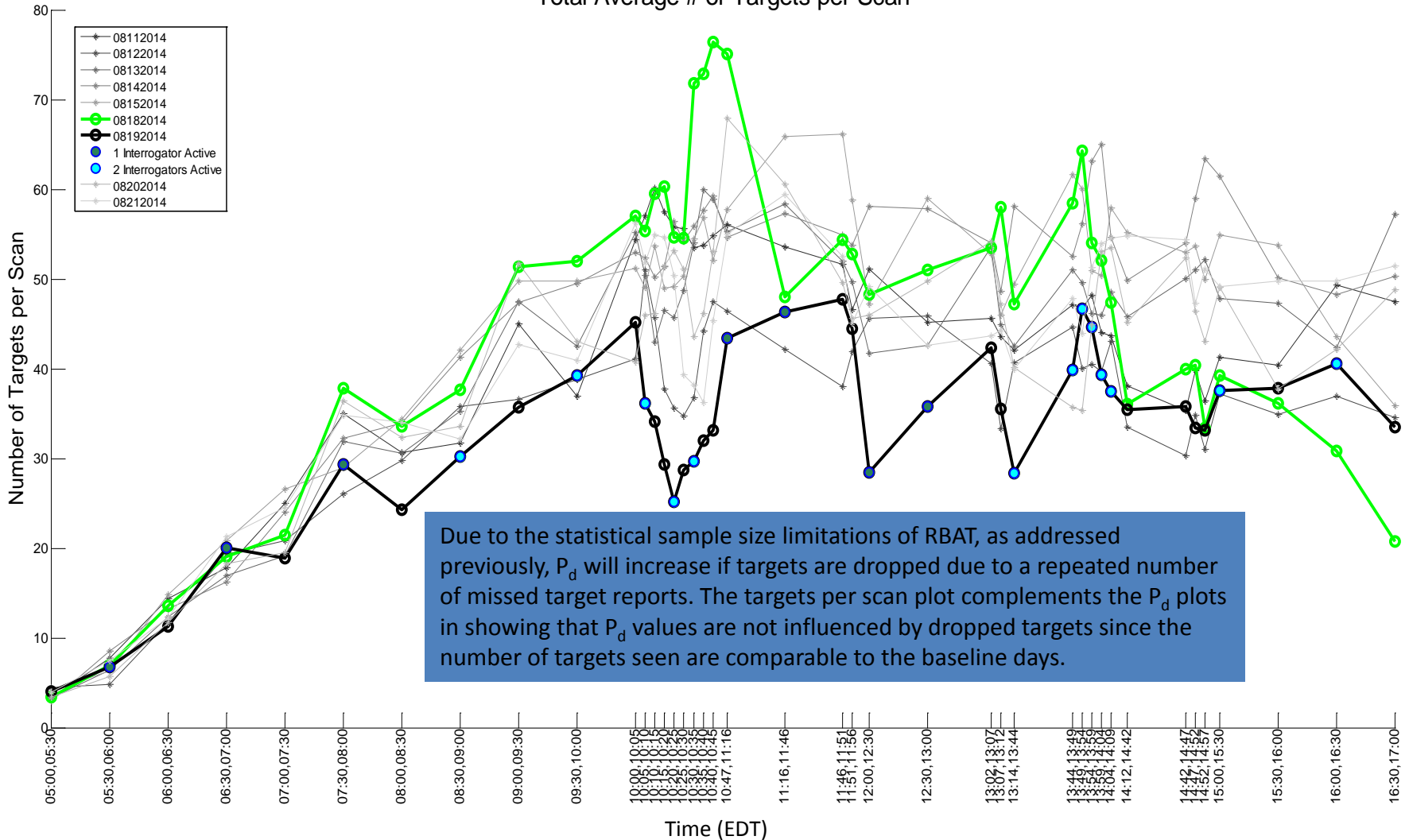
## Individual Aircraft Distribution (zoom-in)

08212014 ORF: Regular Probability of Detection-Beacon



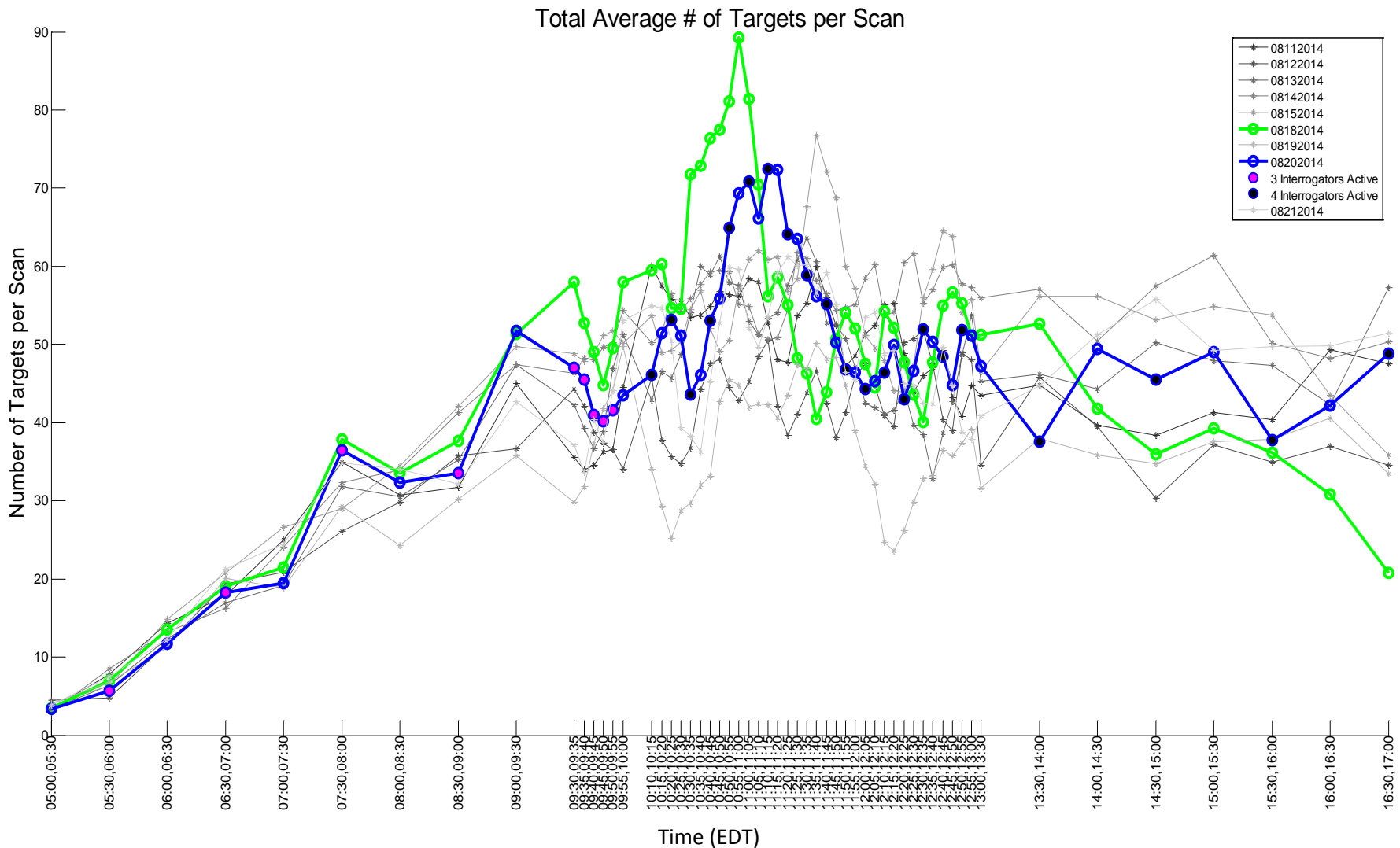
# Targets per Scan – August 19<sup>th</sup>

Total Average # of Targets per Scan



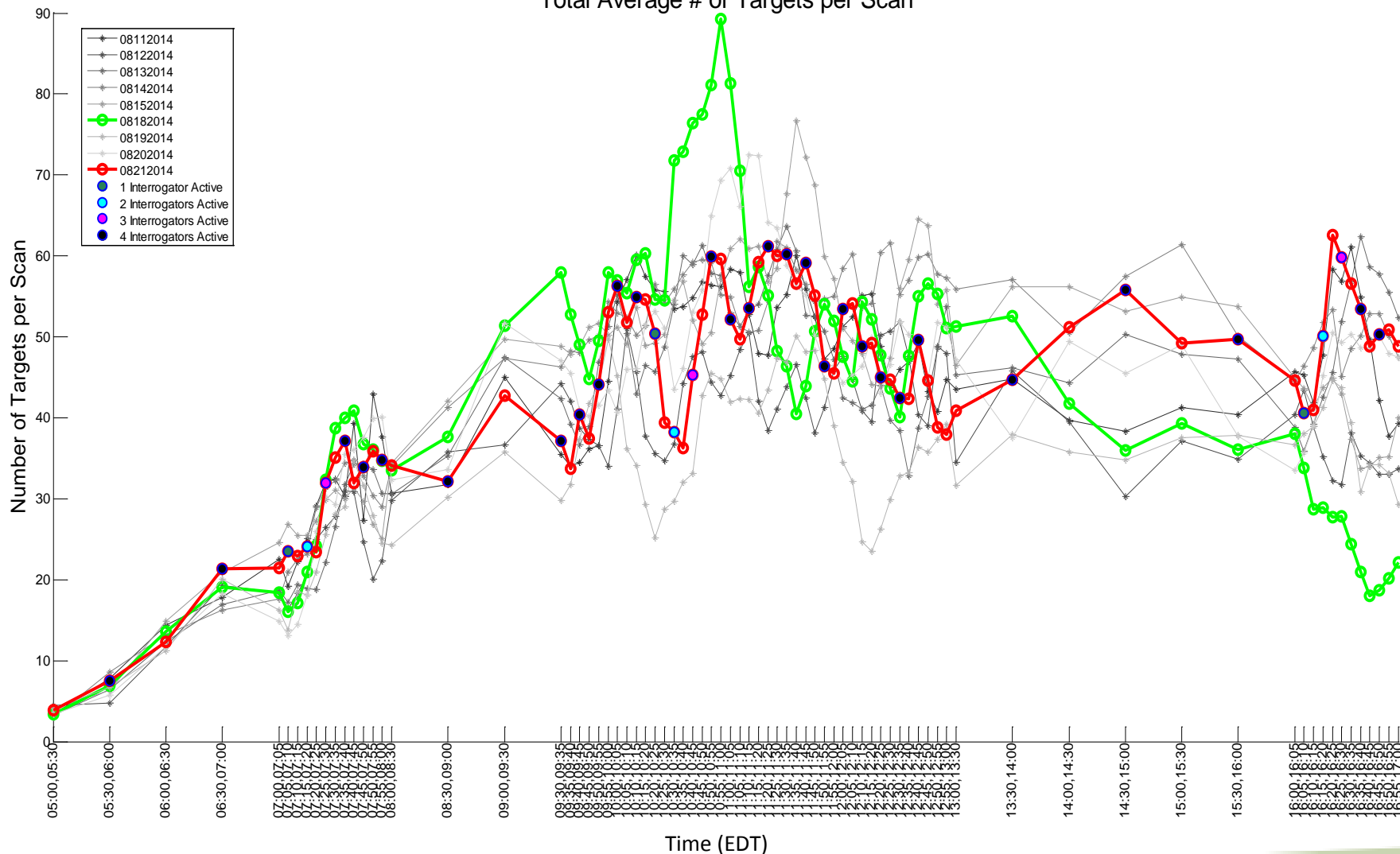
Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 20<sup>th</sup>



# Targets per Scan – August 21<sup>st</sup>

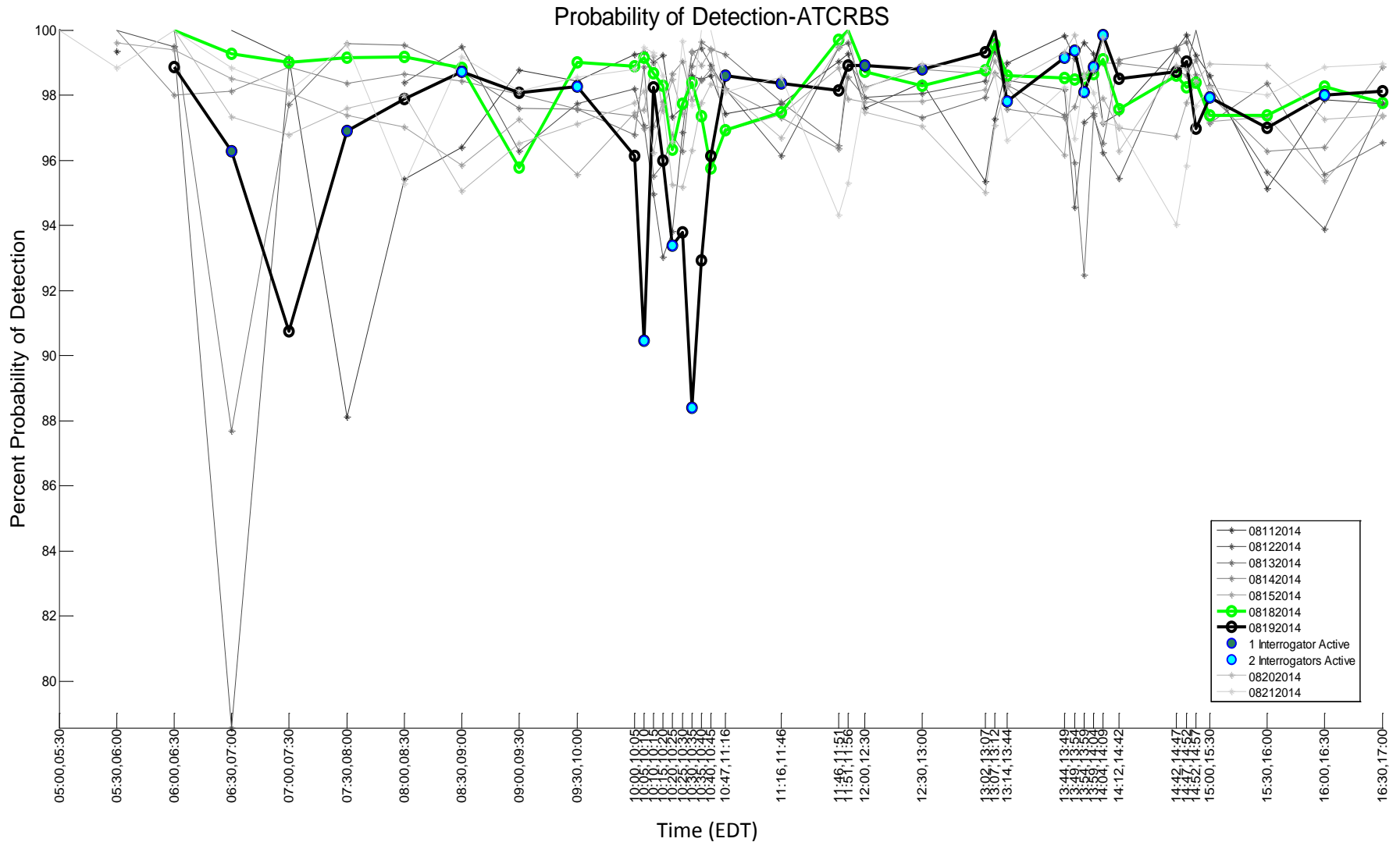
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

## ATCRBS Targets - Discrete

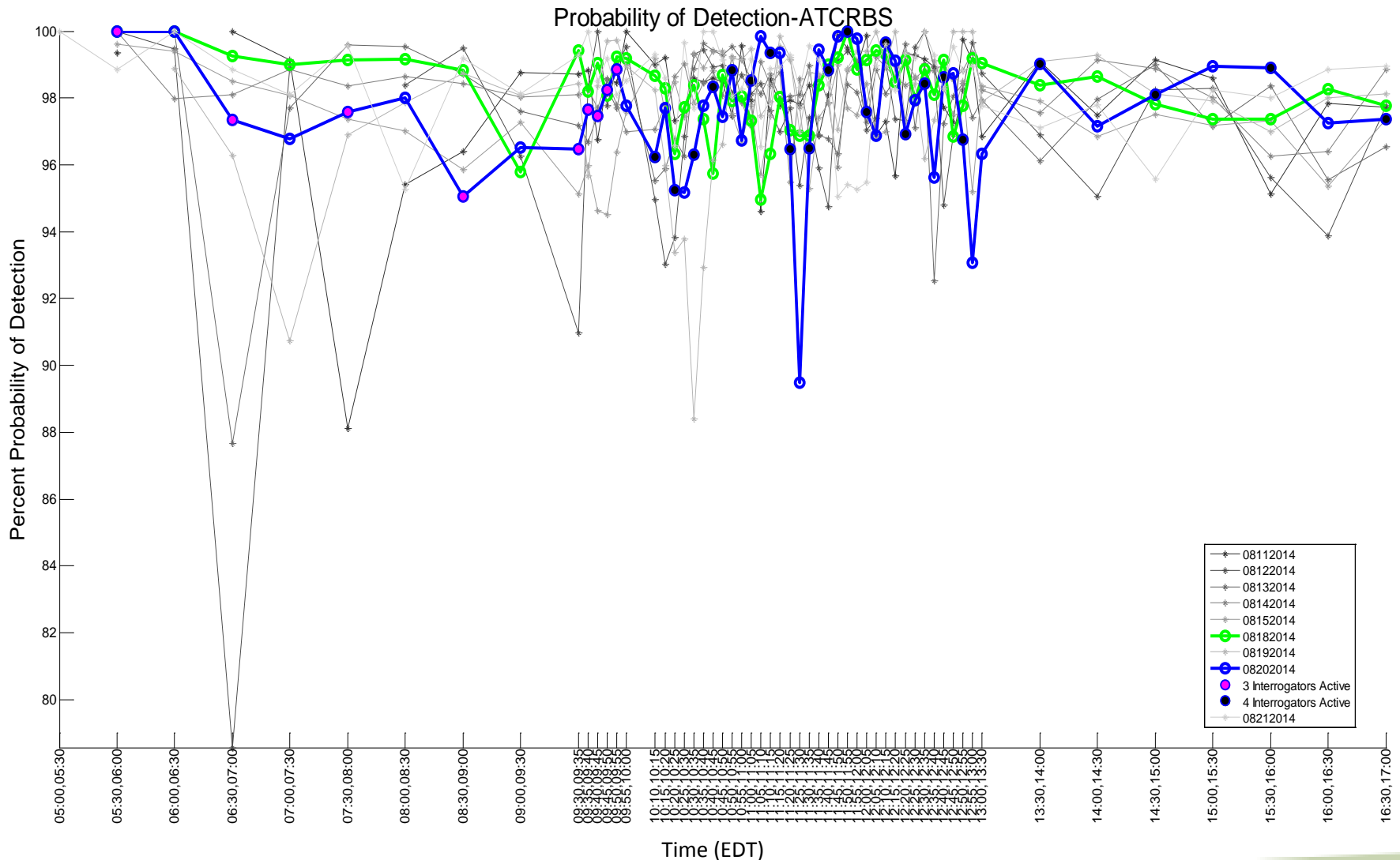


Geographic Filter: None  
Target Filter: None



# Probability of Detection – August 20<sup>th</sup>

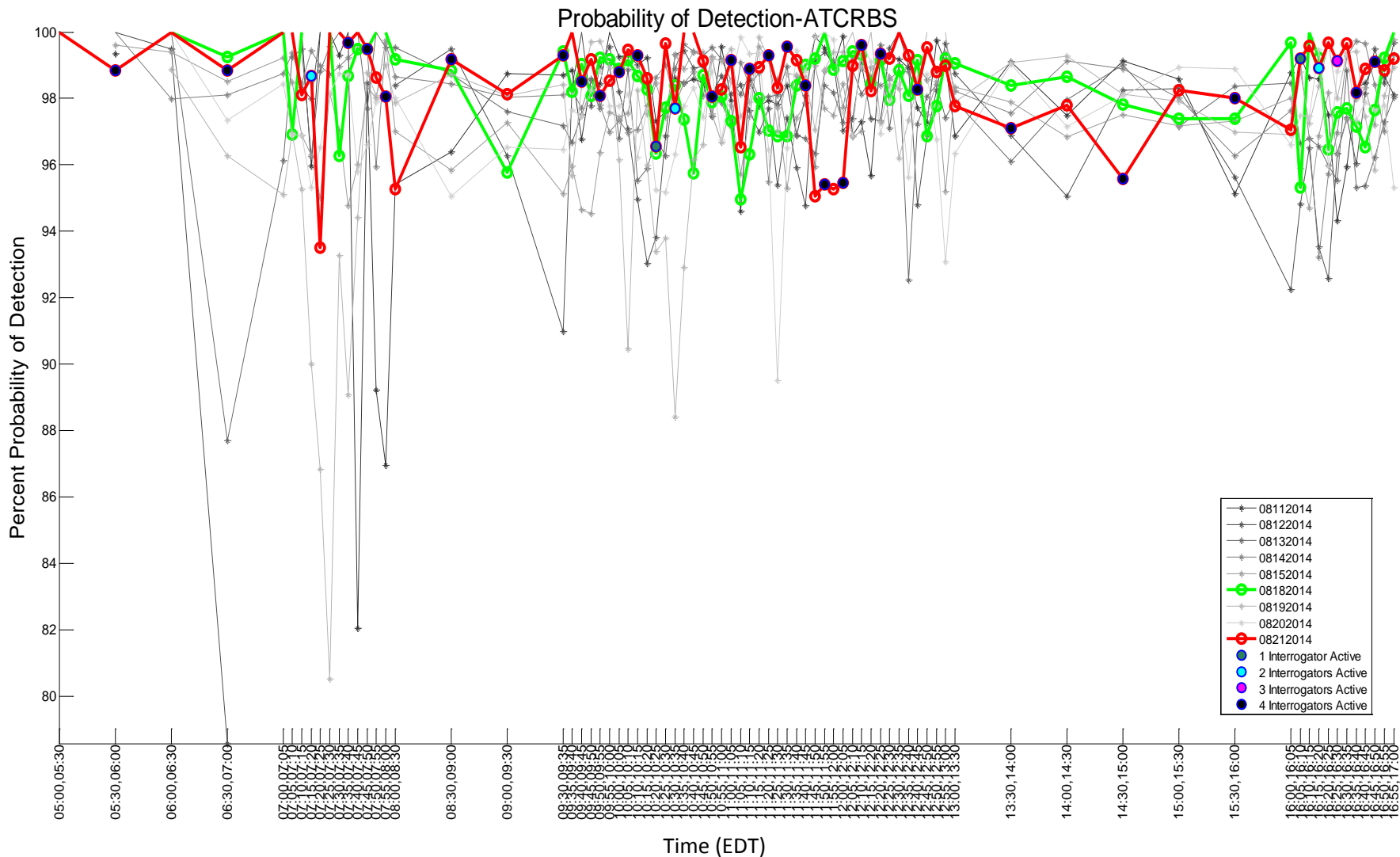
## ATCRBS Targets - Discrete



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

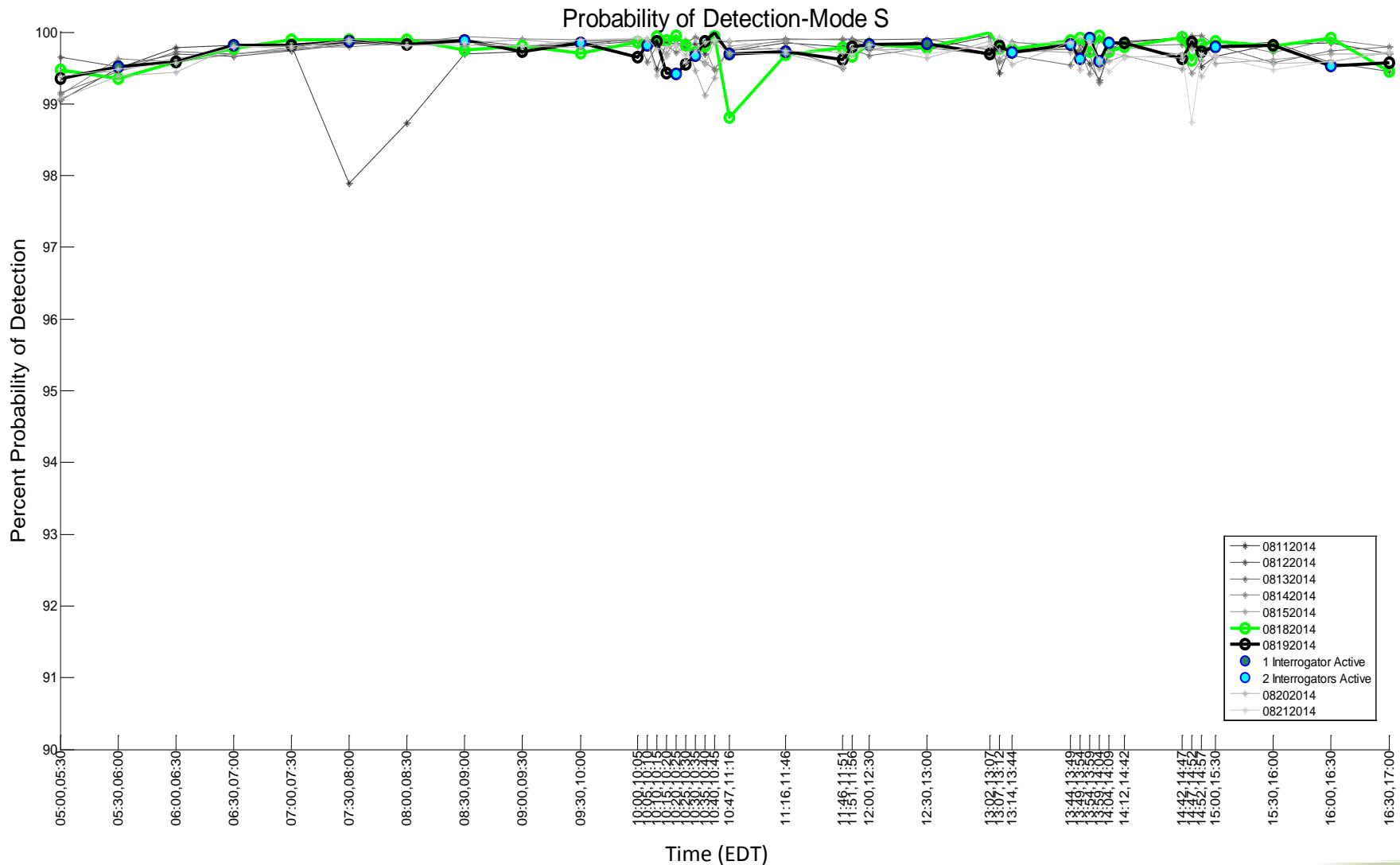
## ATCRBS Targets - Discrete



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

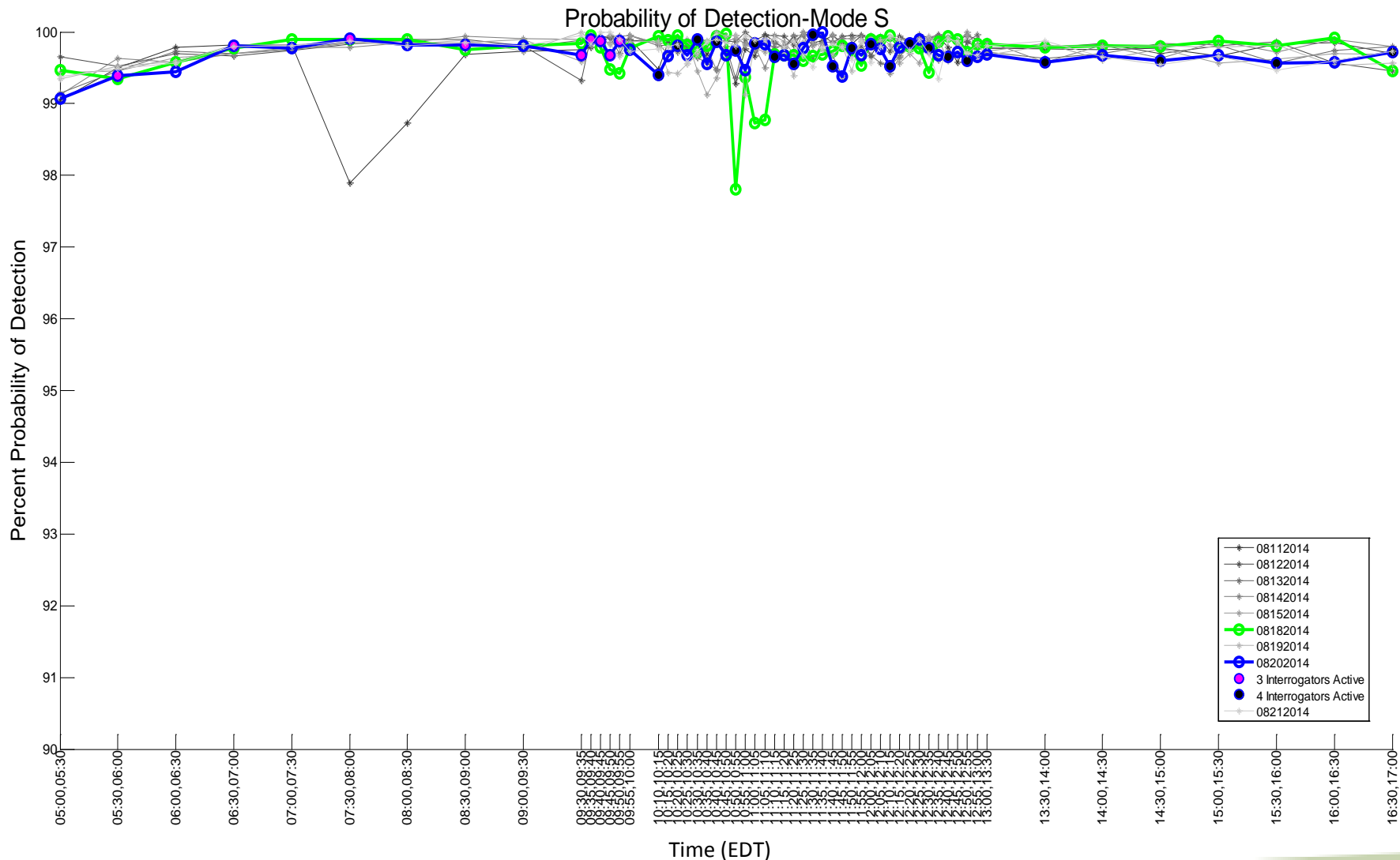
## Mode S Targets



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

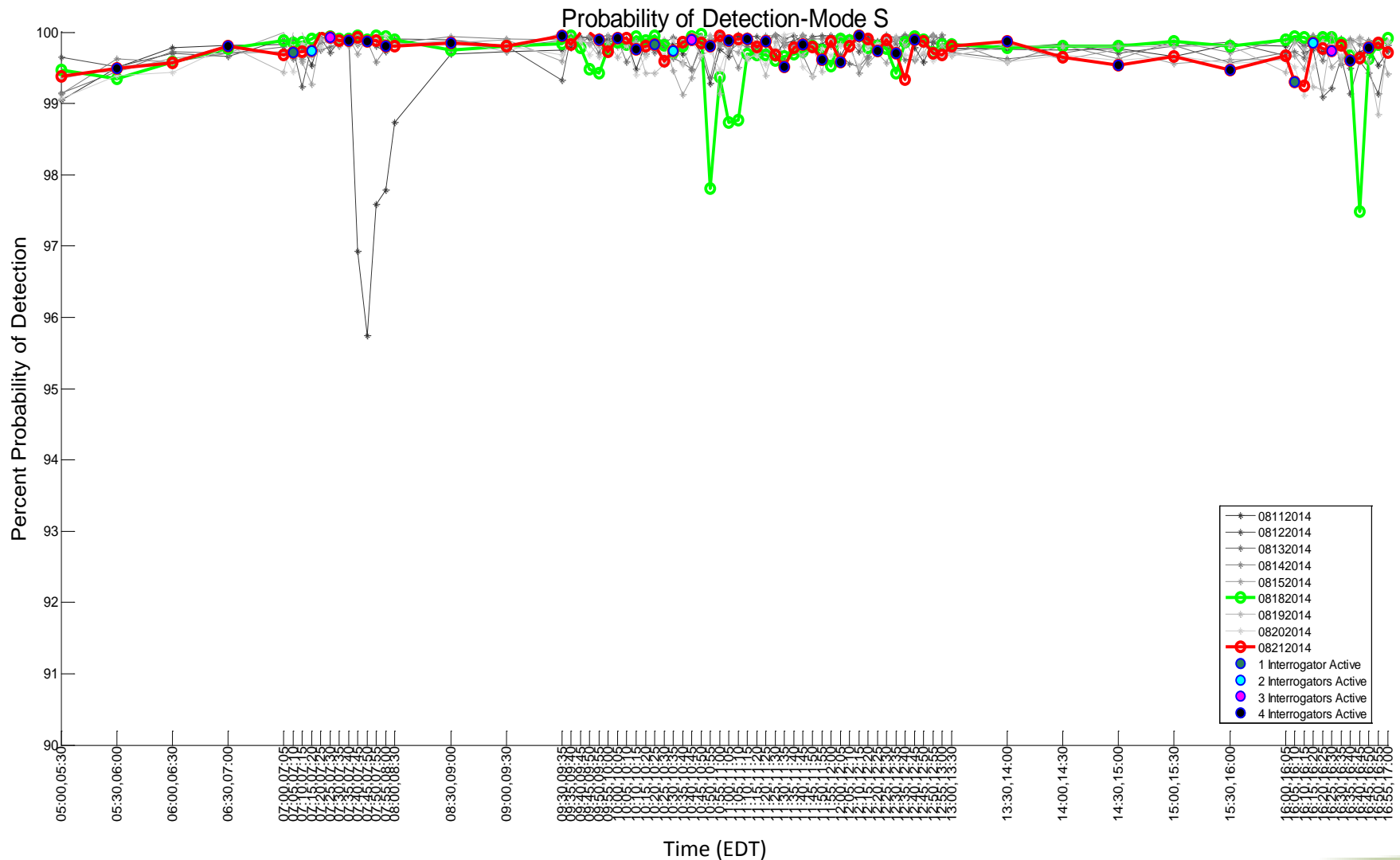
## Mode S Targets



Geographic Filter: None  
Target Filter: None

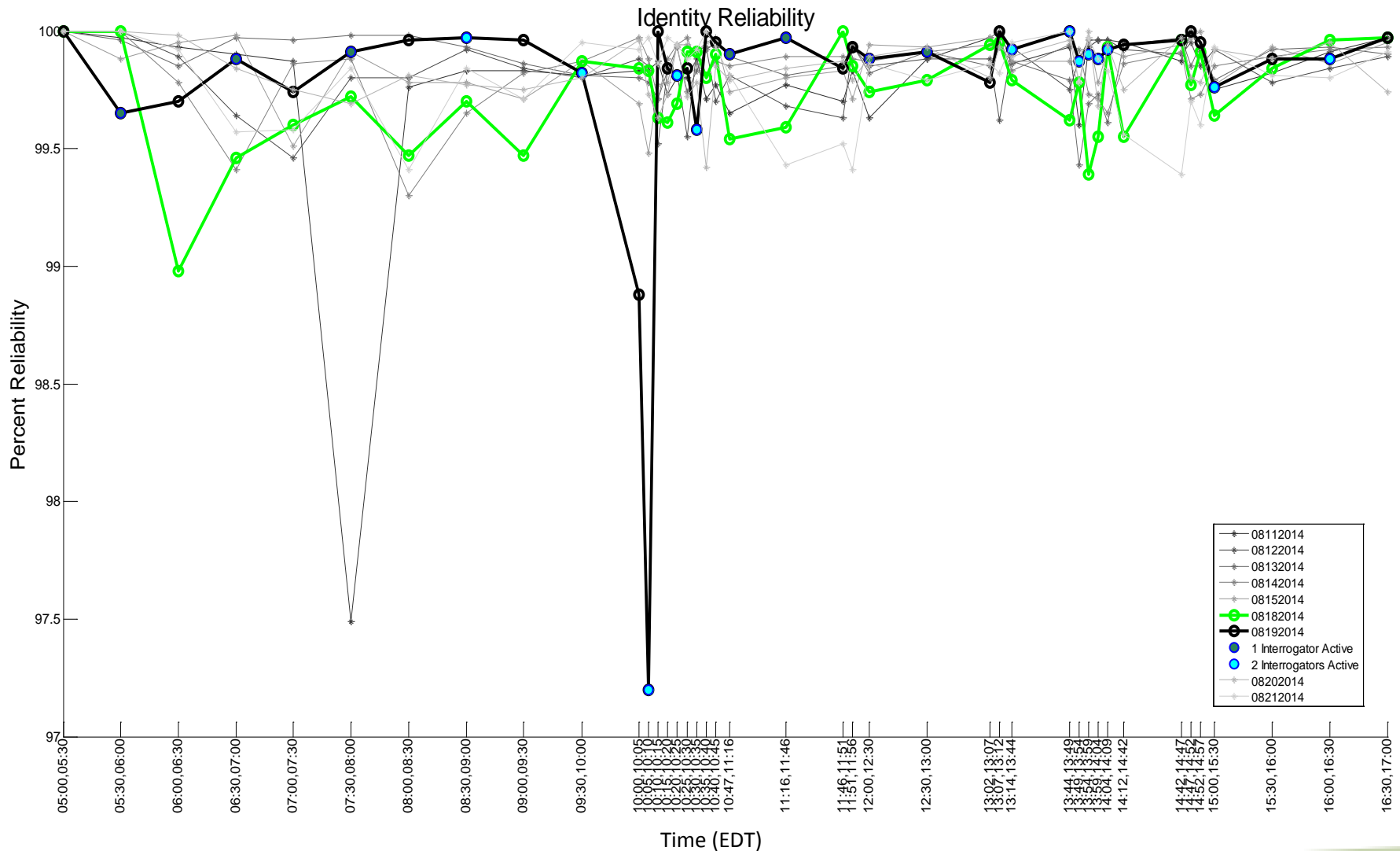
# Probability of Detection – August 21<sup>st</sup>

## Mode S Targets



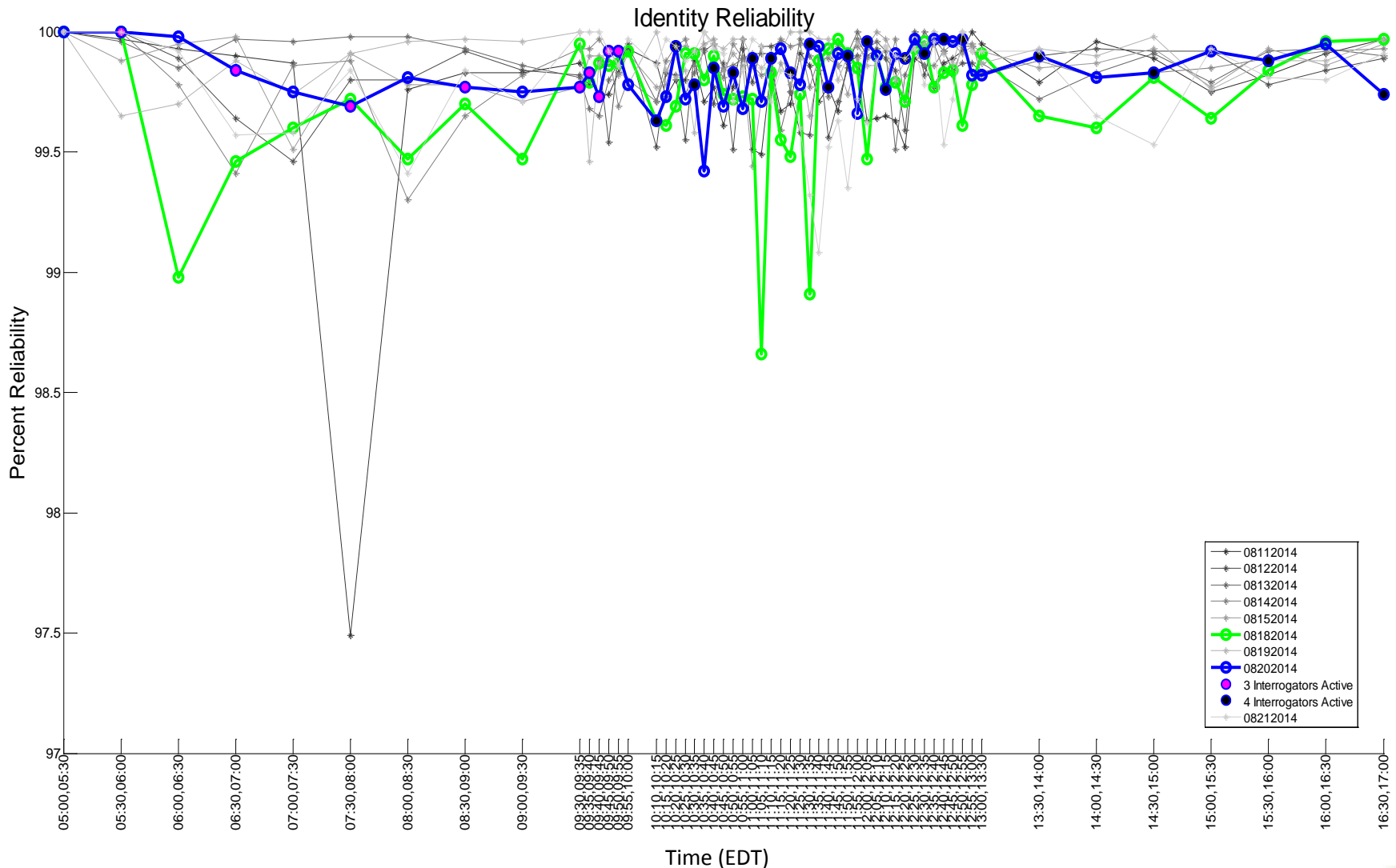
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 19th



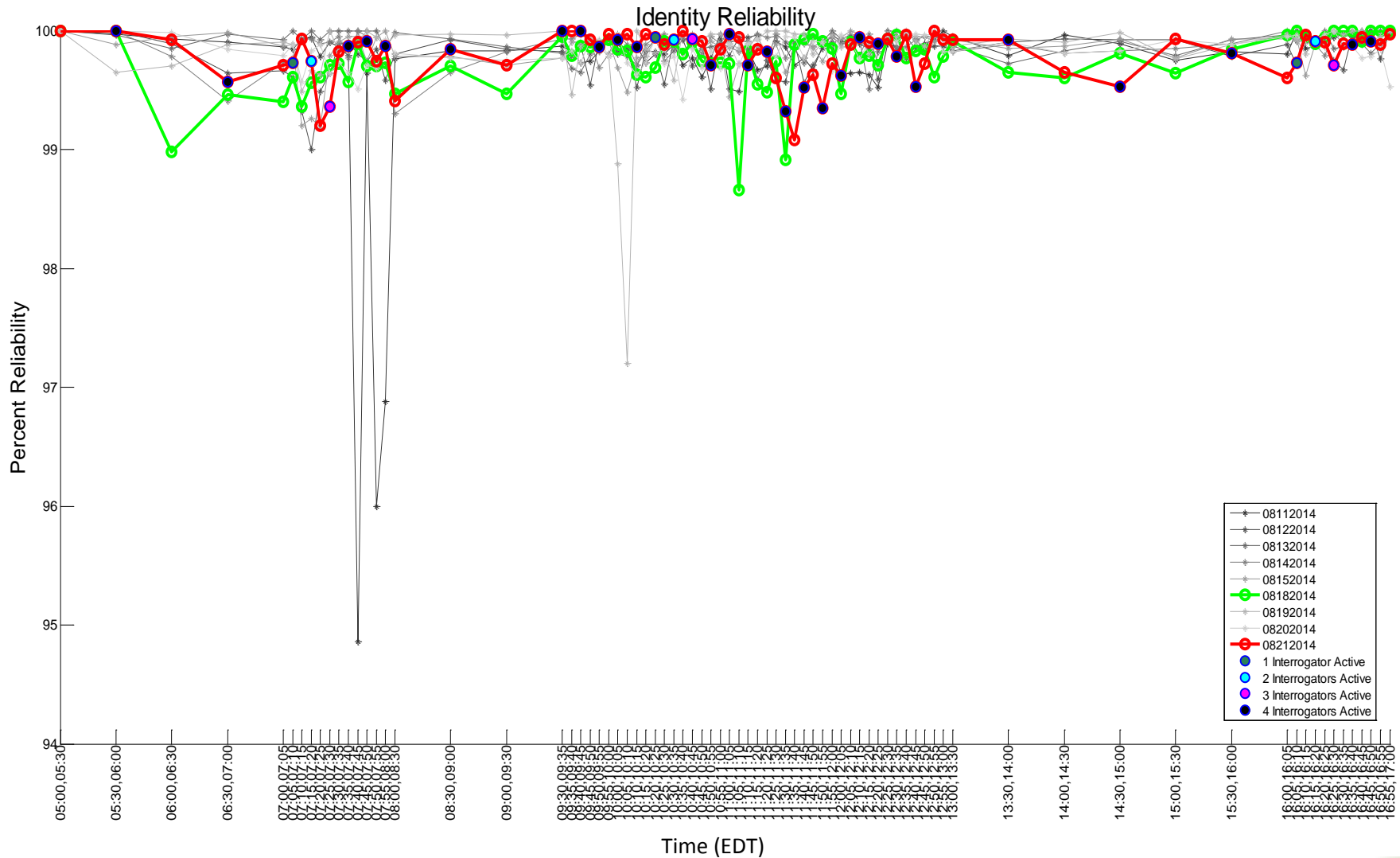
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

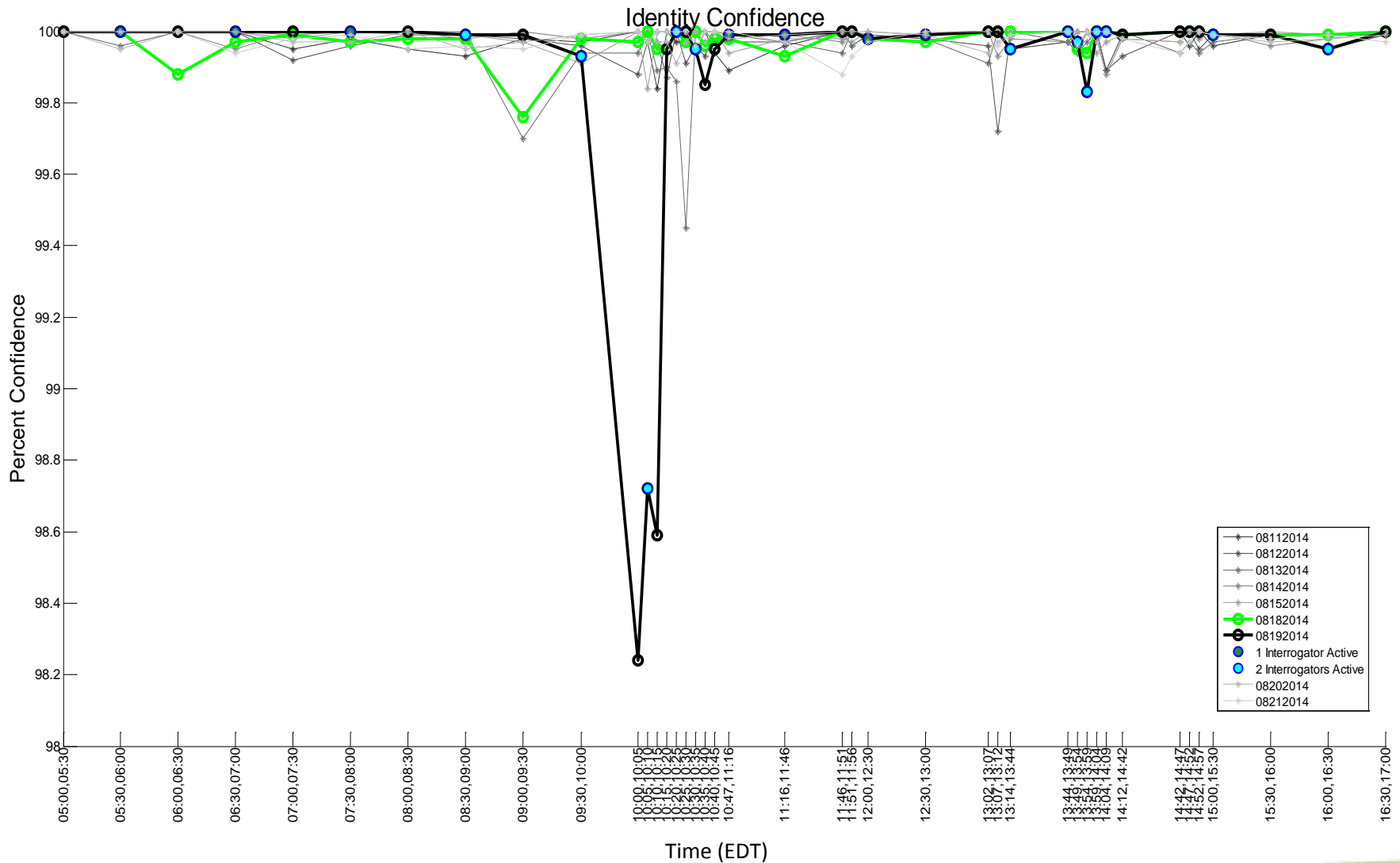
# Identity (3/A) Reliability – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

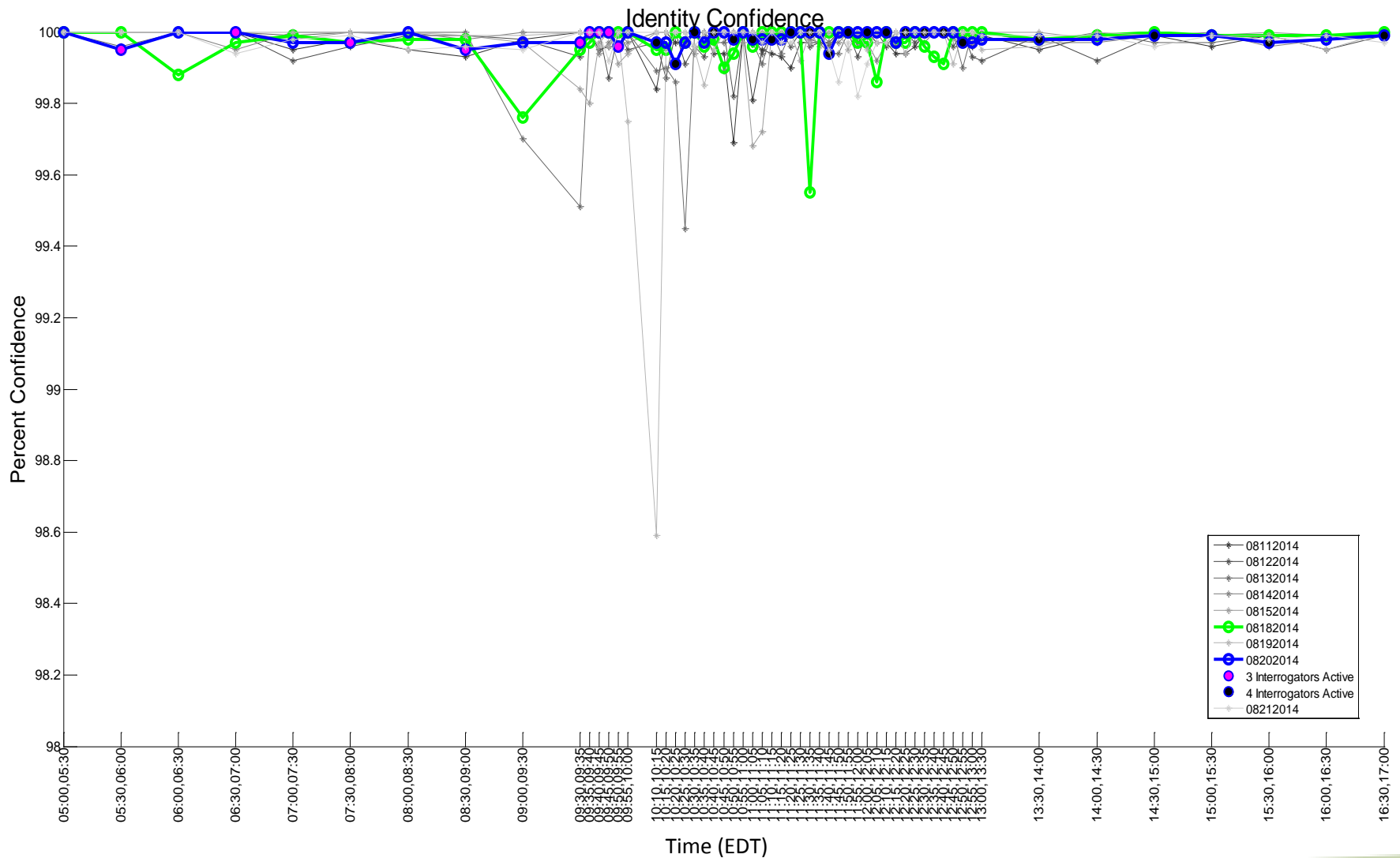


# Identity (3/A) Confidence – August 19th



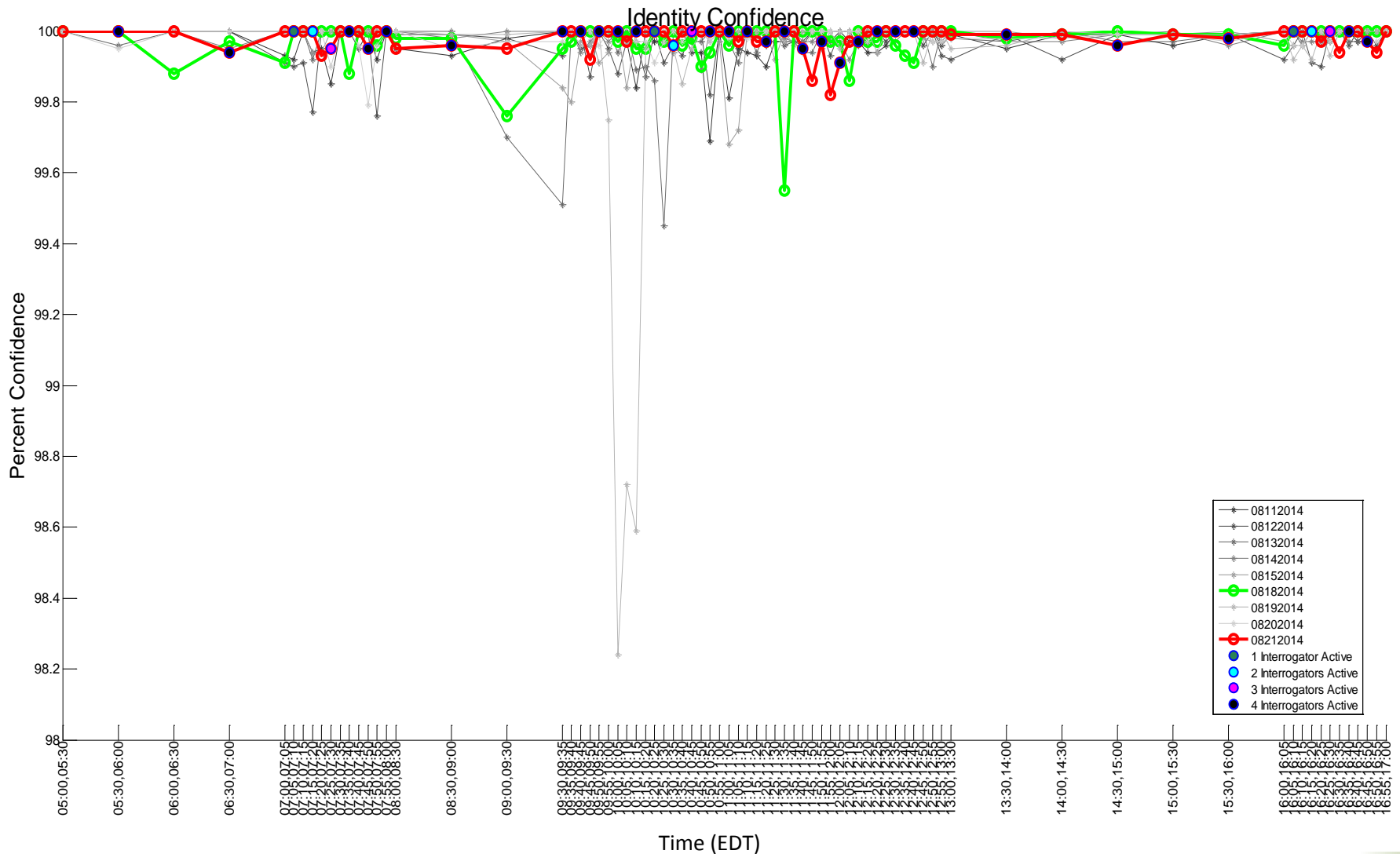
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 20<sup>th</sup>



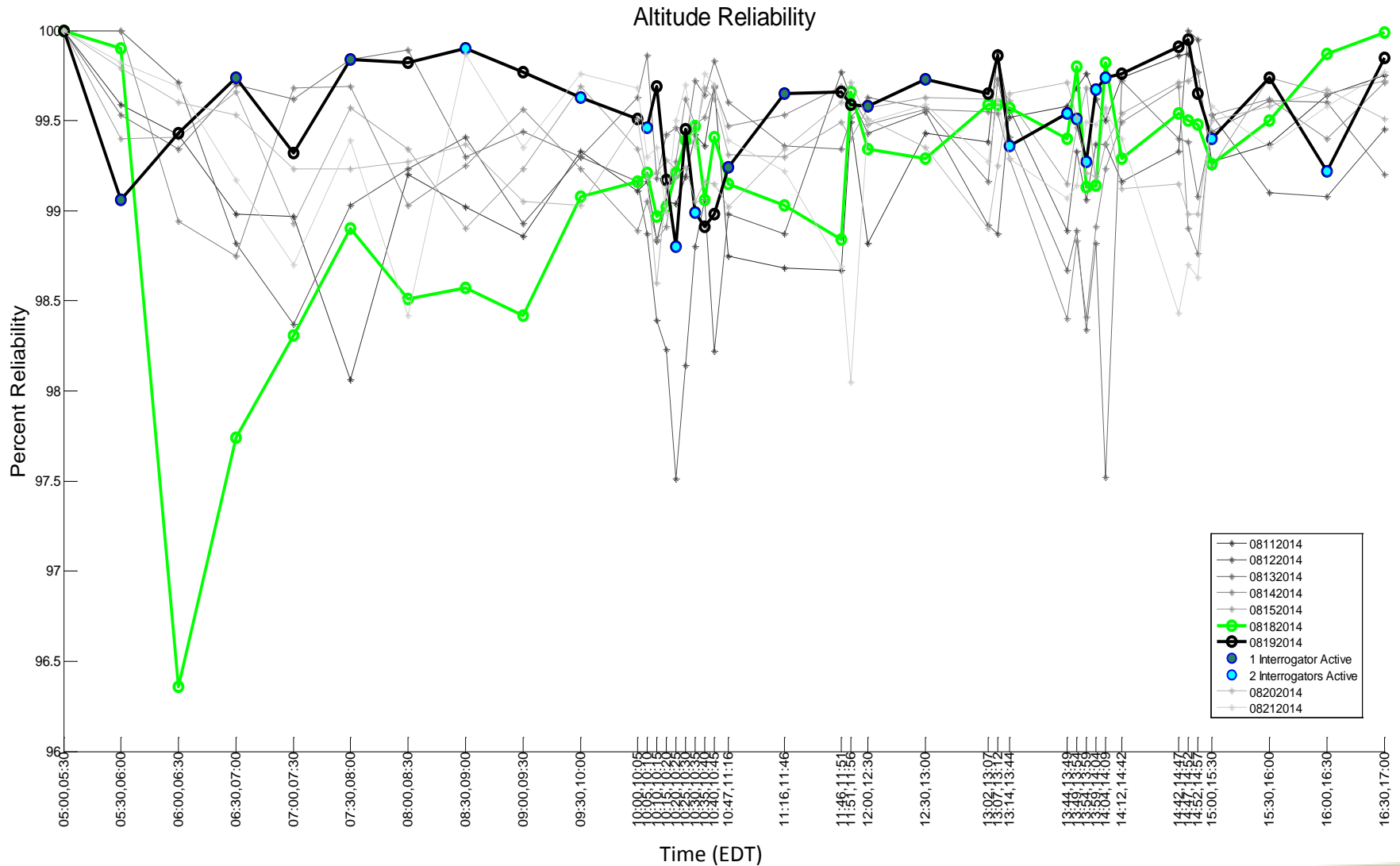
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 21<sup>st</sup>



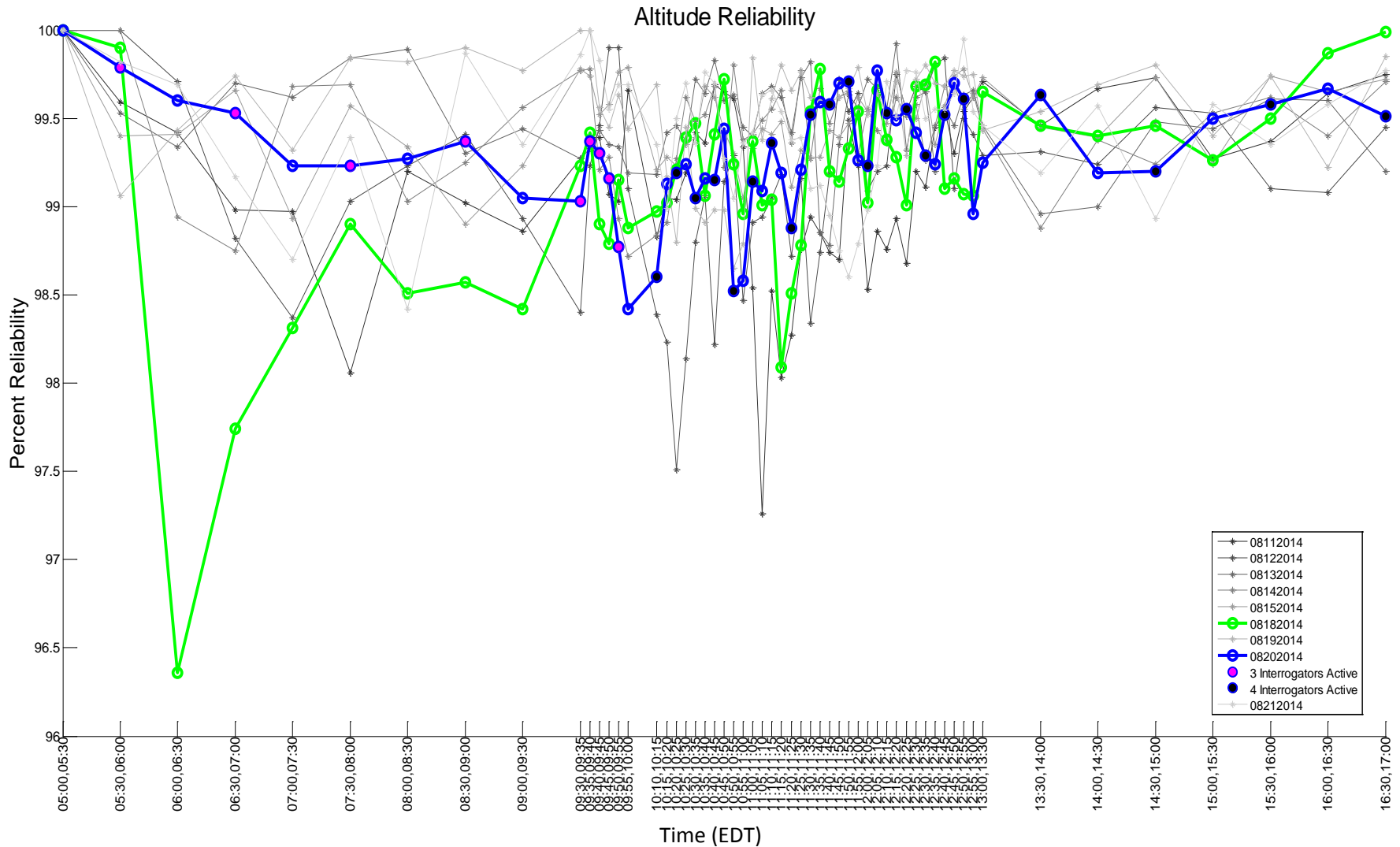
Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 19th



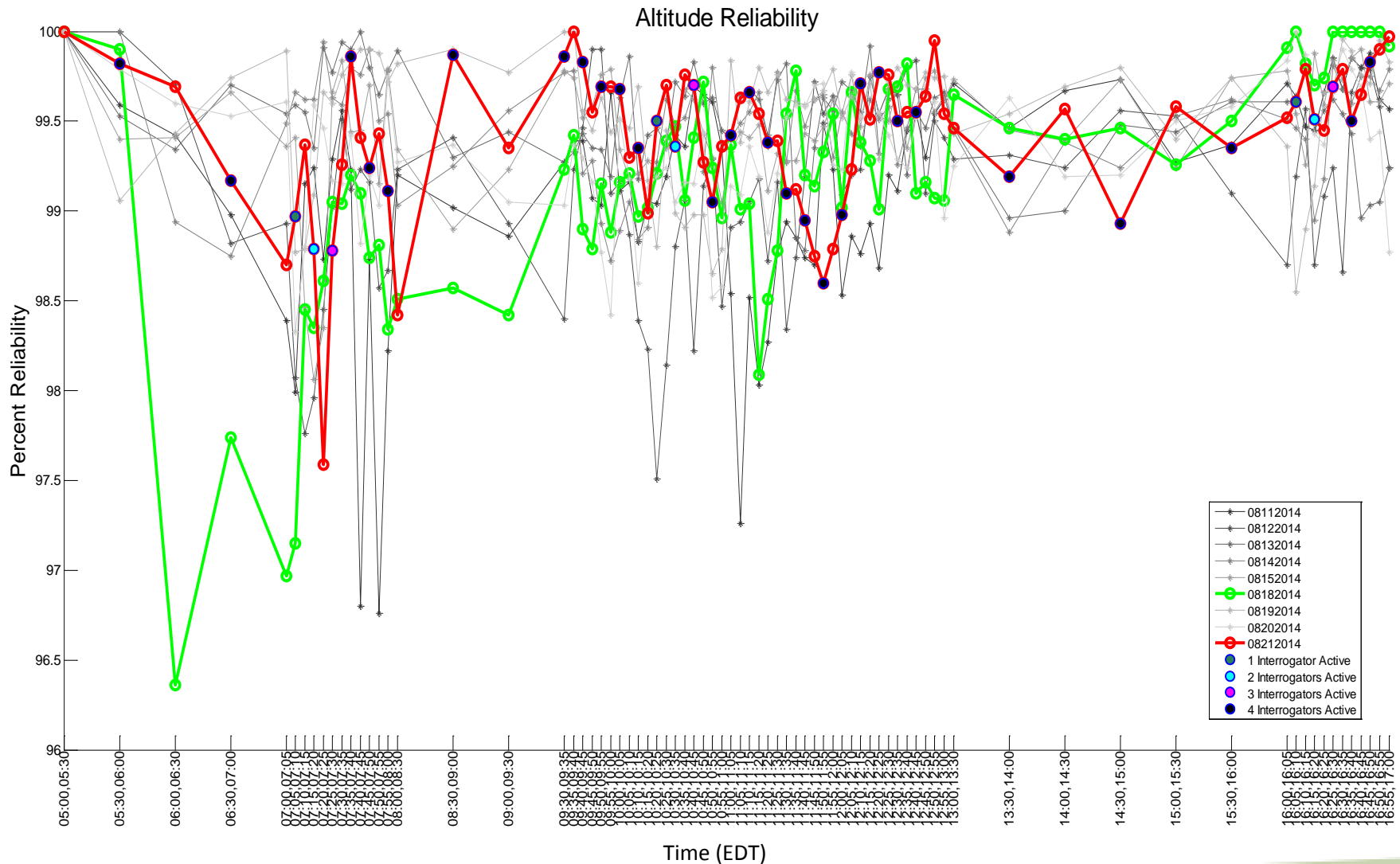
Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 20<sup>th</sup>



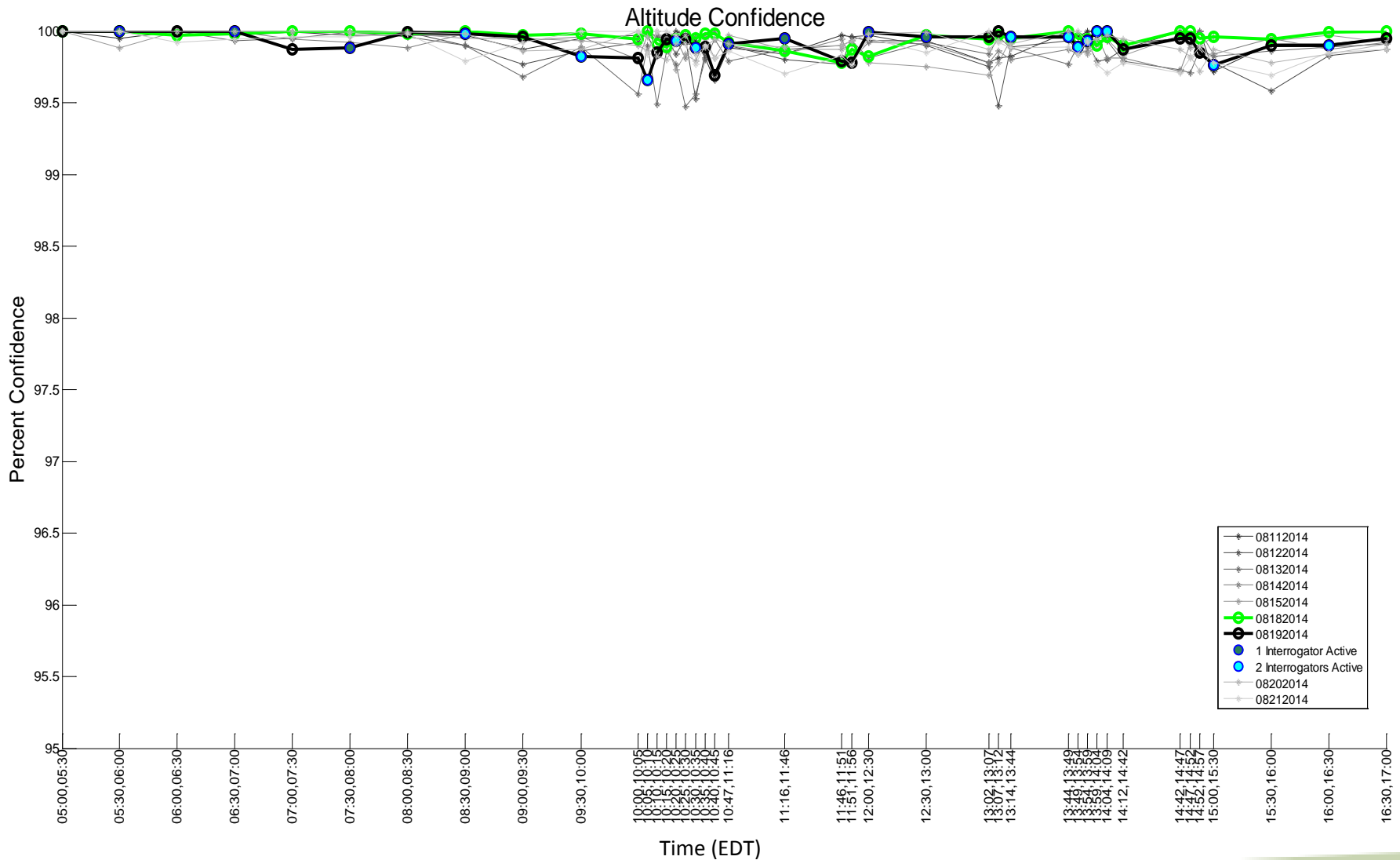
Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

# Altitude (C) Confidence – August 19th

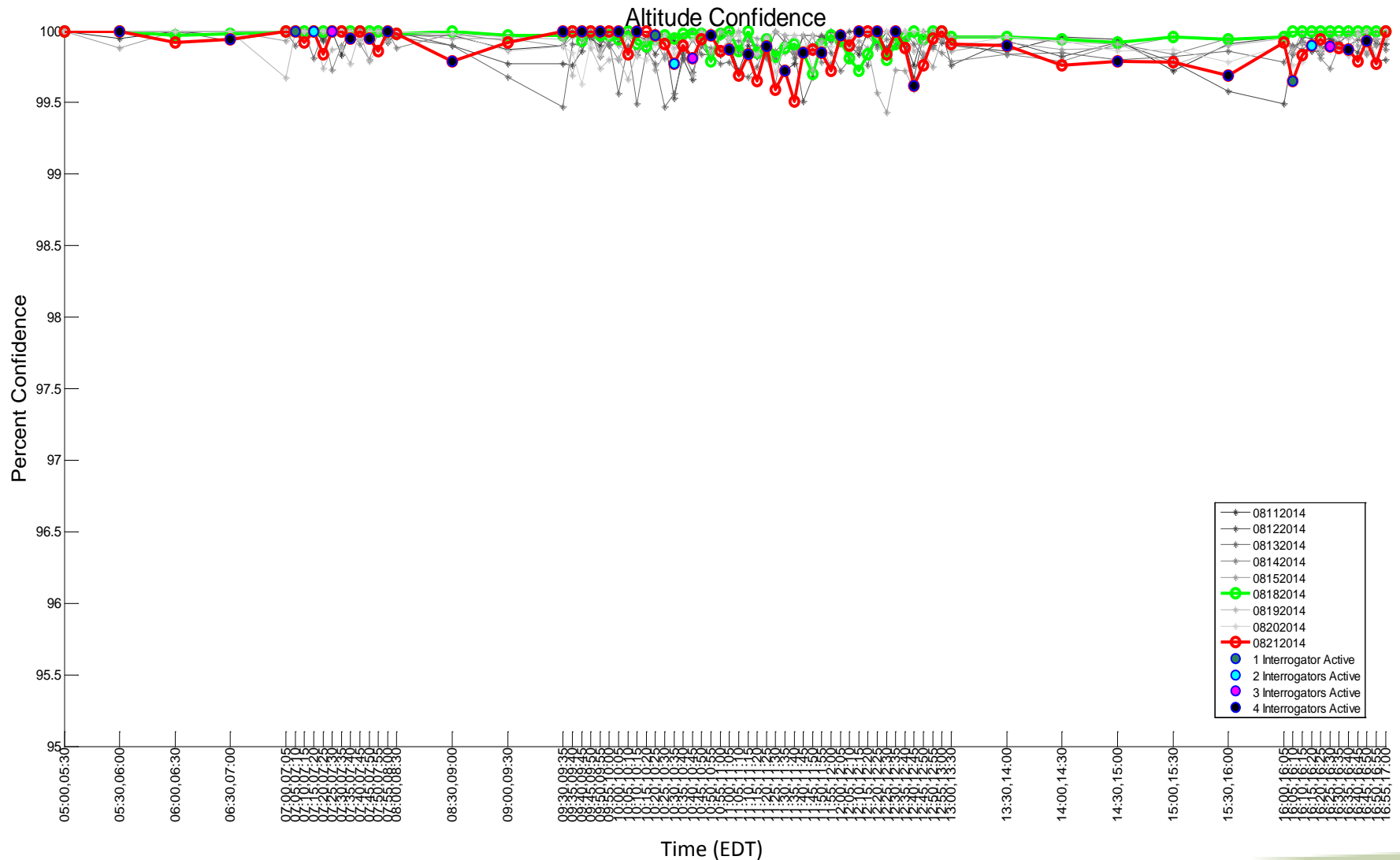


Geographic Filter: None  
Target Filter: None



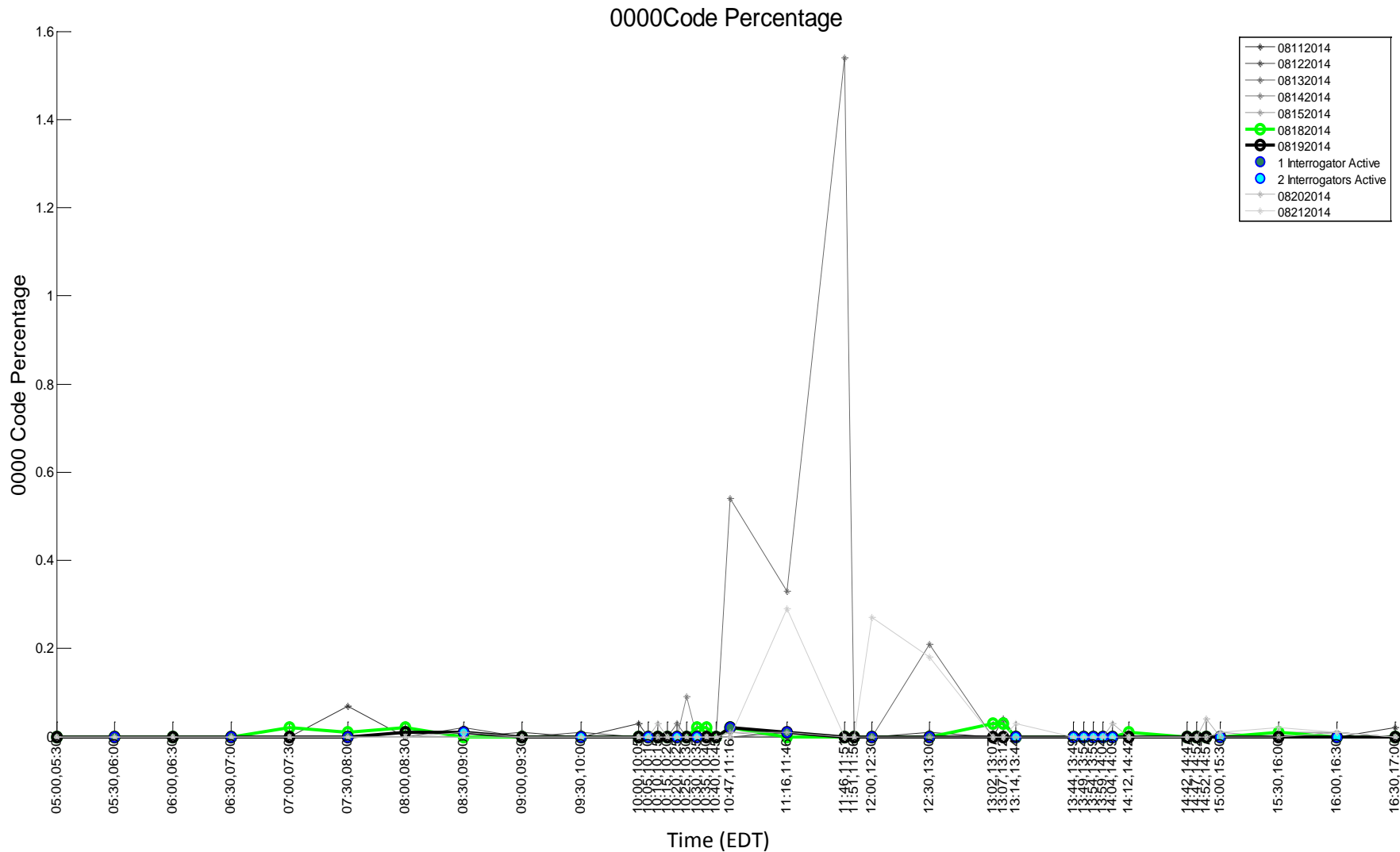


# Altitude (C) Confidence – August 21<sup>st</sup>



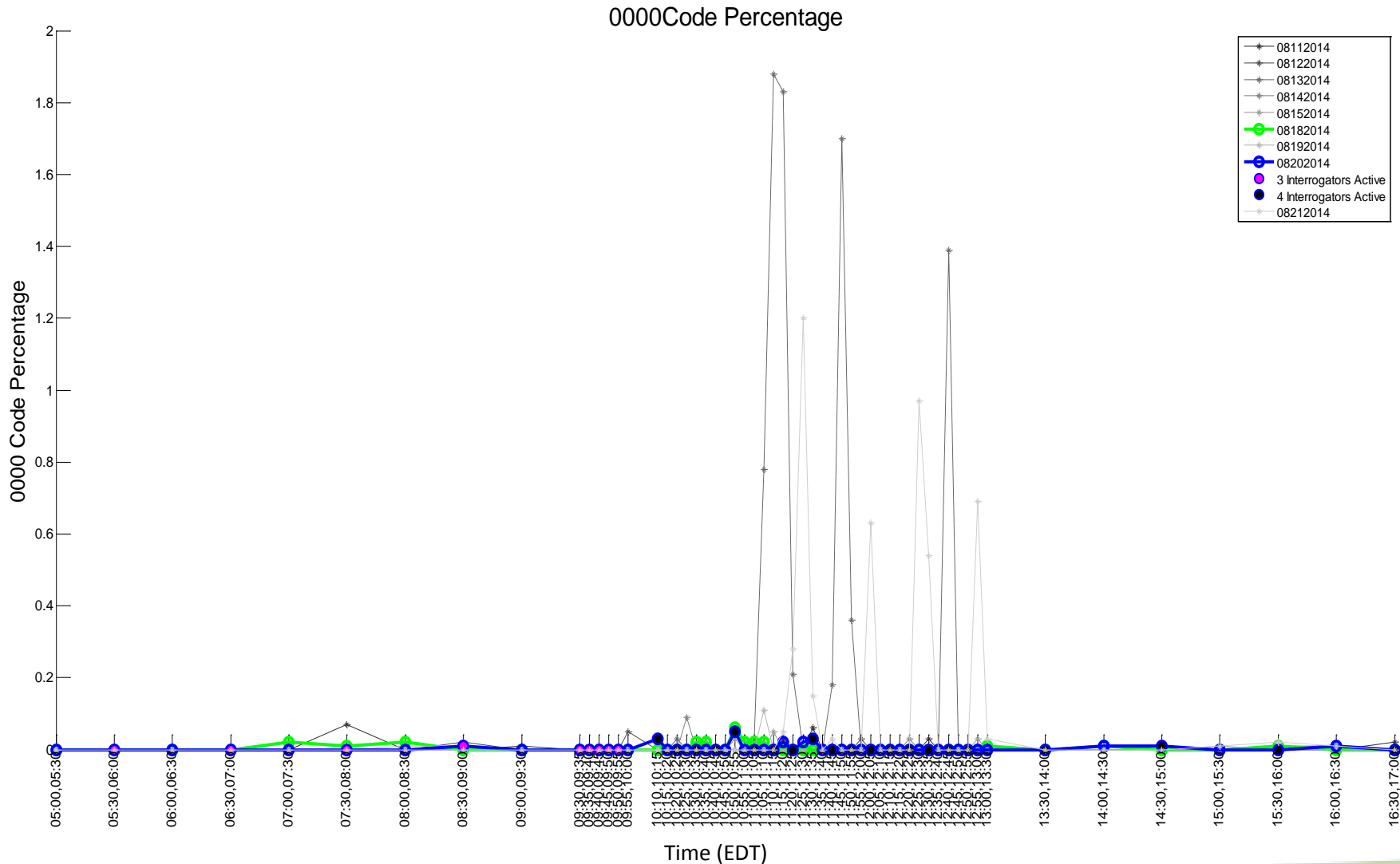
Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 19th



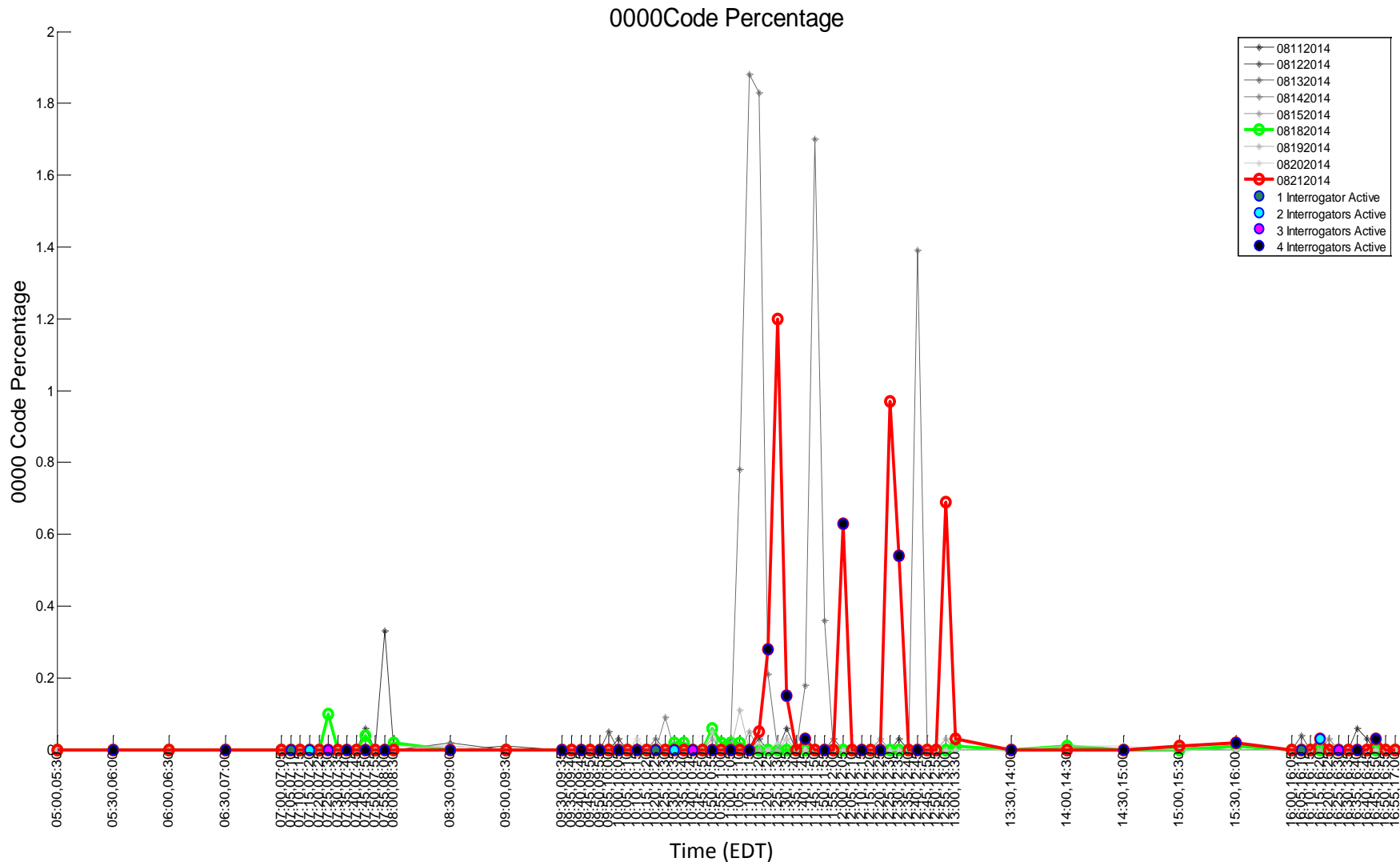
Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 20<sup>th</sup>



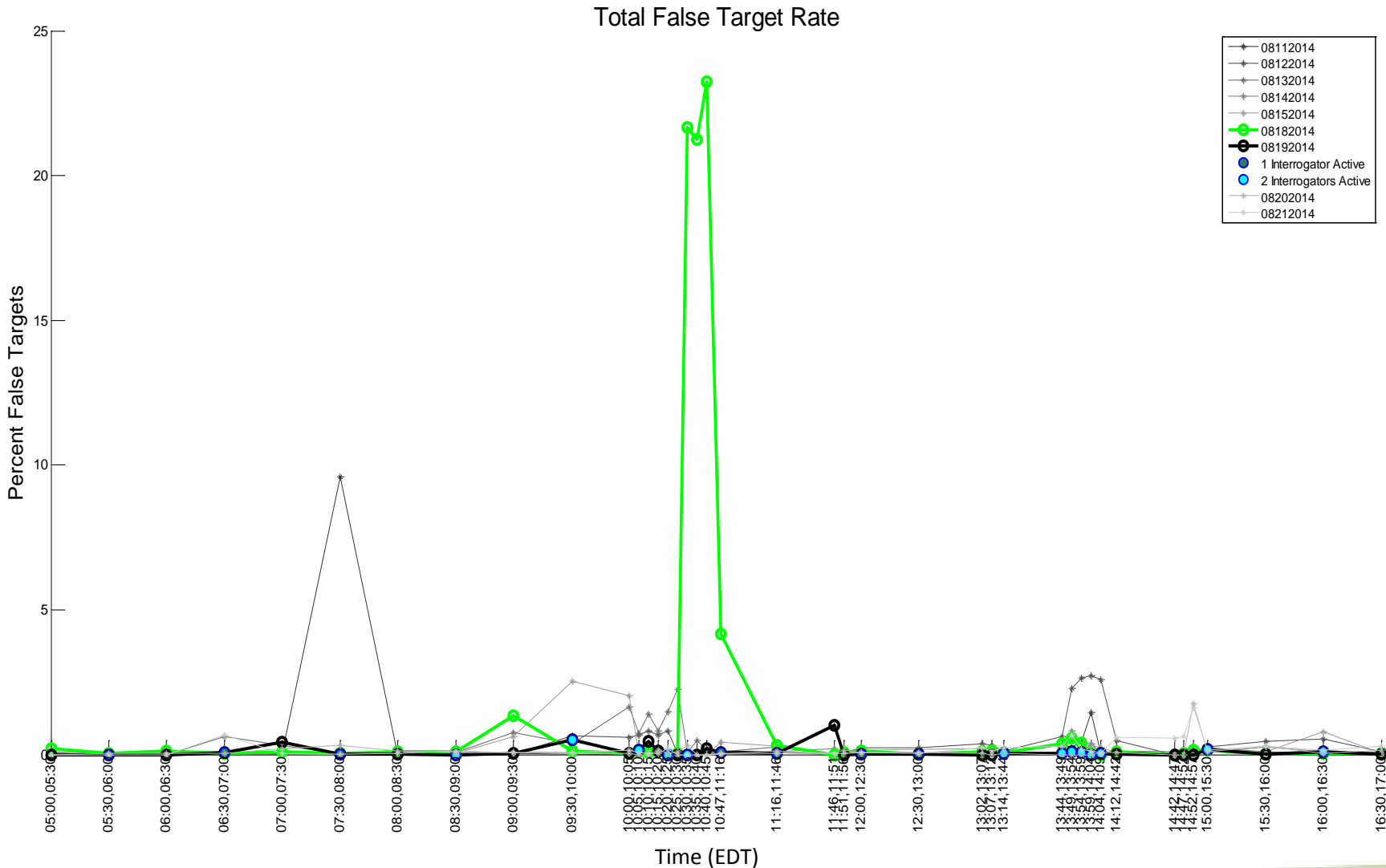
Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 21<sup>st</sup>



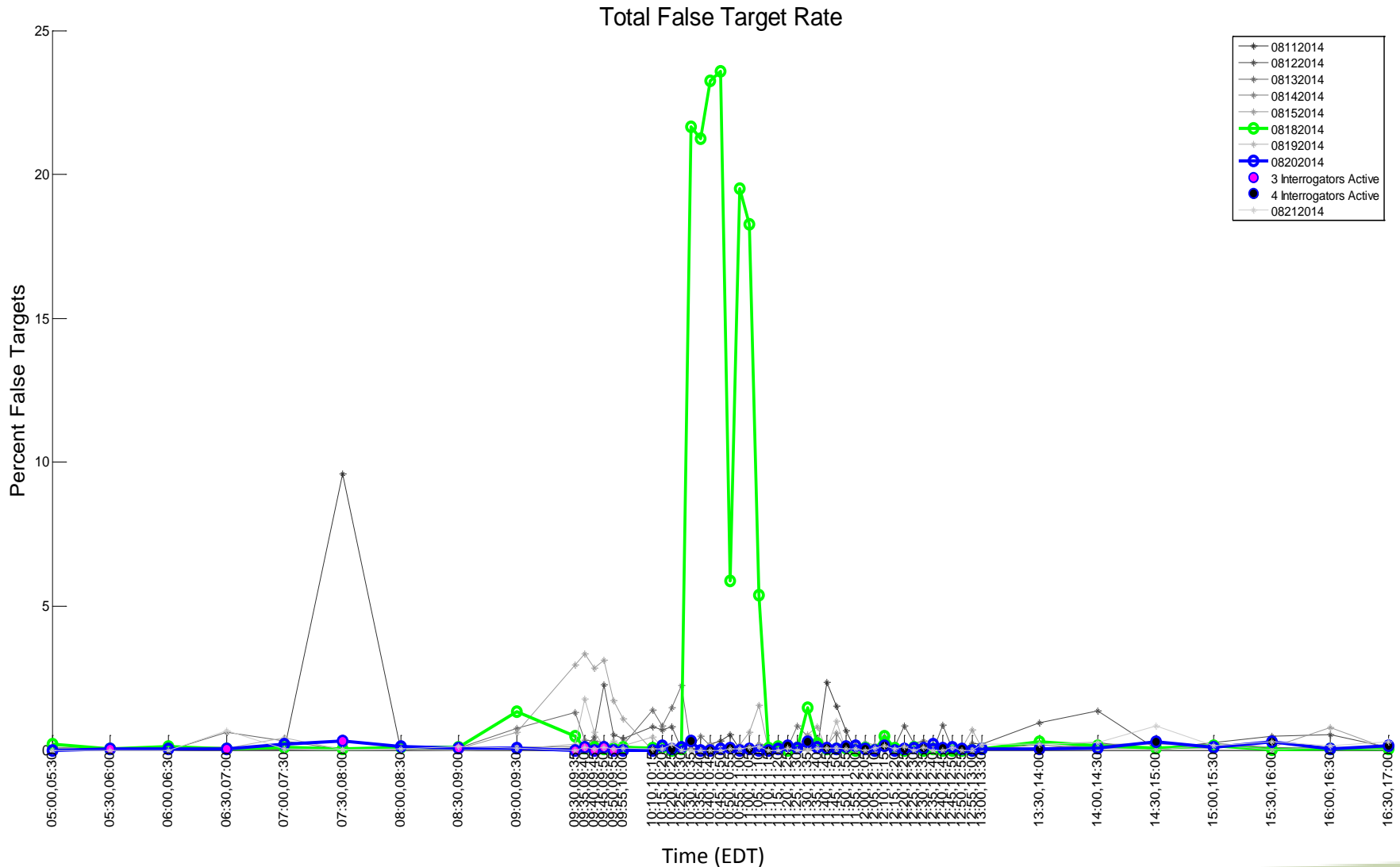
Geographic Filter: None  
Target Filter: None

# False Targets – August 19th



Geographic Filter: None  
Target Filter: None

# False Targets – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None



# Observations and Conclusions

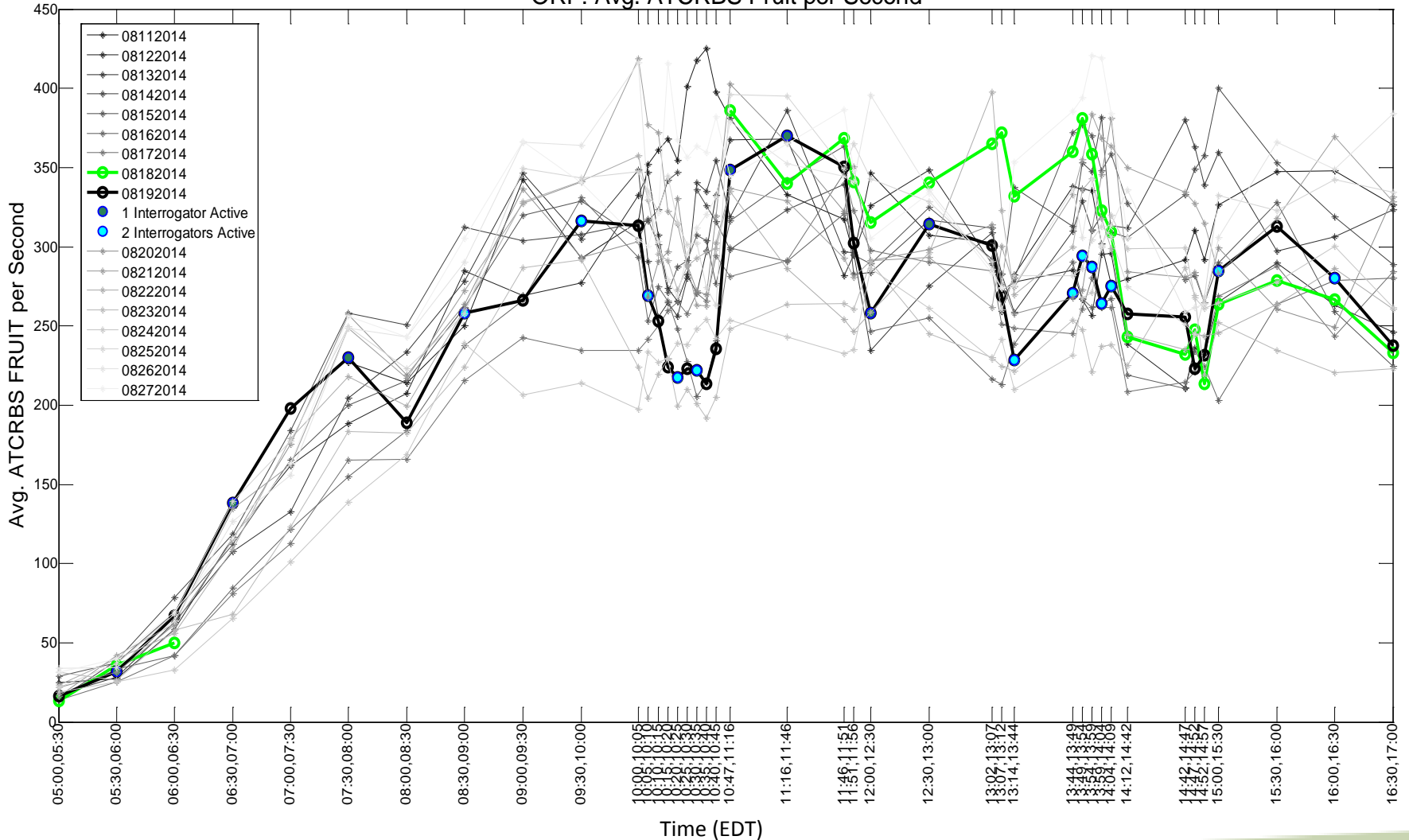
- ❑ The Probability of Detection, Identity Reliability and Confidence, Altitude Reliability and Confidence, False Targets, 0000 Codes, and Targets per Scan exhibit no observable adverse trend with respect to periods of radiation by the AN/UPX-41(C) interrogator.
- ❑ During AN/UPX-41(C) interrogator radiation, the variations or volatility of the aforementioned metrics are within the bounds of the variations of the same metrics on non-test days (baseline).
- ❑ In determining possible cases of interference, targets at low elevation angles exhibited relatively low probabilities of detection regardless of Active/OFF period
  - This inherent skew creates many  $P_d$  outliers that mask the ability to notice downward  $P_d$  movement due to interference
  - An analysis excluding low elevation angle targets is available upon request, but the conclusions are no different than the first two bullets of this slide.



# Mode S Extraction Data Analysis

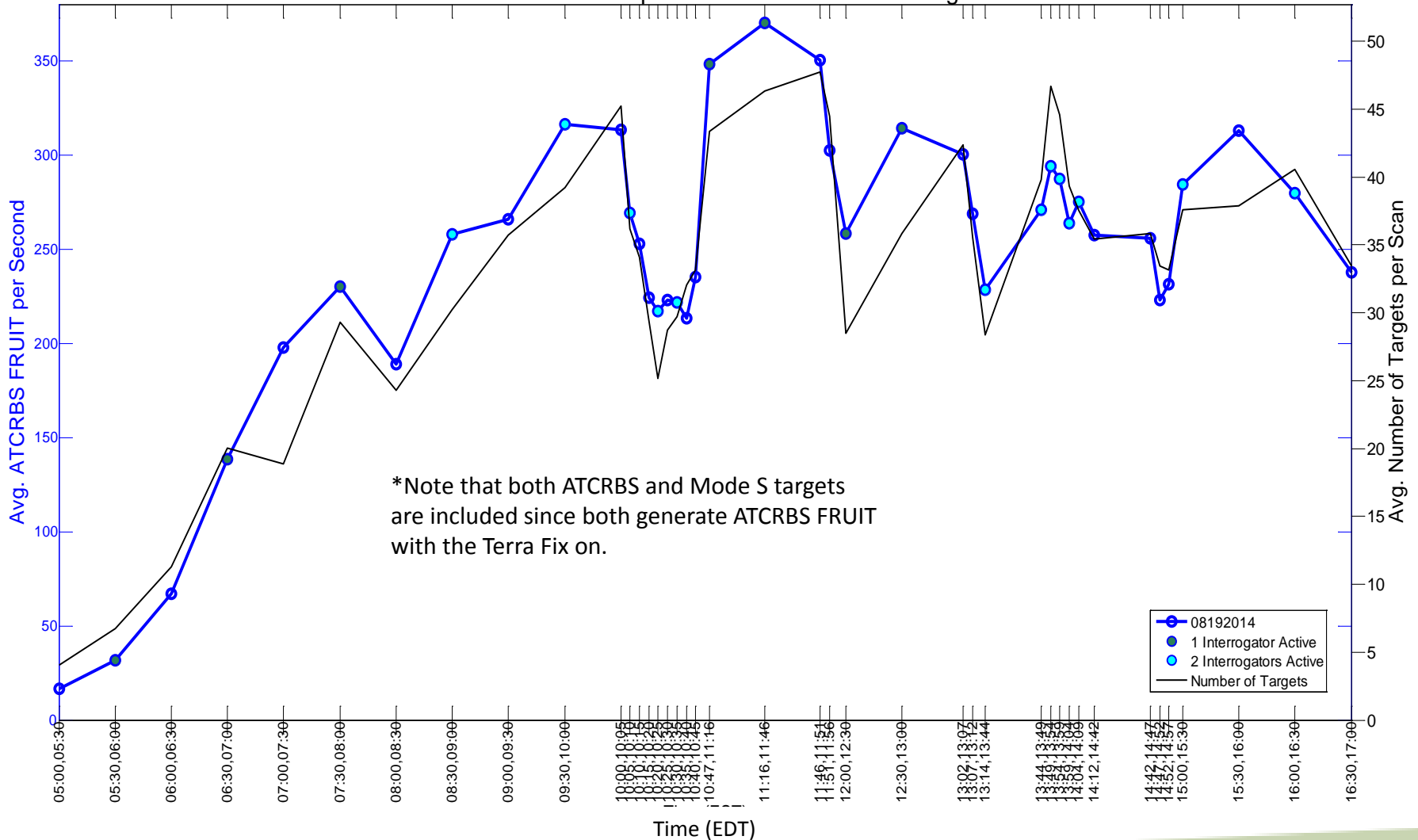
# ATCRBS FRUIT Rate – August 19<sup>th</sup>

ORF: Avg. ATCRBS Fruit per Second



# ATCRBS FRUIT Rate vs # of Targets–August 19<sup>th</sup>

ORF: ATCRBS Fruit per Second vs Number of Targets

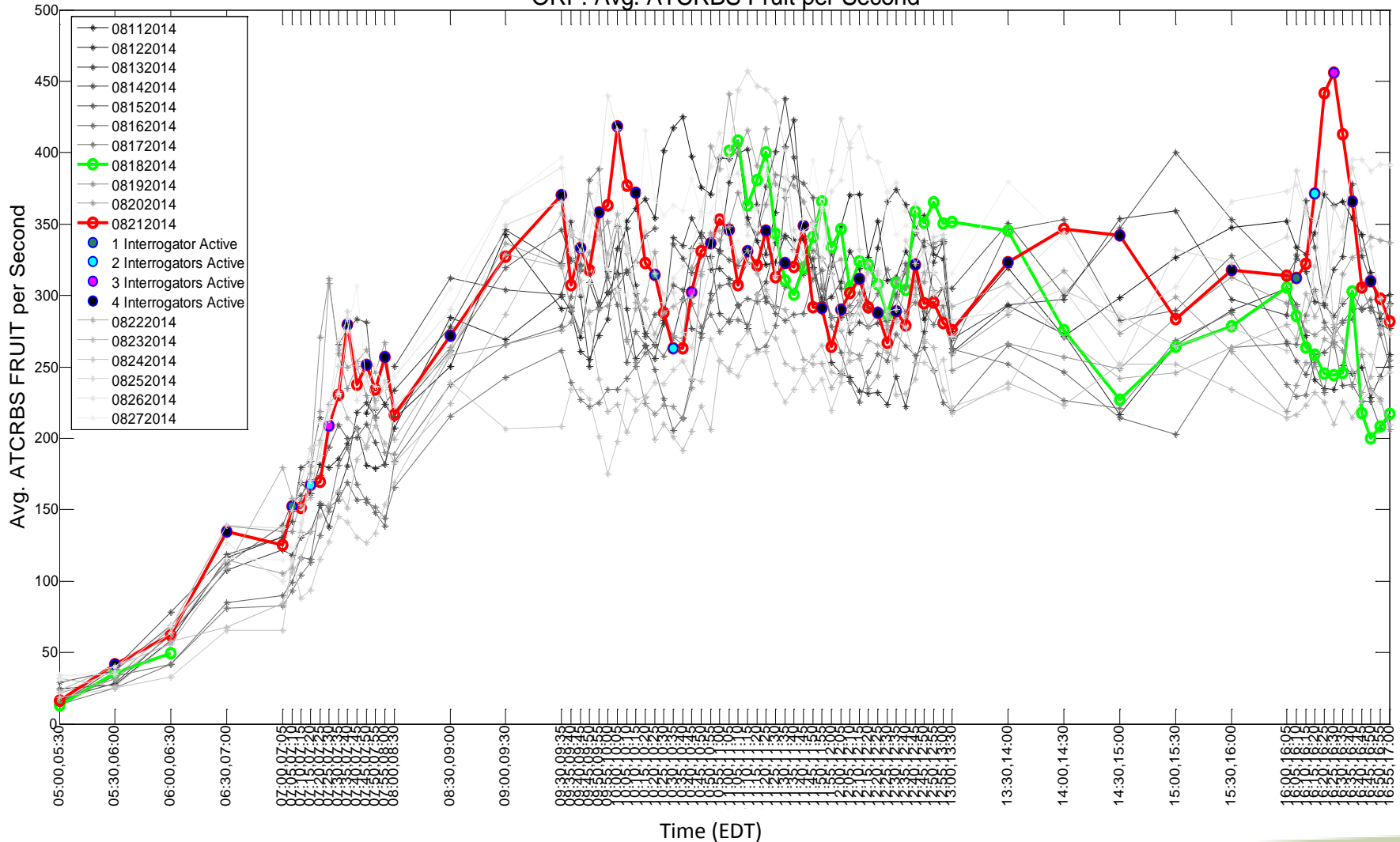






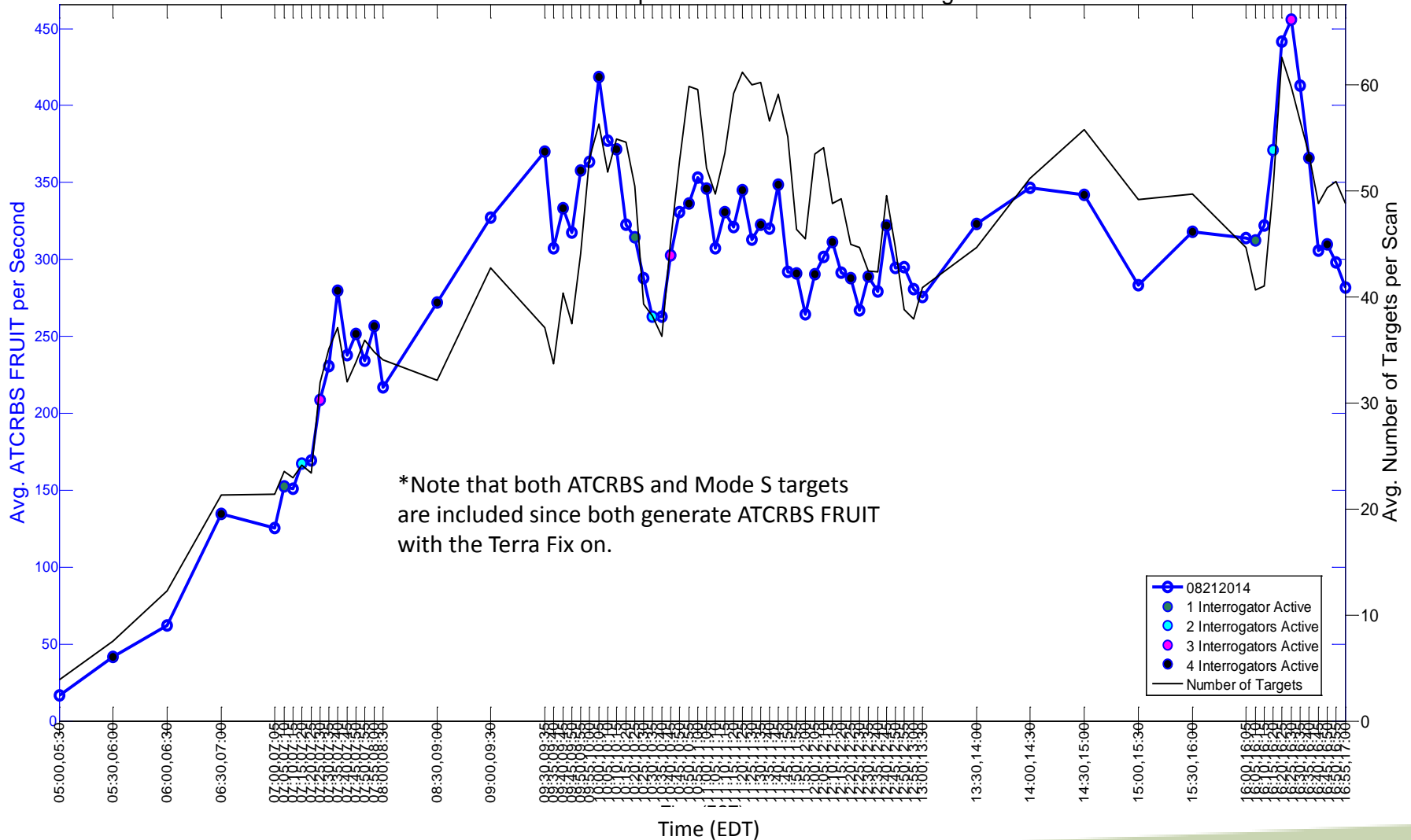
# ATCRBS FRUIT Rate – August 21<sup>st</sup>

ORF: Avg. ATCRBS Fruit per Second



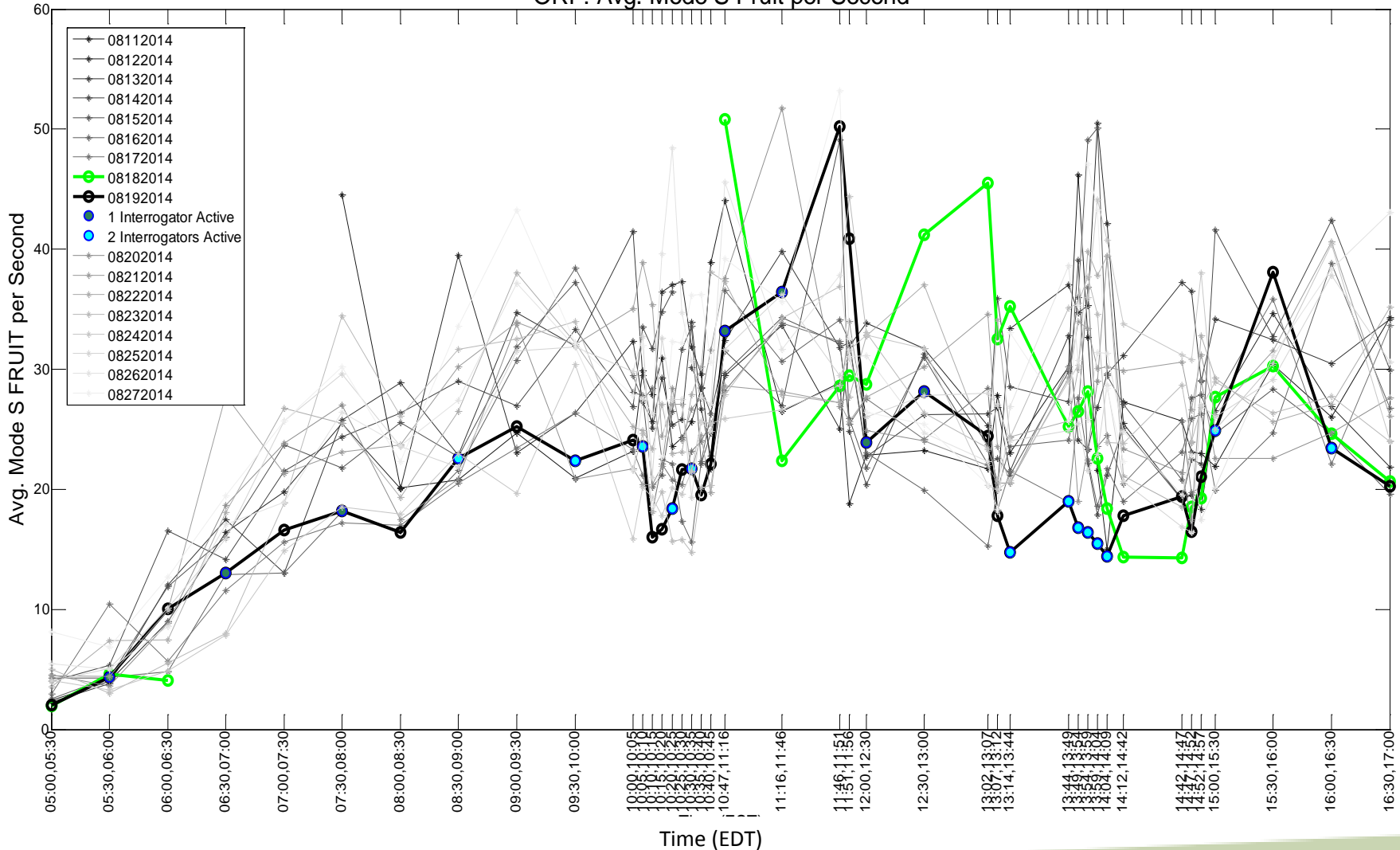
# ATCRBS FRUIT Rate vs # of Targets–August 21<sup>st</sup>

ORF: ATCRBS Fruit per Second vs Number of Targets



# Mode S FRUIT Rate – August 19<sup>th</sup>

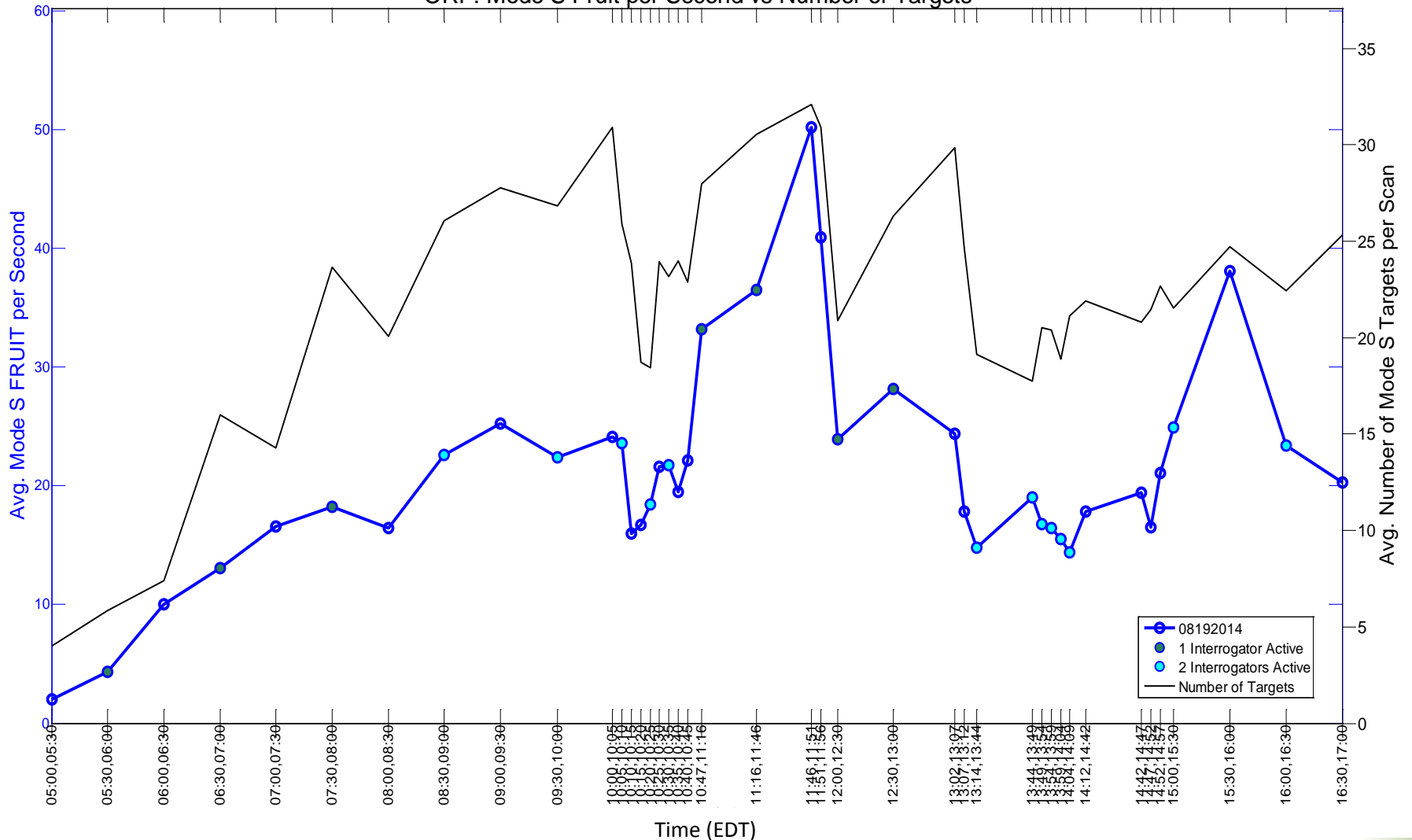
ORF: Avg. Mode S Fruit per Second





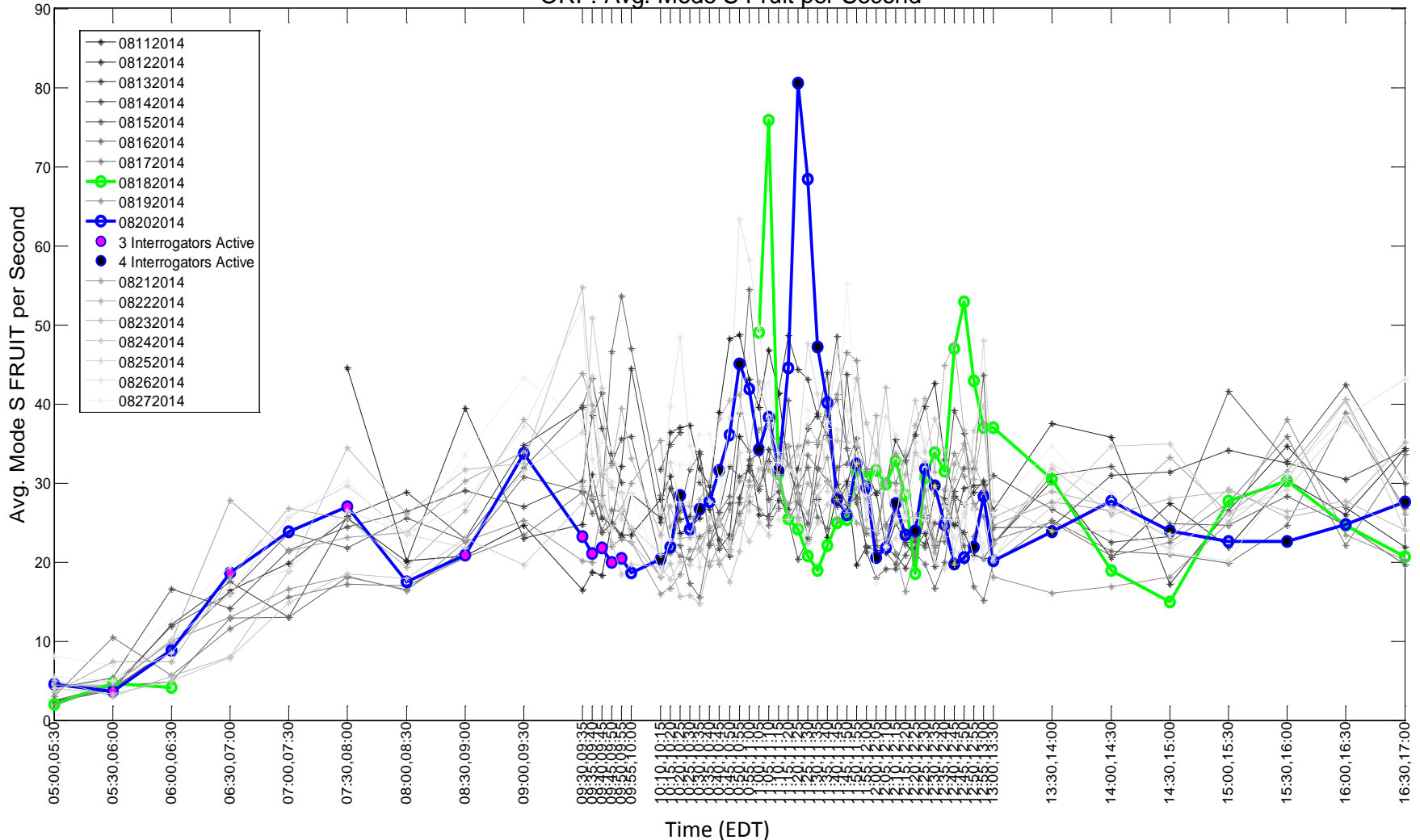
# Mode S FRUIT Rate vs # of Targets—August 19<sup>th</sup>

ORF: Mode S Fruit per Second vs Number of Targets



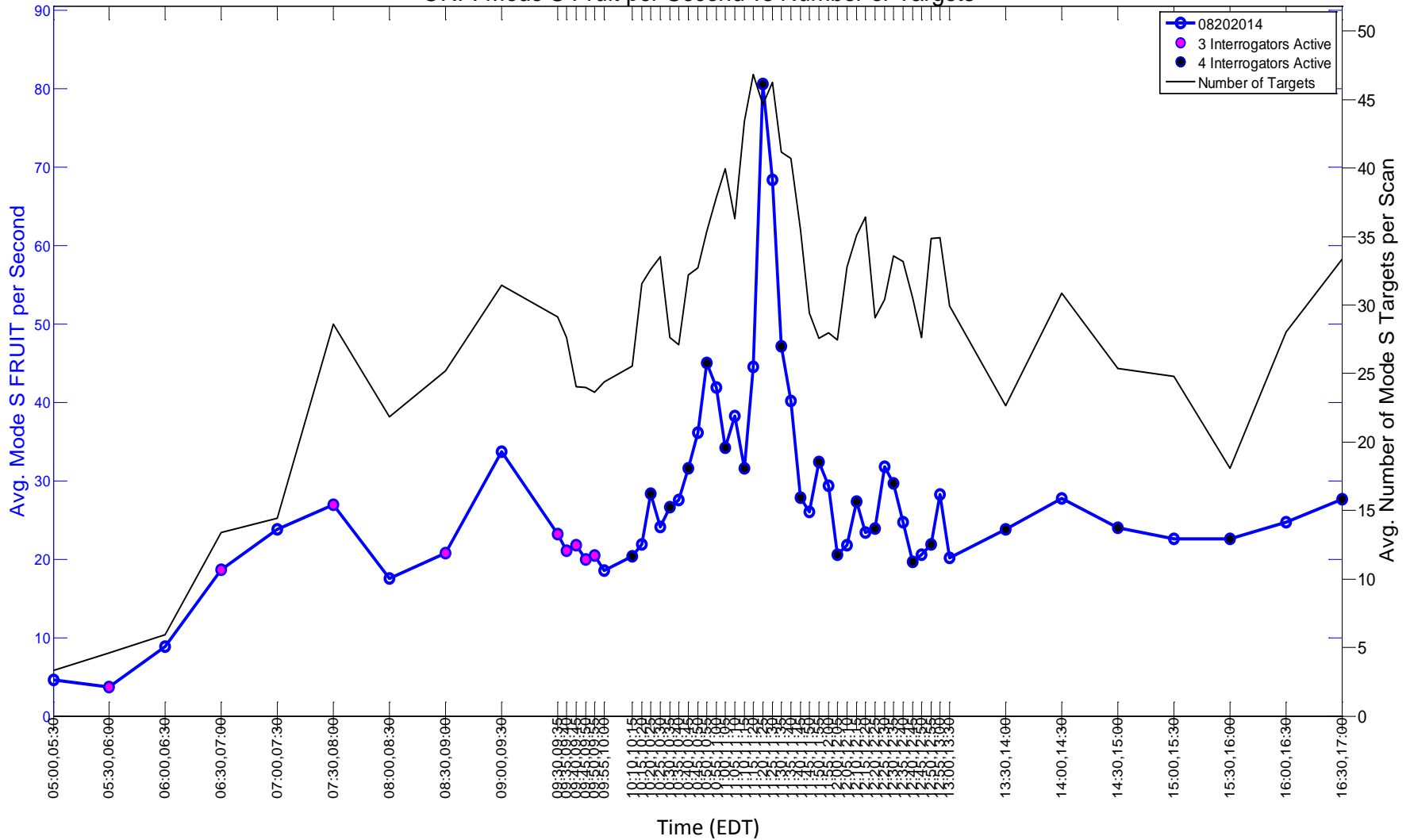
# Mode S FRUIT Rate – August 20<sup>th</sup>

ORF: Avg. Mode S Fruit per Second



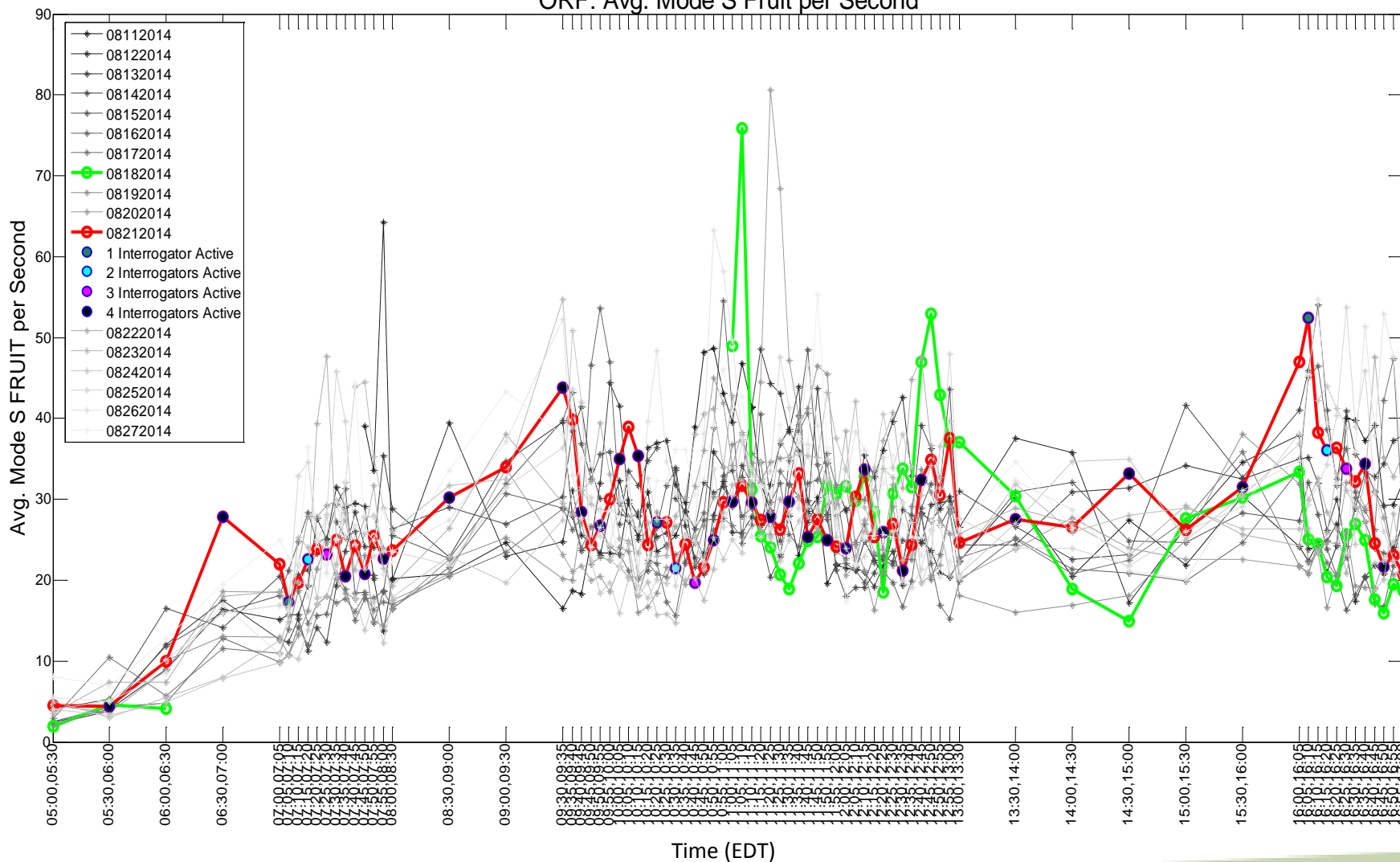
# Mode S FRUIT Rate vs # of Targets—August 20<sup>th</sup>

ORF: Mode S Fruit per Second vs Number of Targets



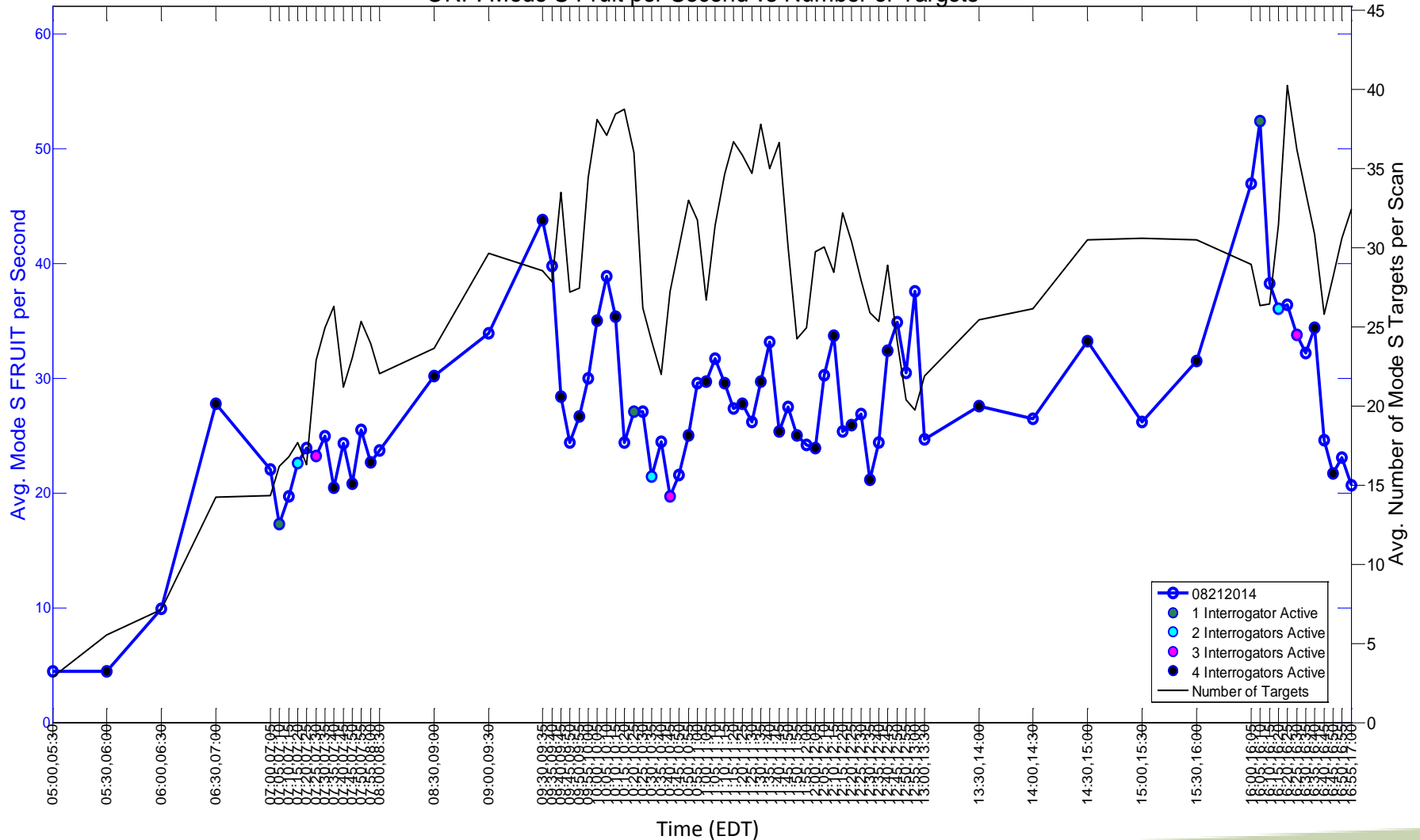
# Mode S FRUIT Rate – August 21<sup>st</sup>

ORF: Avg. Mode S Fruit per Second



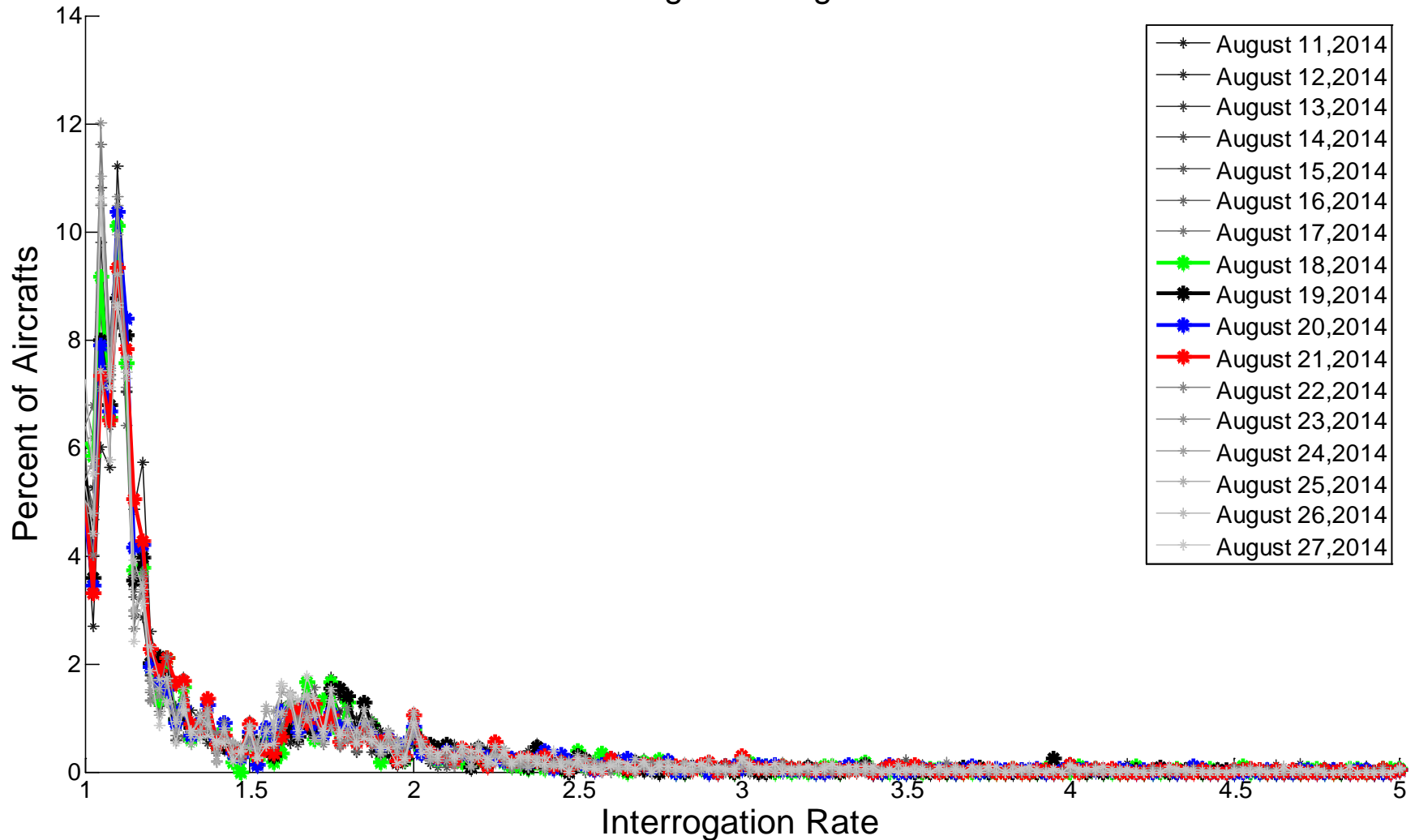
# Mode S FRUIT Rate vs # of Targets–August 21<sup>st</sup>

ORF: Mode S Fruit per Second vs Number of Targets



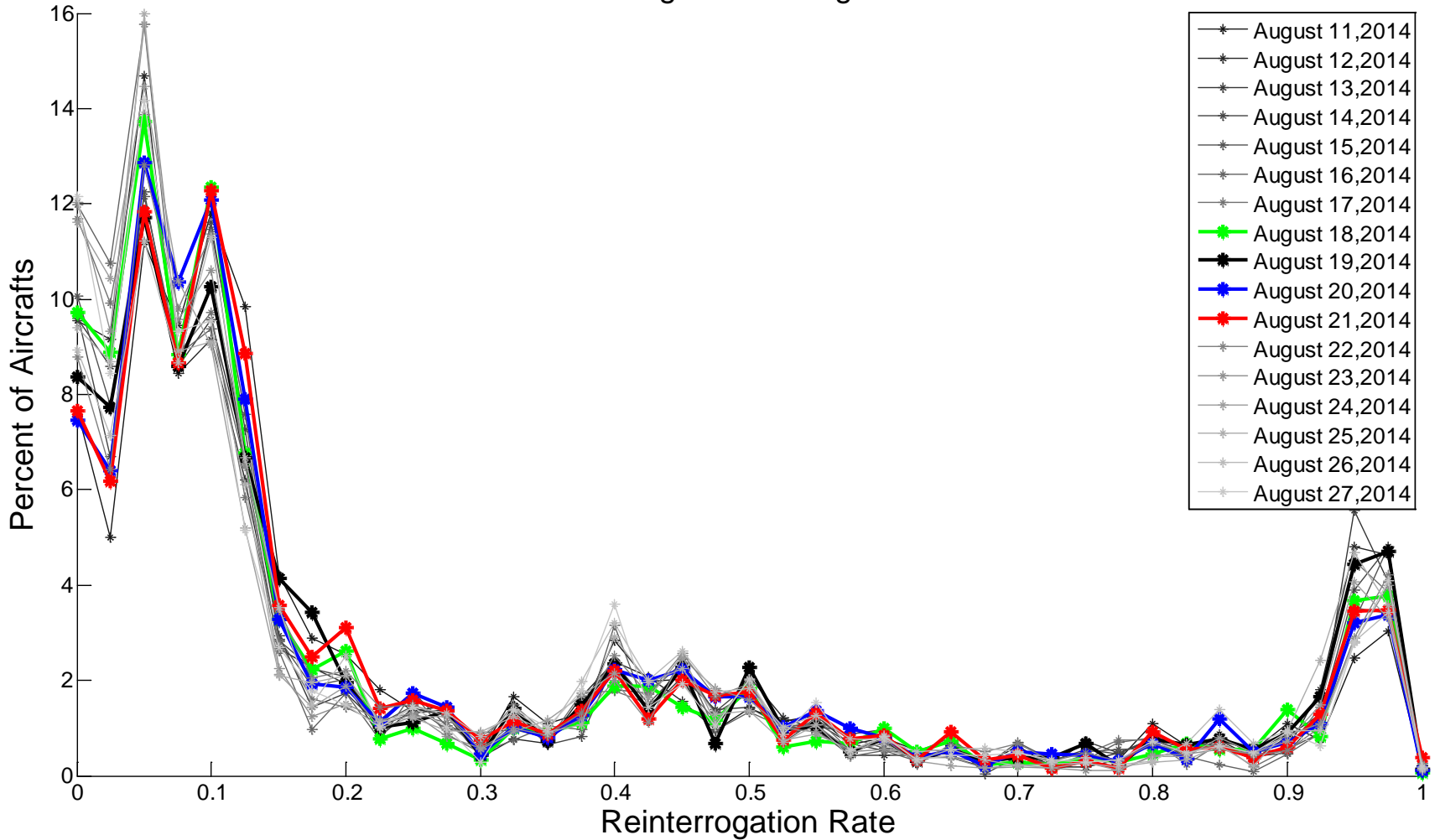
# Interrogation Rate – All Days

ORF: Average Interrogation Rate



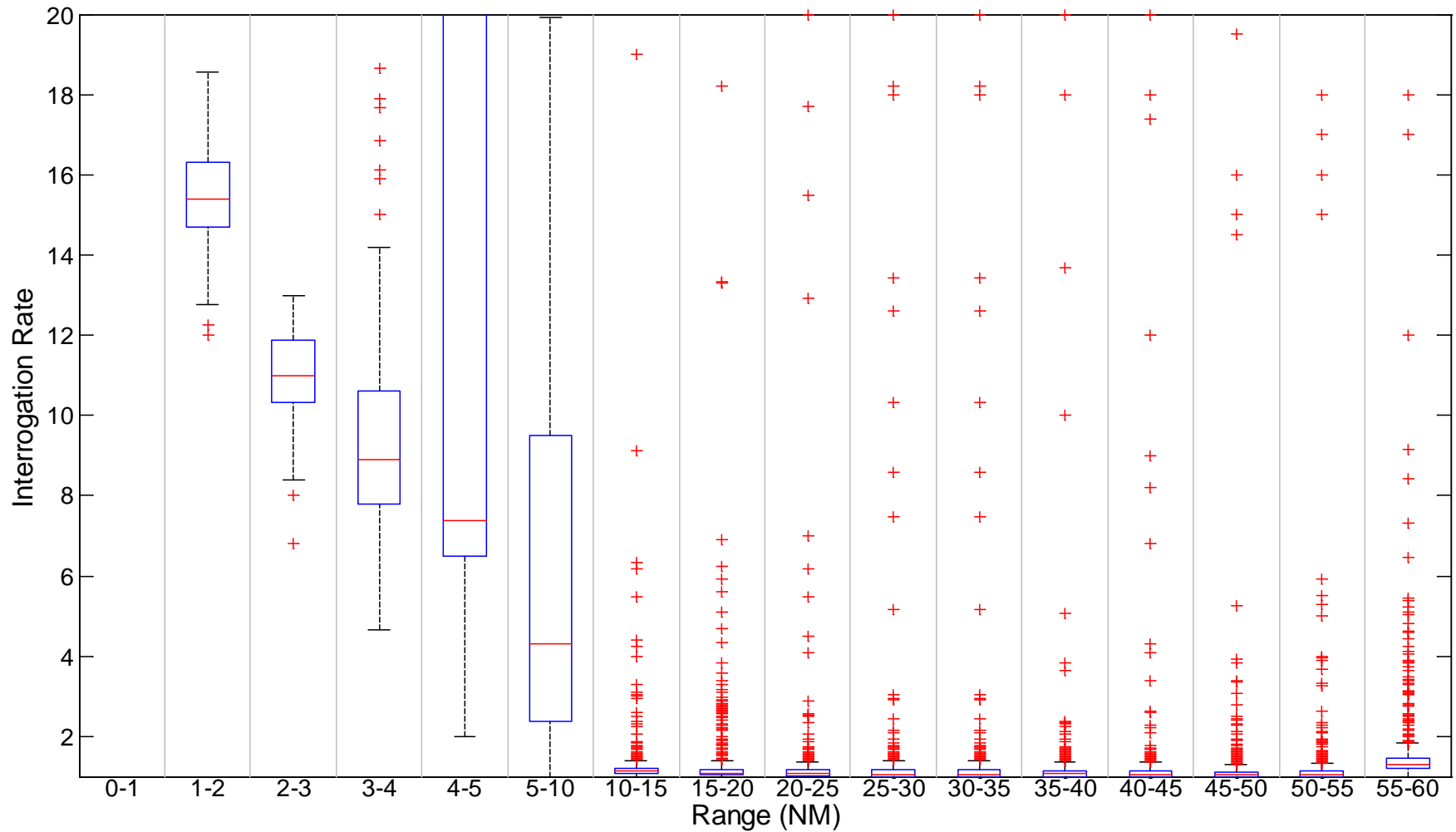
# Reinterrogation Rate – All Days

ORF: Average Reinterrogation Rate



# Interrogation Rate vs Range – August 19<sup>th</sup>

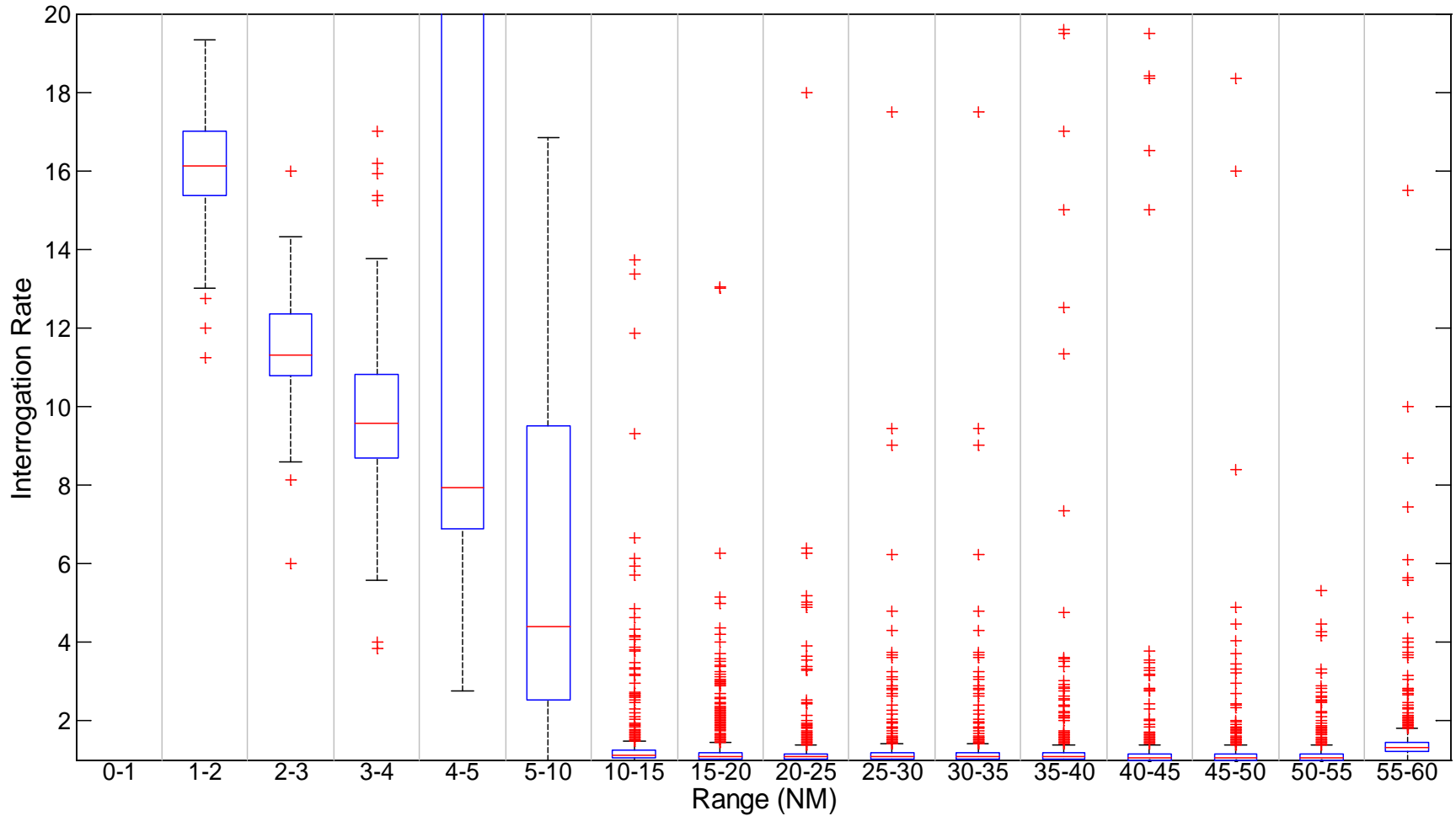
Site: ORF





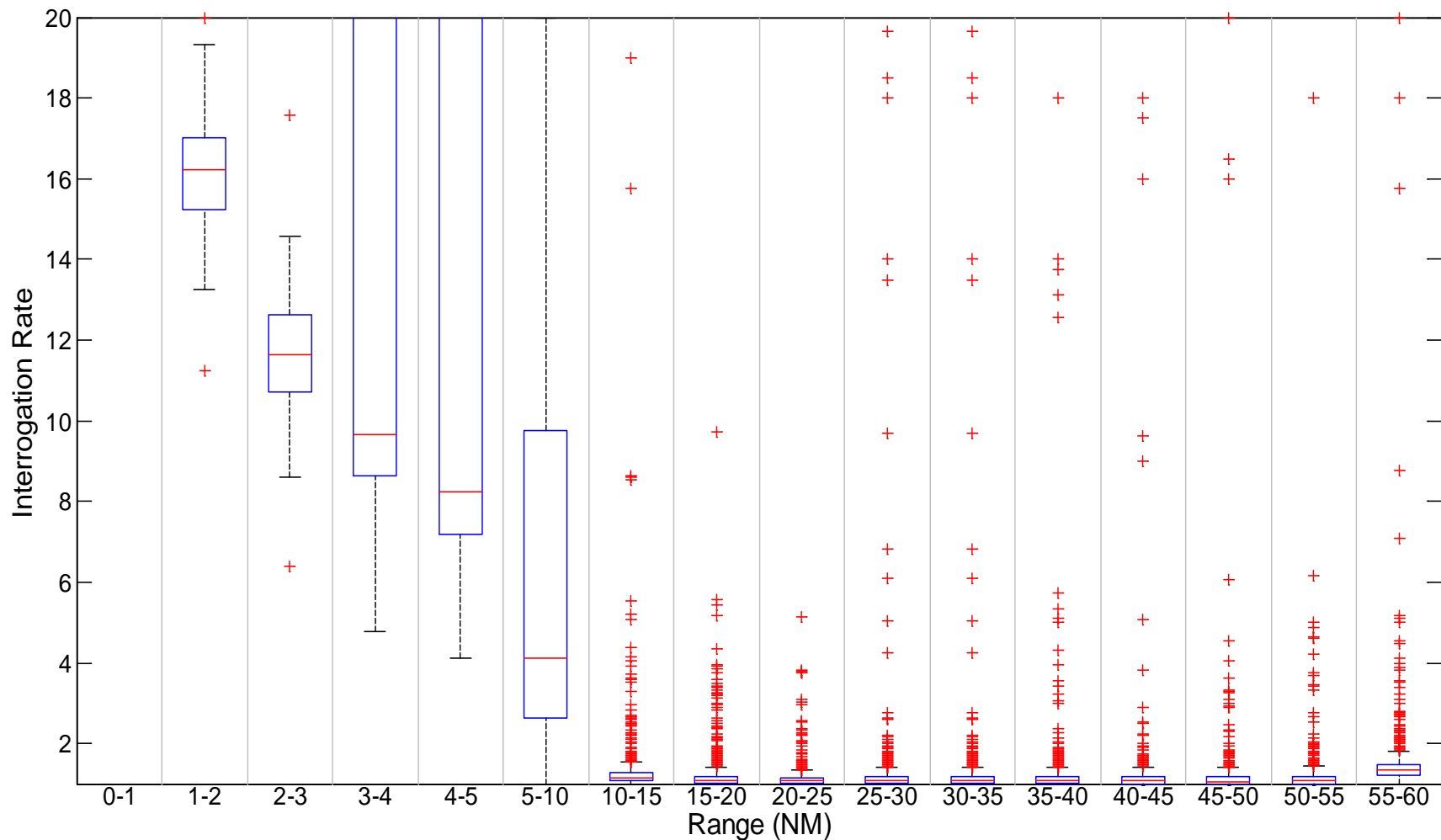
# Interrogation Rate vs Range – August 20<sup>th</sup>

Site: ORF



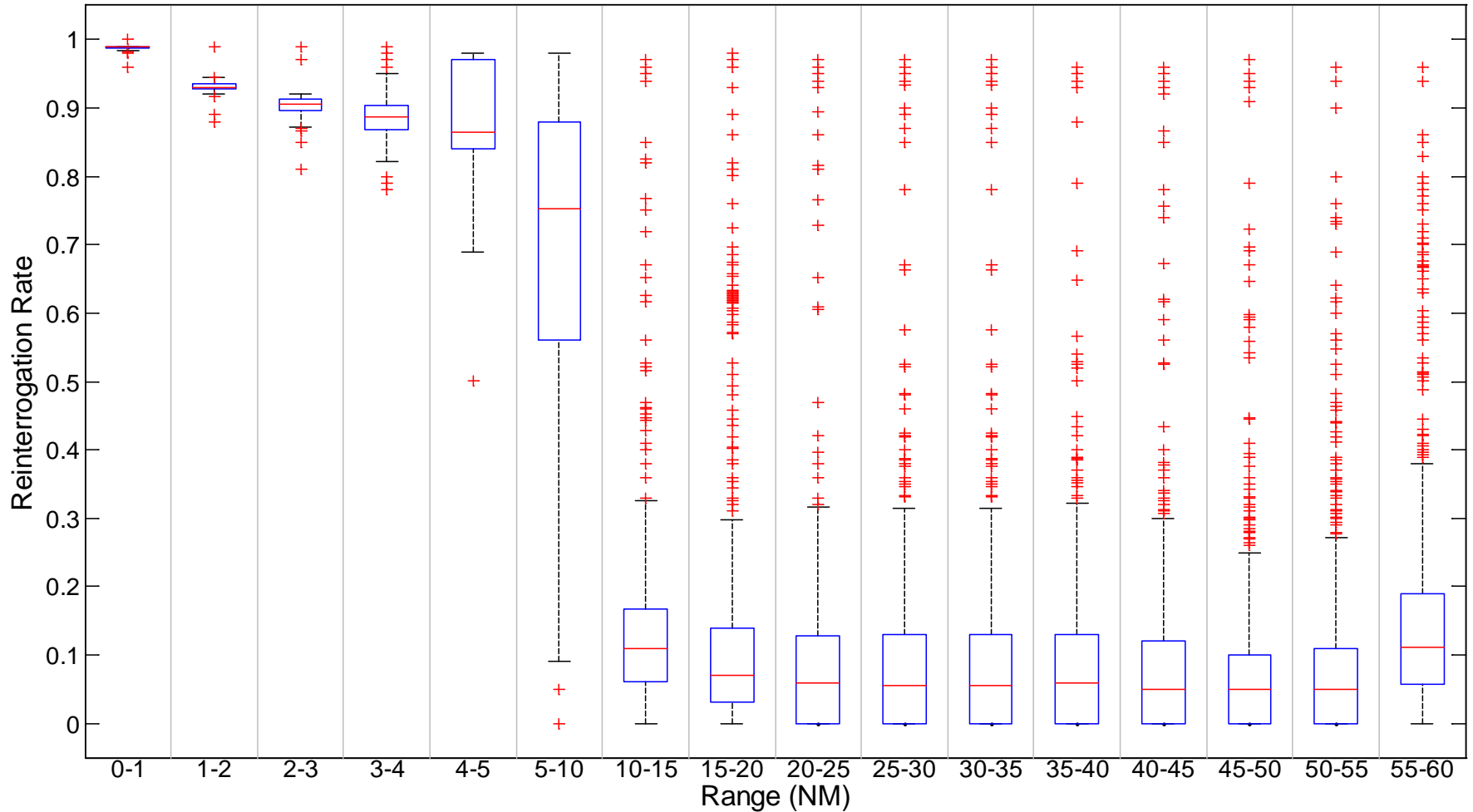
# Interrogation Rate vs Range – August 21<sup>st</sup>

Site: ORF



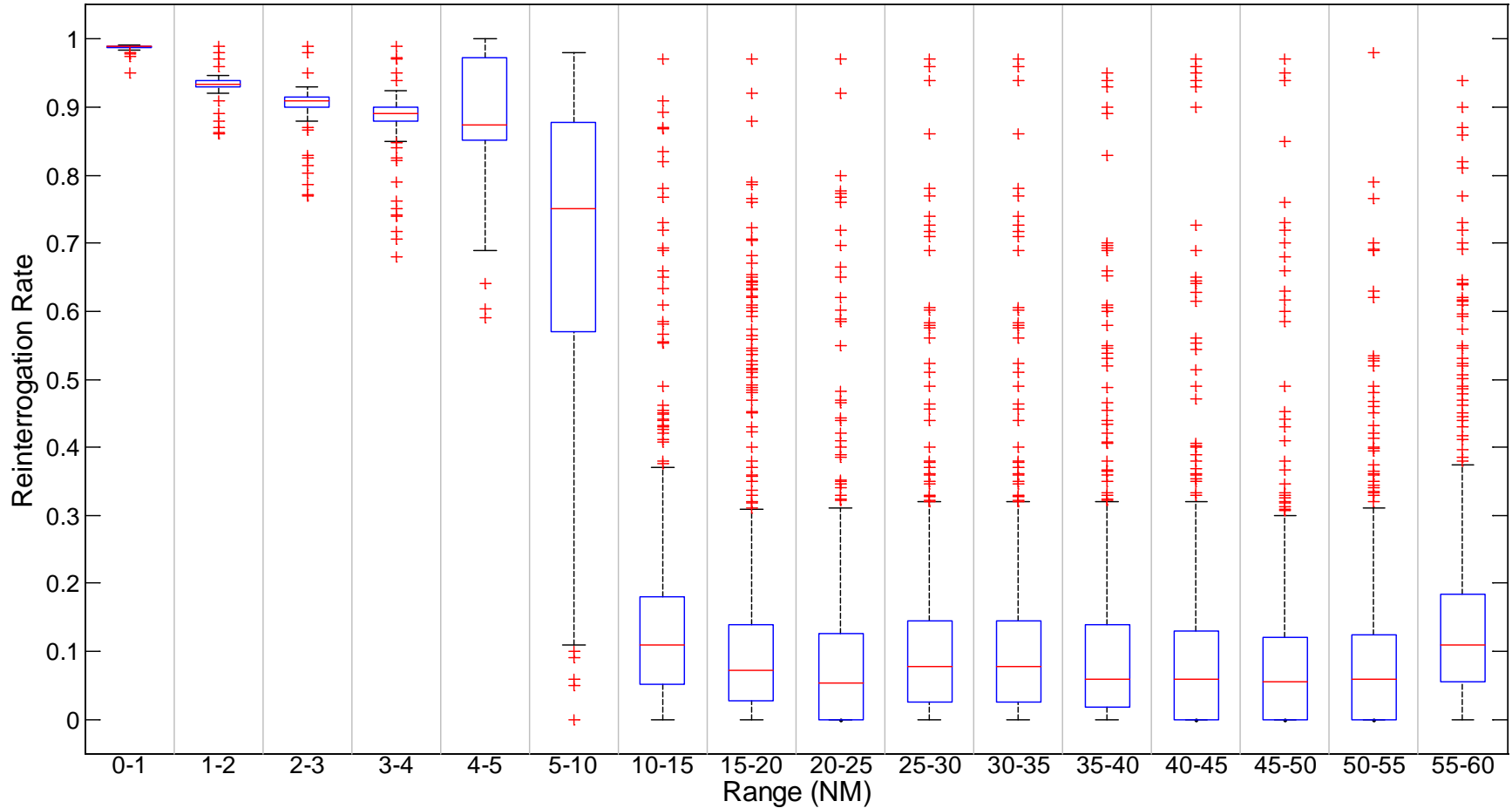
# Reinterrogation Rate vs Range – August 19<sup>th</sup>

Site: ORF



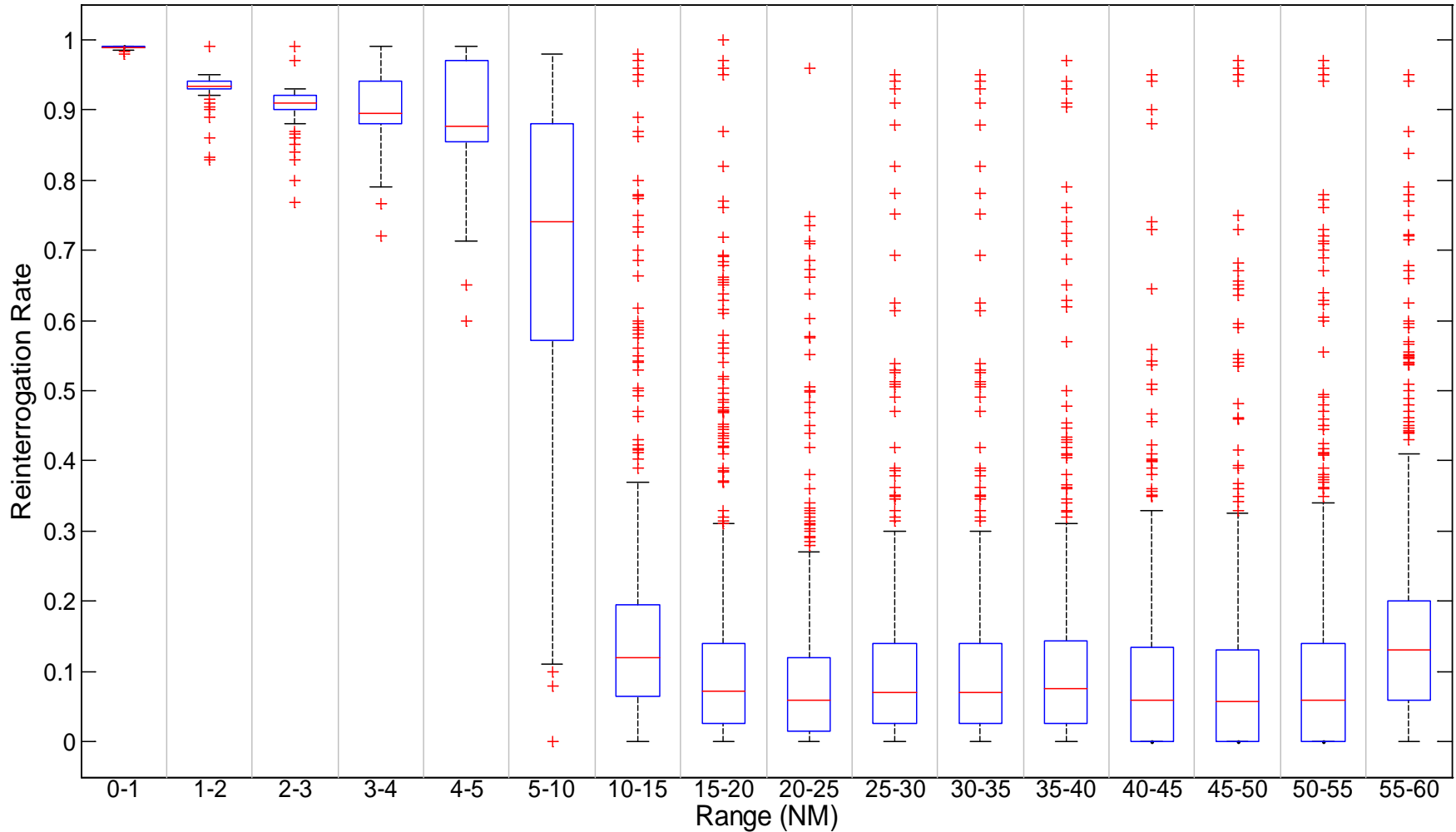
# Reinterrogation Rate vs Range – August 20<sup>th</sup>

Site: ORF



# Reinterrogation Rate vs Range – August 21<sup>st</sup>

Site: ORF



# Observations and Conclusions

## ❑ FRUIT Analysis

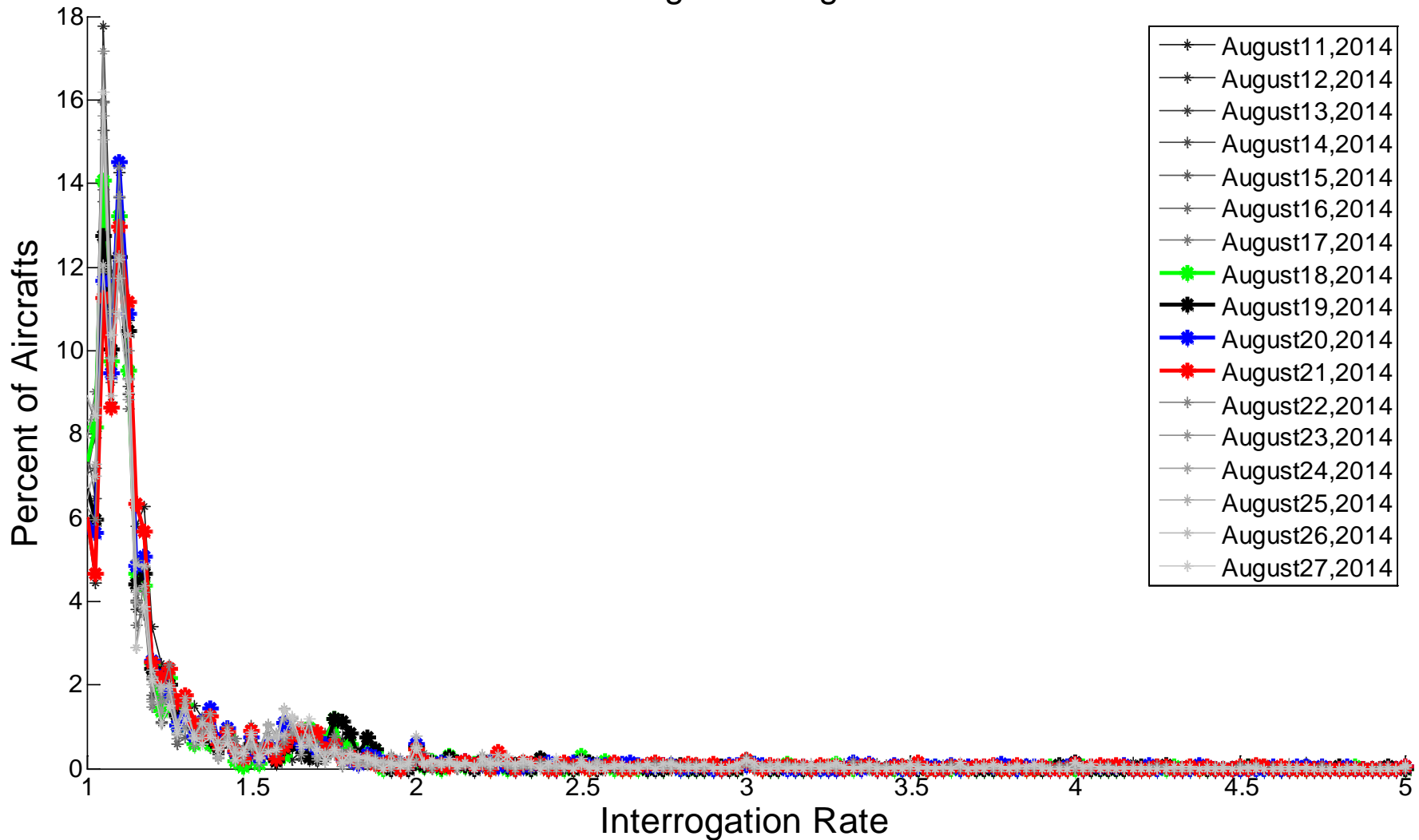
- ATCRBS FRUIT rates do not always increase when AN/UPX-41(C) interrogators are Active. This means the AN/UPX-41(C) FRUIT impact, for the Stage 4 configuration, generates less ATCRBS FRUIT than the normal daily fluctuations of ATCRBS FRUIT due to changes in traffic densities. This is also confirmed by the generally high correlation between traffic count and ATCRBS FRUIT rate movements.
- AN/UPX-41(C) interrogators should have produced no extra Mode S FRUIT and the plots confirm this.

## ❑ Channel Management Statistics

- Targets within 10 NM showed consistently high interrogation/reinterrogation rates
  - This phenomenon is due to the unpredictability of roll call target azimuths at close ranges. The Mode S roll call scheduler starts interrogations many degrees before the tracker's predicted azimuth to ensure that unknown changes in speed and heading will not limit the ability of the Mode S system to get an update on the target.
  - So while the reinterrogation rate is high within 10 NM, it is not due to transponder occupancy or receiver garble.
  - To notice any possible change in interrogation/reinterrogation rates between Active/OFF periods, targets within 10 NM of SSR site were excluded in the next section of analysis.

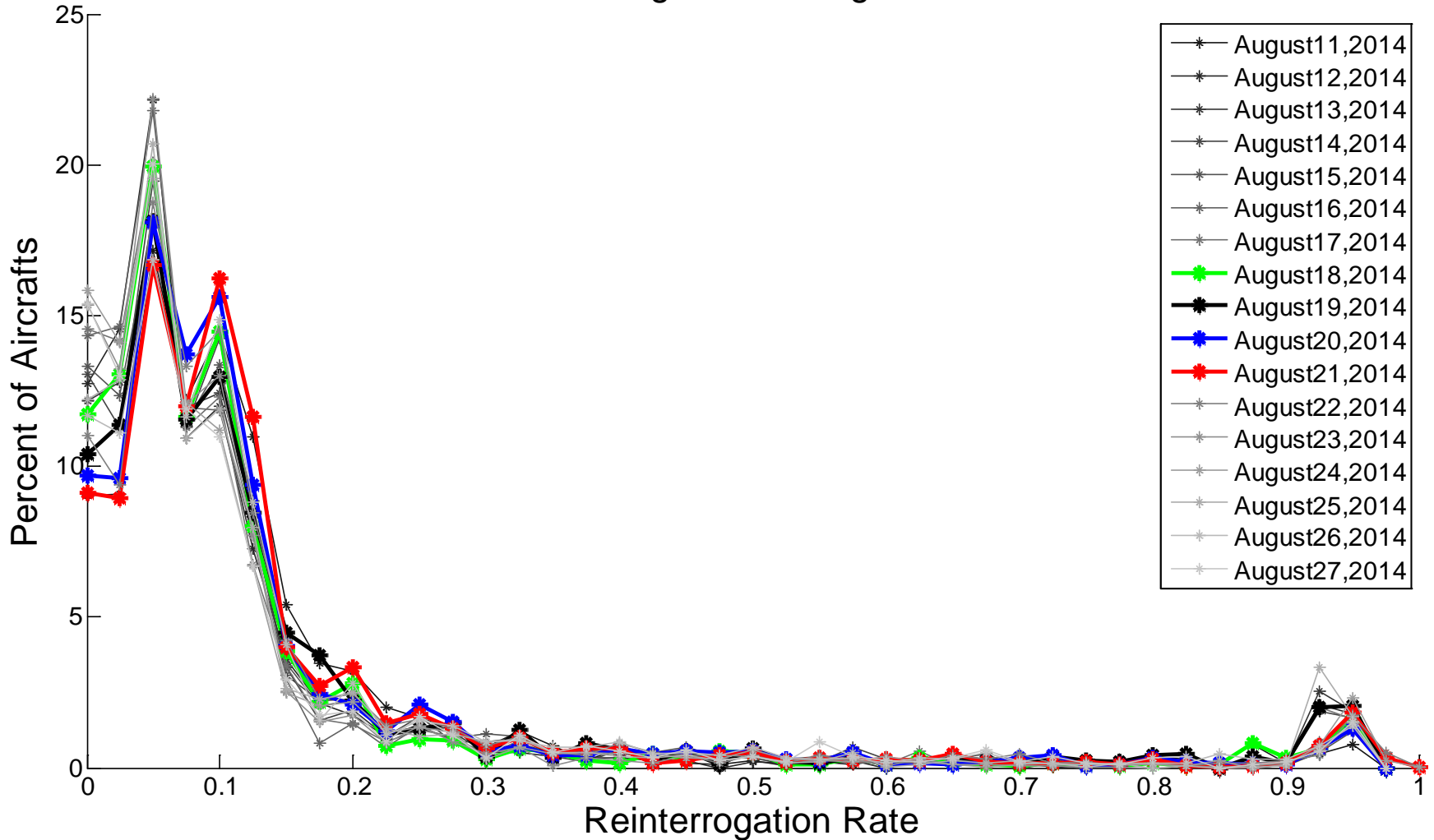
# Interrogation Rate – All Days

ORF: Average Interrogation Rate



# Reinterrogation Rate – All Days

ORF: Average Reinterrogation Rate

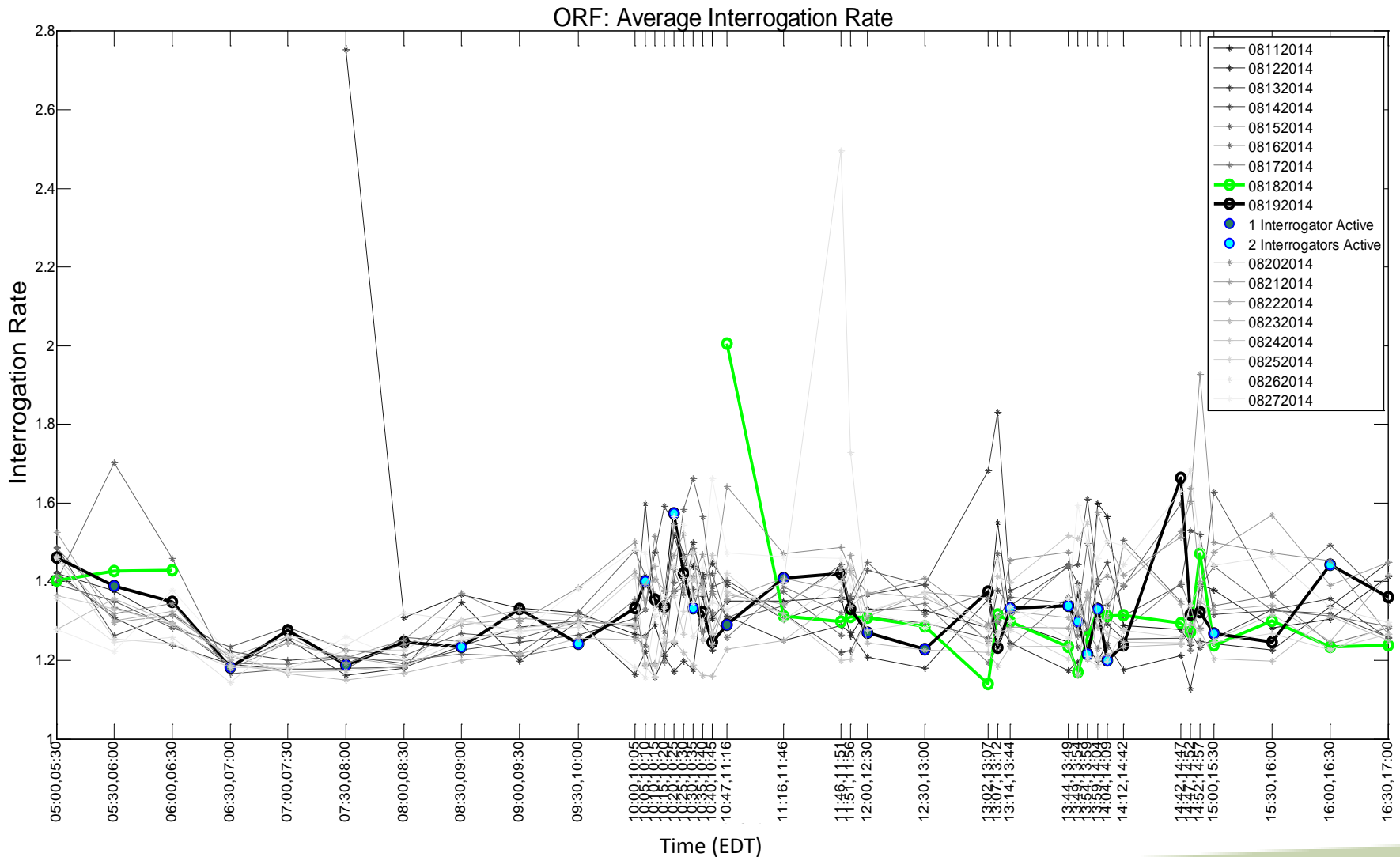


Geographic Filter: None

Target Filter: Targets > 10 NM from SSR

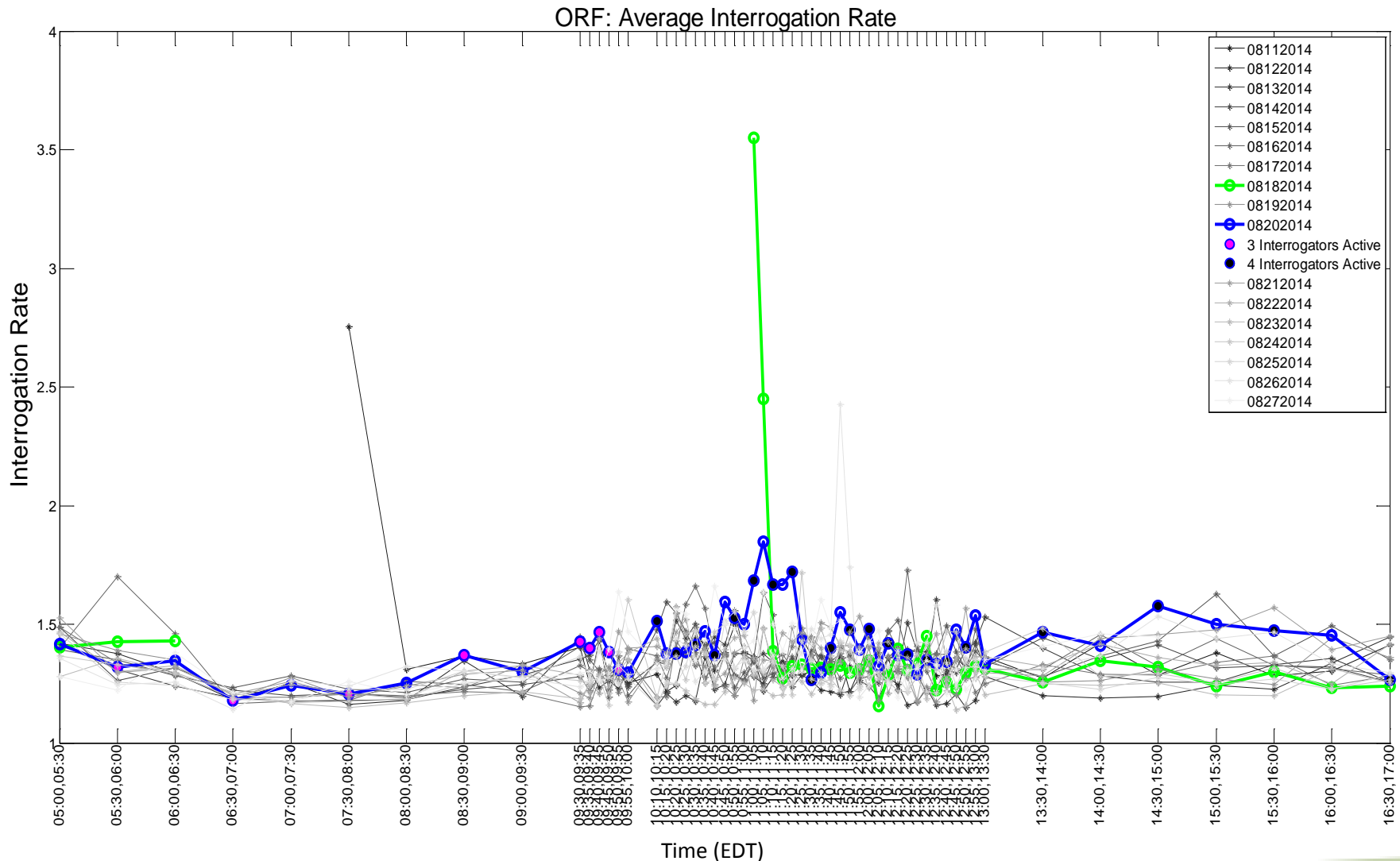


# Interrogation Rate – August 19<sup>th</sup>



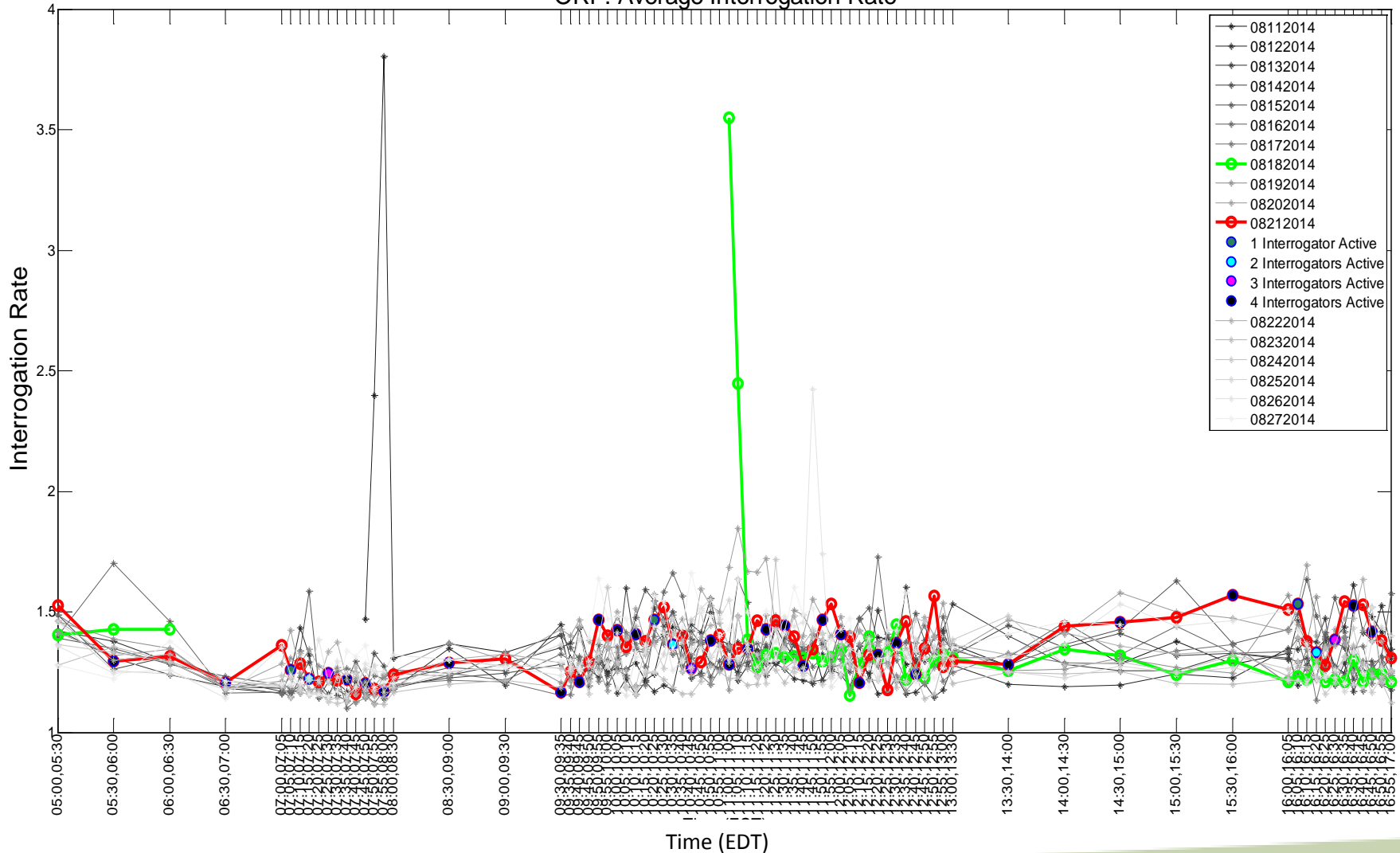
Geographic Filter: None  
 Target Filter: Targets > 10 NM from SSR

# Interrogation Rate – August 20<sup>th</sup>



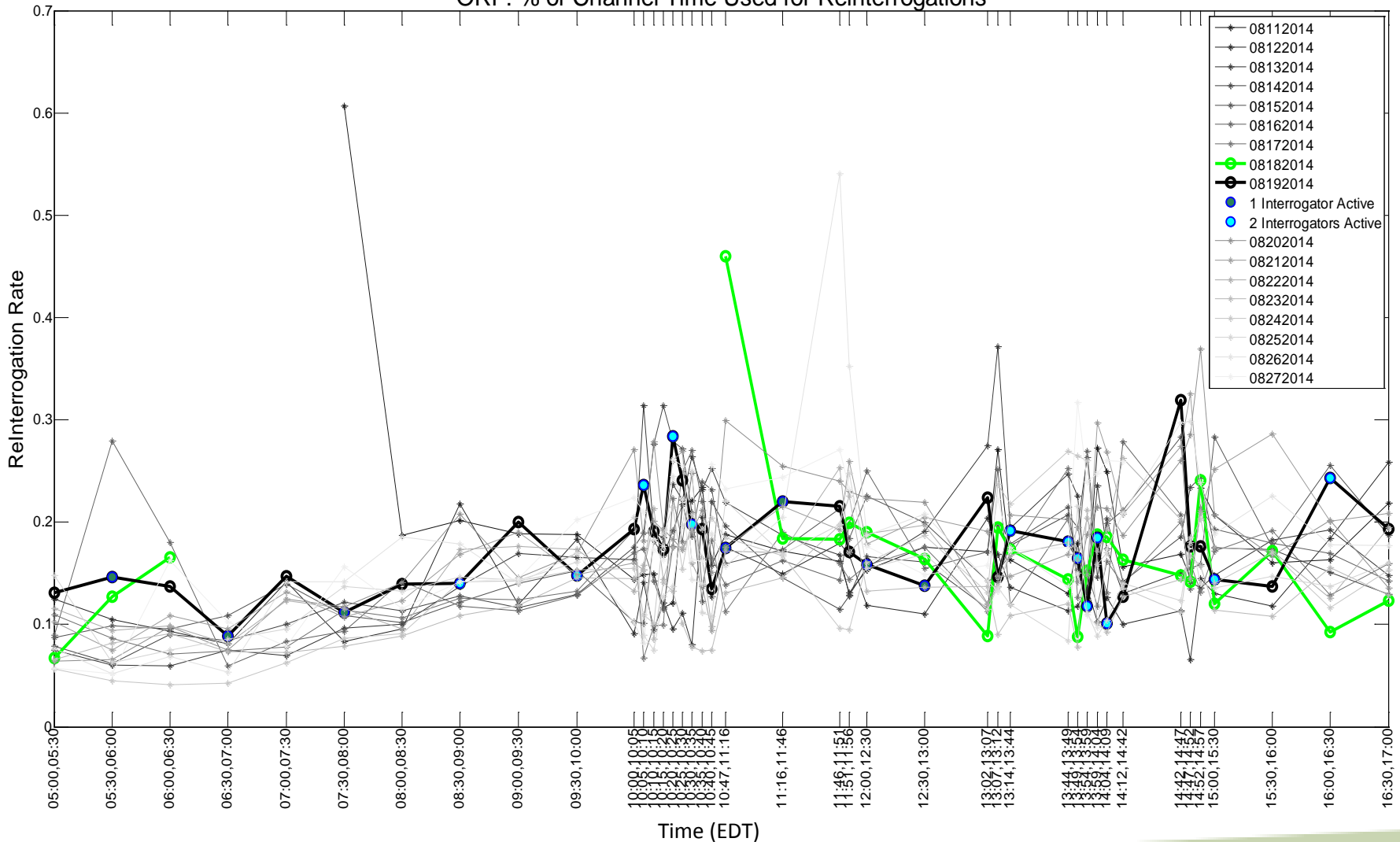
# Interrogation Rate – August 21<sup>st</sup>

ORF: Average Interrogation Rate



# Reinterrogation Rate – August 19<sup>th</sup>

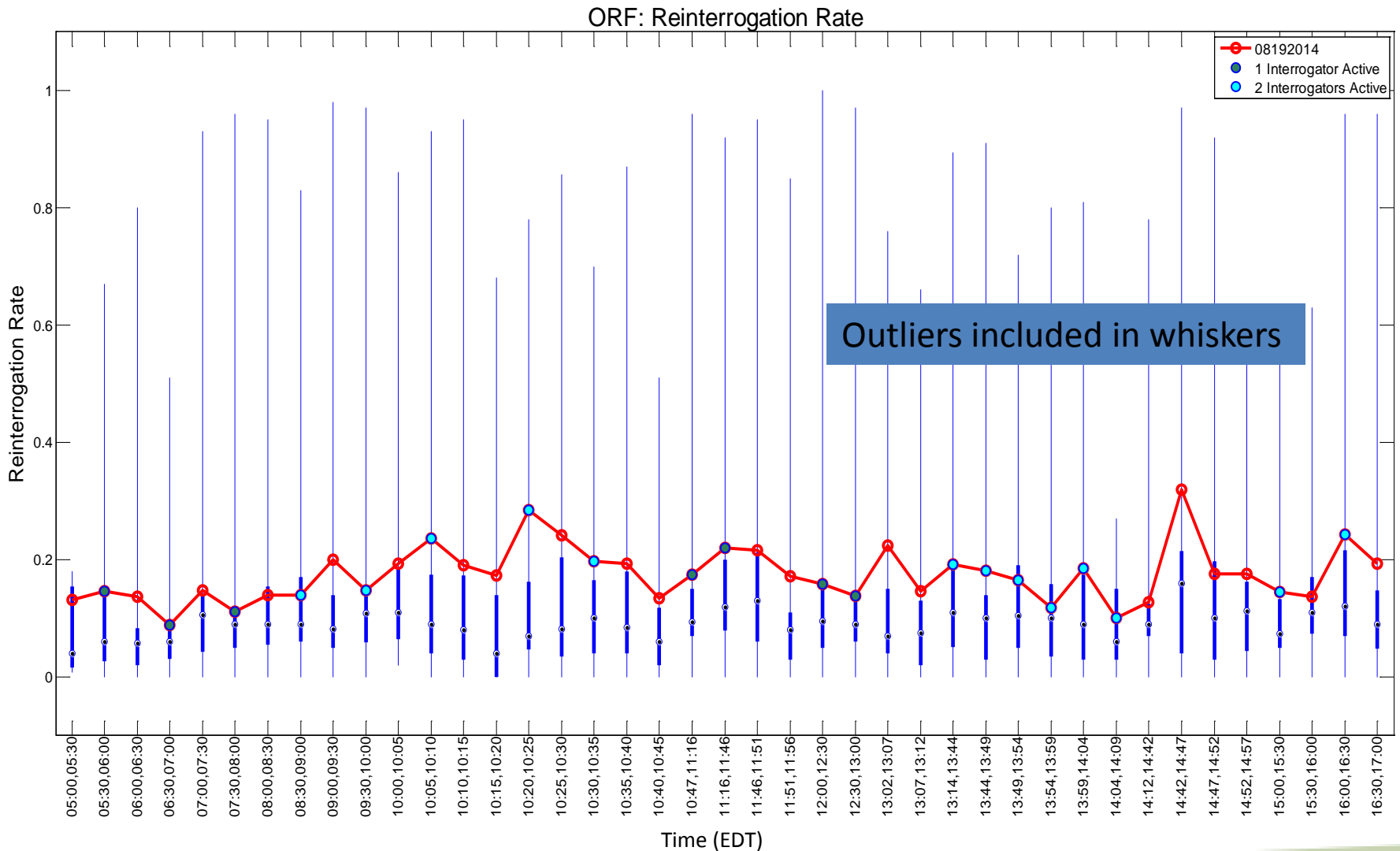
ORF: % of Channel Time Used for Reinterrogations



Geographic Filter: None  
Target Filter: Targets > 10 NM from SSR

# Reinterrogation Rate – August 19<sup>th</sup>

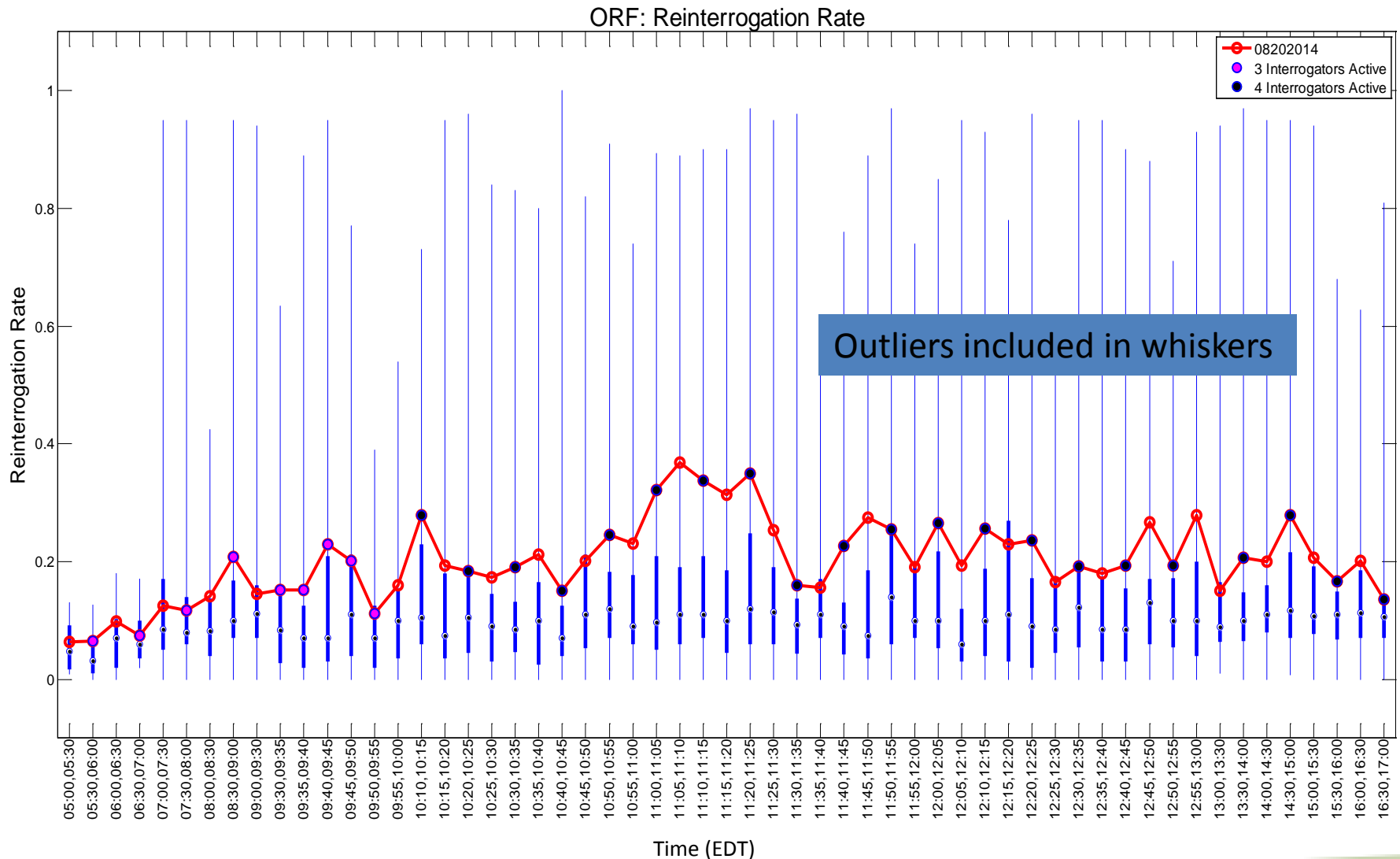
## Individual Aircraft Distribution





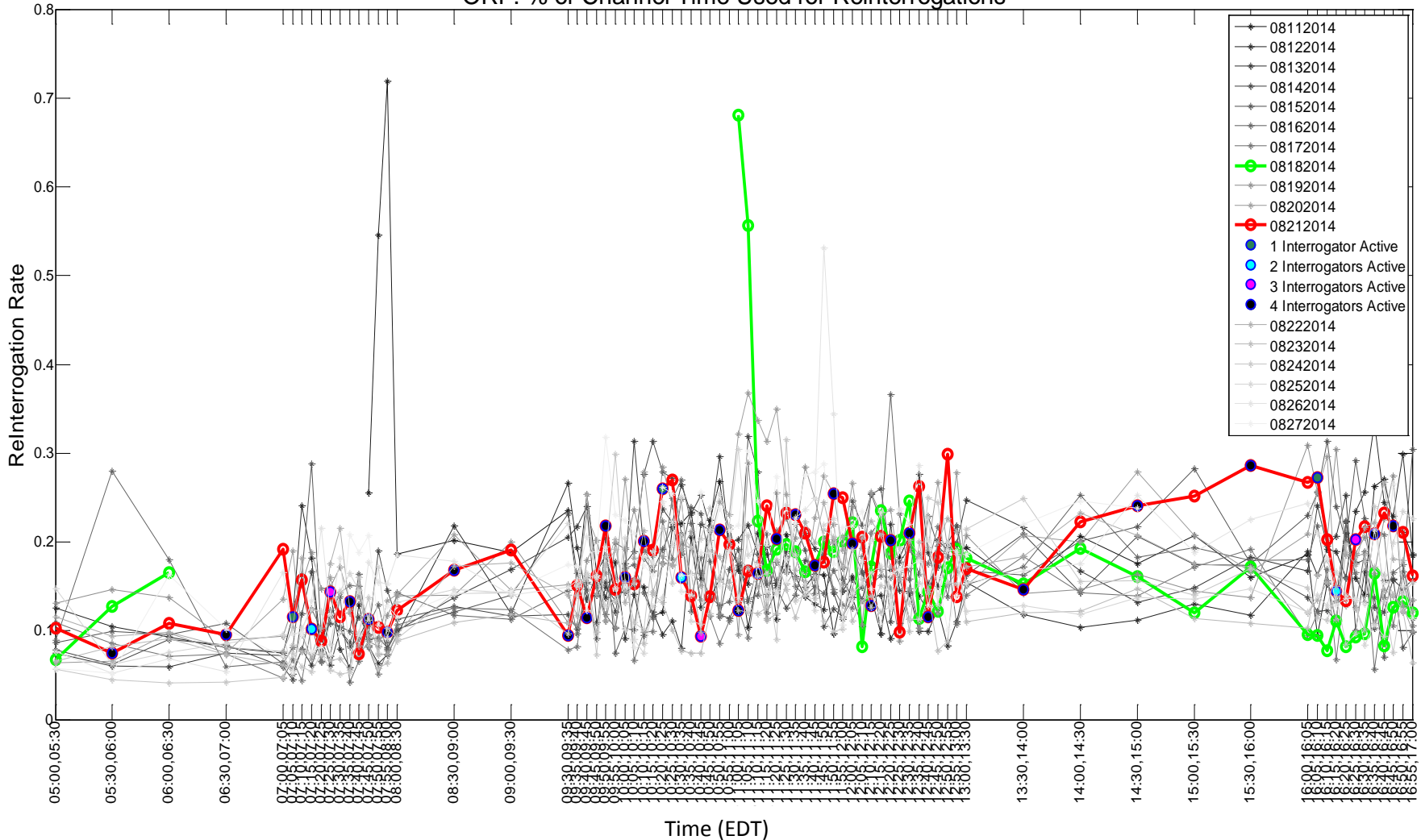
# Reinterrogation Rate – August 20<sup>th</sup>

## Individual Aircraft Distribution



# Reinterrogation Rate – August 21<sup>st</sup>

ORF: % of Channel Time Used for Reinterrogations

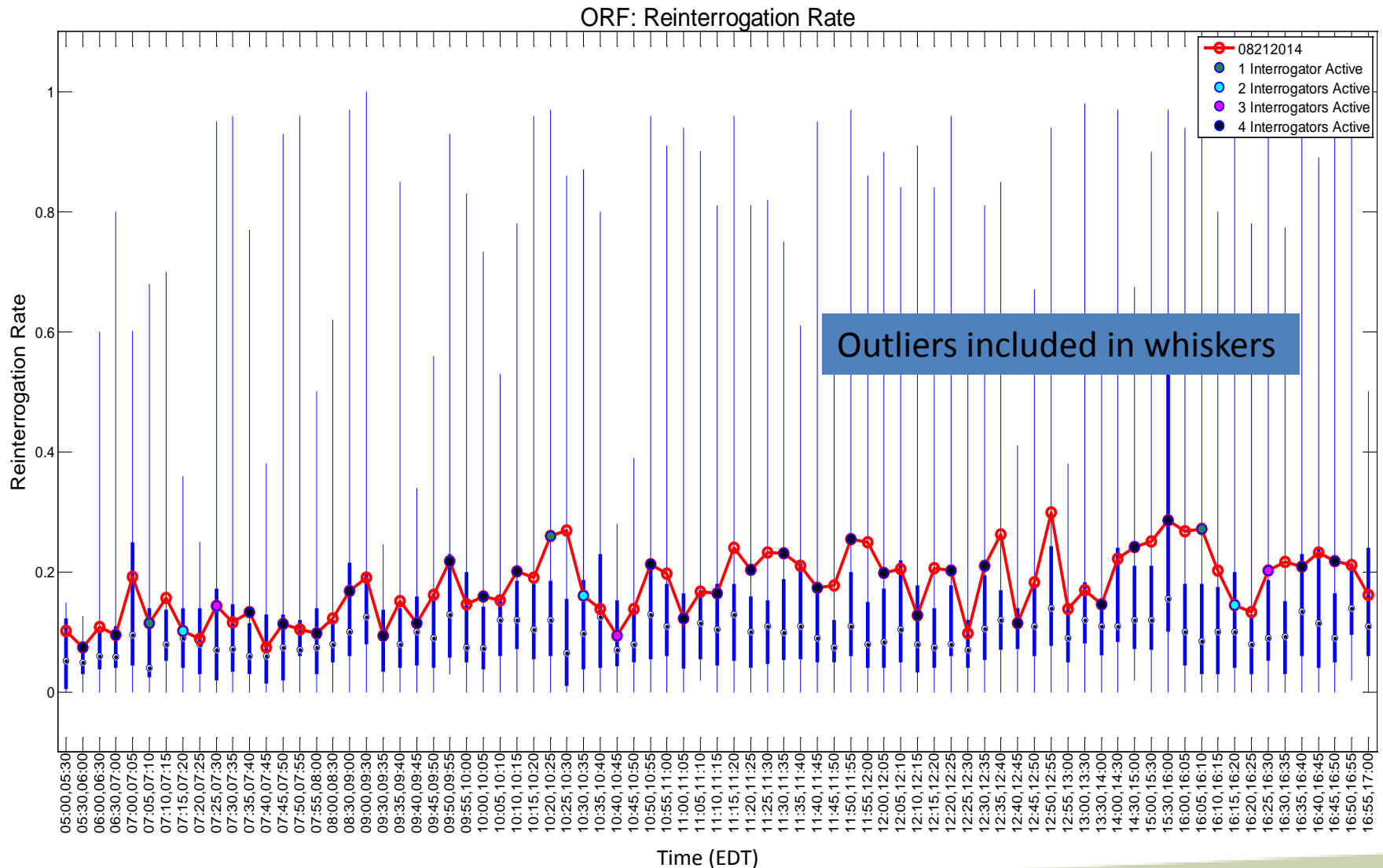


Geographic Filter: None  
Target Filter: Targets > 10 NM from SSR



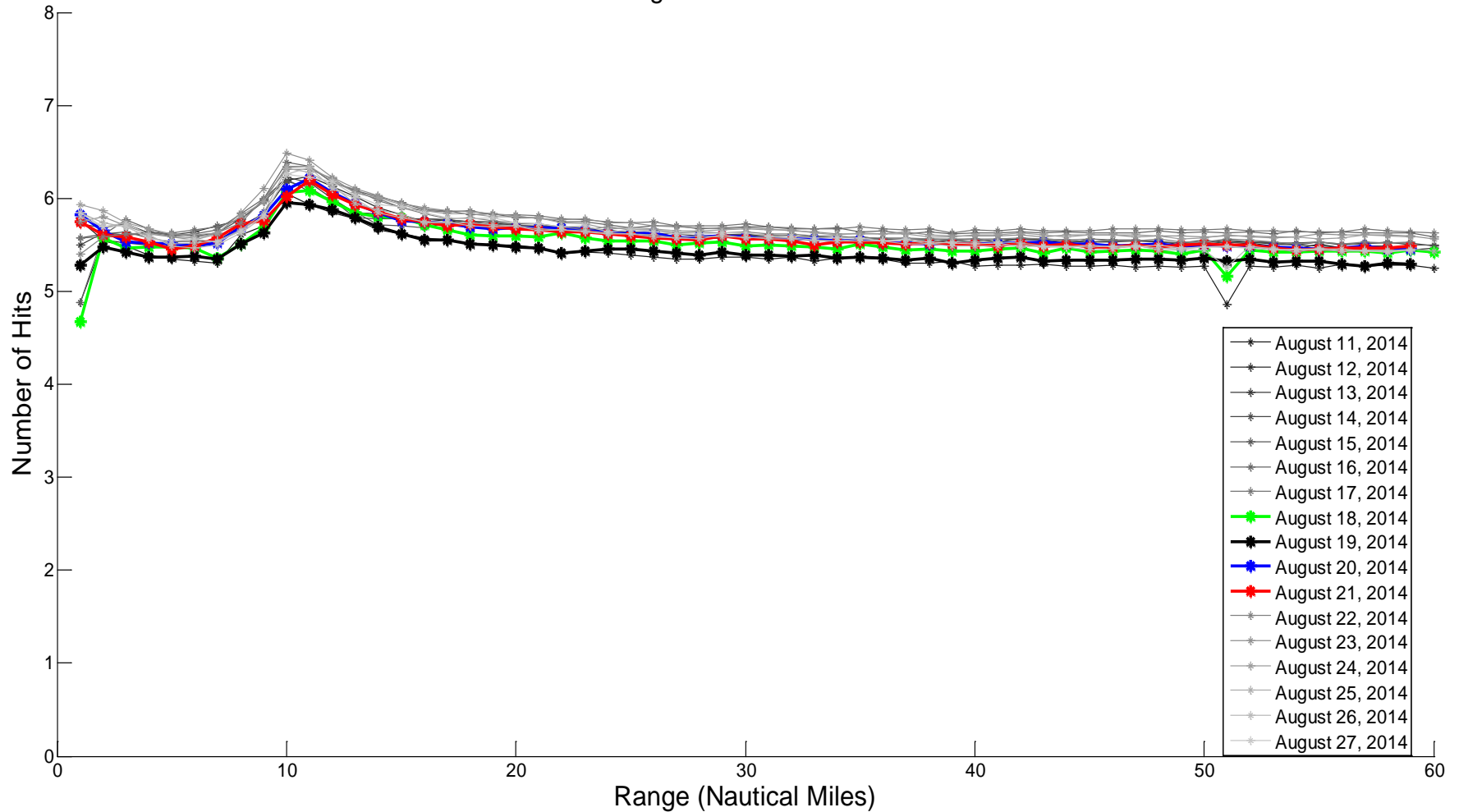
# Reinterrogation Rate – August 21<sup>st</sup>

## Individual Aircraft Distribution



# ATCRBS Number of Hits vs Range – All Days

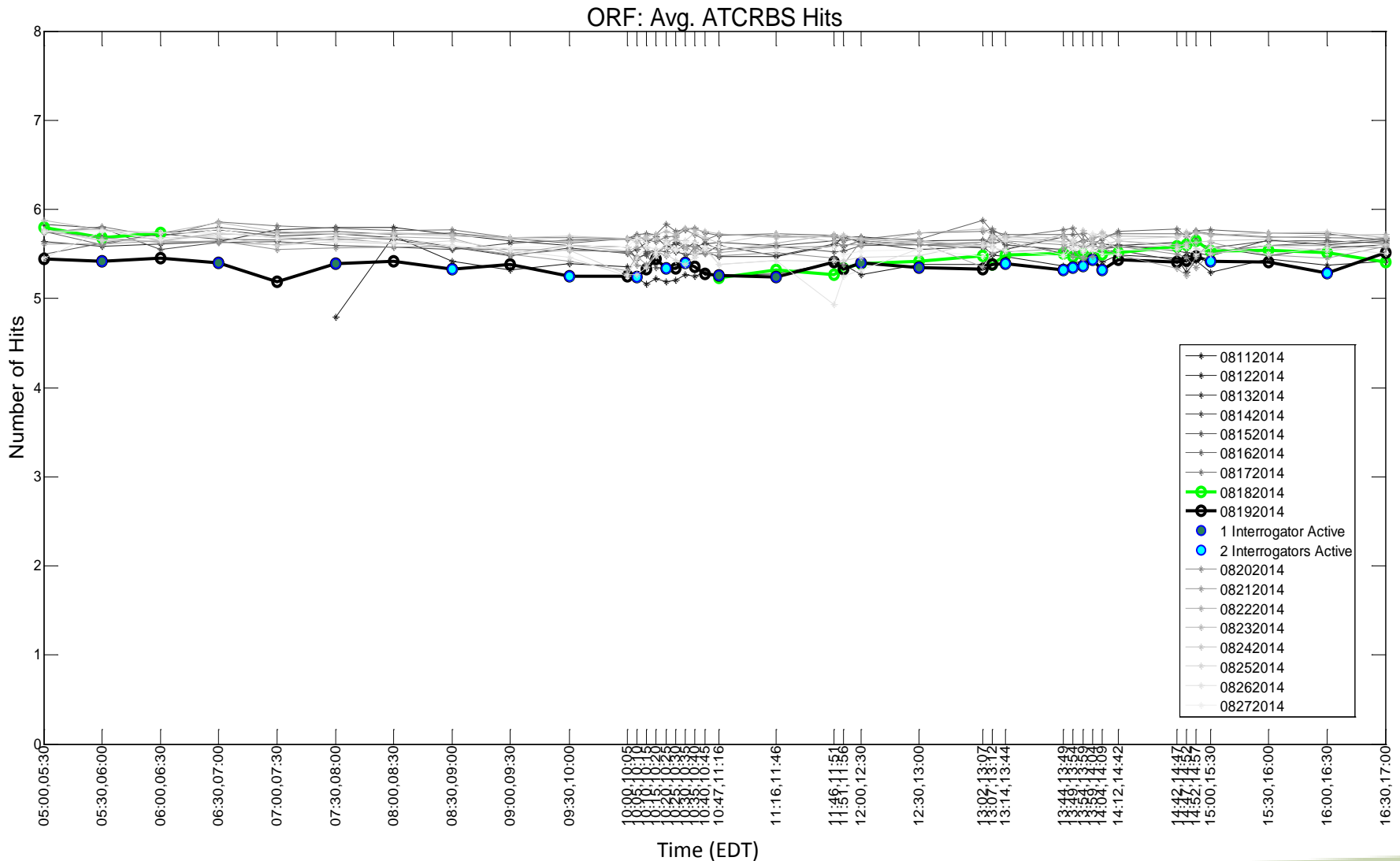
ORF: Average Number of ATCRBS Hits



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 19<sup>th</sup>



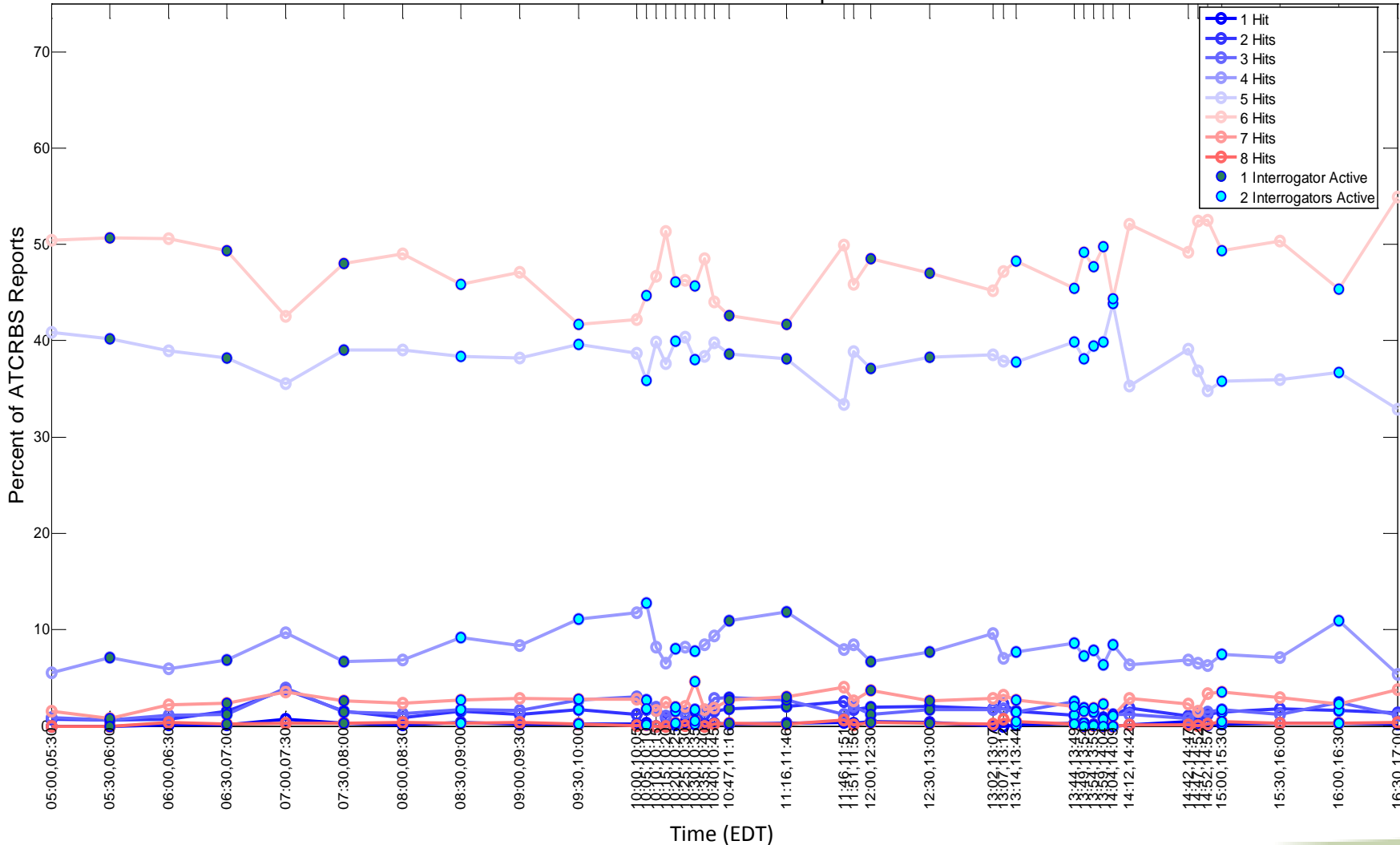
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 19<sup>th</sup>

## Number of Hits Distribution

08192014 ORF: Percent of ATCRBS Report vs Number of Hits

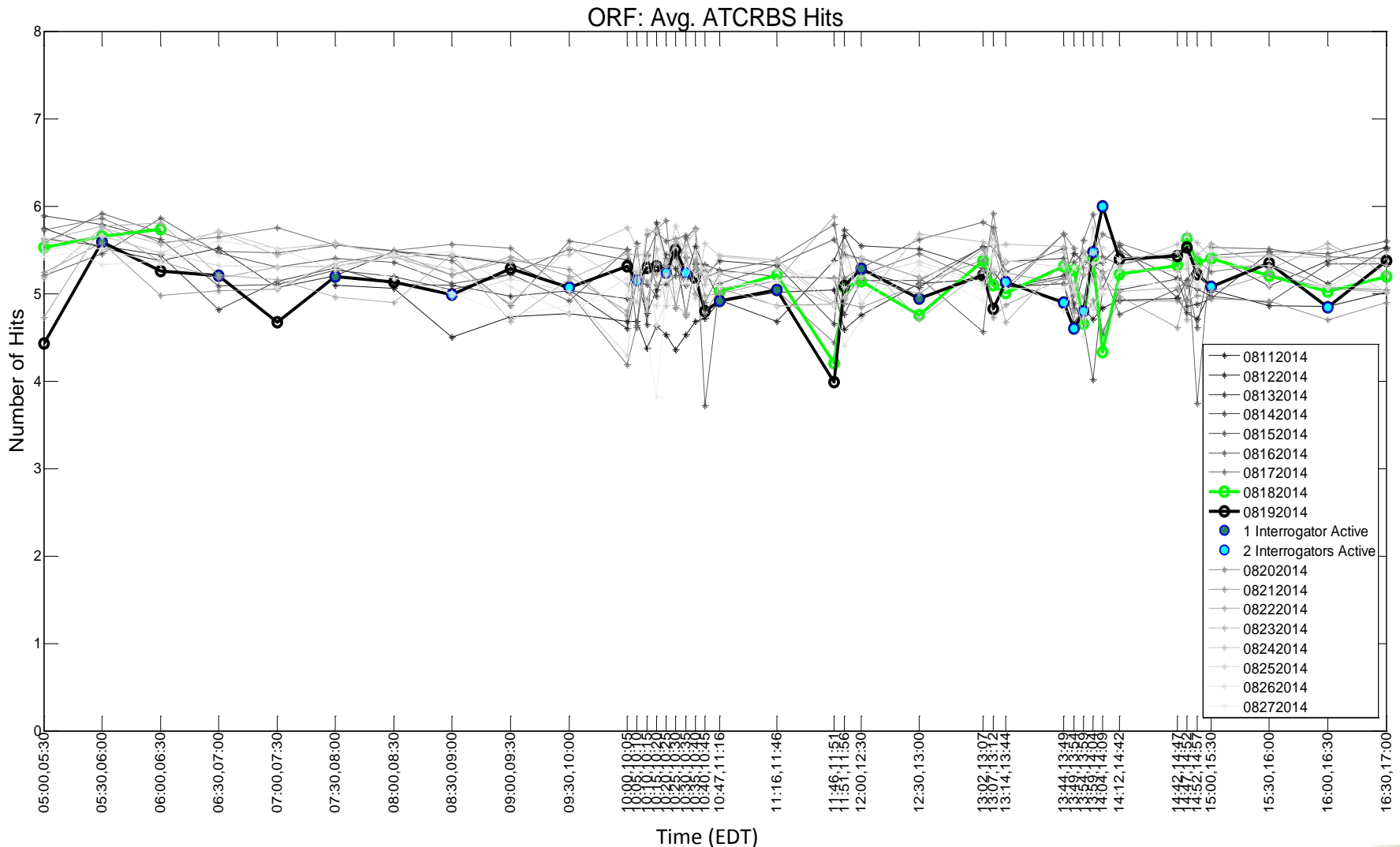


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 19<sup>th</sup>

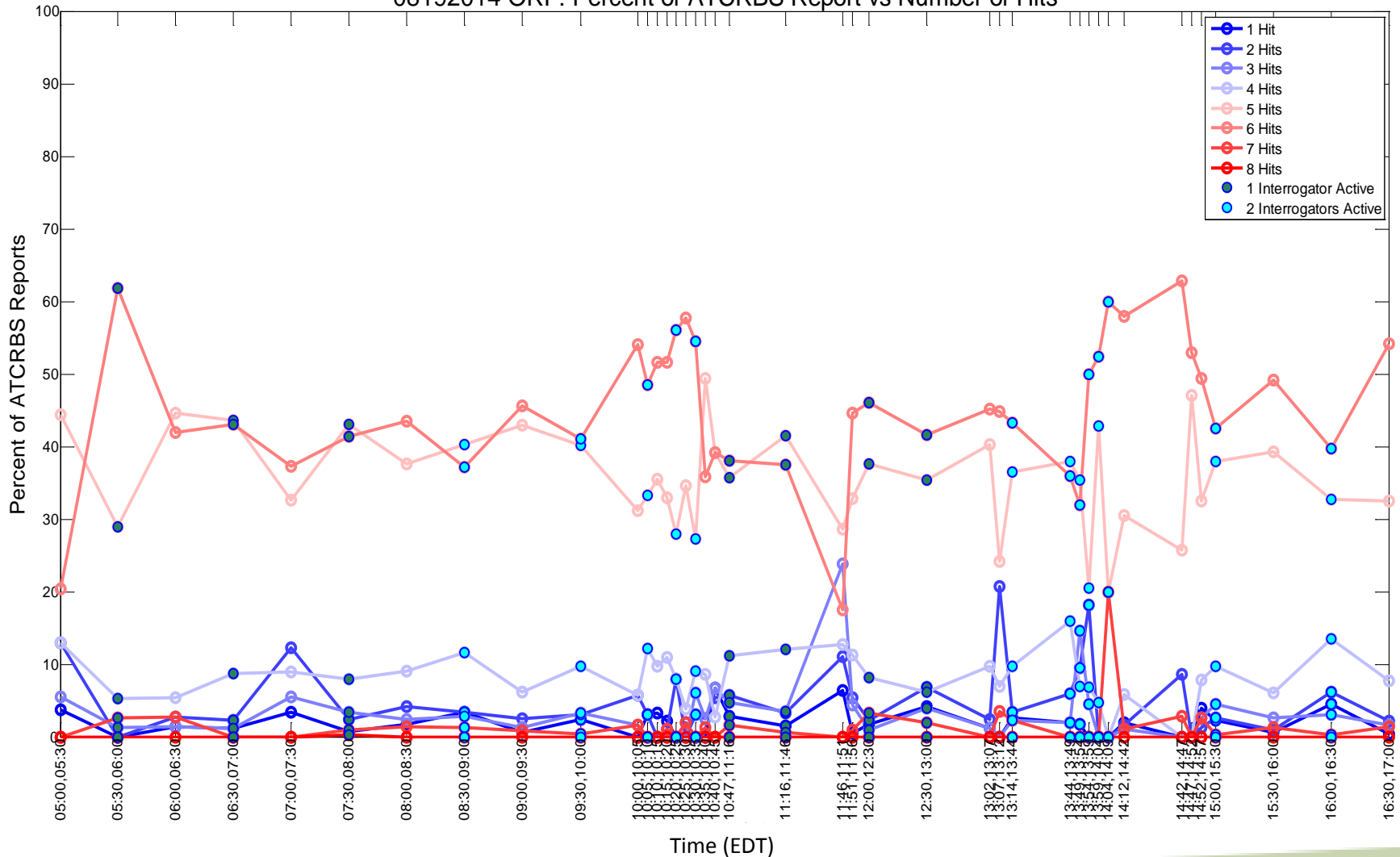
## 20 NM of AN/UPX-41(C) systems



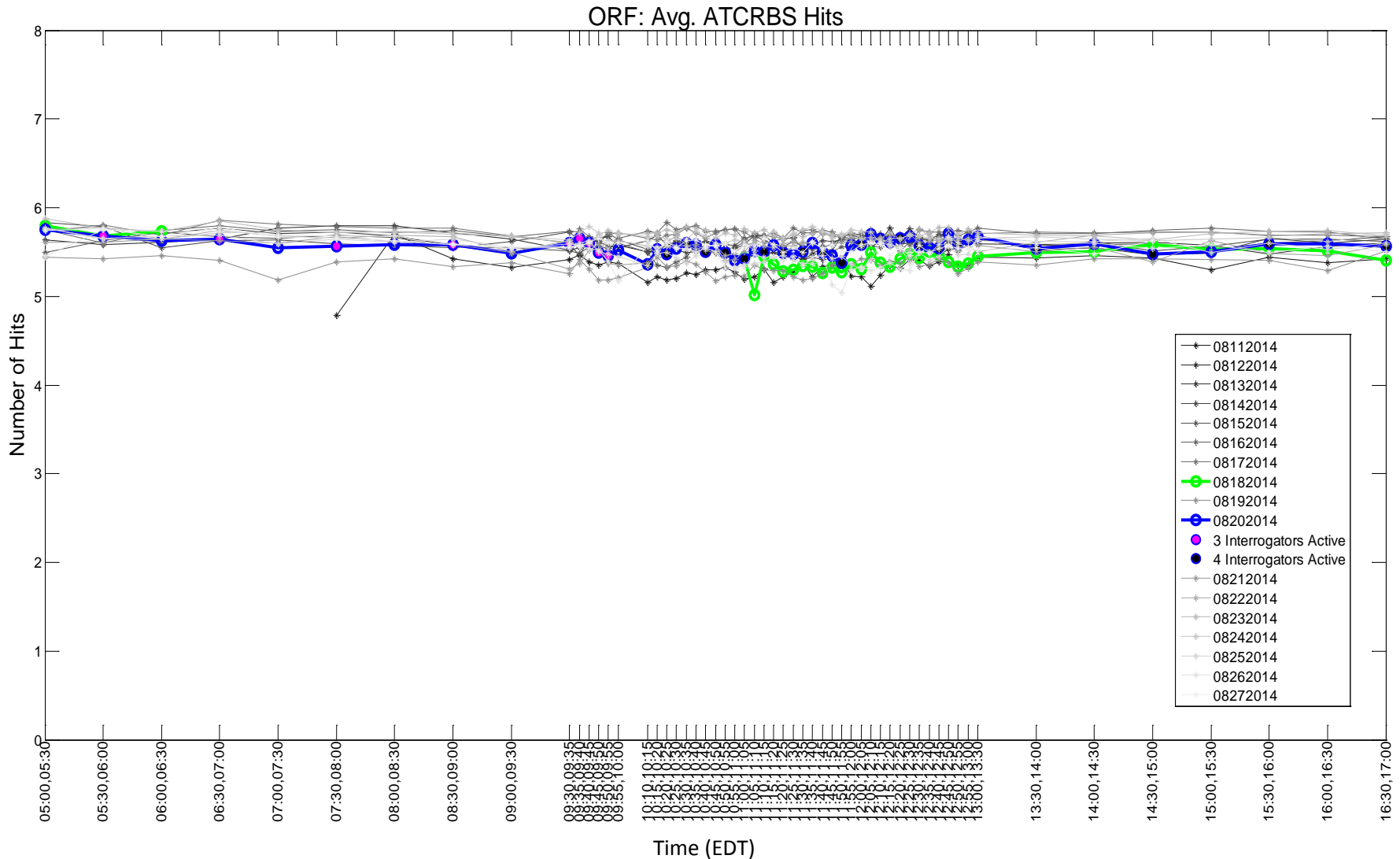
# ATCRBS Number of Hits – August 19<sup>th</sup>

## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution

08192014 ORF: Percent of ATCRBS Report vs Number of Hits



# ATCRBS Number of Hits – August 20<sup>th</sup>



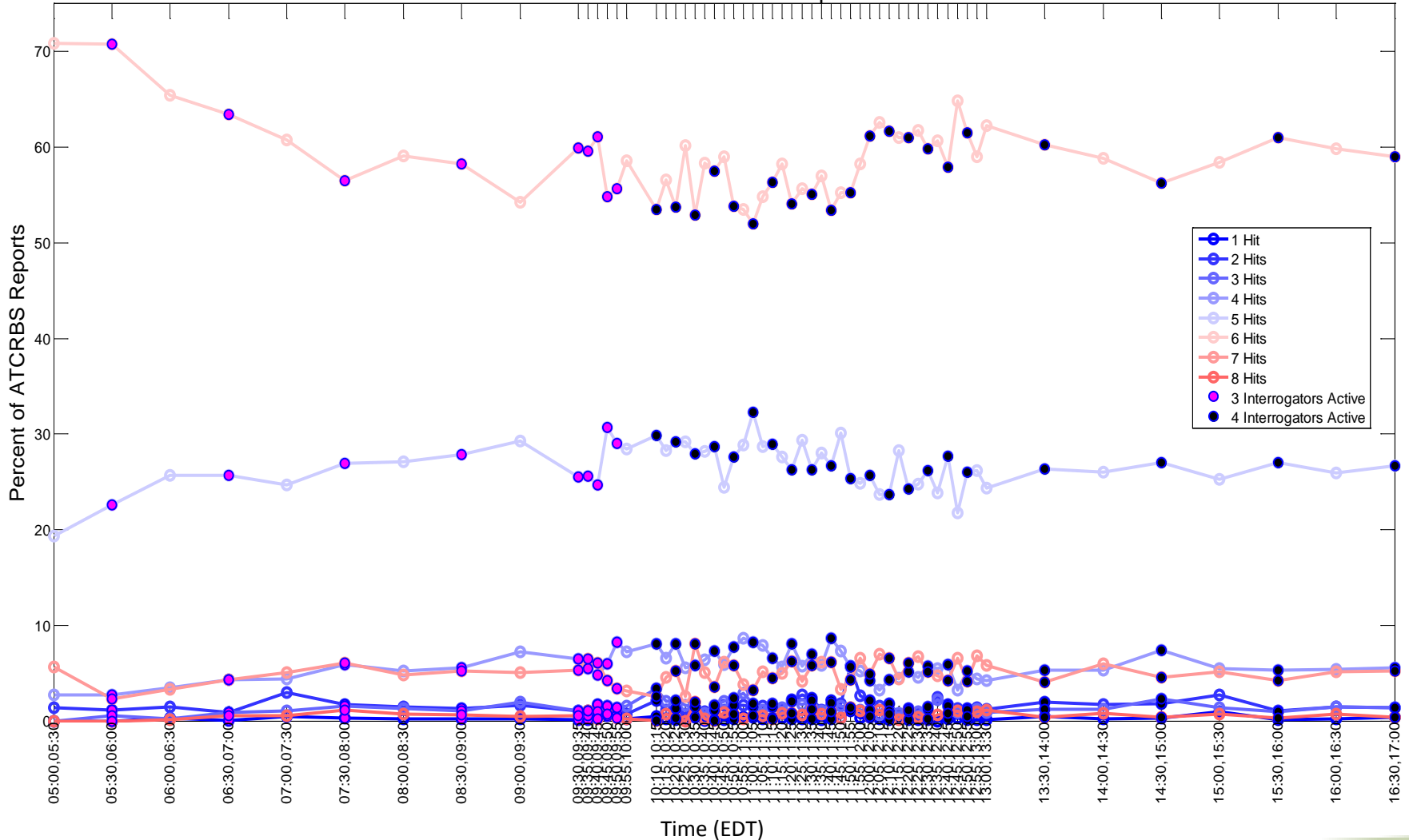
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 20<sup>th</sup>

## Number of Hits Distribution

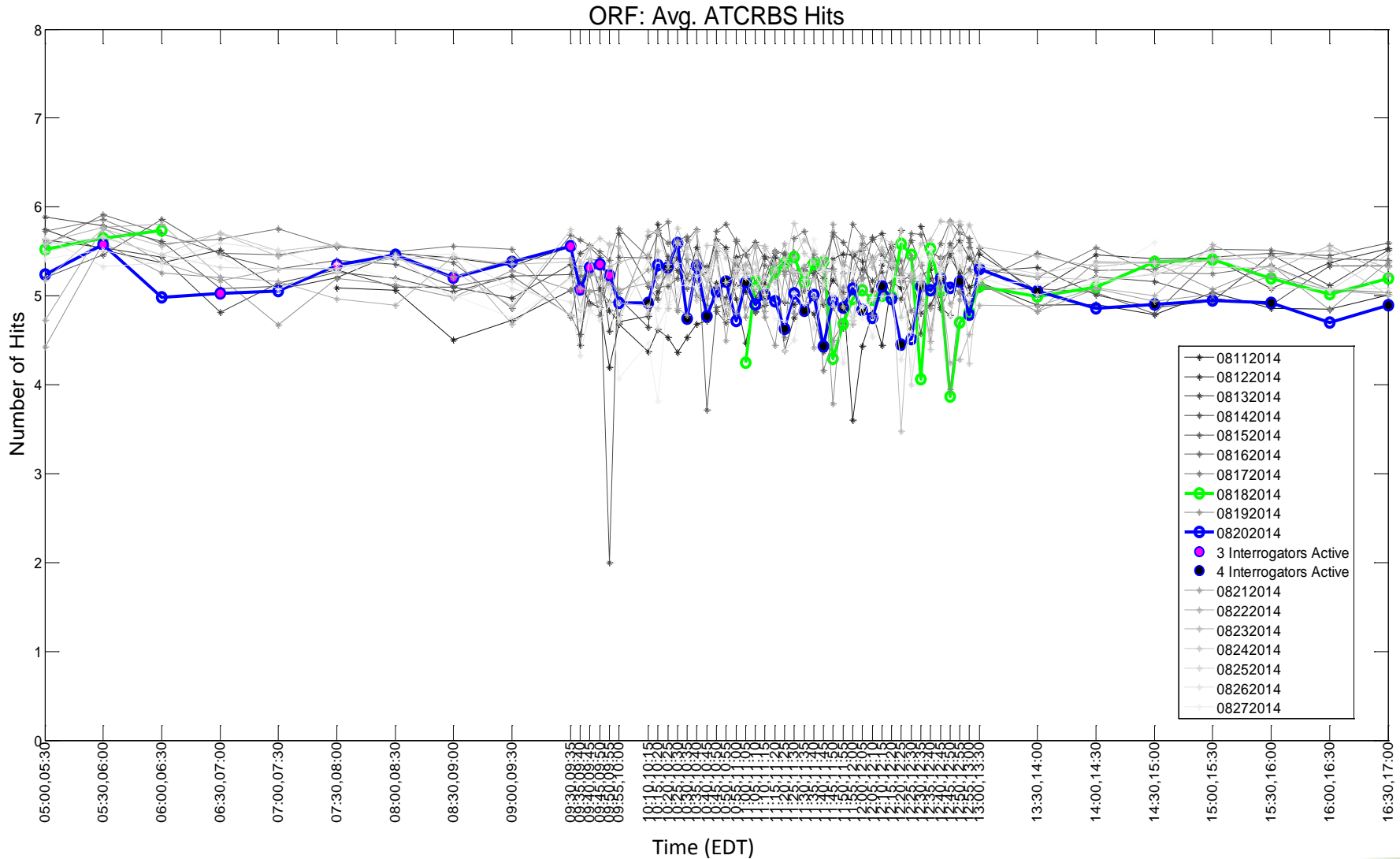
08202014 ORF: Percent of ATCRBS Report vs Number of Hits





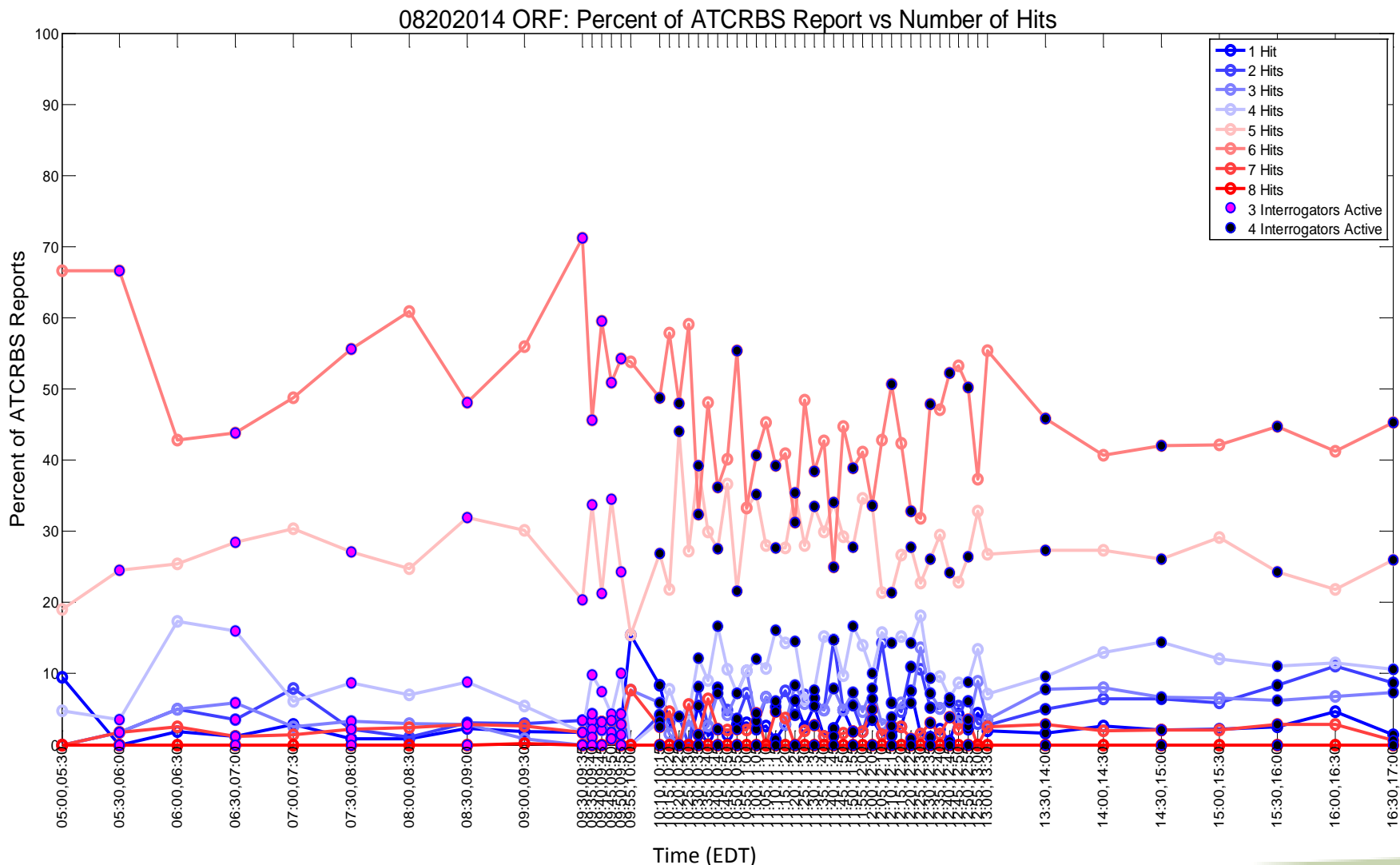
# ATCRBS Number of Hits – August 20<sup>th</sup>

## 20 NM of AN/UPX-41(C) systems

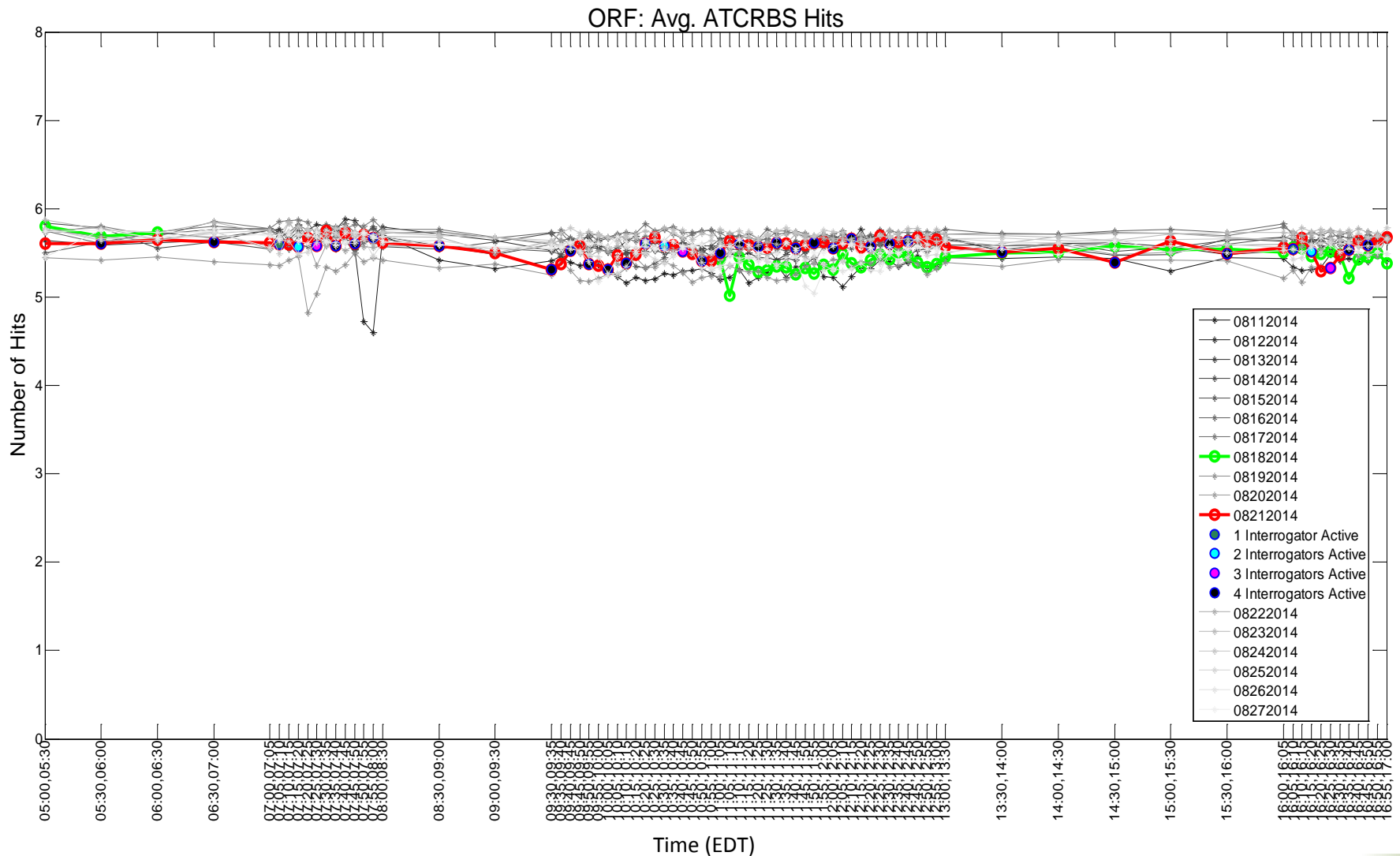


# ATCRBS Number of Hits – August 20<sup>st</sup>

## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution



# ATCRBS Number of Hits – August 21<sup>st</sup>



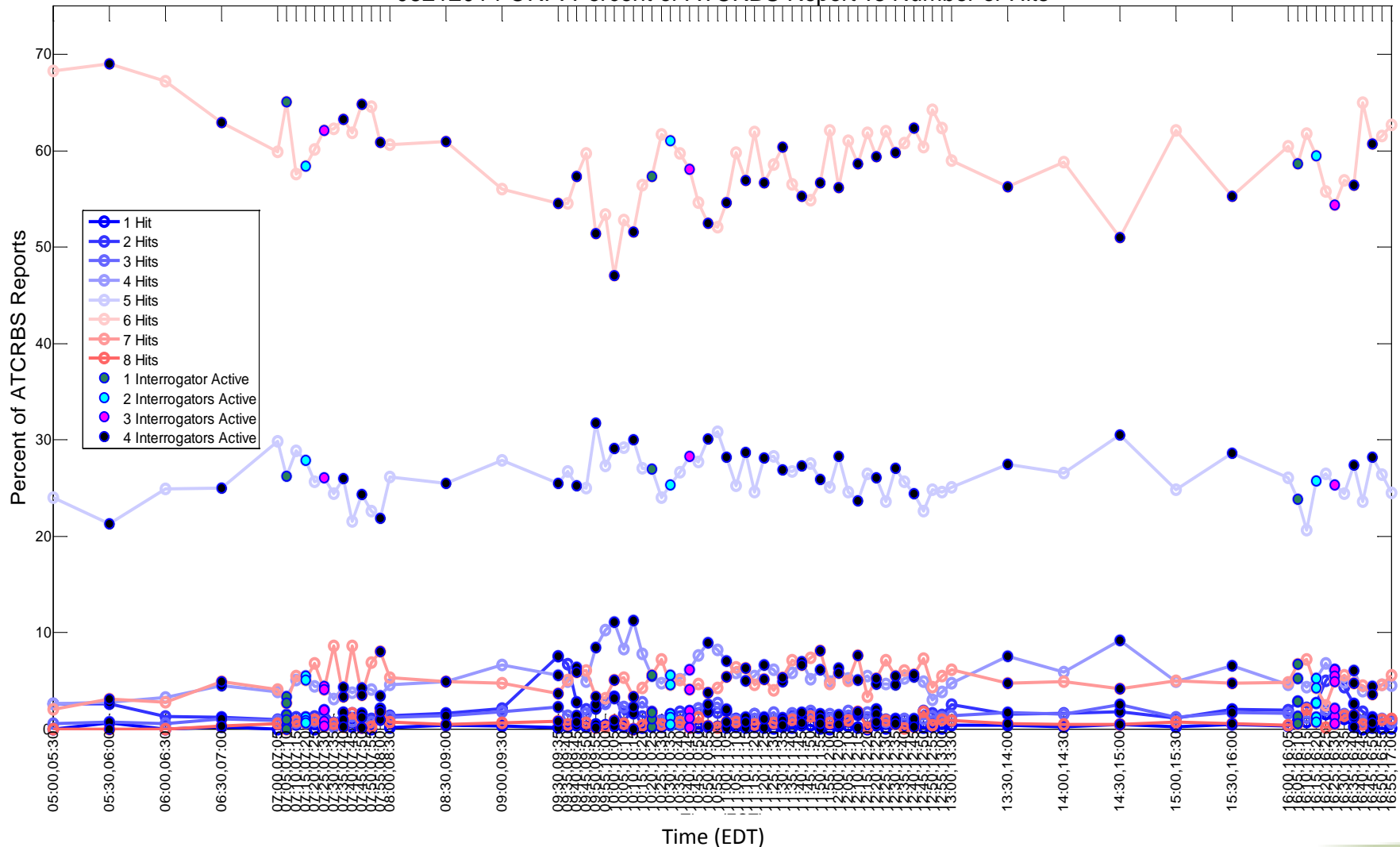
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 21<sup>st</sup>

## Number of Hits Distribution

08212014 ORF: Percent of ATCRBS Report vs Number of Hits

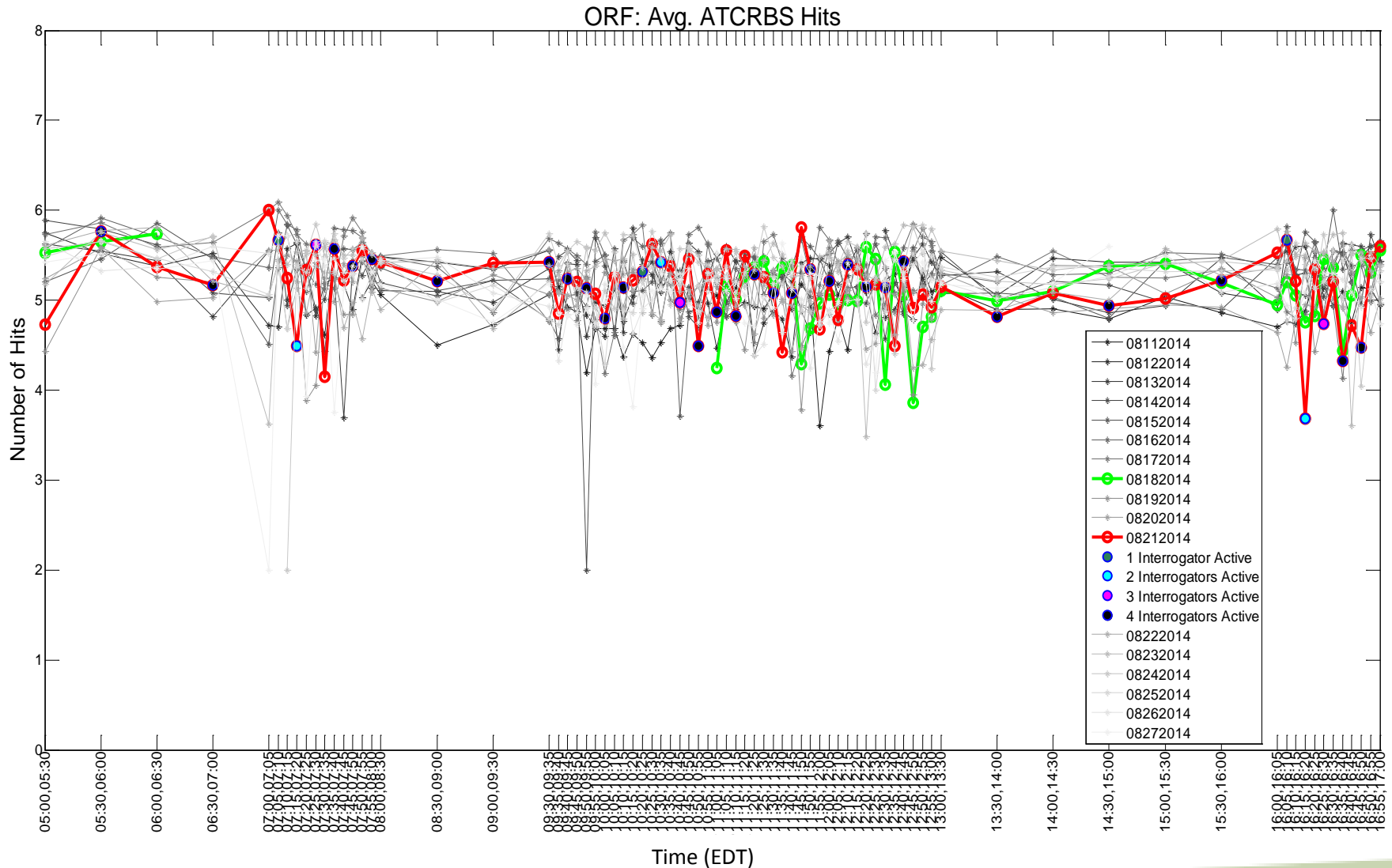


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# ATCRBS Number of Hits – August 21<sup>st</sup>

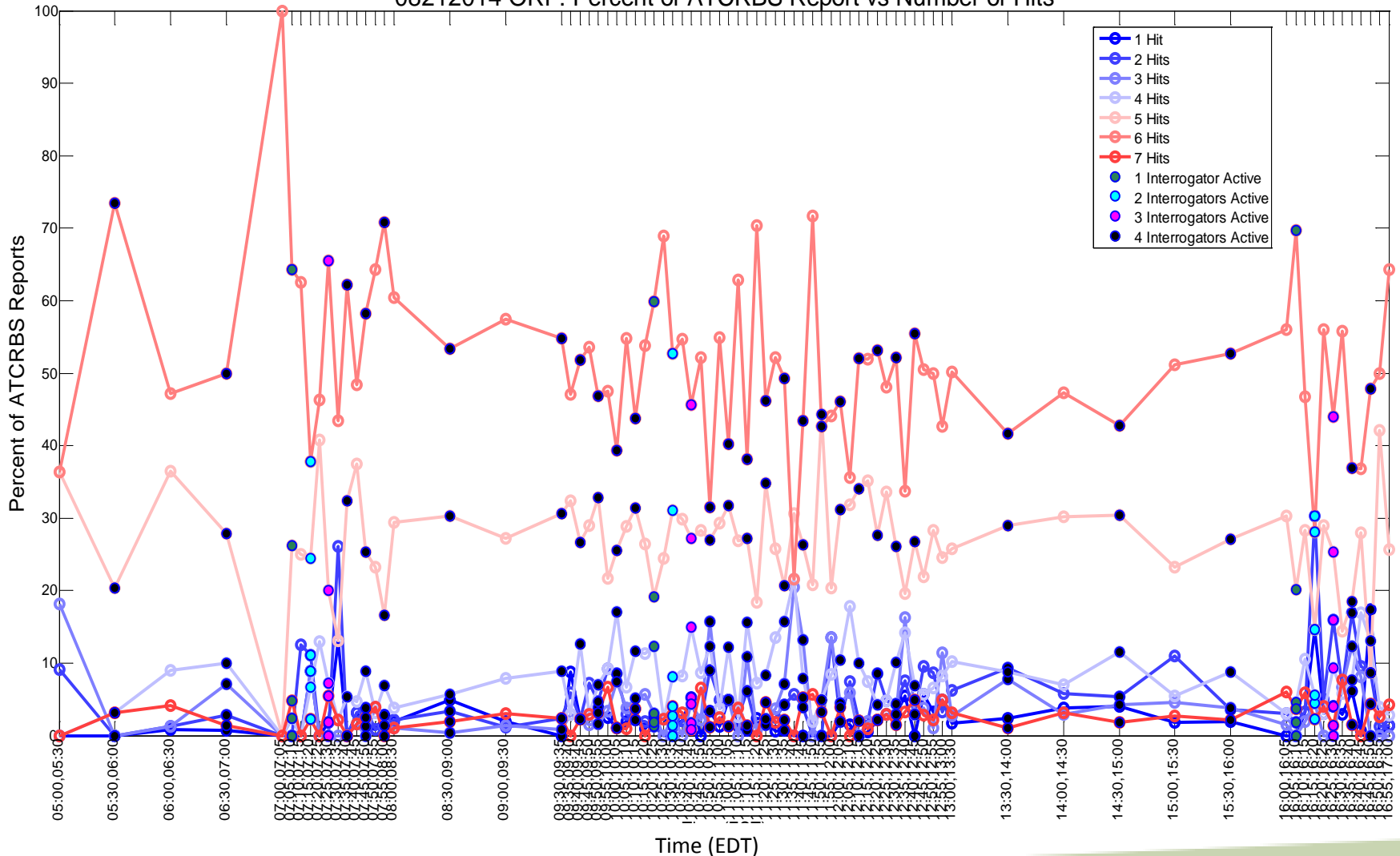
## 20 NM of AN/UPX-41(C) systems



# ATCRBS Number of Hits – August 21<sup>st</sup>

## 20 NM of AN/UPX-41(C) systems: Number of Hits Distribution

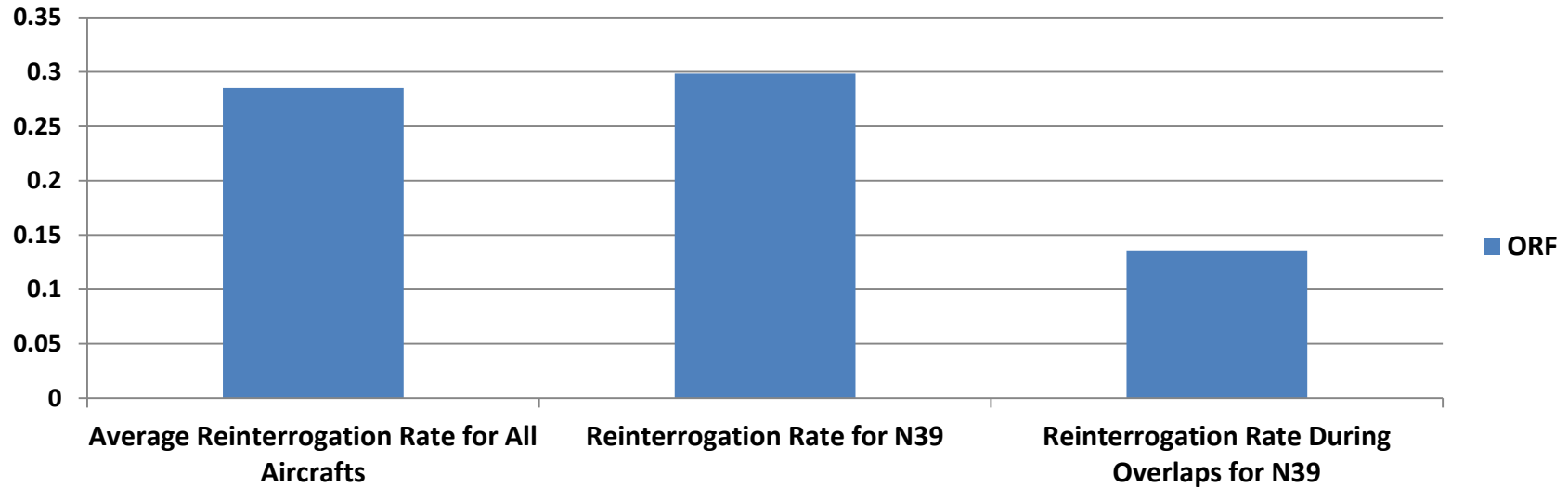
08212014 ORF: Percent of ATCRBS Report vs Number of Hits



# N39 Statistics

# N39 Reinterrogation Rate – August 20<sup>th</sup>

August 20, 2014

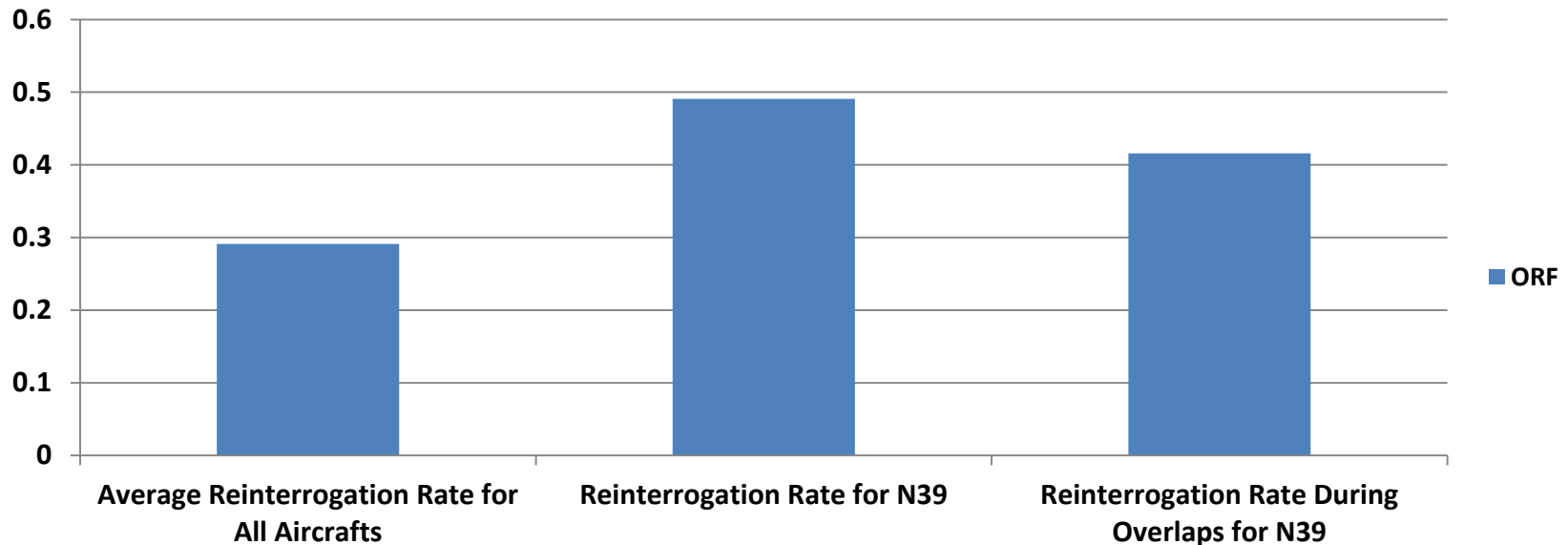


- Reinterrogation rate for N39 is about the same as the average reinterrogation rate across all aircrafts.
- The timings of 104 reinterrogations of N39 are missing when N39 was near ORF. Therefore, the reinterrogation rate during overlaps is not accurate.



# N39 Reinterrogation Rate – August 21<sup>th</sup>

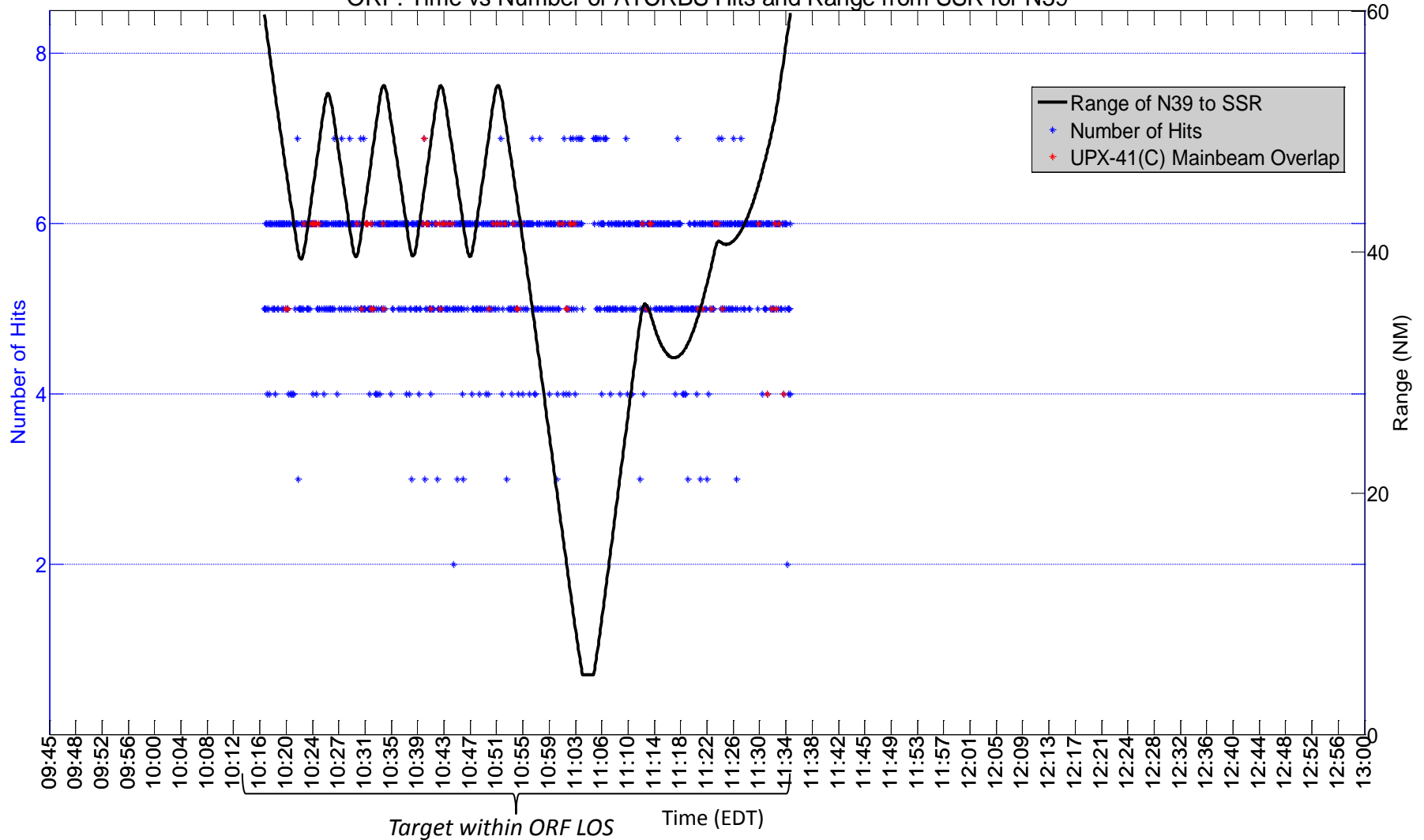
August 21, 2014



- ❑ Reinterrogation rate for N39 is higher than reinterrogation rate for all aircrafts.
- ❑ The timings of 407 reinterrogations of N39 at ORF are missing when N39 was flying close to ORF.

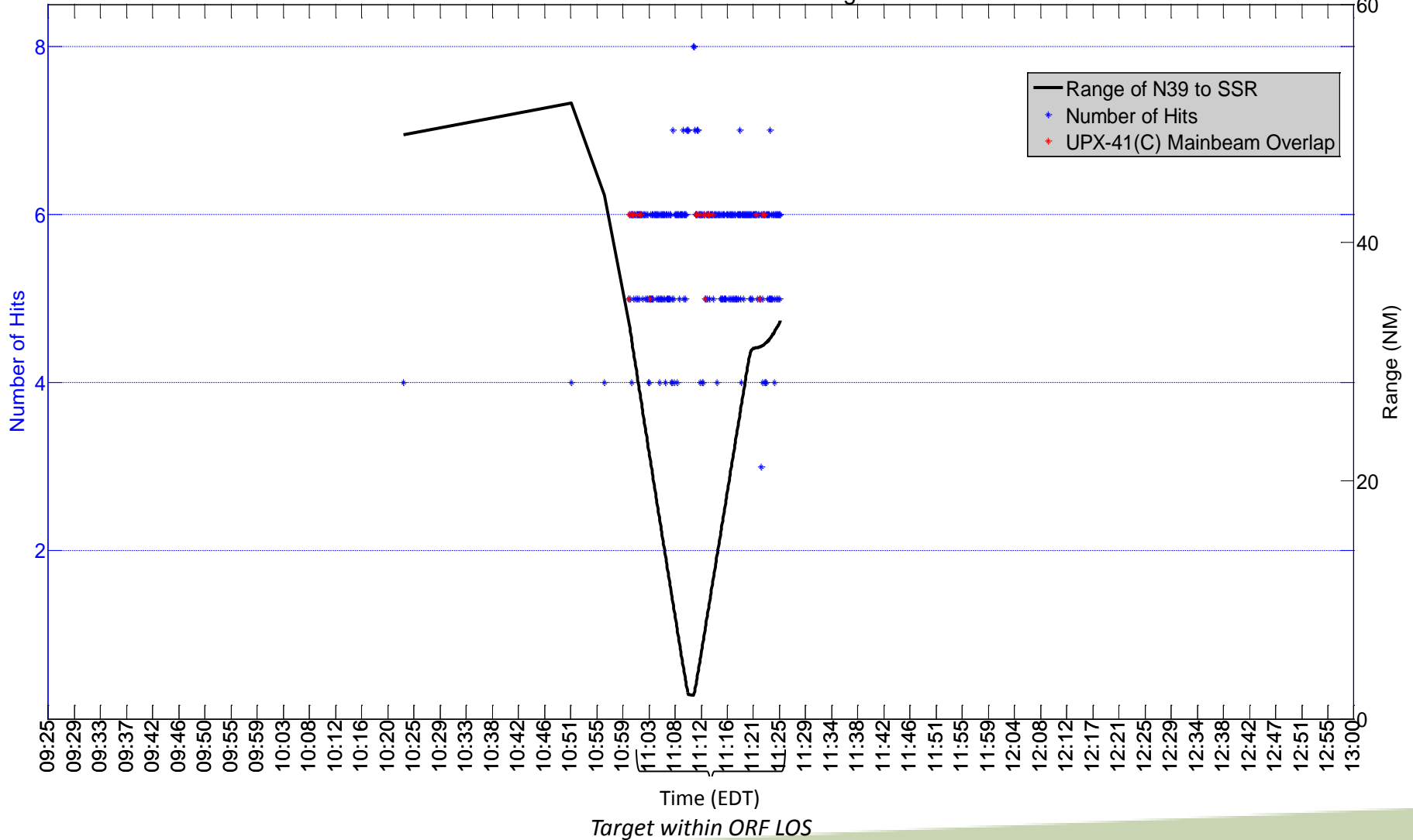
# Time vs Range and Number of ATCRBS Hits on N39 – August 20<sup>th</sup>

ORF: Time vs Number of ATCRBS Hits and Range from SSR for N39



# Time vs Range and Number of ATCRBS Hits on N39 – August 21<sup>st</sup>

ORF: Time vs Number of ATCRBS Hits and Range from SSR for N39



# Observations and Conclusions

- ❑ Beyond 10 NM, where reinterrogation rates are not artificially high due to tracker predictor performance, changes in target reinterrogation rate average and distribution show no correlation with times when the AN/UPX-41(C) interrogators were active.
- ❑ When reinterrogation rates are compared with days when no AN/UPX-41(C) interrogators were active, the average shows no departure from the normal performance of the Mode S sensor.
- ❑ Similarly, ATCRBS hit count averages and distribution changes show no correlation with AN/UPX-41(C) active periods.
  - The one exception is August 21 when about 80% of the active periods showed a drop in percent of aircraft with hit count equal to six.
  - However, examination of the same day for the other three Mode S sites does not show this trend.

# Observations and Conclusions (cont'd)

- ❑ The Mode S data extraction files are the only ground sensor recorded data at the interrogation and reply level.
  - Degradation will begin here before it flows up to the track level (i.e.  $P_d$ , Conf., Rel.).
  - Hence, this analysis gives the clearest picture of spectrum interference that material affects the SSR surveillance environment.
- ❑ With virtually no observable change in reinterrogation rate and ATCRBS hit count, it is difficult to use this data to predict how more AN/UPX-41(C) interrogators, beyond the Stage 4 certification, would change the surveillance environment.
- ❑ Yet, by virtue of the fact that no change was observed at the interrogation and reply level, the Stage 4 certification restrictions are more than sufficient to protect FAA SSRs and relaxation of those restrictions should be considered to help the Navy meet its operational goals.



# Executive Summary

- ❑ Excluding periods of data loss, the Probability of Detection, Identity Reliability and Confidence, Altitude Reliability and Confidence, False Targets, 0000 Codes, and Targets per Scan exhibit no observable adverse trend with respect to periods of radiation by the AN/UPX-41(C) interrogator.
- ❑ During AN/UPX-41(C) interrogator radiation, the variations or volatility of the aforementioned metrics are within the bounds of the variations of the same metrics on non-test days (baseline).

# Background

- ❑ The AN/UPX-41(C)\* Stage-4 operational transmit certification for AEGIS-Class ships was signed by NTIA on June 22, 2012 with geographic and platform number restrictions when operating in proximity to the NAS.<sup>†</sup>
- ❑ Additionally, the Stage-4 certification contained a requirement for a joint FAA-Navy test to validate the operational restrictions.
- ❑ The Volpe Center, in conjunction with the Navy, FAA Spectrum, and FAA aeronautical surveillance and collision avoidance systems (ASCAS) SMEs created a test plan to validate the operational restrictions.
- ❑ From August 18-21, 2014 the FAA and Navy conducted the above-mentioned joint test, under the management of the Volpe Center.
- ❑ Since the test, the Volpe Center has analyzed recorded data to look for instances of harmful interference that would affect ASCAS system performance.

\*AN/UPX-41(C) Digital Interrogator System when operated in conjunction with the OE-120 antenna, the AN/UPX-29(V) Identification Friend or Foe (IFF) system, and the AN/UPX-24 software interface Version 2.1.2, controlled by the Cooperative Engagement Capability (CEC), in Naval surface vessels

<sup>†</sup>See SPS-18778\_1 Navy AN-UPX-41 V5.5 St4



# Test Plan Refresher

- ❑ **Baseline week: August 11<sup>th</sup> – 15<sup>th</sup>**
  - Baseline recording of data from 5 AM – 5 PM
    - No AN/UPX-41(C) systems Active
- ❑ **Test week: August 18<sup>th</sup> – 21<sup>st</sup>**
  - August 18<sup>th</sup> – Baseline recording of data from 5 AM – 5 PM
    - No AN/UPX-41(C) systems Active
  - August 19<sup>th</sup> – Record data from 5 AM – 5 PM
    - Cycle 1 and 2 AN/UPX-41(C) systems Active and OFF
  - August 20<sup>th</sup> – Record data from 5 AM – 5 PM
    - Cycle 3 and 4 AN/UPX-41(C) systems Active and OFF
  - August 21<sup>st</sup> – Record data from 5 AM – 5 PM
    - Cycle 1, 2, 3, and 4 AN/UPX-41(C) systems Active and OFF
- ❑ **Cycling of AN/UPX-41(C) systems Active/OFF occurred every 30 minutes; however, if N39 (Tech Center signal recording aircraft) was in the air, cycling occurred every 5 minutes**

# Data Recording

- ❑ During the August test, Enroute Common Gateway (ECG) data was recorded at the Tech Center from the NHK site.
- ❑ The Radar Beacon Analysis Tool (RBAT) was used to analyze ECG data to produce statistics for the following list of parameters:
  - Targets per Scan
  - Probability of Detection
  - Identity Reliability
  - Identity Confidence
  - Altitude Reliability
  - Altitude Confidence
  - False Target Percentage
  - 0000 Code Percentage

# Data Analysis Methodology

- ❑ Applied time bins that corresponded to the AN/UPX-41(C) Active/OFF periods from test days (August 19<sup>th</sup>-21<sup>st</sup>) to baseline days to produce baseline statistics
- ❑ Data was first analyzed without any geographic or target filters
  - In analyzing possible cases of interference, it was determined that targets at low elevation angles exhibited relatively low probabilities of detection regardless of Active/OFF period
  - This behavior was not conducive to pinpointing interference events
- ❑ Analysis of targets at elevation angles greater than 2 degrees was prepared
  - Interference events would be easier to see if targets that were already behaving poorly were excluded from the analysis
- ❑ Next, data was analyzed using a geographic filter that represented the area of AN/UPX-41(C) systems' sidelobes (subsequently referred to as the Hotspot area)
  - Assumption: AN/UPX-41(C) sidelobes extend 40 NM
  - Recent developments from flight test data show that P2 pulse can be seen up to 40 NM; however, only caused N39 ownship transponder suppressions up to 20 NM
- ❑ Targets that are beyond 50 NM from the SSR site and within the hotspot area were analyzed
  - Targets at the edge of coverage area and within the hotspot area are more likely to display signs of interference

# Analysis Limitations

- ❑ The theoretical or textbook definition of probability of detection is a function of interrogation/reply round reliability.
- ❑ However, probability of detection in RBAT is the percentage of target updates versus total number of beam dwells over all targets.
- ❑ Therefore, the ability for probability of detection calculated by RBAT to properly represent theoretical probability of detection is minimized as the sample size decreases (either through geographical or time constraints) since it no longer reliably reflects the target population mean.
- ❑ Example: A target population of two where both targets miss one update out of ten scans (approximately 50 seconds) results in a probability of detection of 90%. While this is unacceptable by QARS blip/scan minimums, we have no knowledge of the updates that occurred outside of the given time constraint . If both targets received ten out of ten updates for the previous as well as the next 10 scans, the probability of detection is now 96.7%.

# Objective

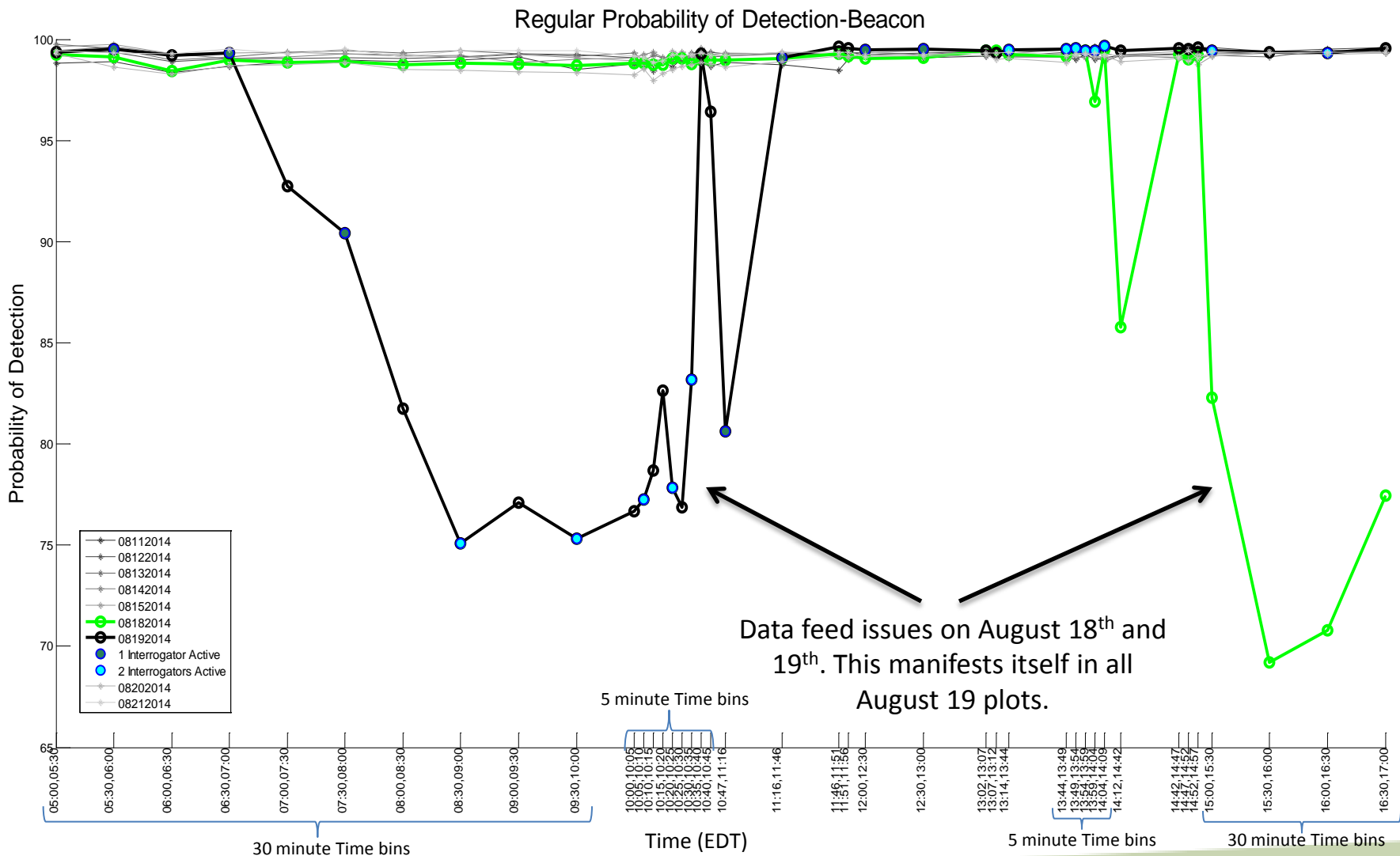
- ❑ We are attempting to observe distinct patterns of change in the metrics of interest between times when the AN/UPX-41(C) systems are OFF and when they are Active.
- ❑ While geographic and time filters reduces target update sample sizes such that a small sample size itself influences the metric of interest, it is more important to focus on the change from Off to Active since both the Off and Active periods have the same constraints applied.

# Plot Guide

- ❑ There are four sets of plots that correspond to the data analysis methodology discussed previously
  1. No filters
  2. Filter on targets with elevation angle greater than two degrees
  3. Filter on targets within Hotspot
  4. Filter on targets within Hotspot with range greater than 50 NM from SSR
- ❑ Plots with multiple days of data utilize the time filters from the Active/Off periods for the date given in the slide's title

# Target Metrics with No Filter

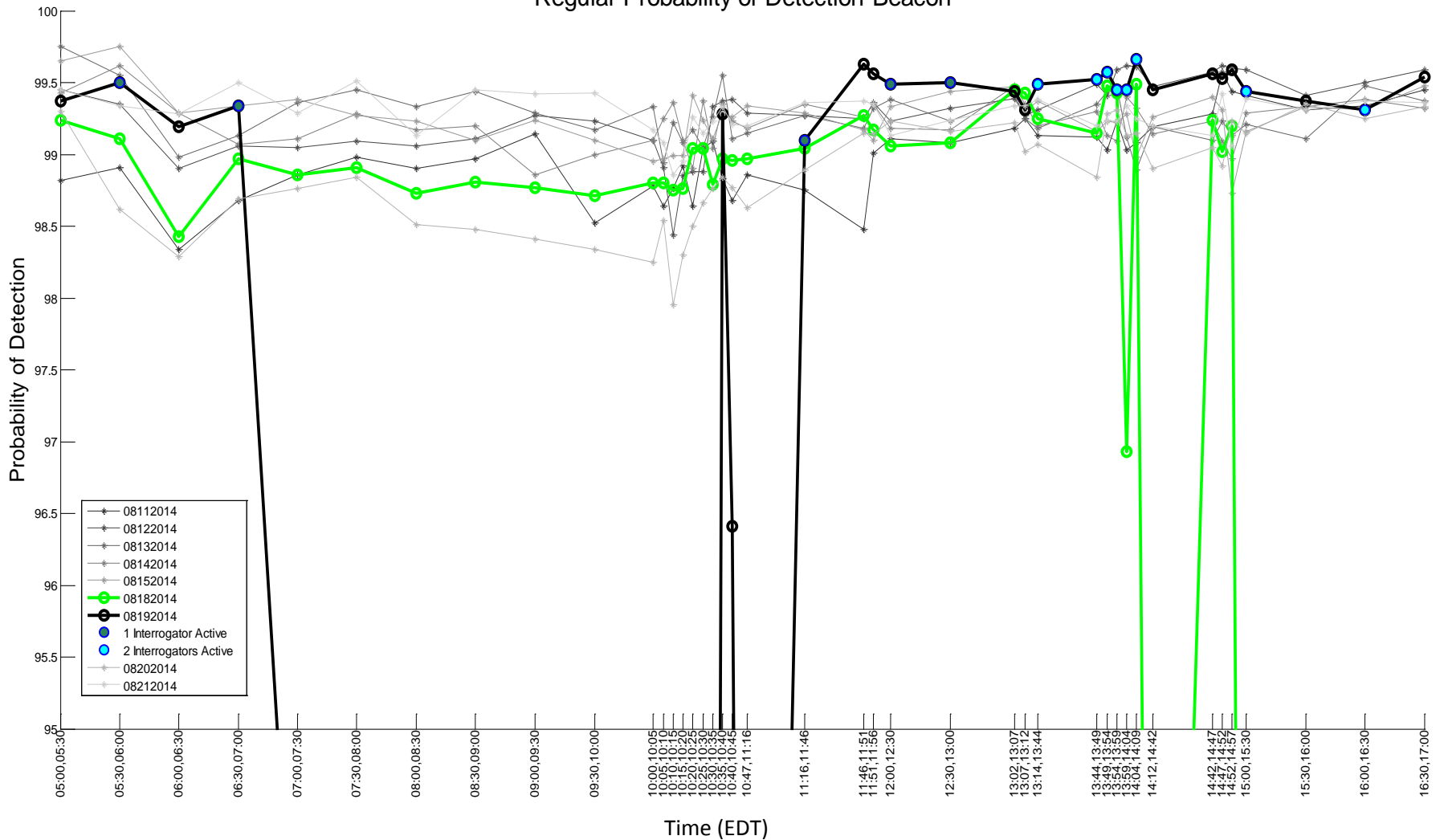
# Probability of Detection – All Days





# Probability of Detection – All Days (zoom-in)

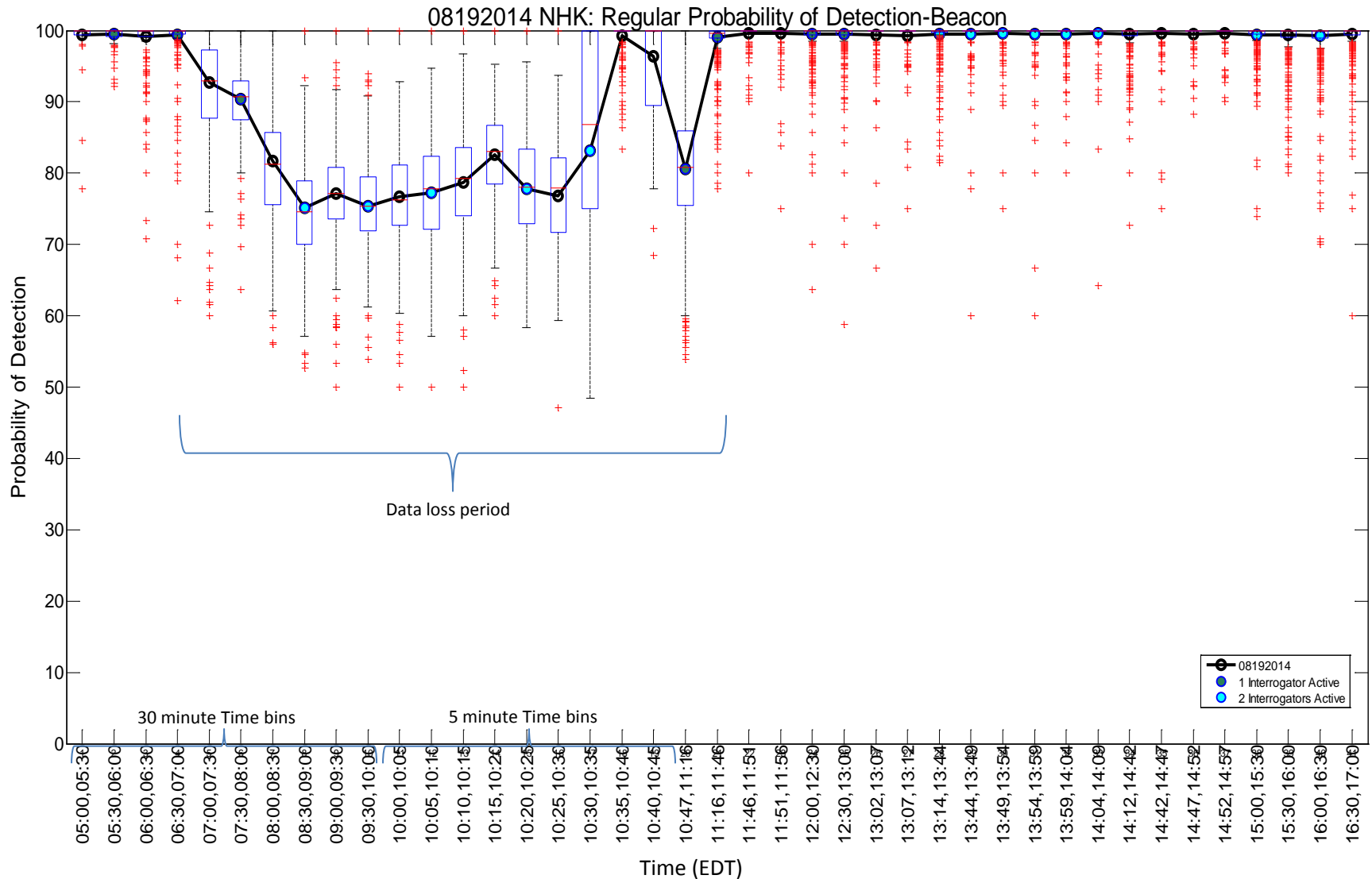
Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

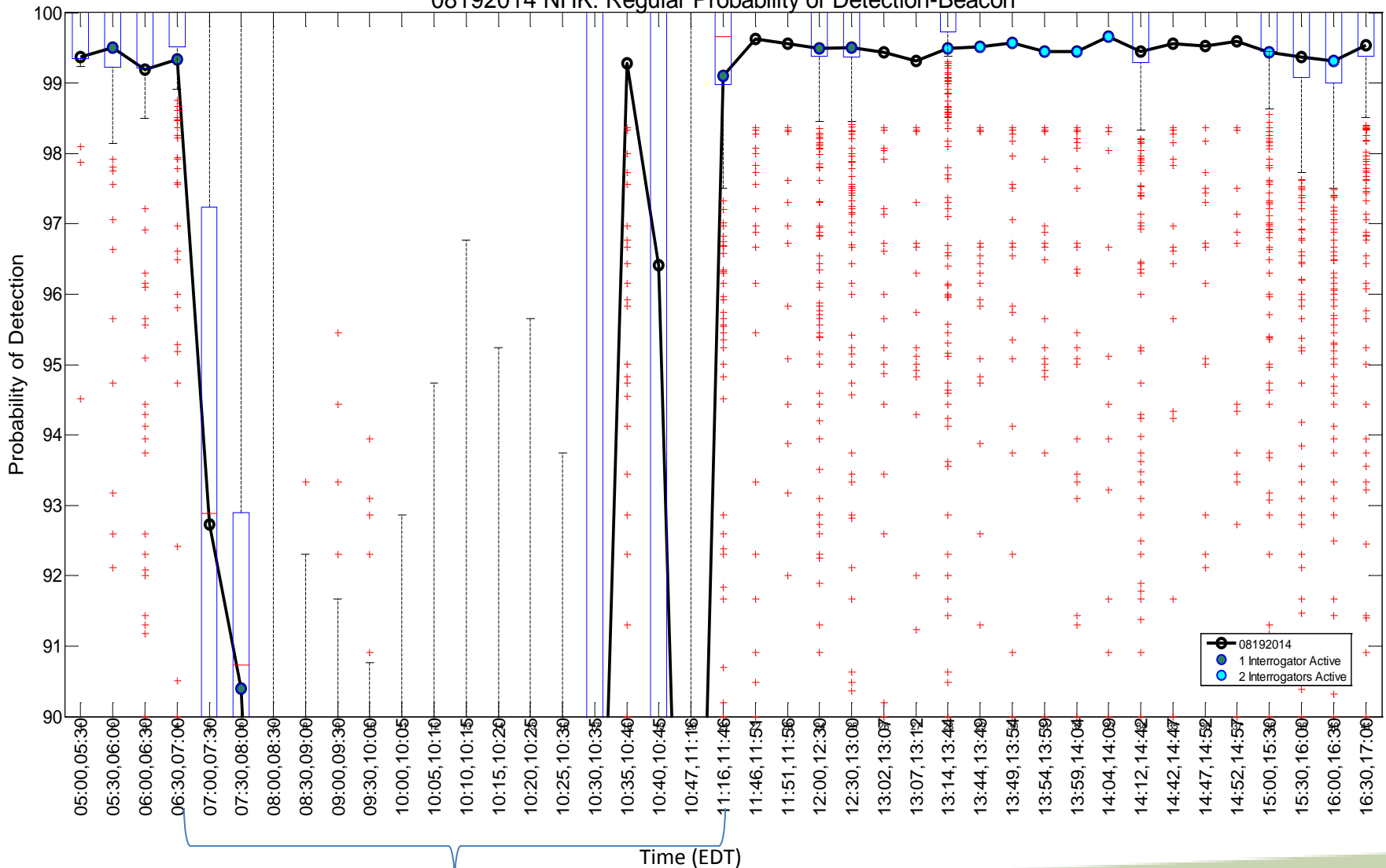
## Individual Aircraft Distribution



# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08192014 NHK: Regular Probability of Detection-Beacon

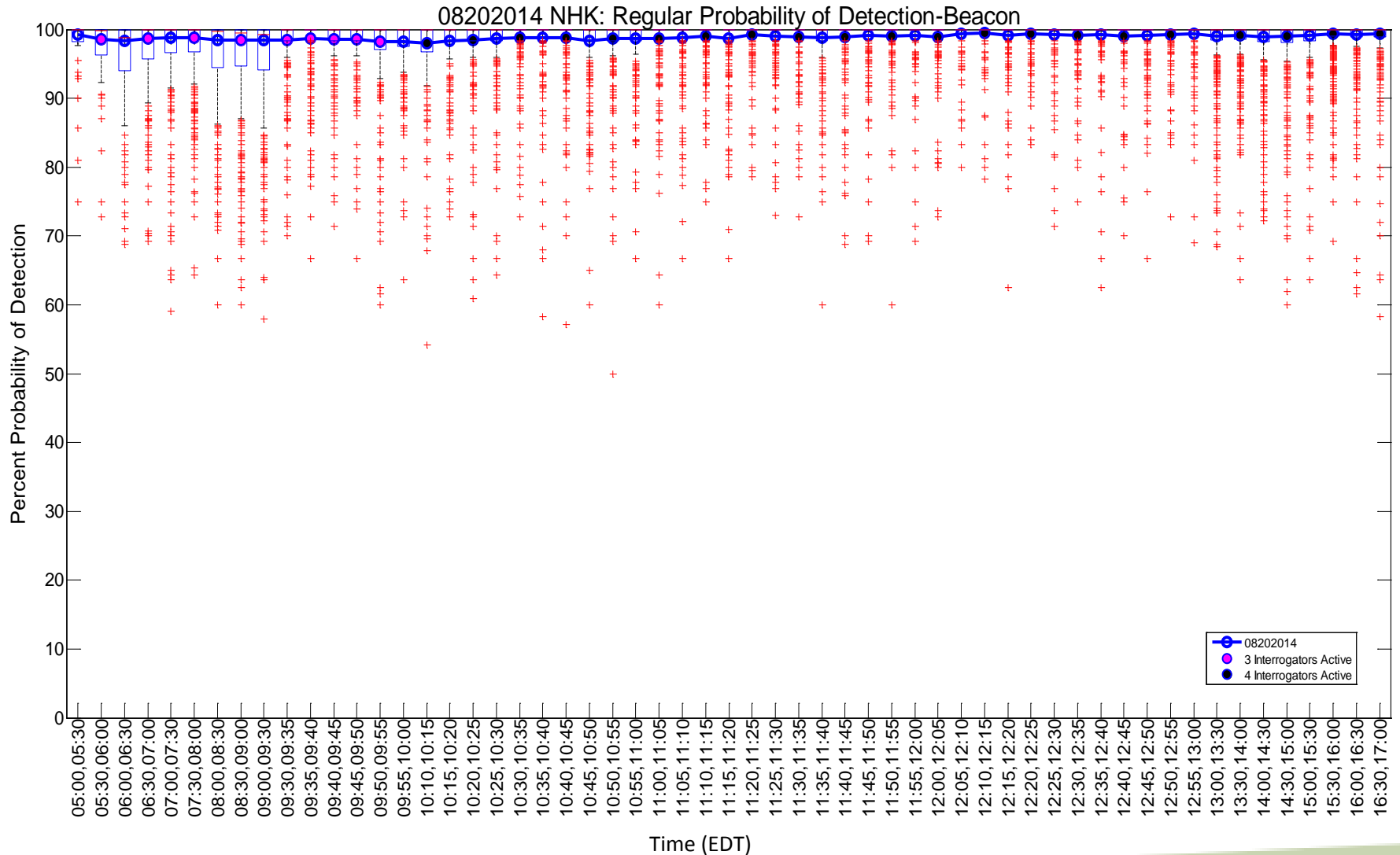


Geographic Filter: None  
Target Filter: None

Data loss period

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

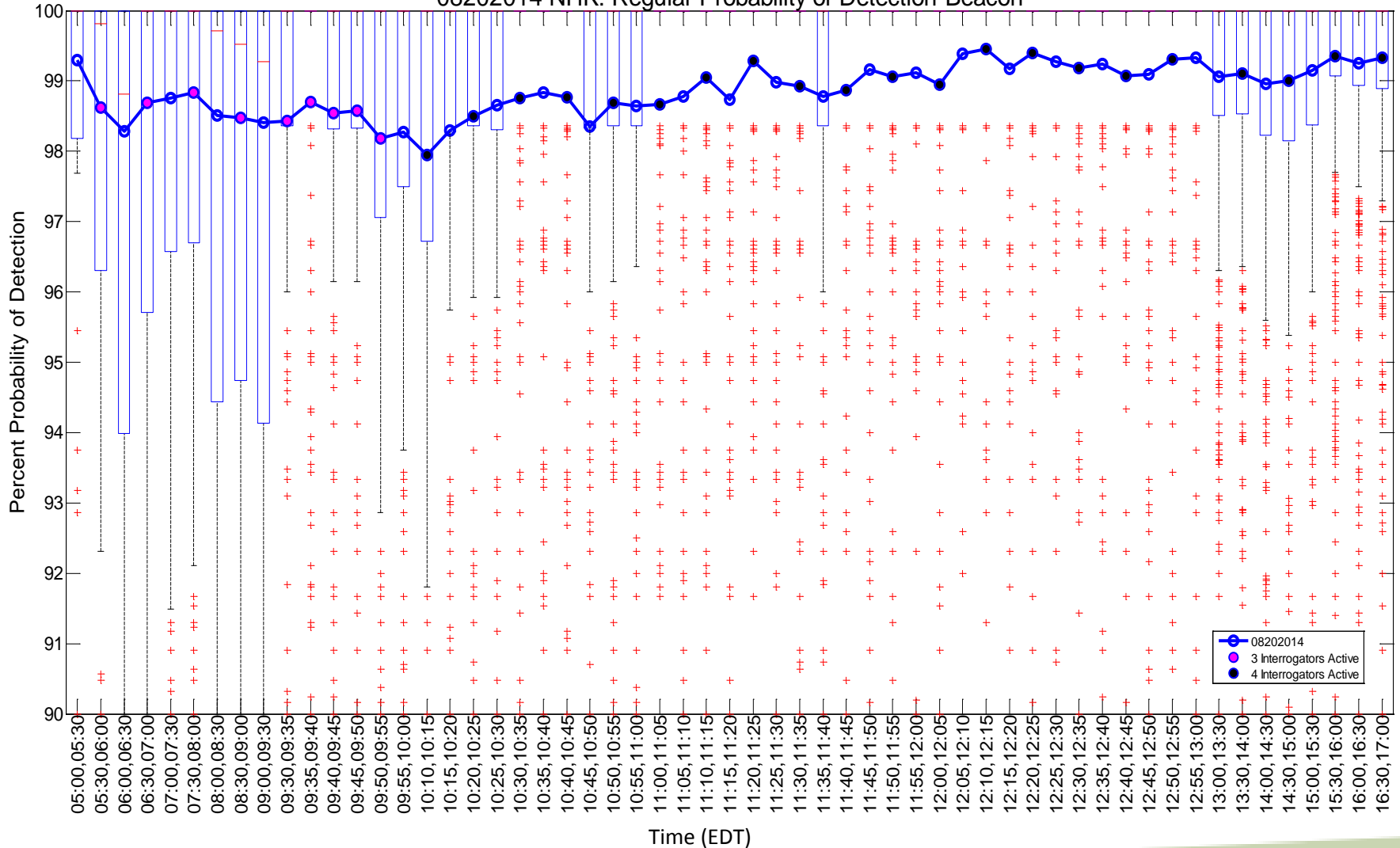


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08202014 NHK: Regular Probability of Detection-Beacon

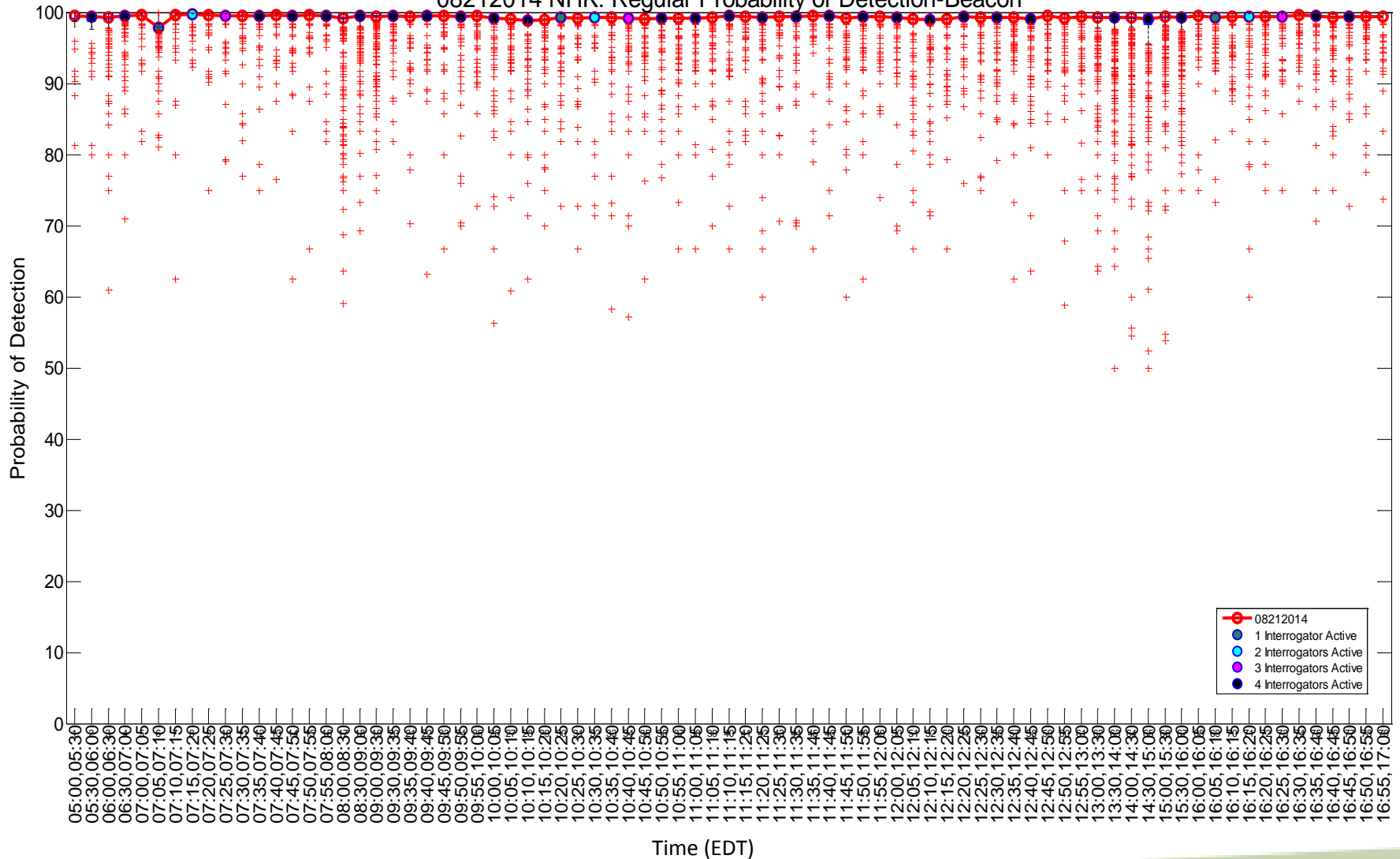


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

08212014 NHK: Regular Probability of Detection-Beacon

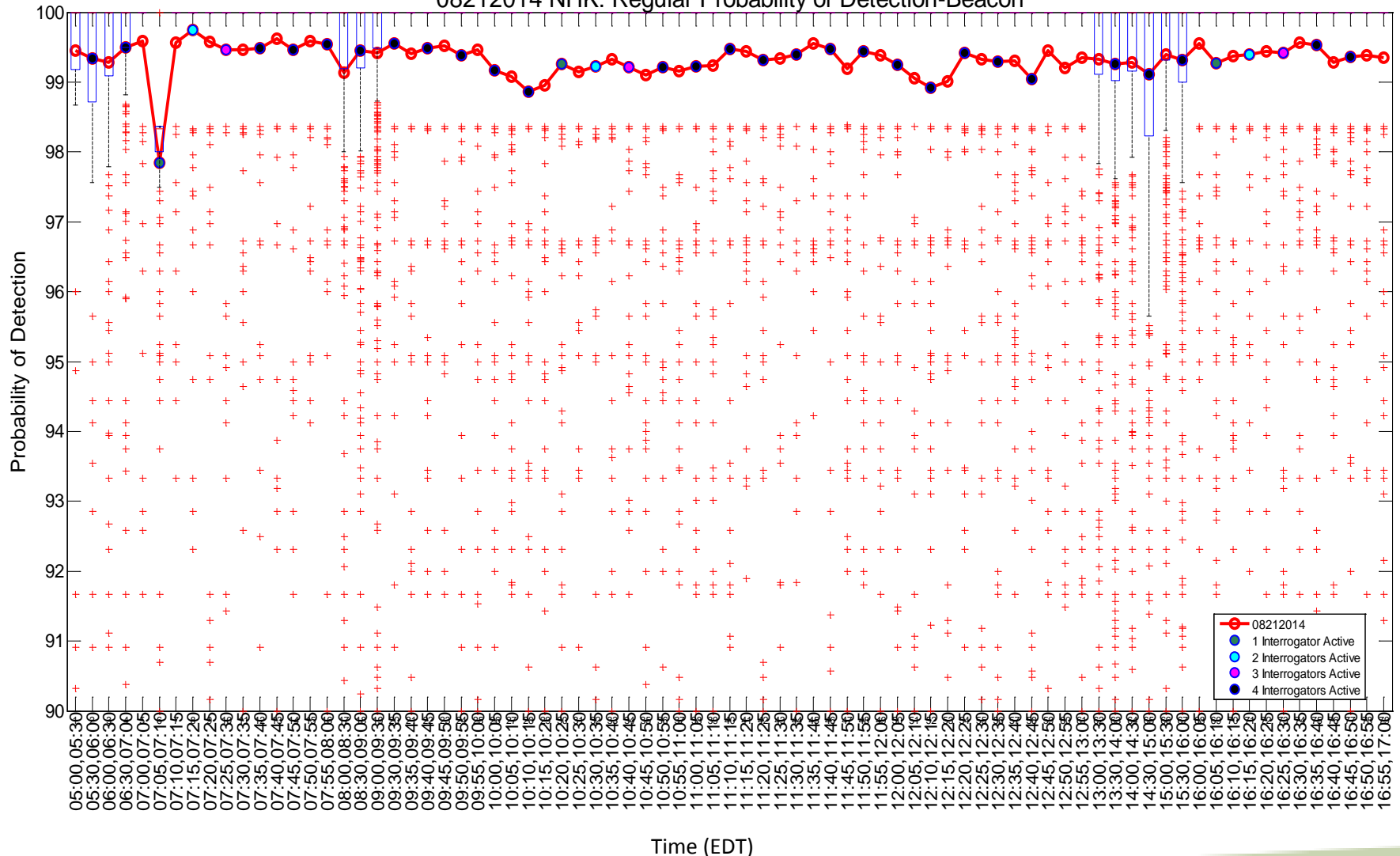


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)

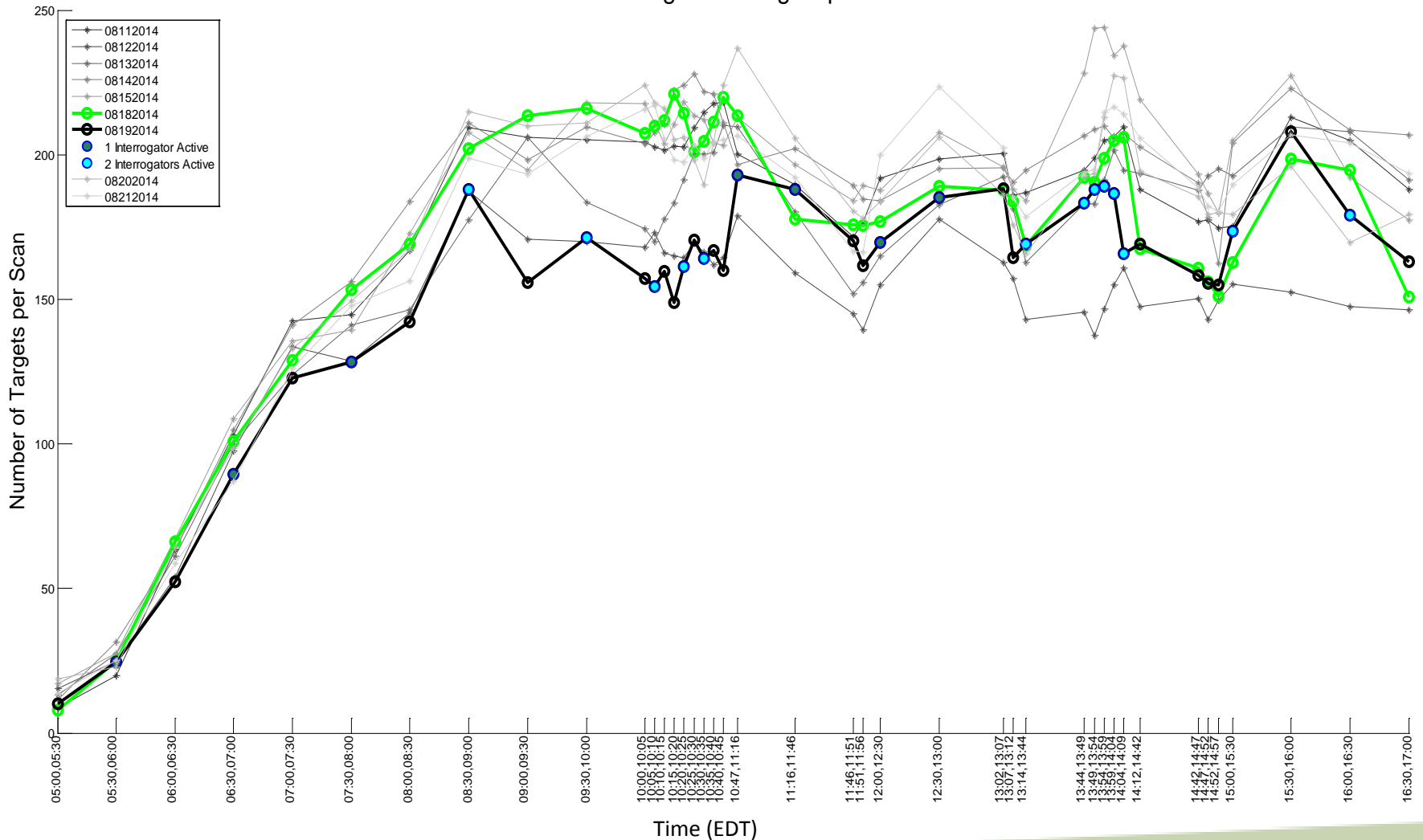
08212014 NHK: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 19<sup>th</sup>

Total Average # of Targets per Scan

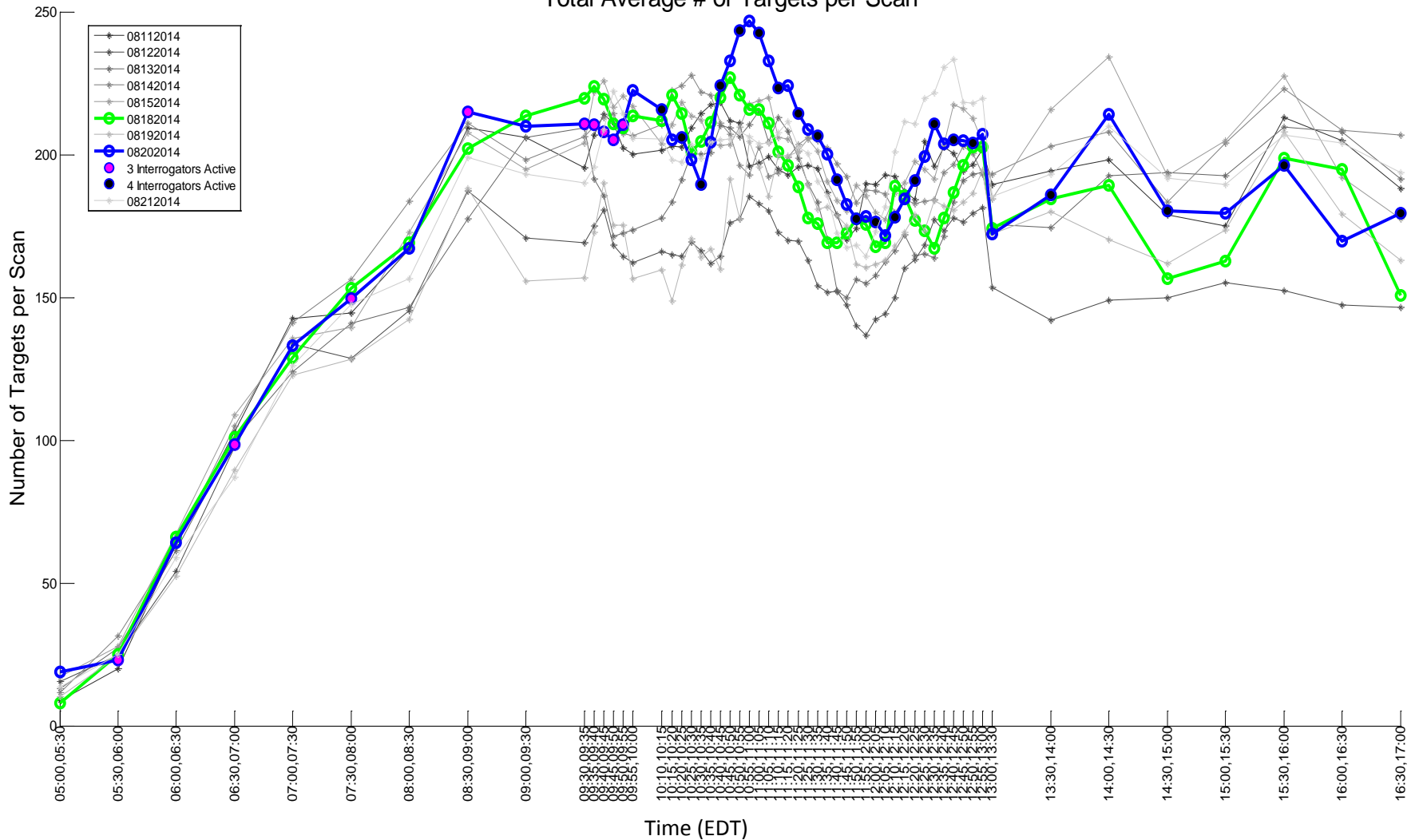


Geographic Filter: None  
Target Filter: None



# Targets per Scan – August 20<sup>th</sup>

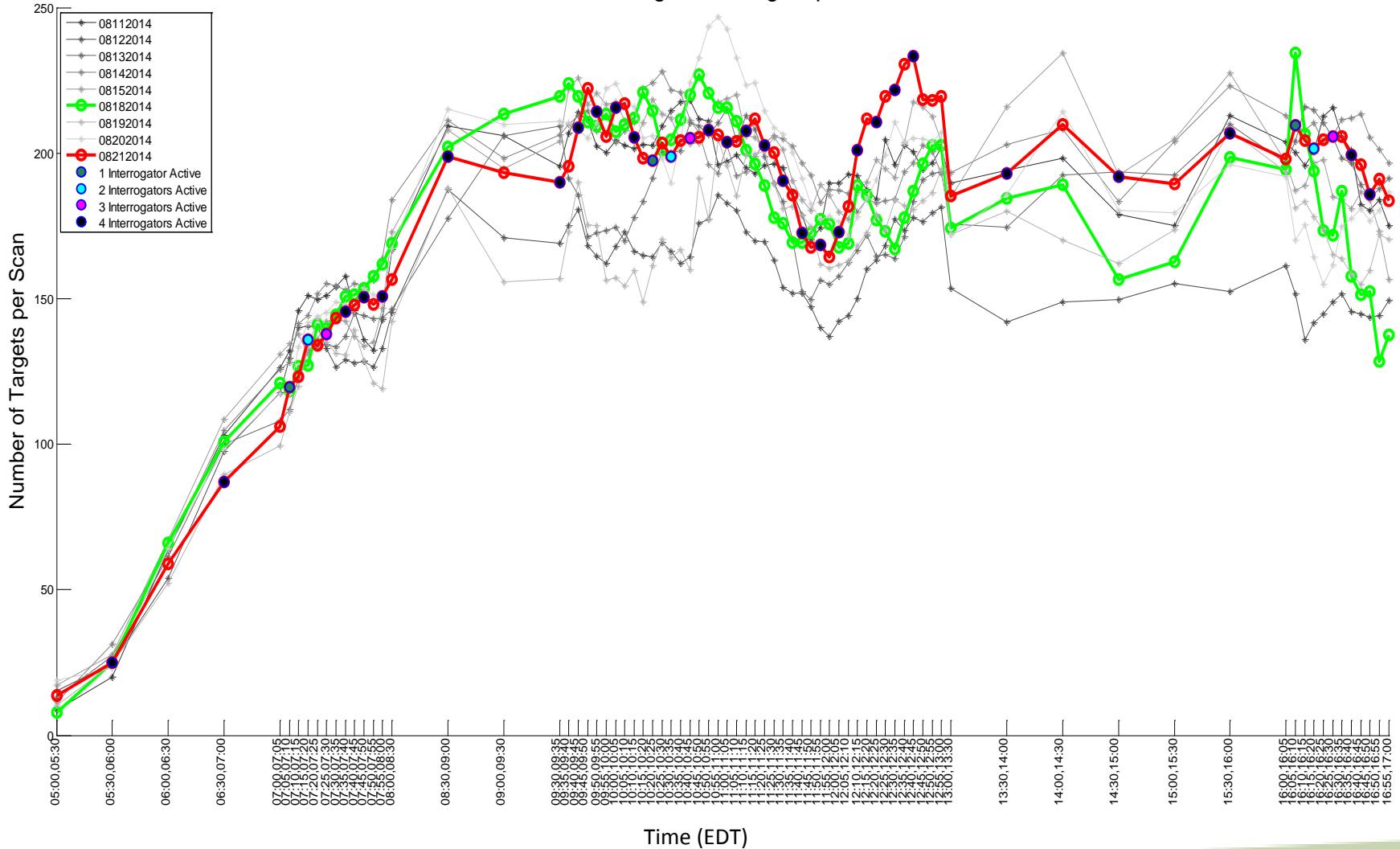
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 21<sup>st</sup>

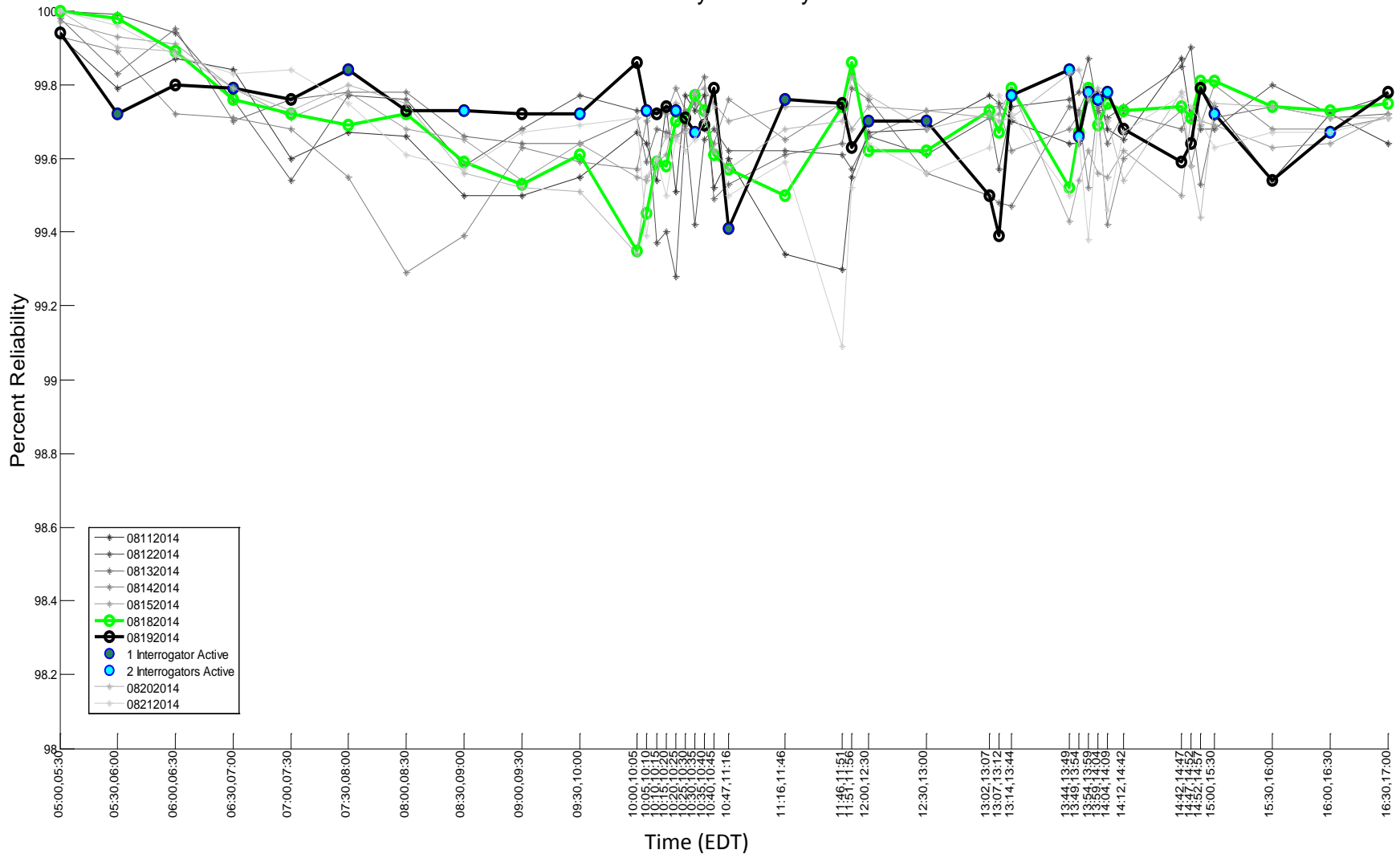
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

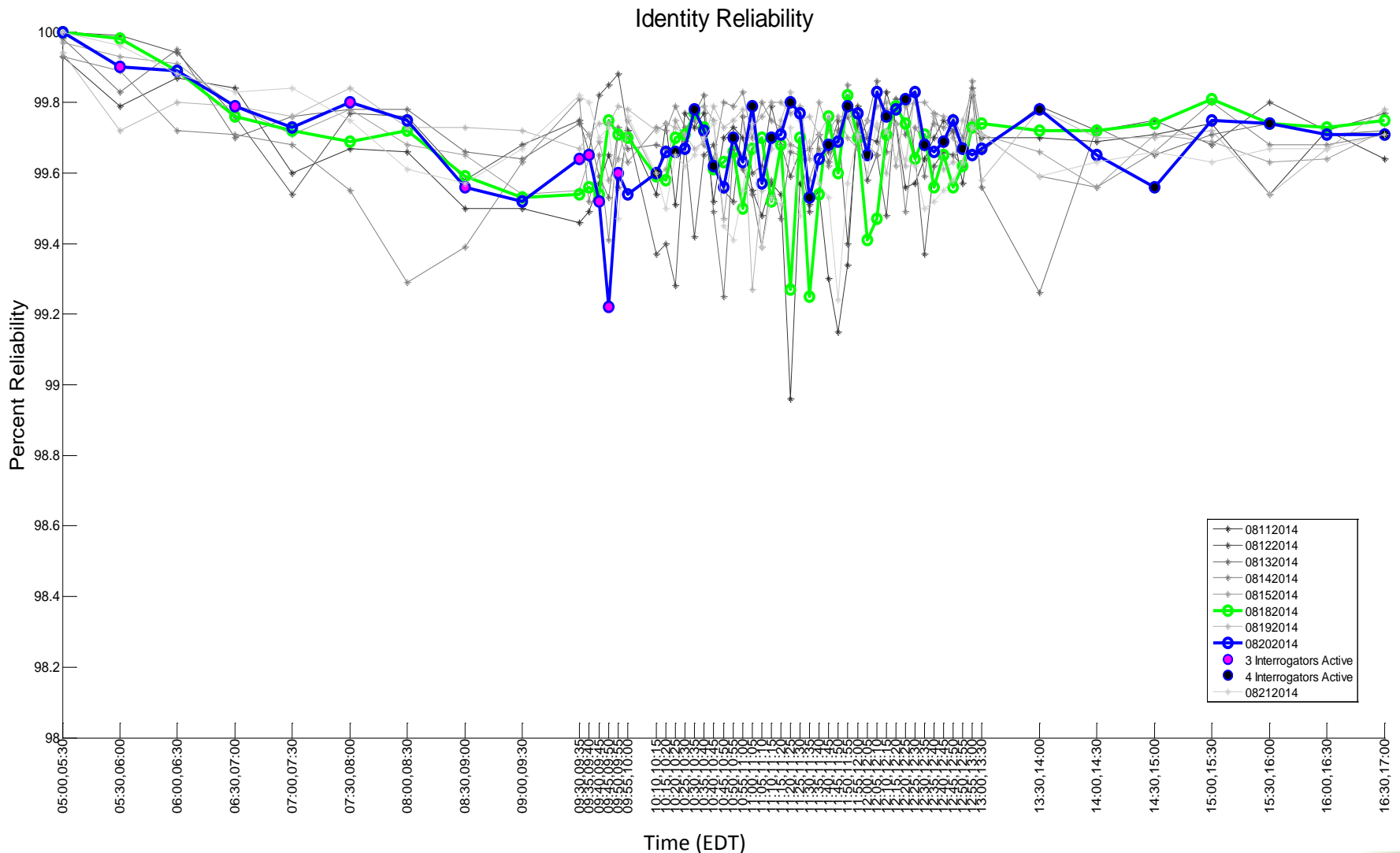
# Identity (3/A) Reliability – August 19th

Identity Reliability



Geographic Filter: None  
Target Filter: None

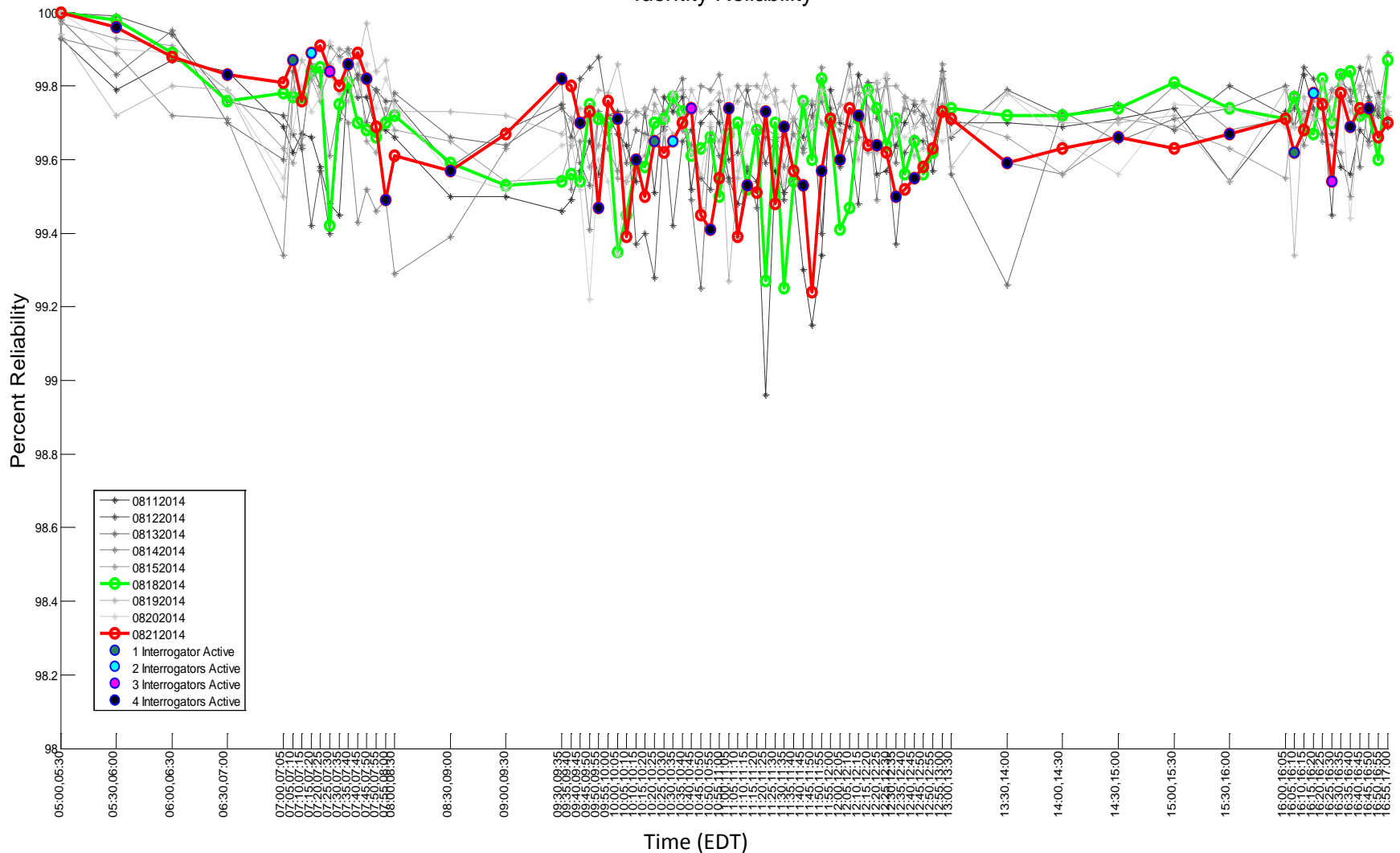
# Identity (3/A) Reliability – August 20<sup>th</sup>



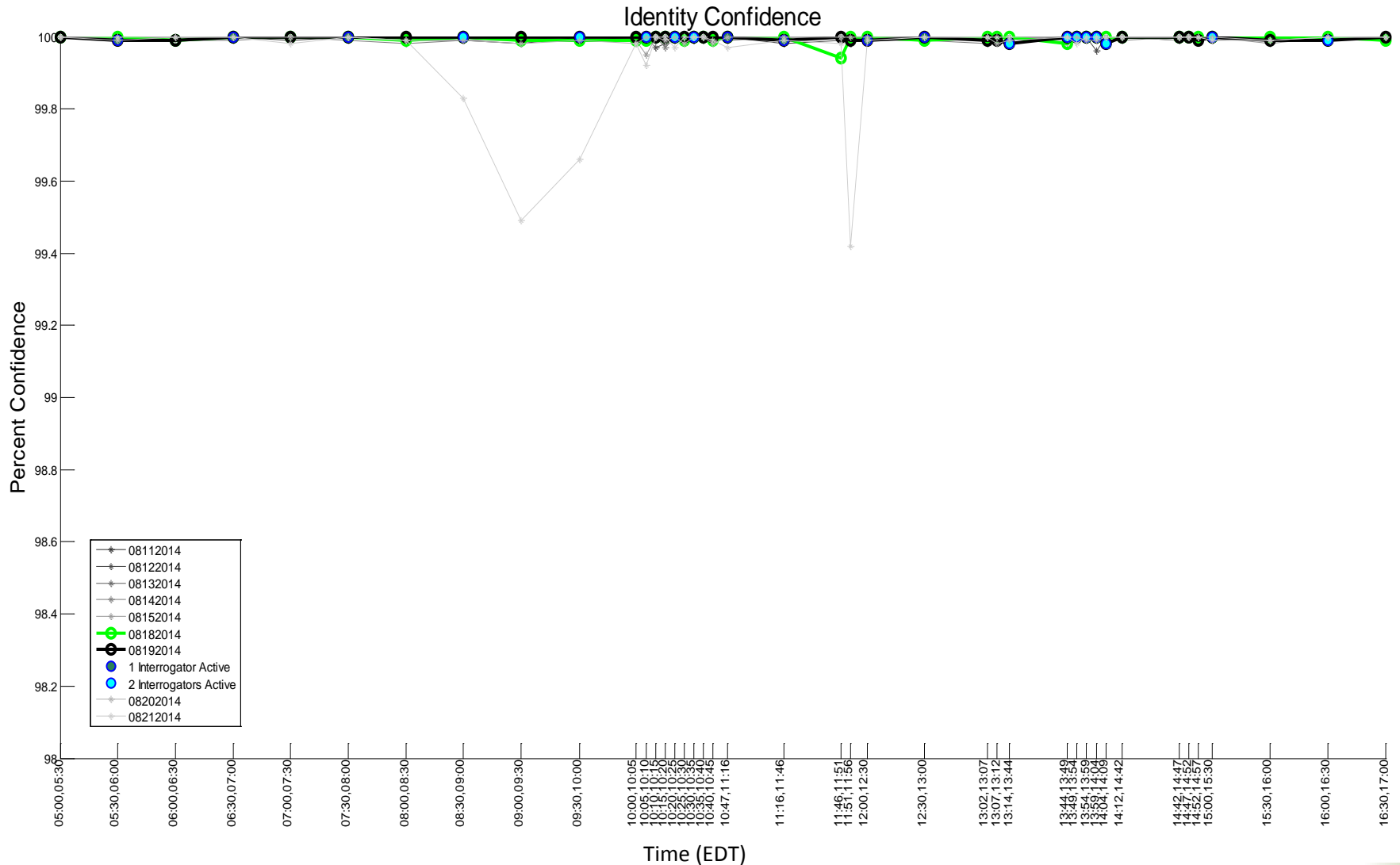
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 21<sup>st</sup>

Identity Reliability

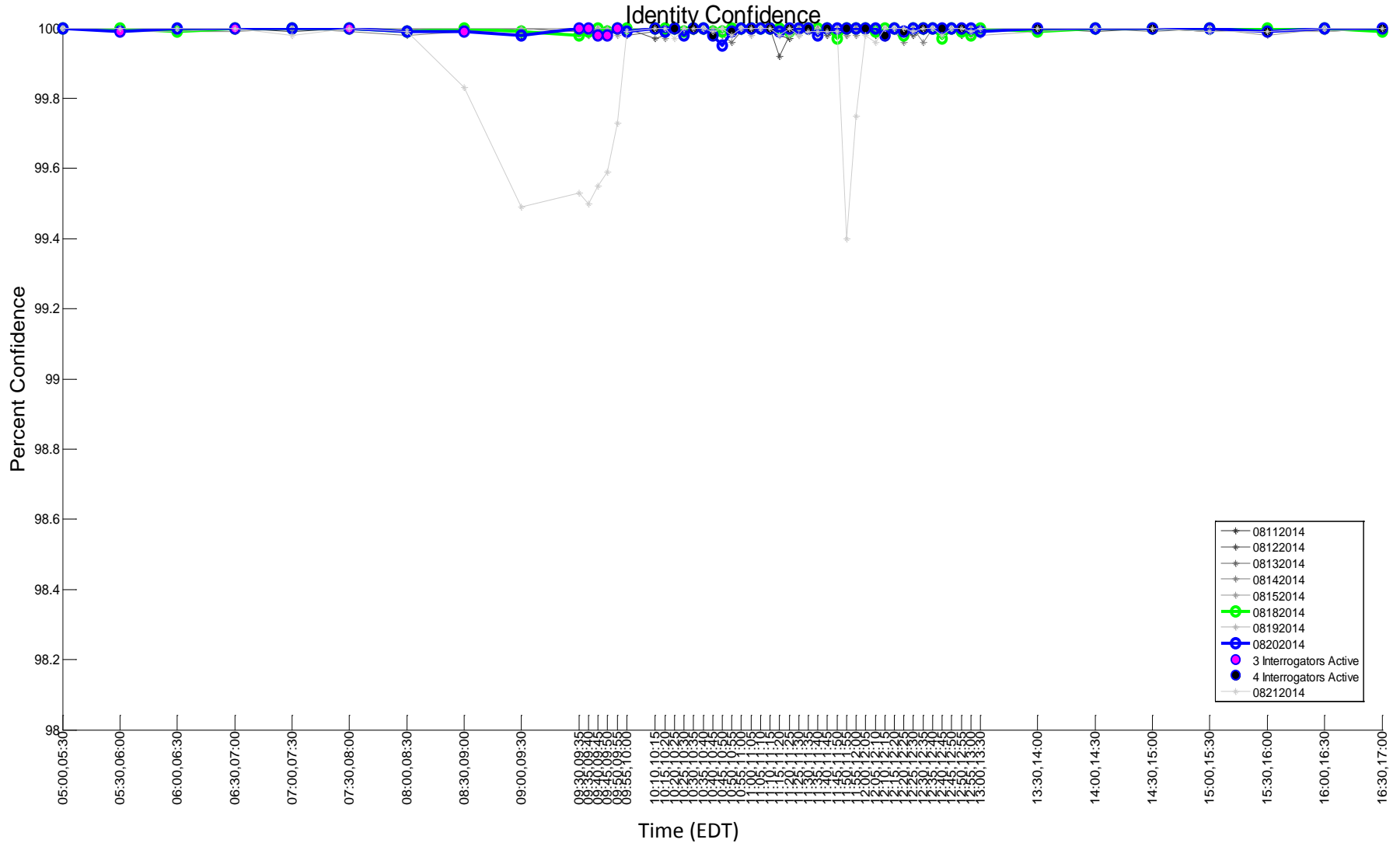


# Identity (3/A) Confidence – August 19th



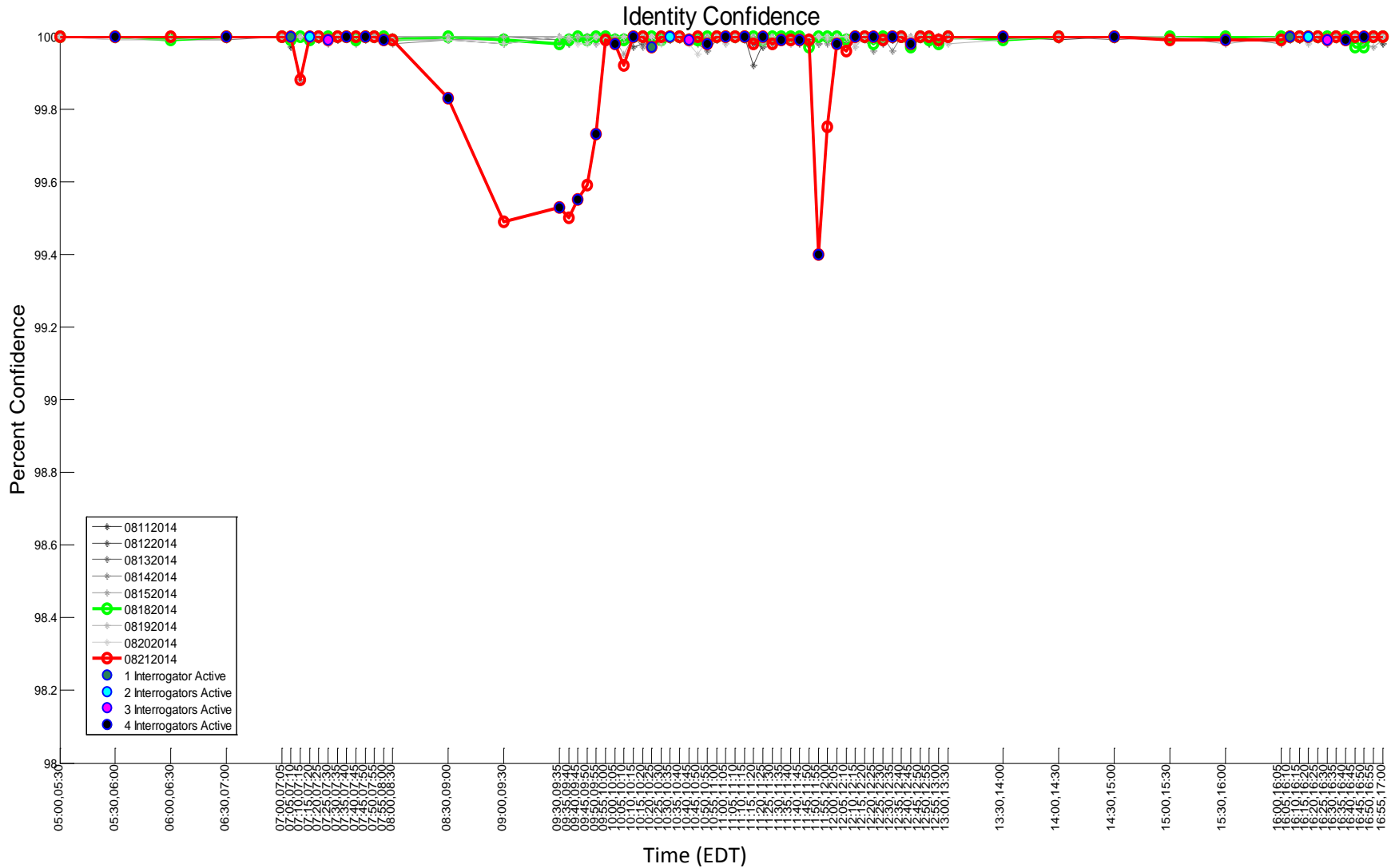
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

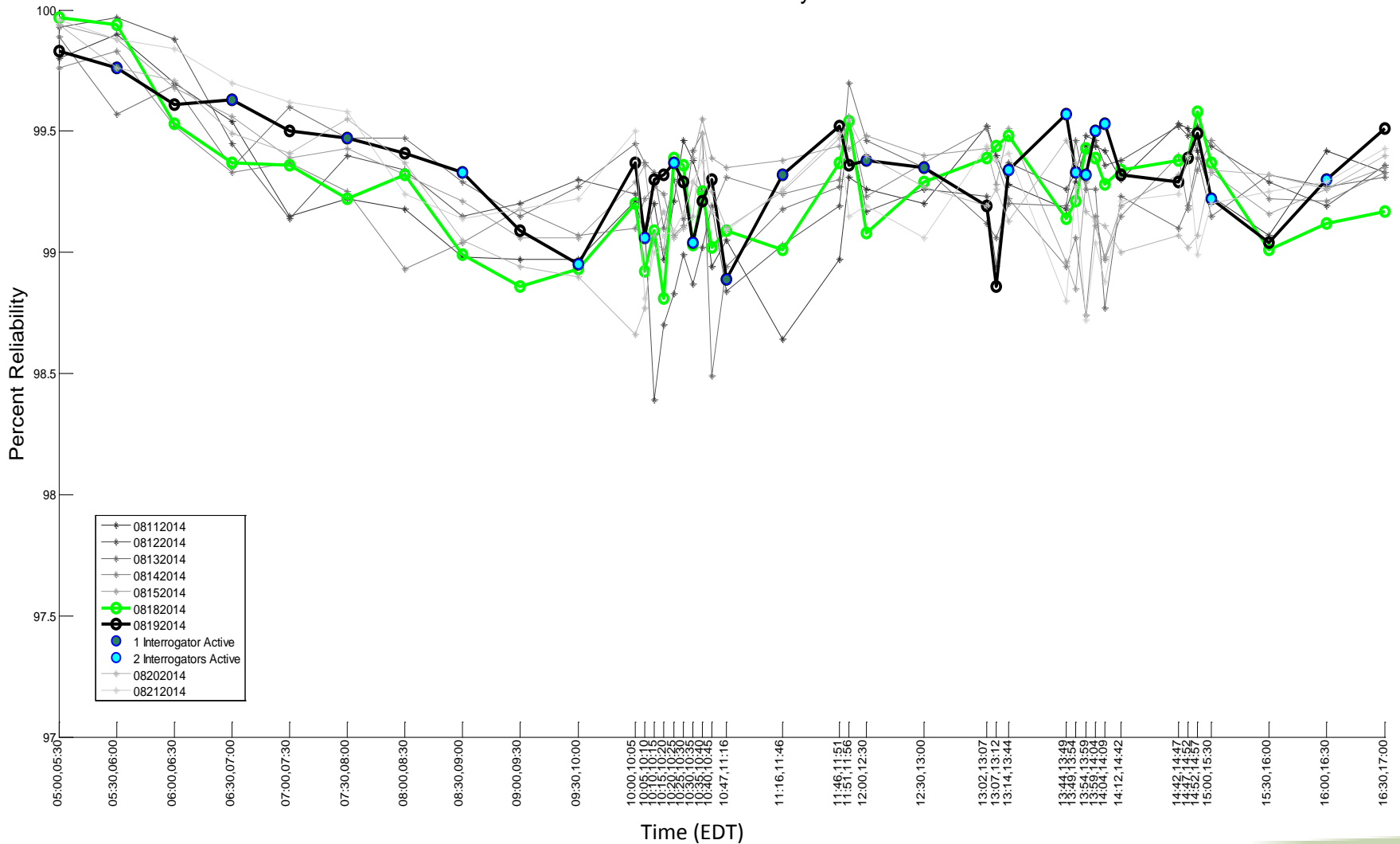
# Identity (3/A) Confidence – August 21<sup>st</sup>





# Altitude (C) Reliability – August 19th

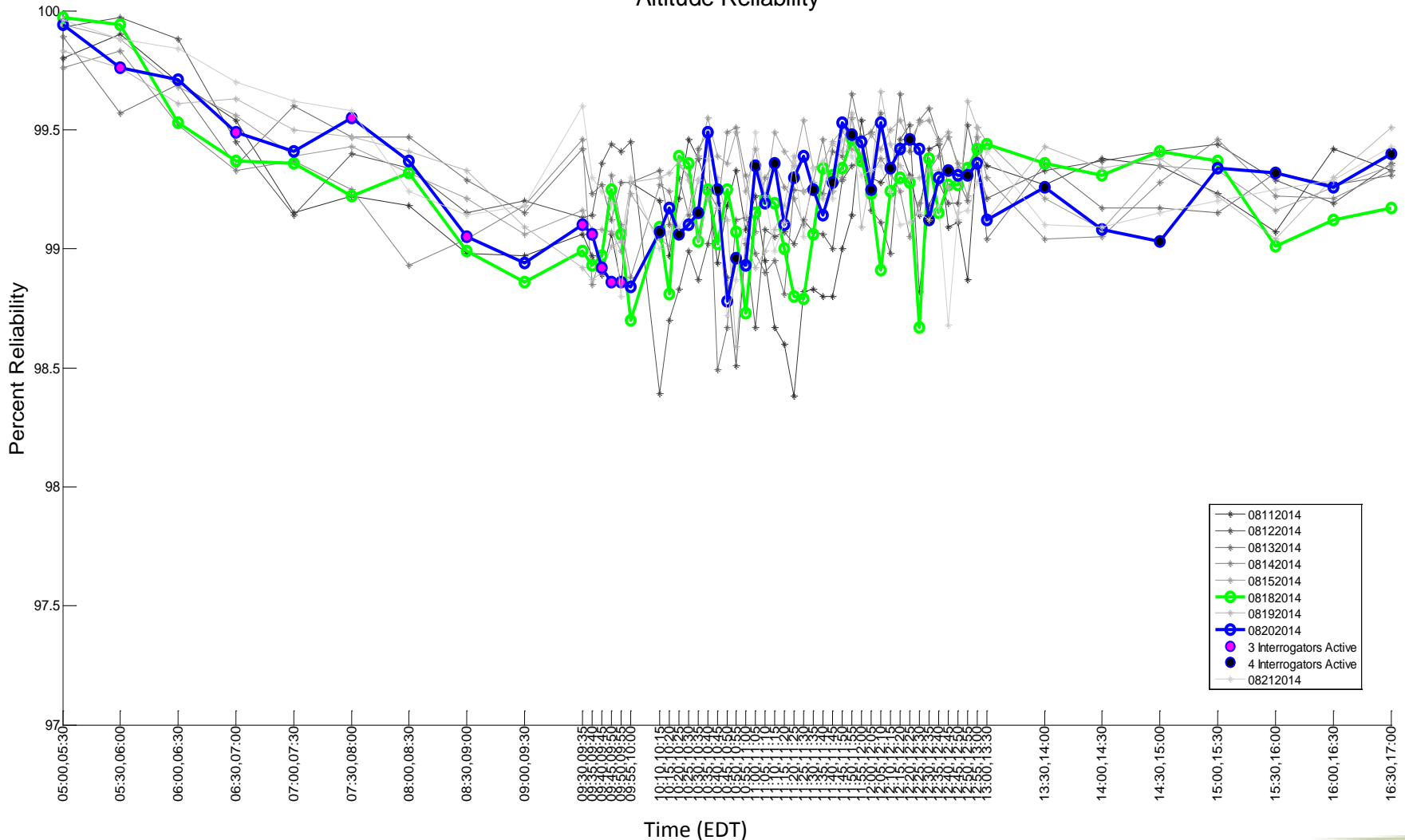
Altitude Reliability



Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 20<sup>th</sup>

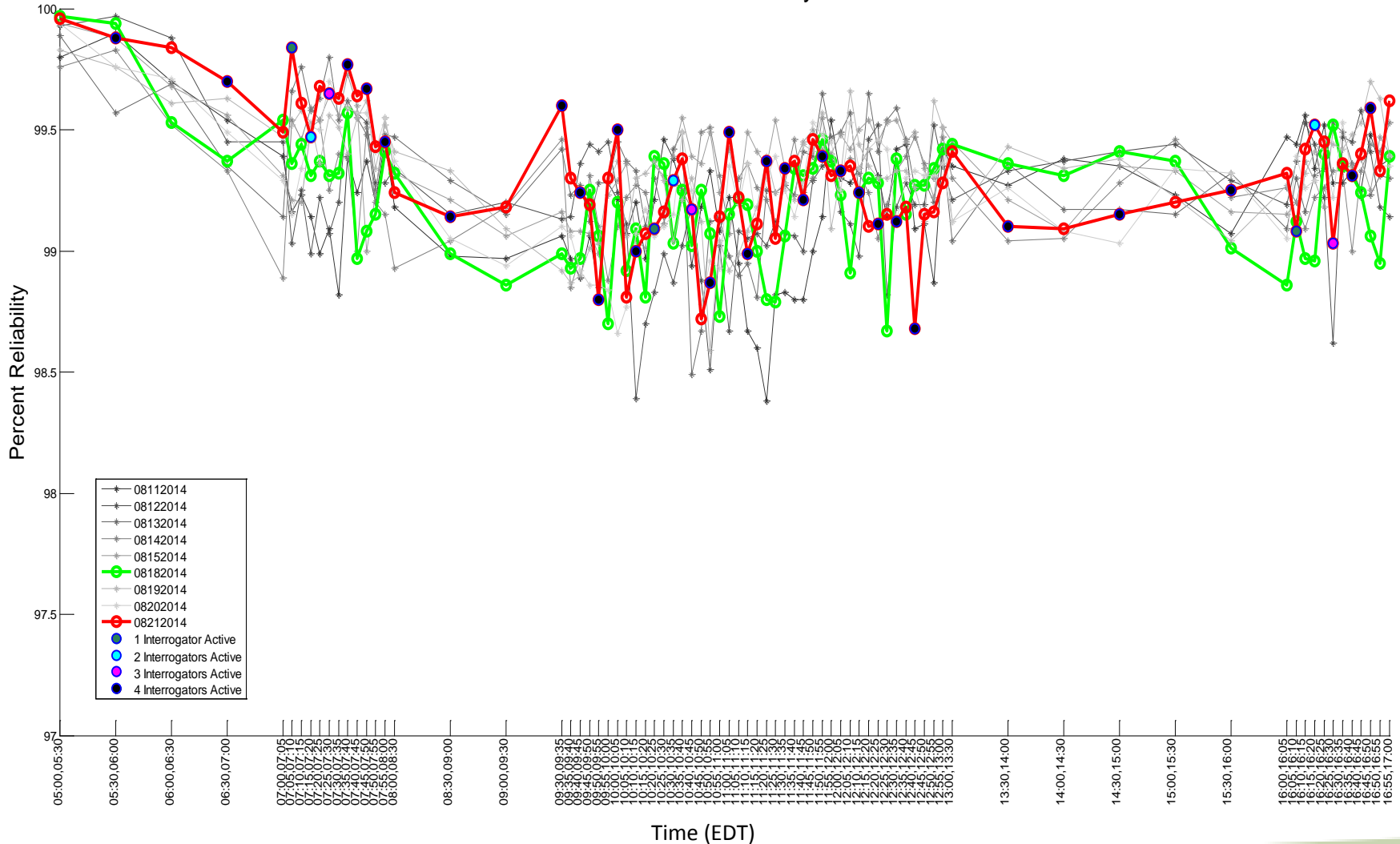
Altitude Reliability



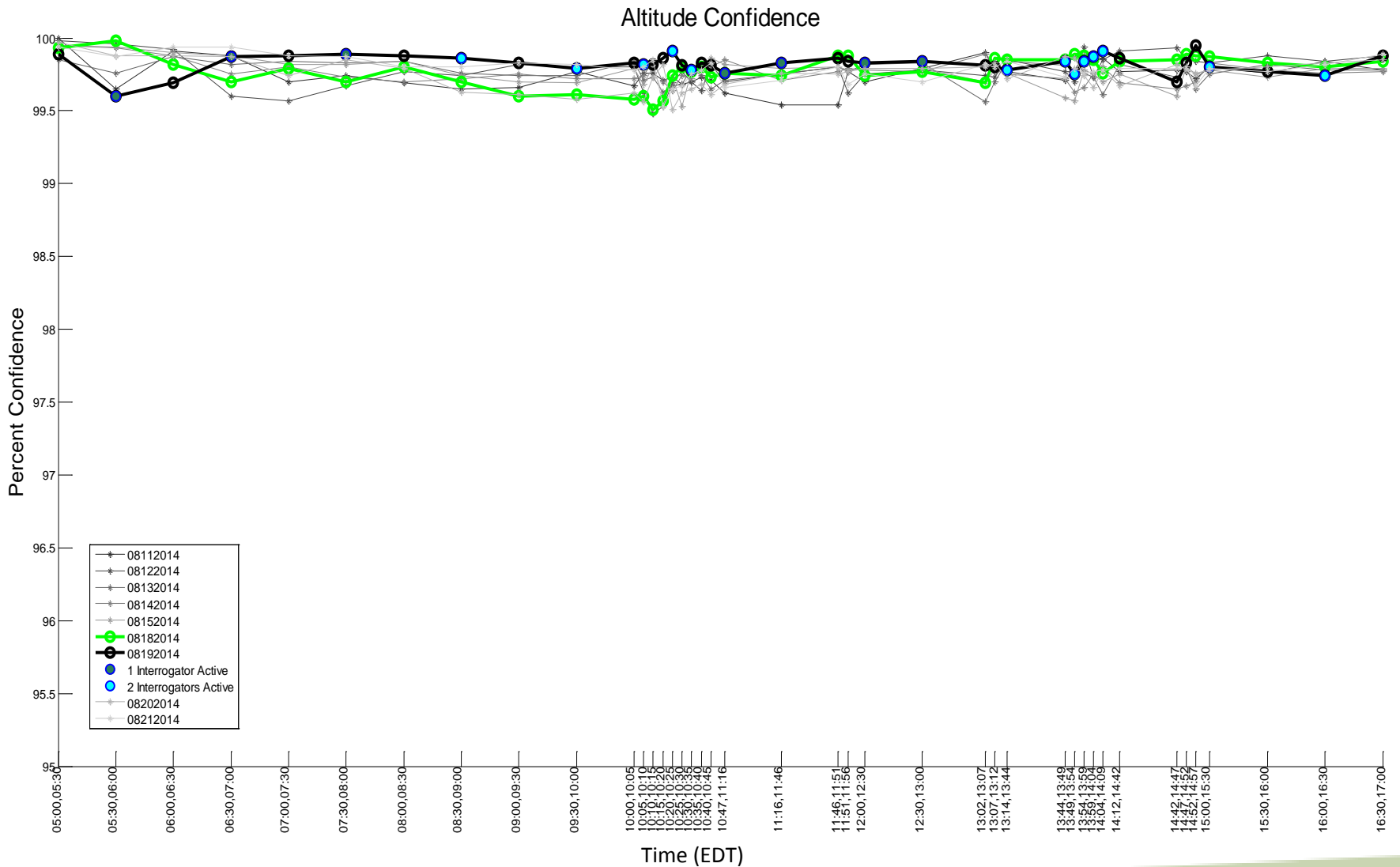
Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 21<sup>st</sup>

Altitude Reliability

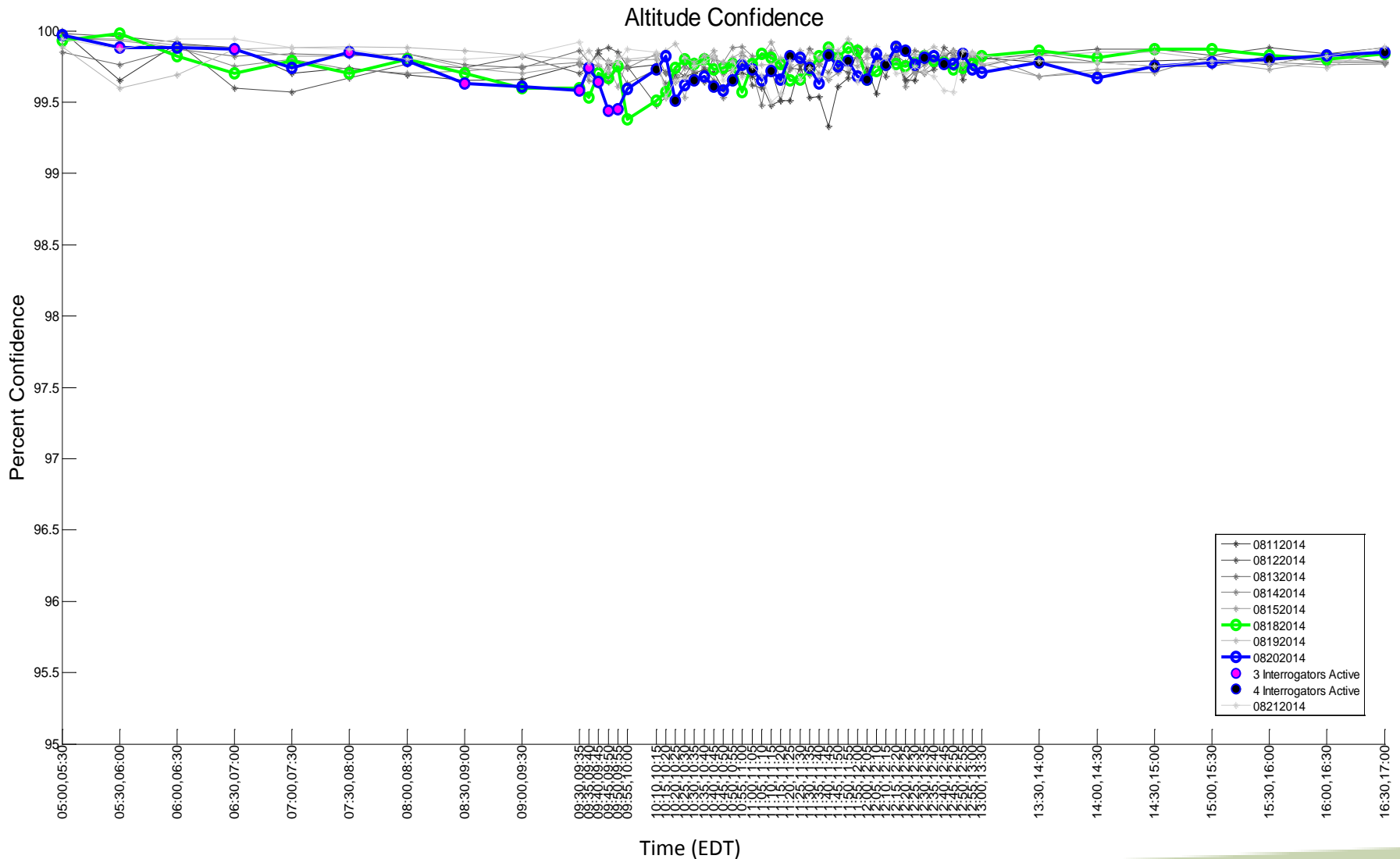


# Altitude (C) Confidence – August 19th



Geographic Filter: None  
Target Filter: None

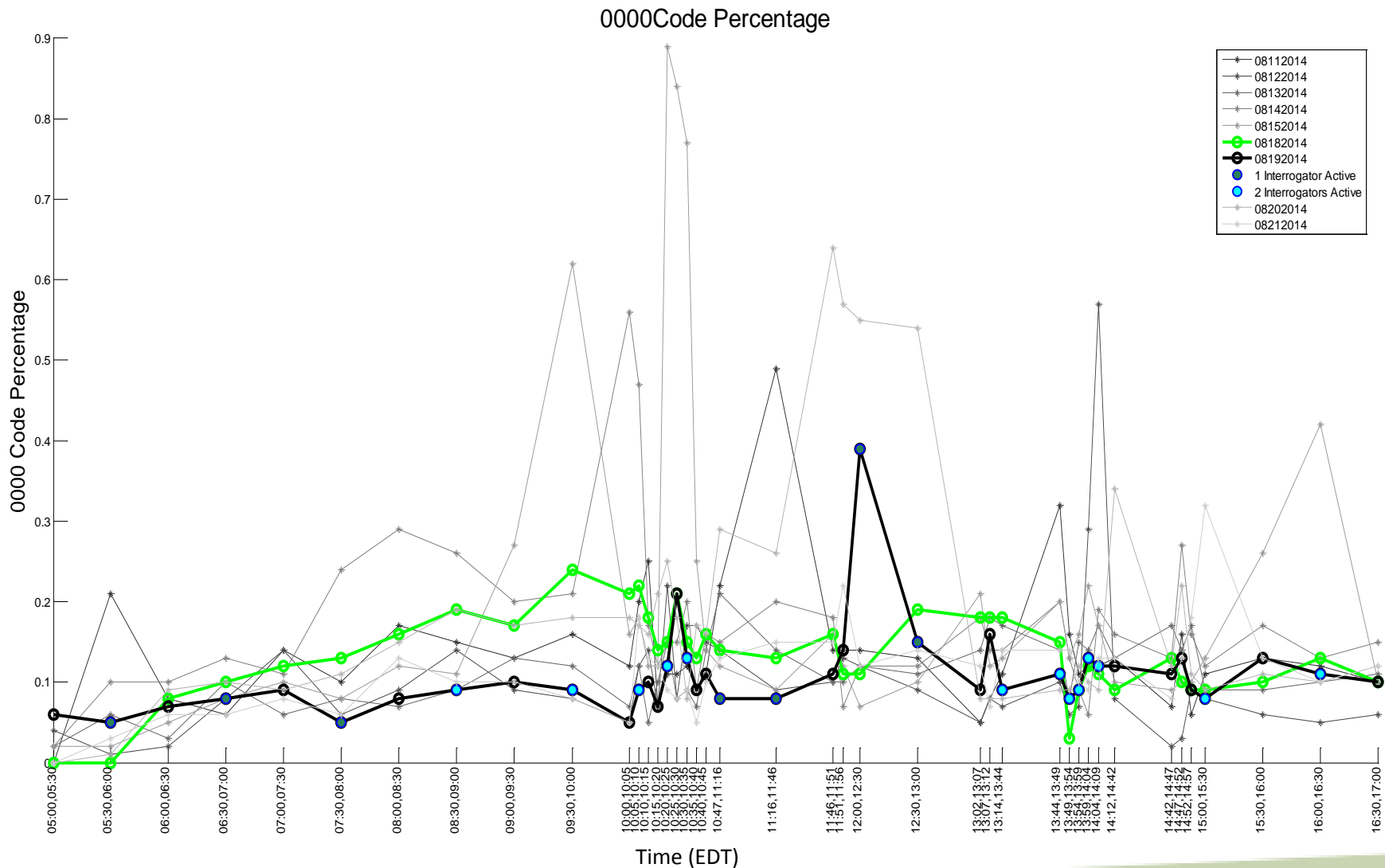
# Altitude (C) Confidence – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

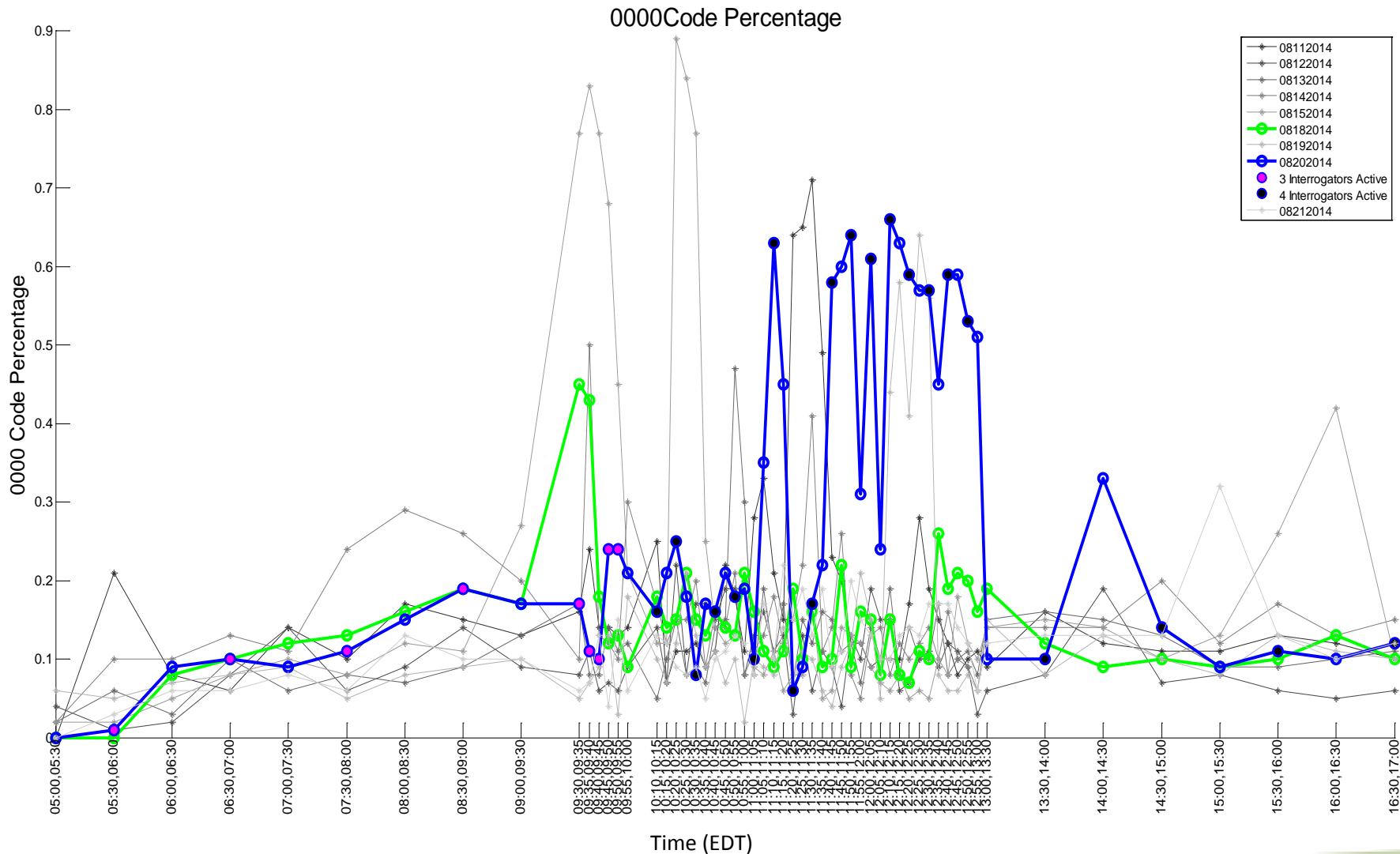


# 0000 Codes – August 19th



Geographic Filter: None  
Target Filter: None

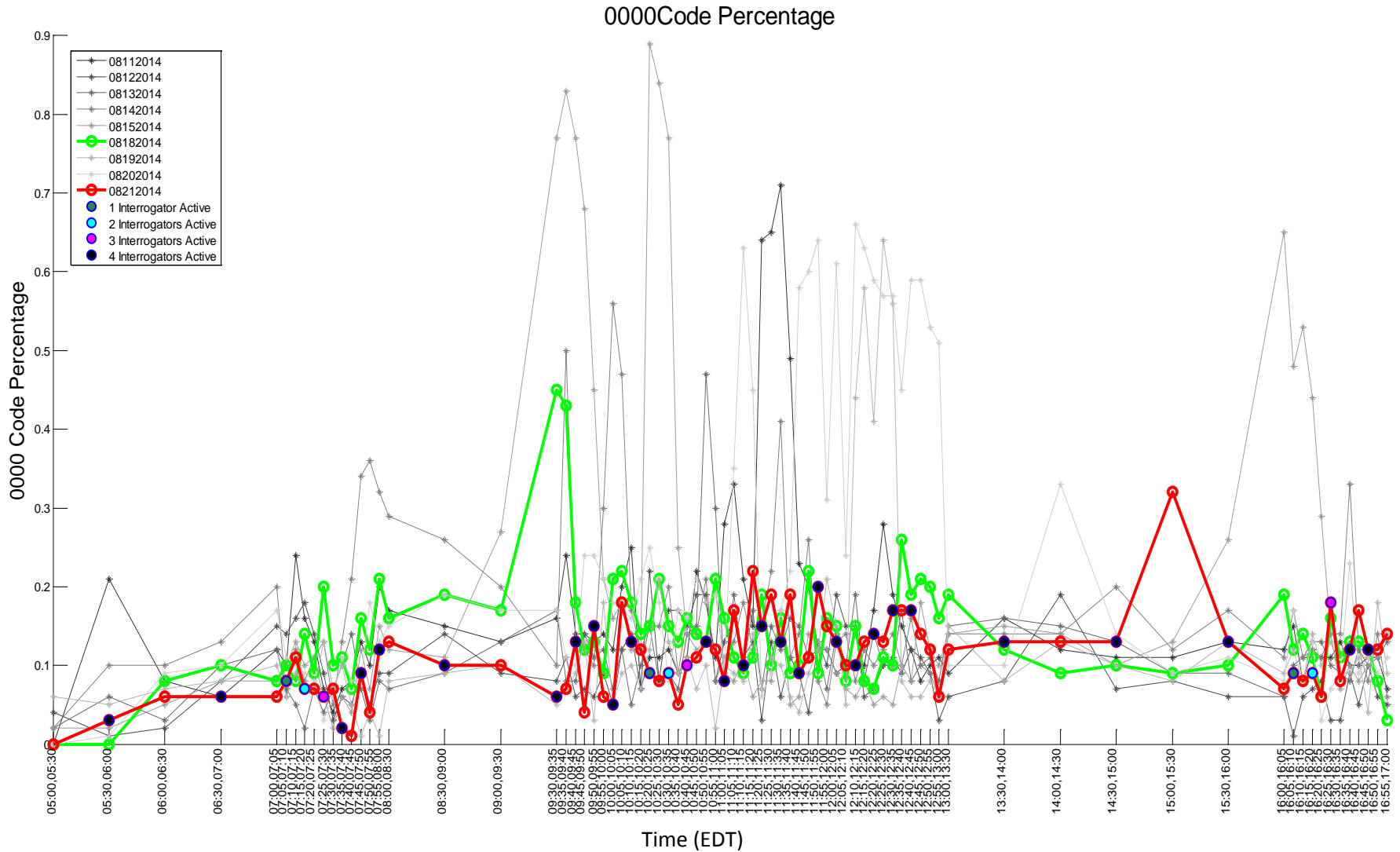
# 0000 Codes – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None



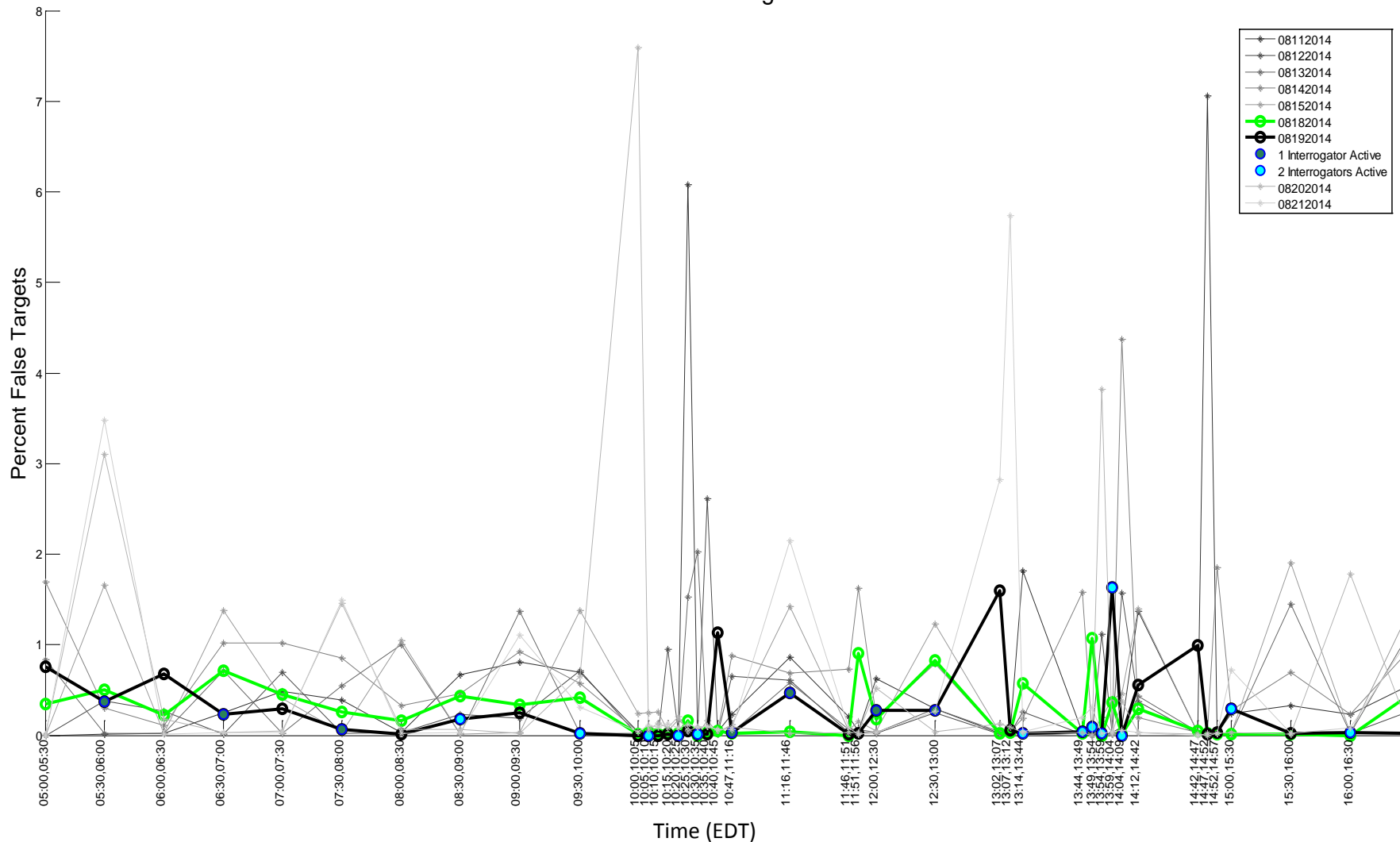
# 0000 Codes – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

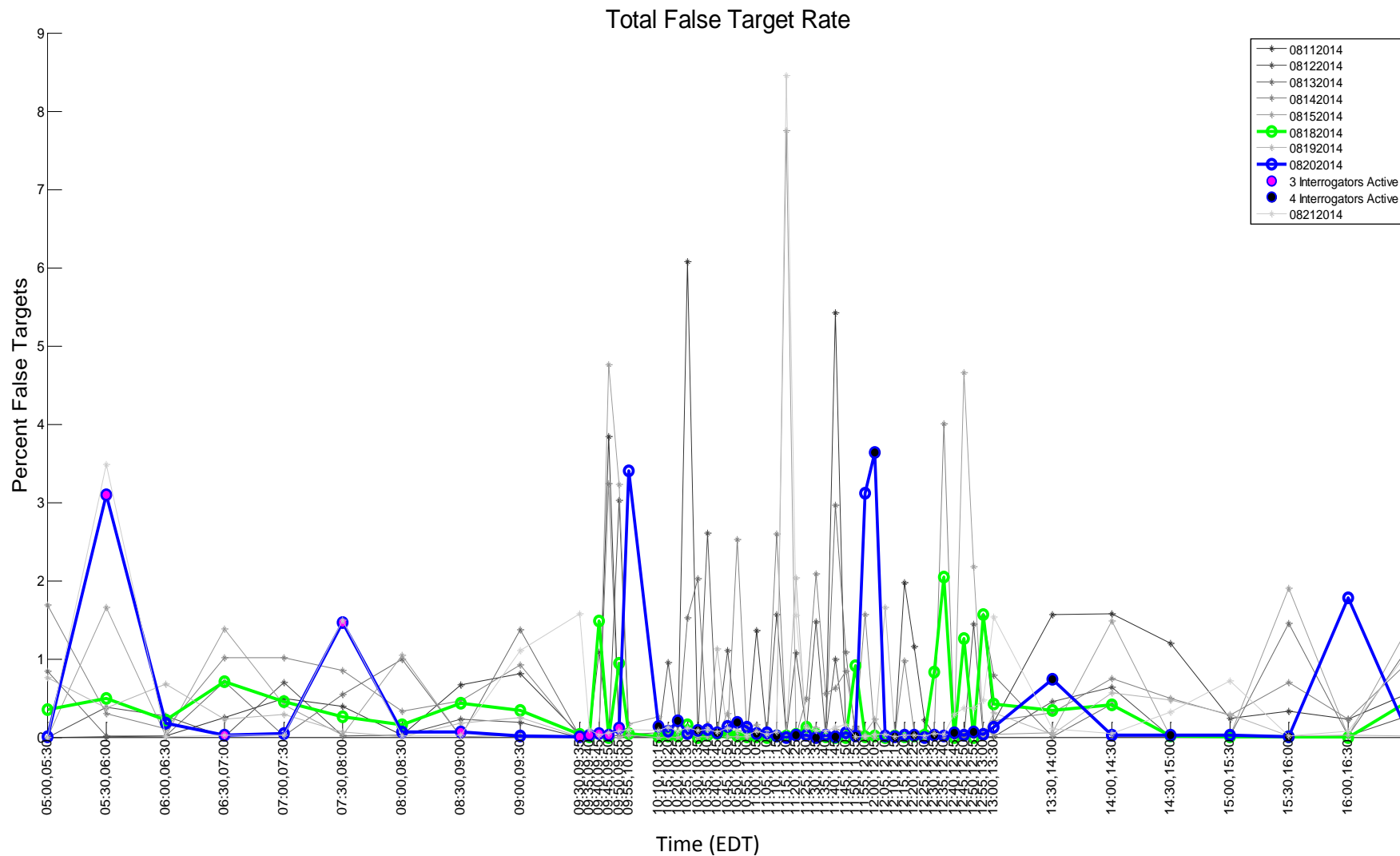
# False Targets – August 19th

Total False Target Rate



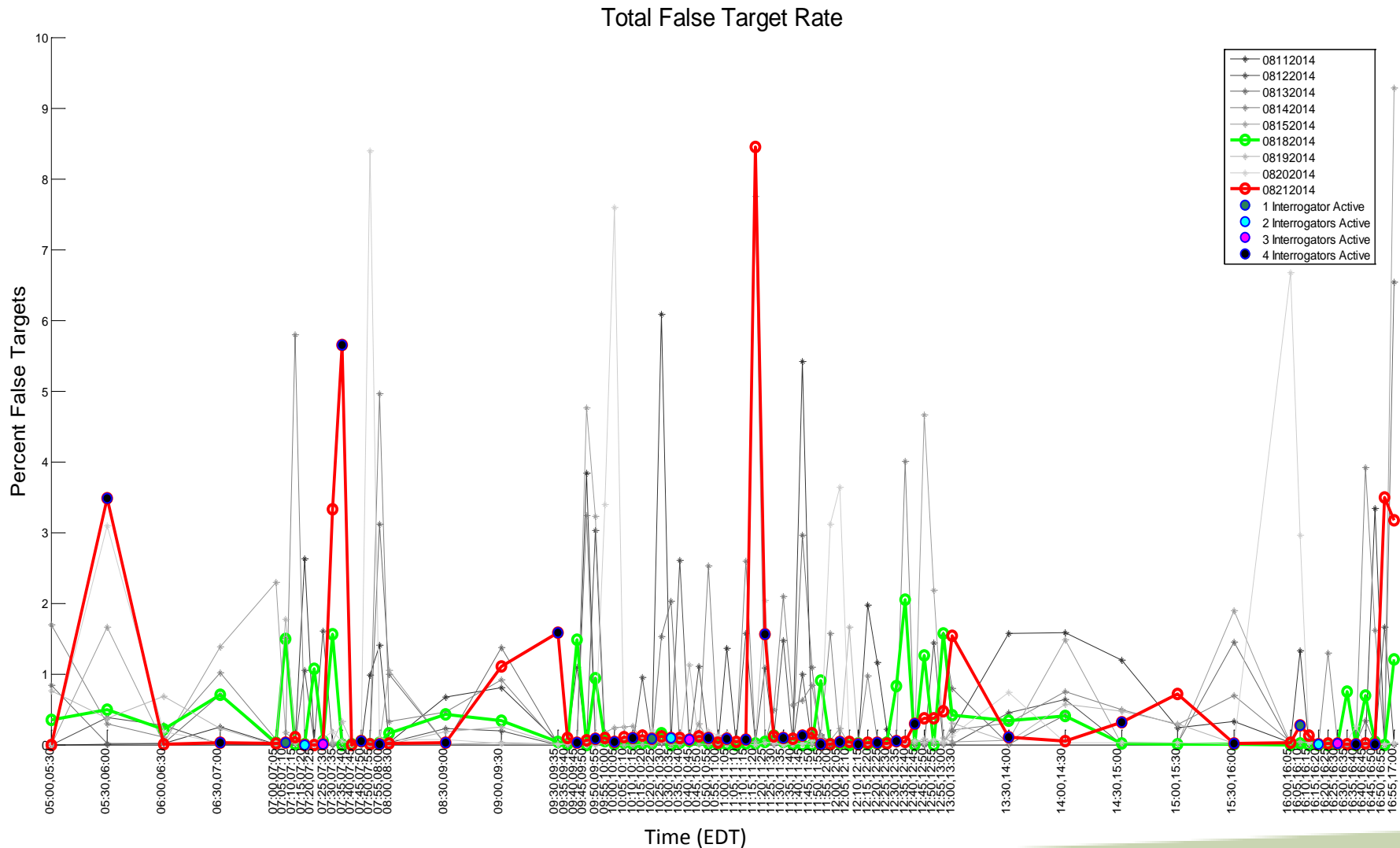
Geographic Filter: None  
Target Filter: None

# False Targets – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

# False Targets – August 21<sup>st</sup>



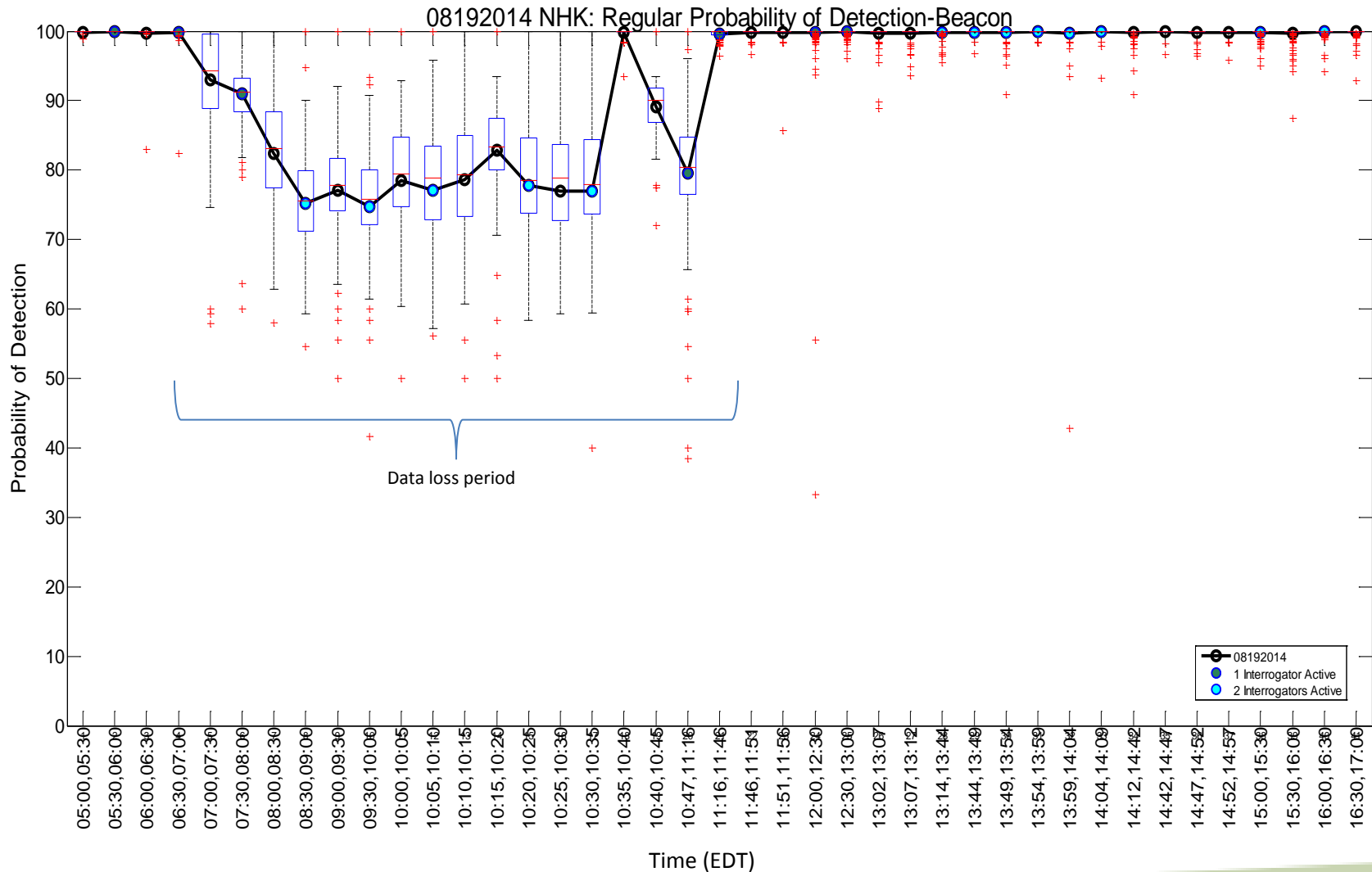
Geographic Filter: None  
Target Filter: None

# Target Metrics with Elevation Angle Greater than Two Degrees

*\* Number of Targets Unavailable*

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution

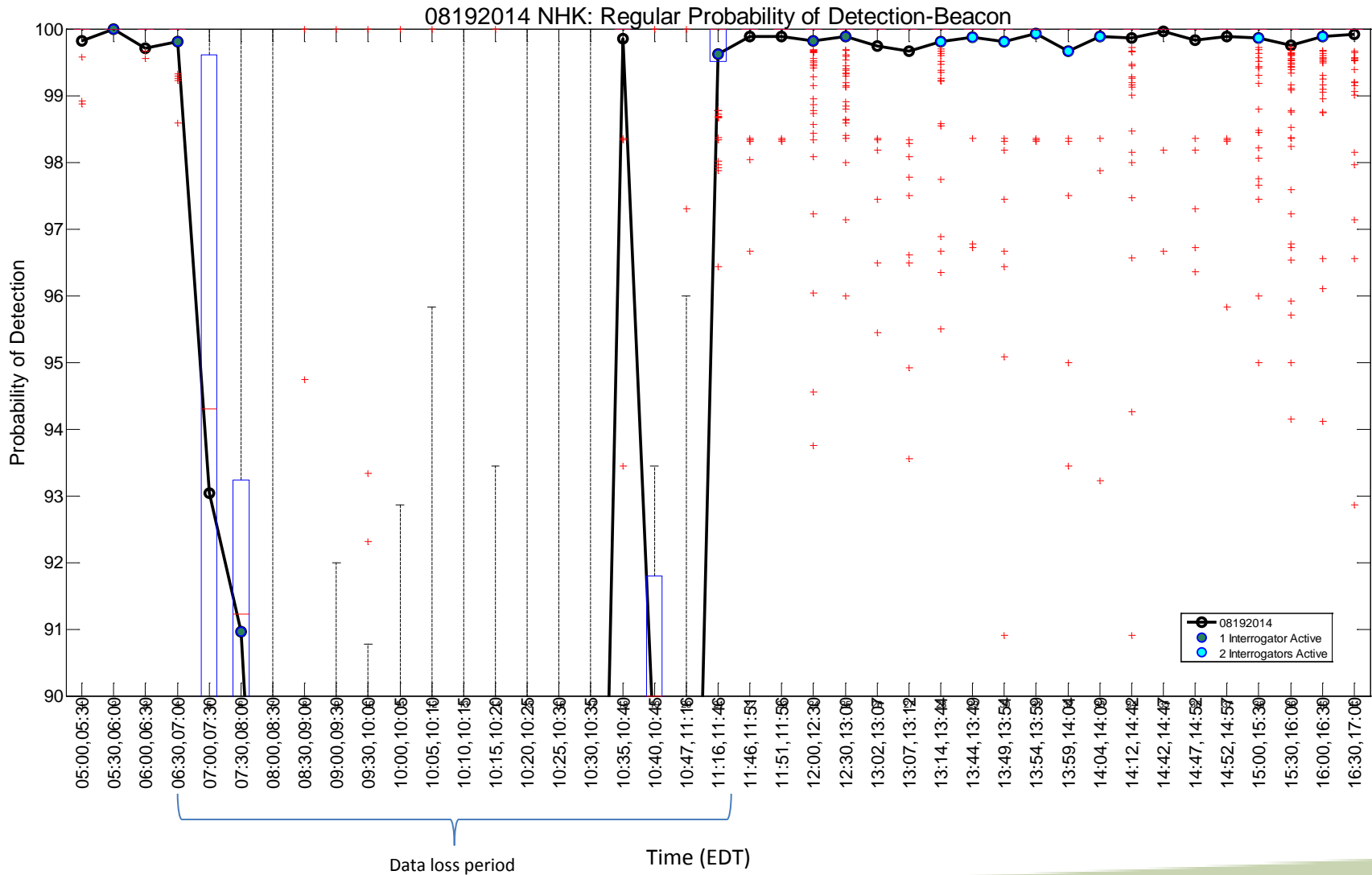


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

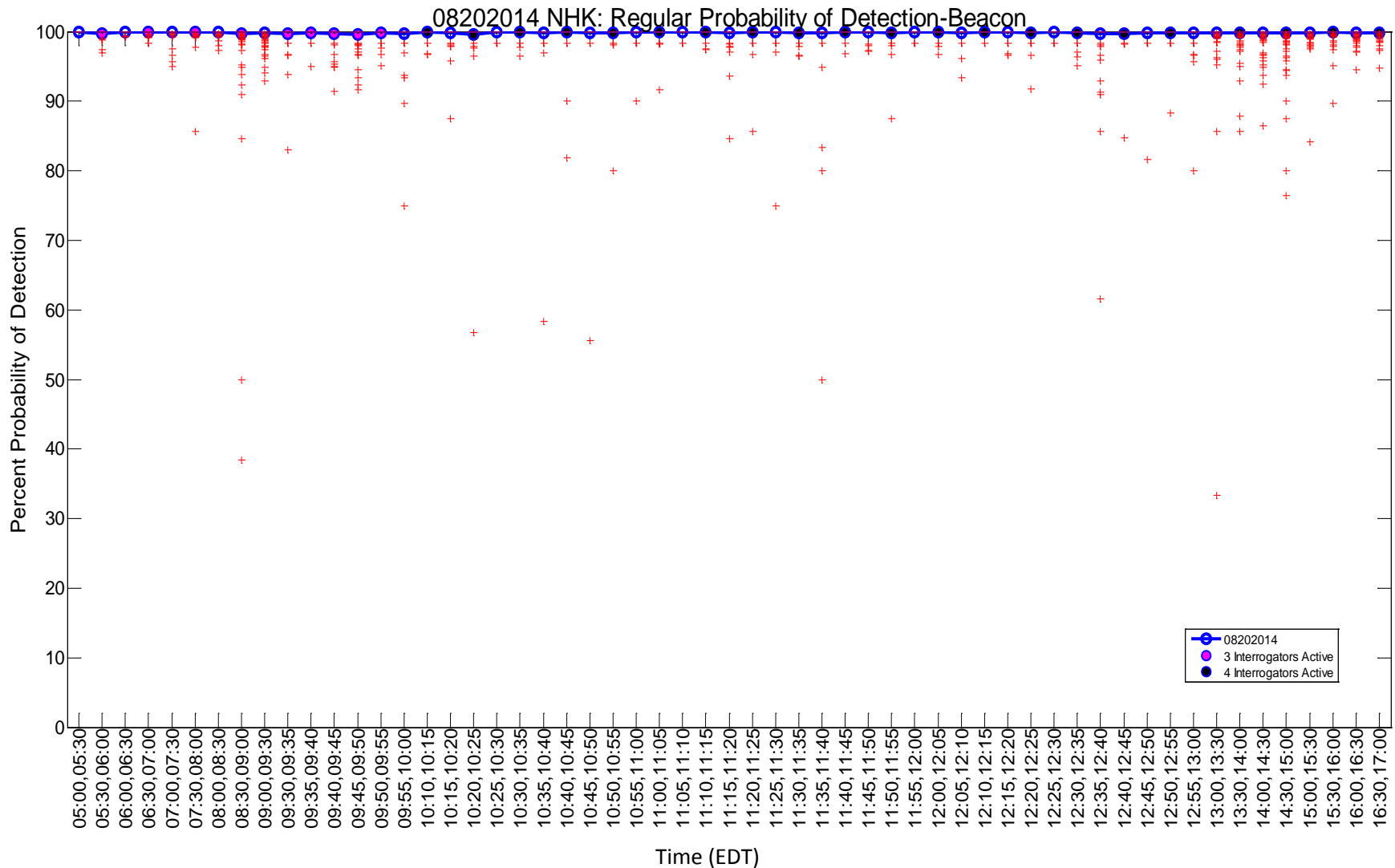
# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution



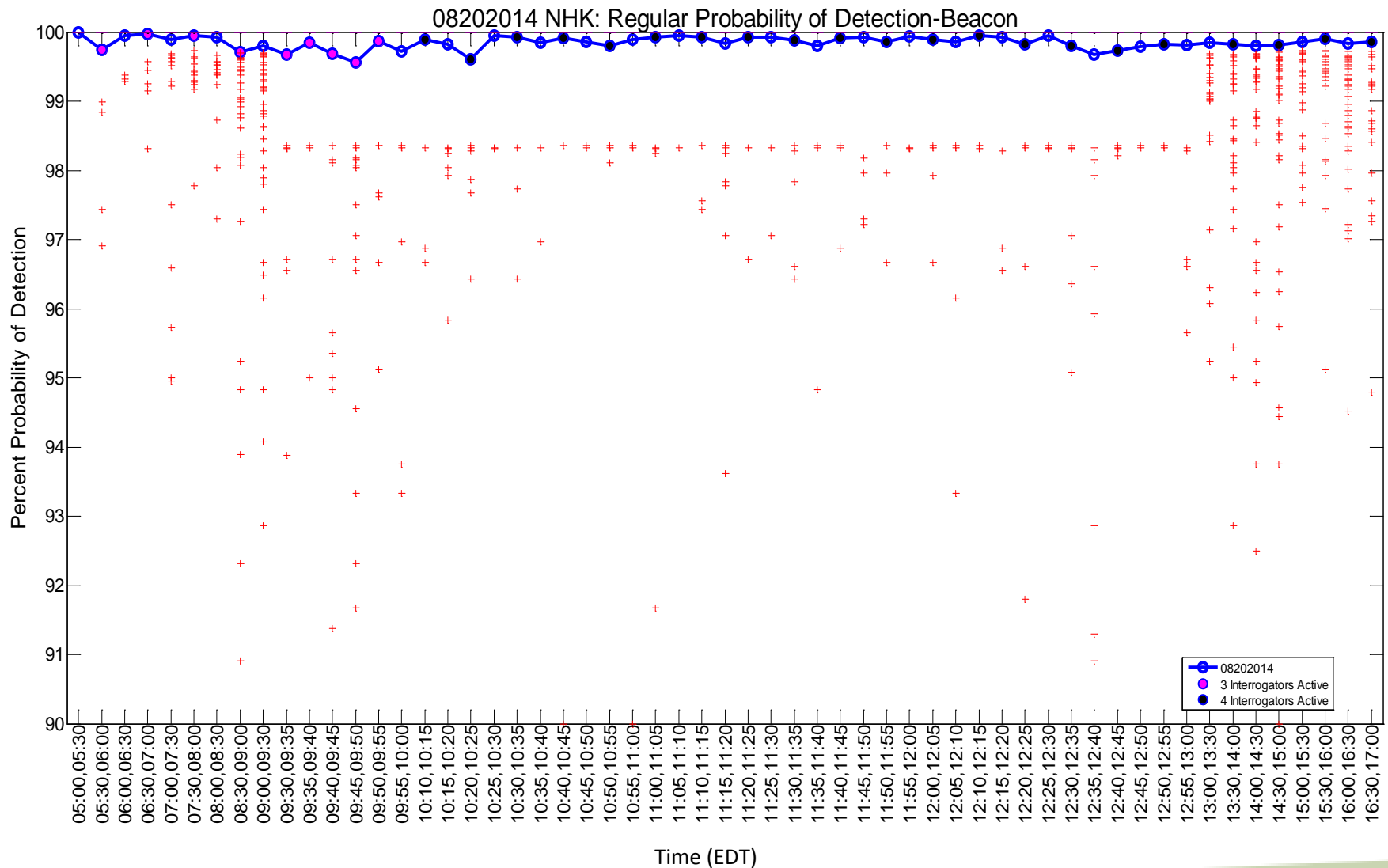
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

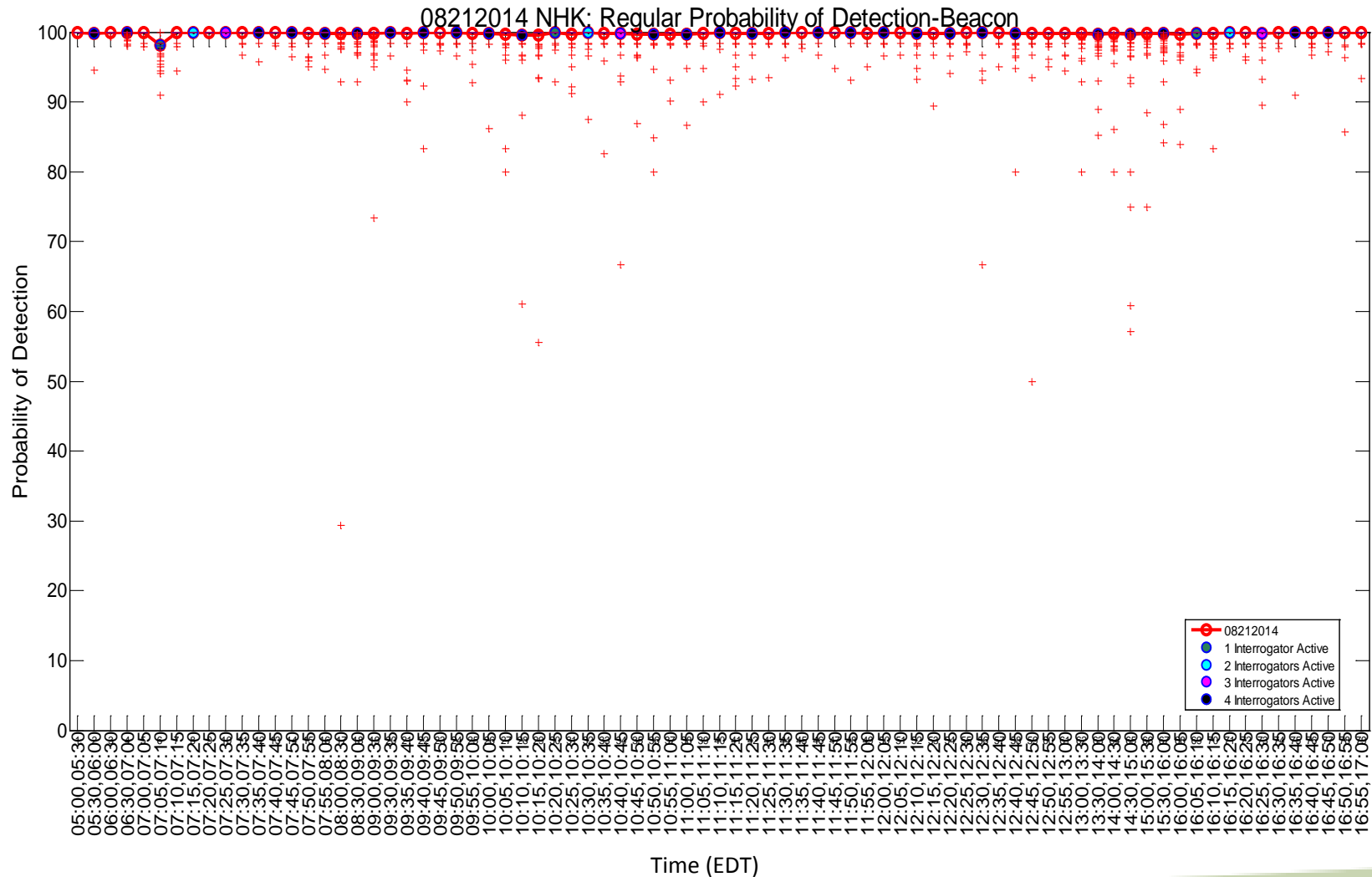


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

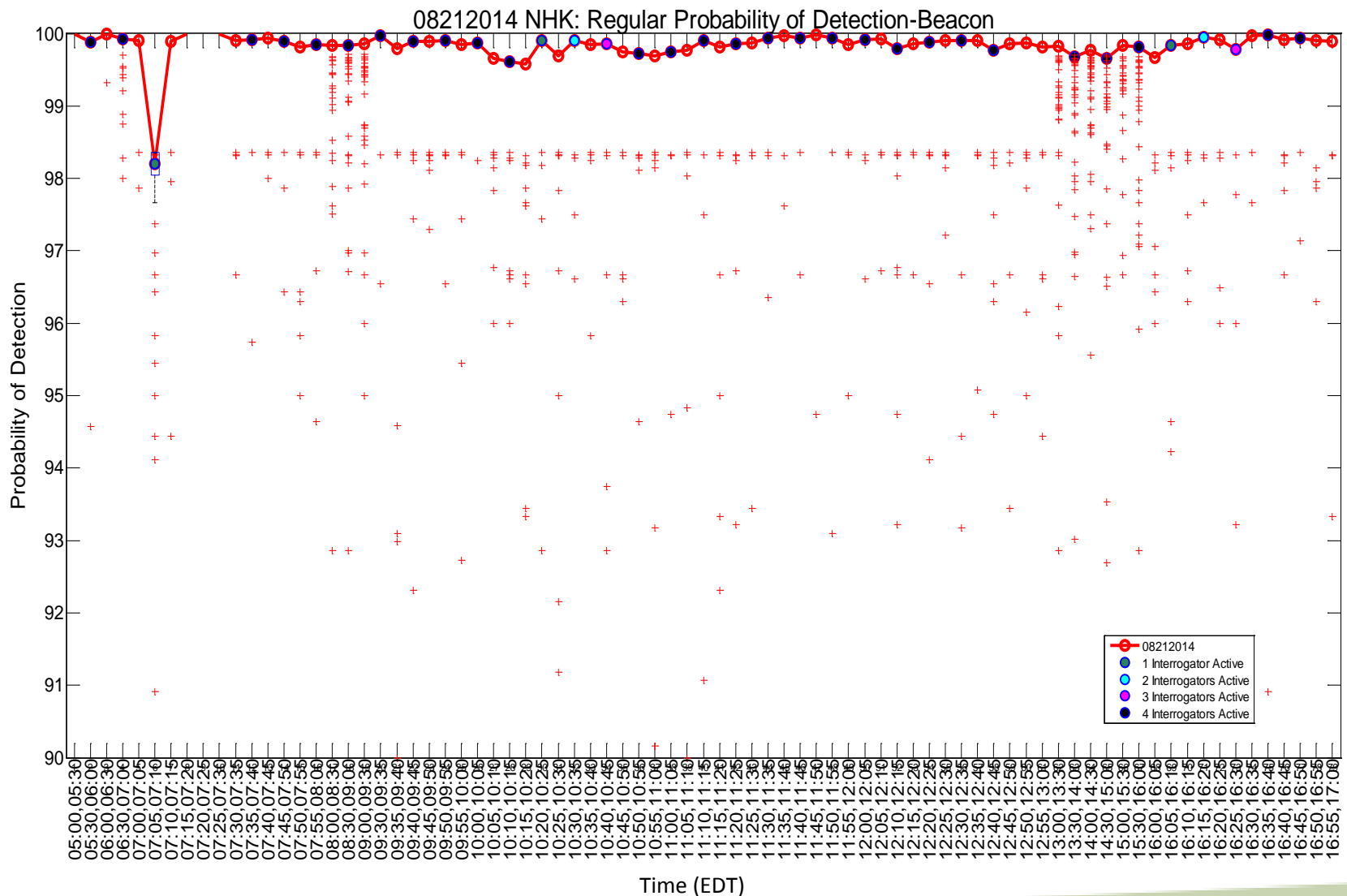


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Probability of Detection – August 21<sup>st</sup>

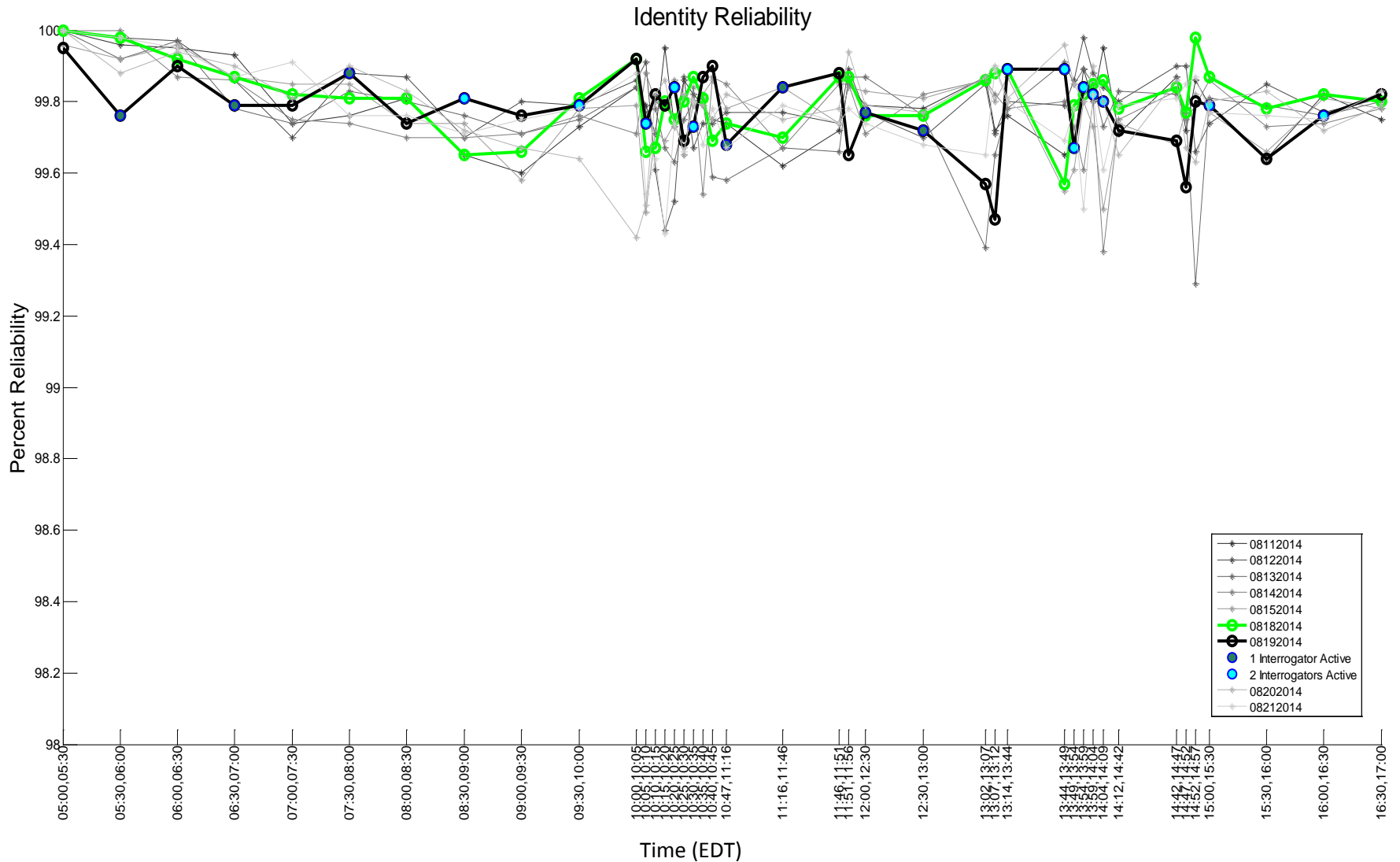
## Individual Aircraft Distribution (zoom-in)



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

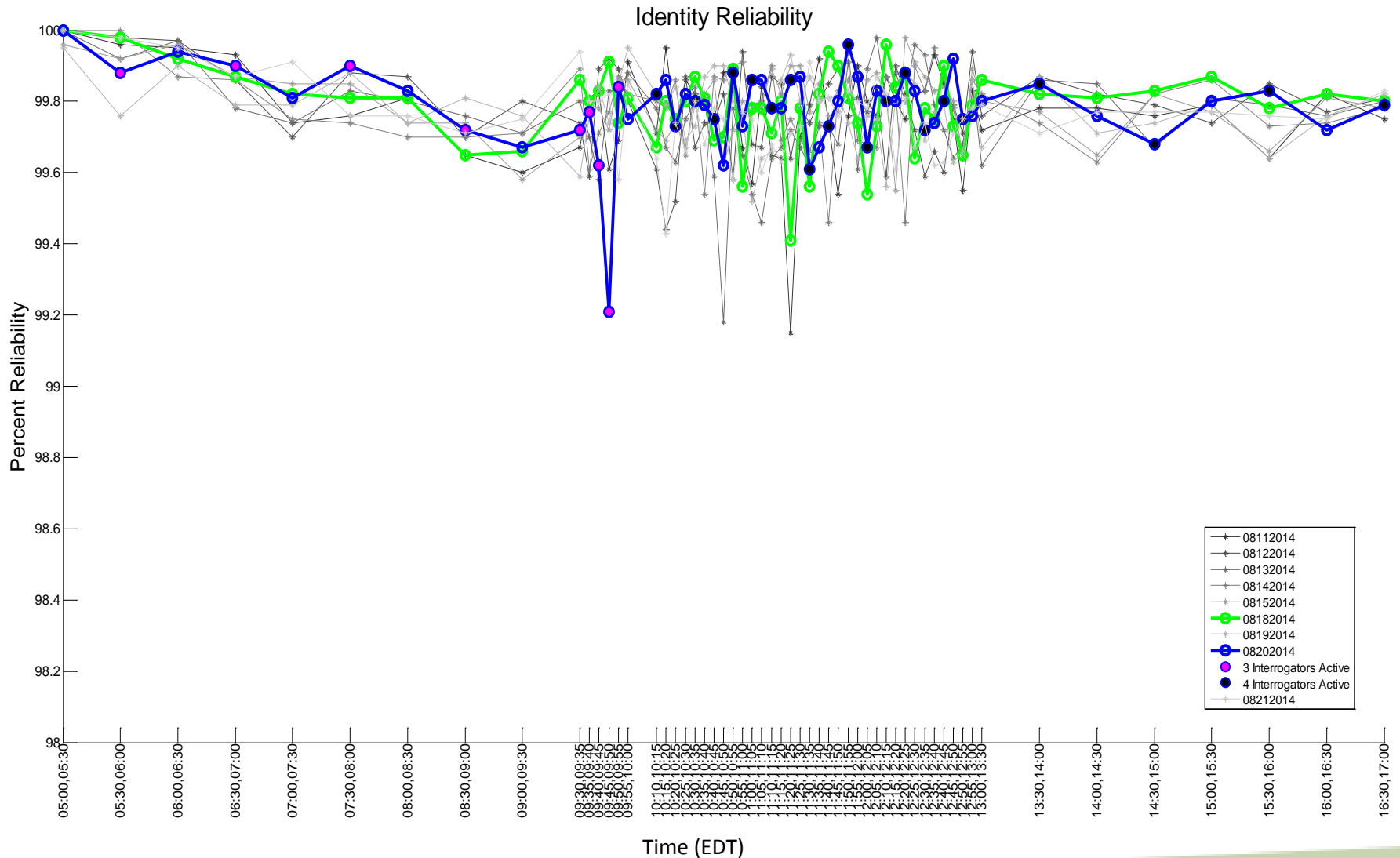
# Identity (3/A) Reliability – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

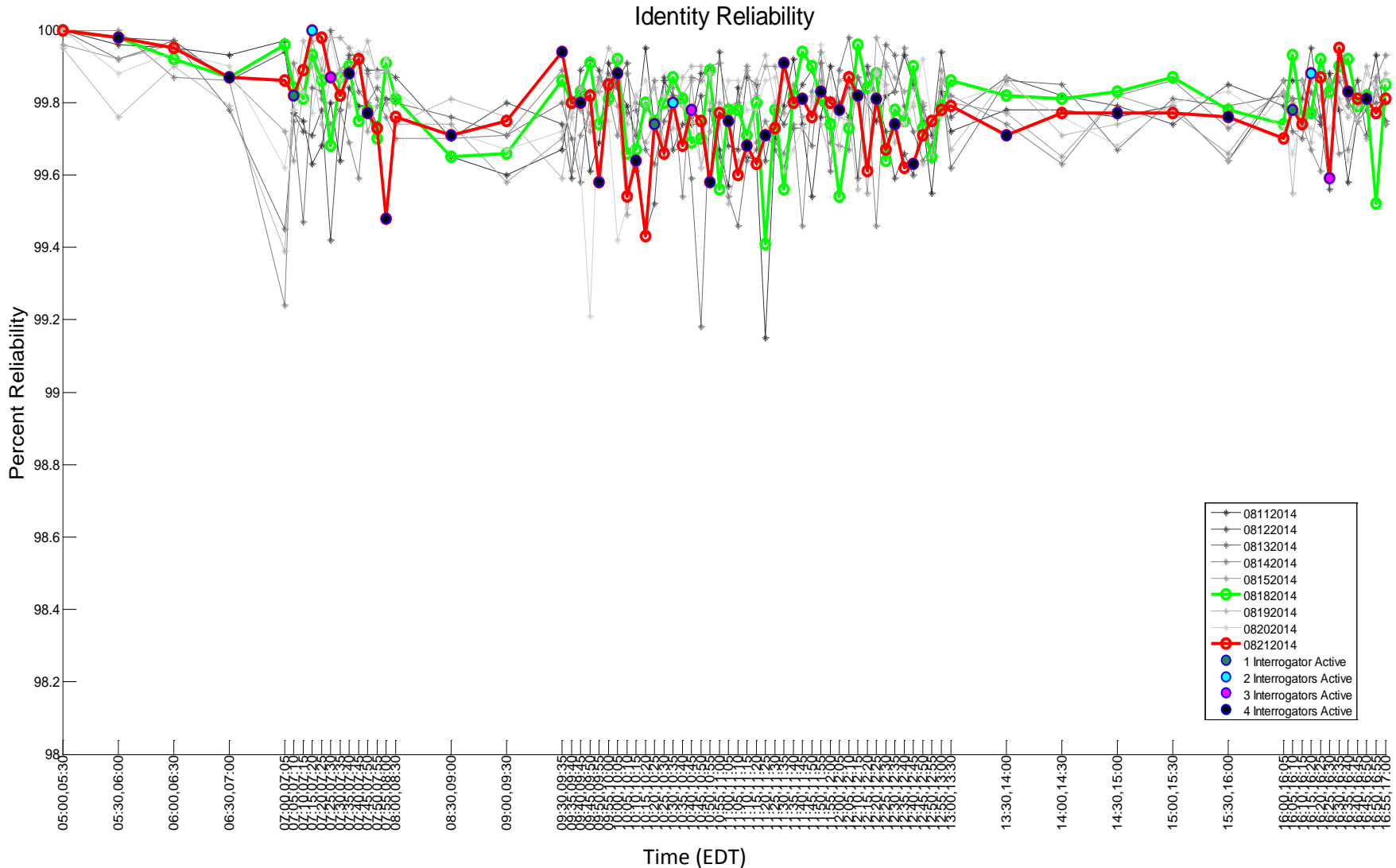
# Identity (3/A) Reliability – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

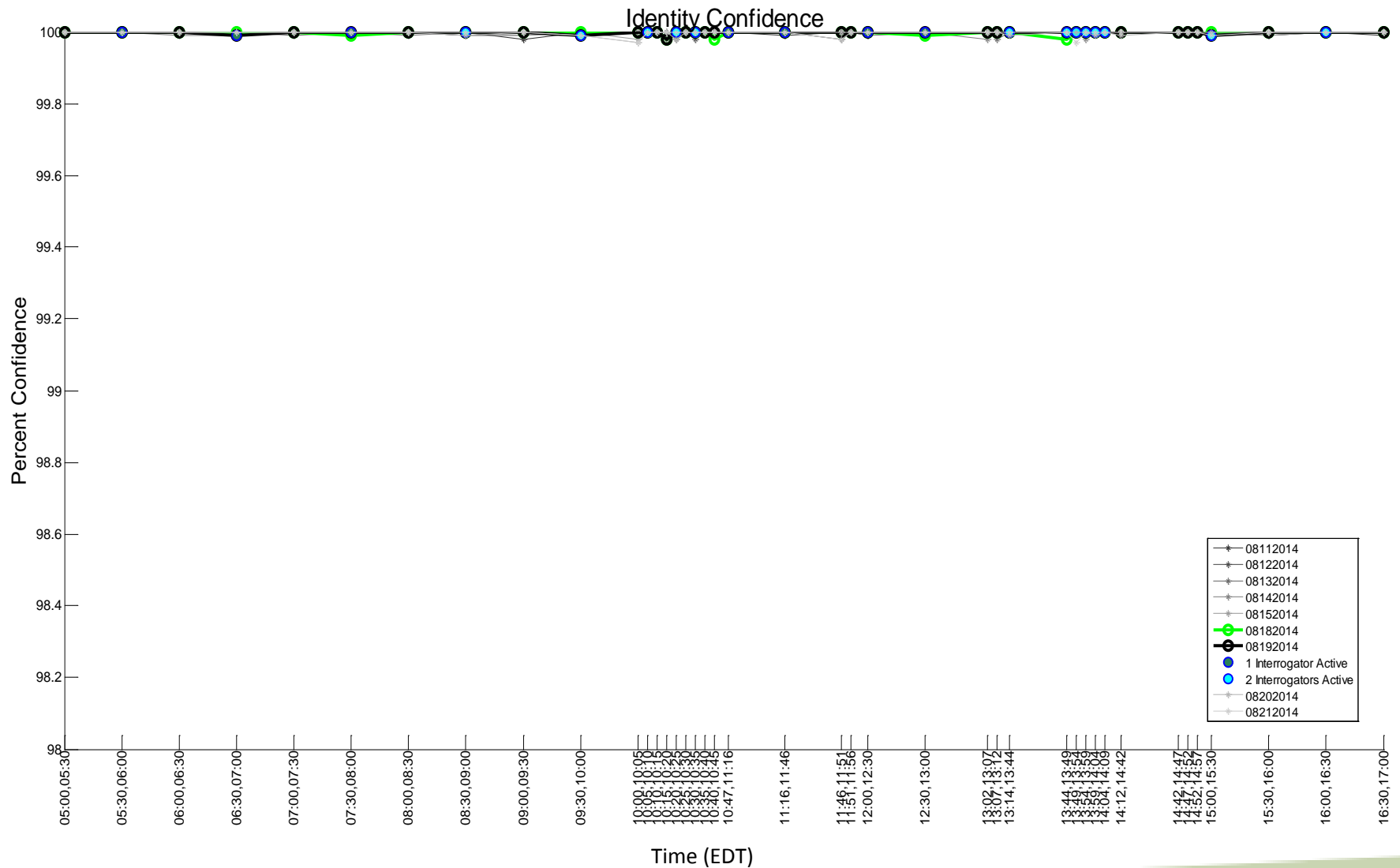
# Identity (3/A) Reliability – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

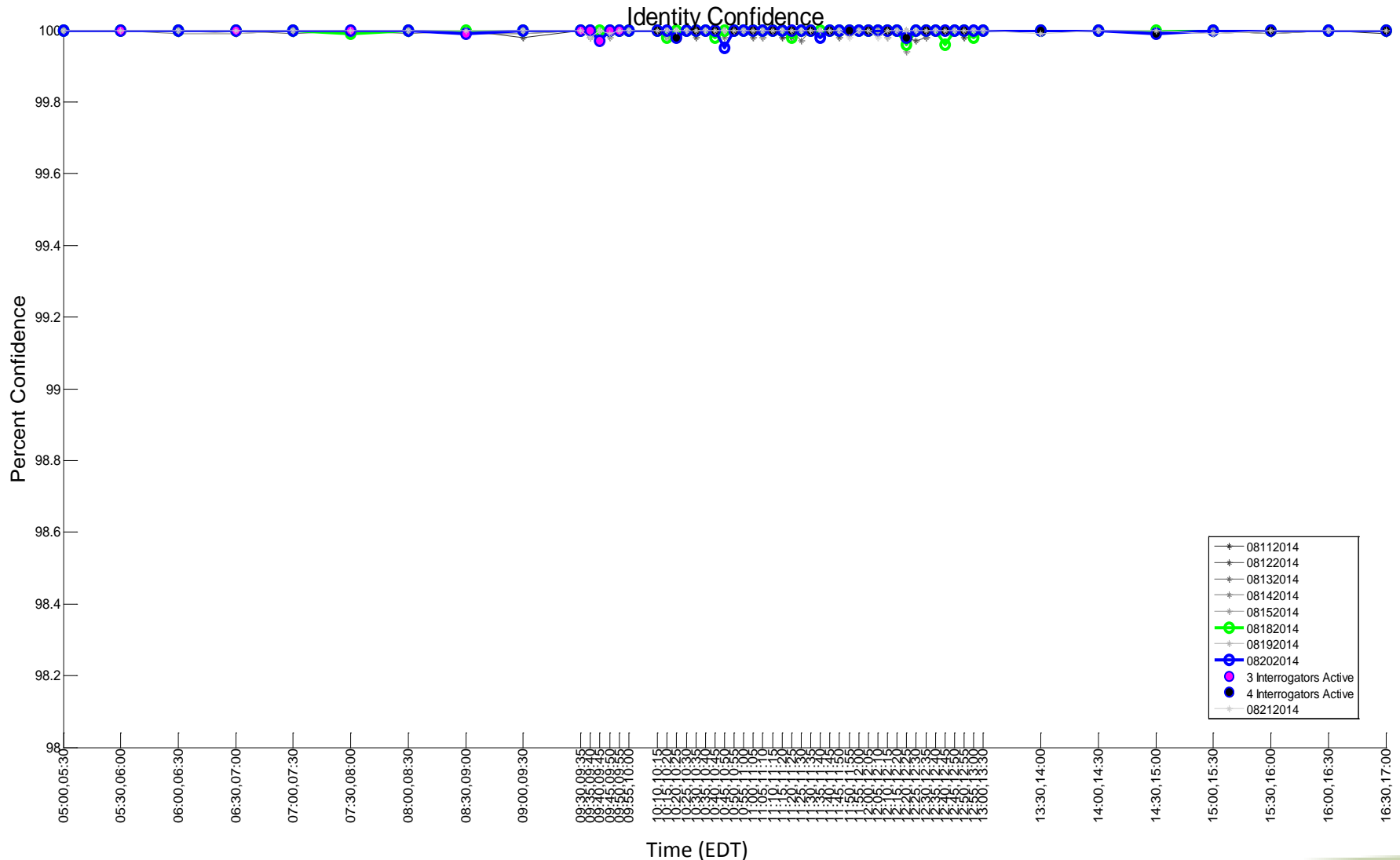
# Identity (3/A) Confidence – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Identity (3/A) Confidence – August 20<sup>th</sup>

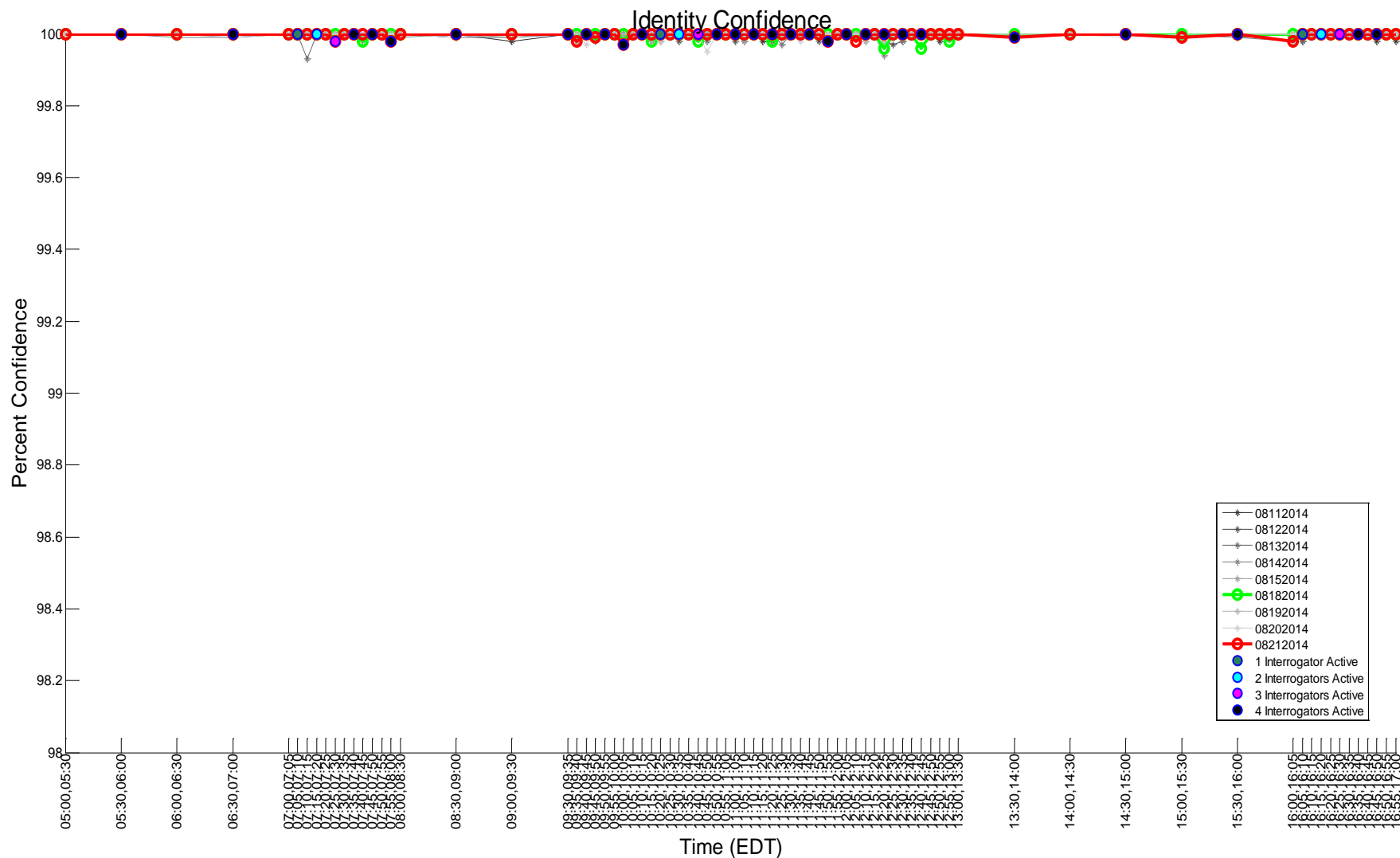


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°



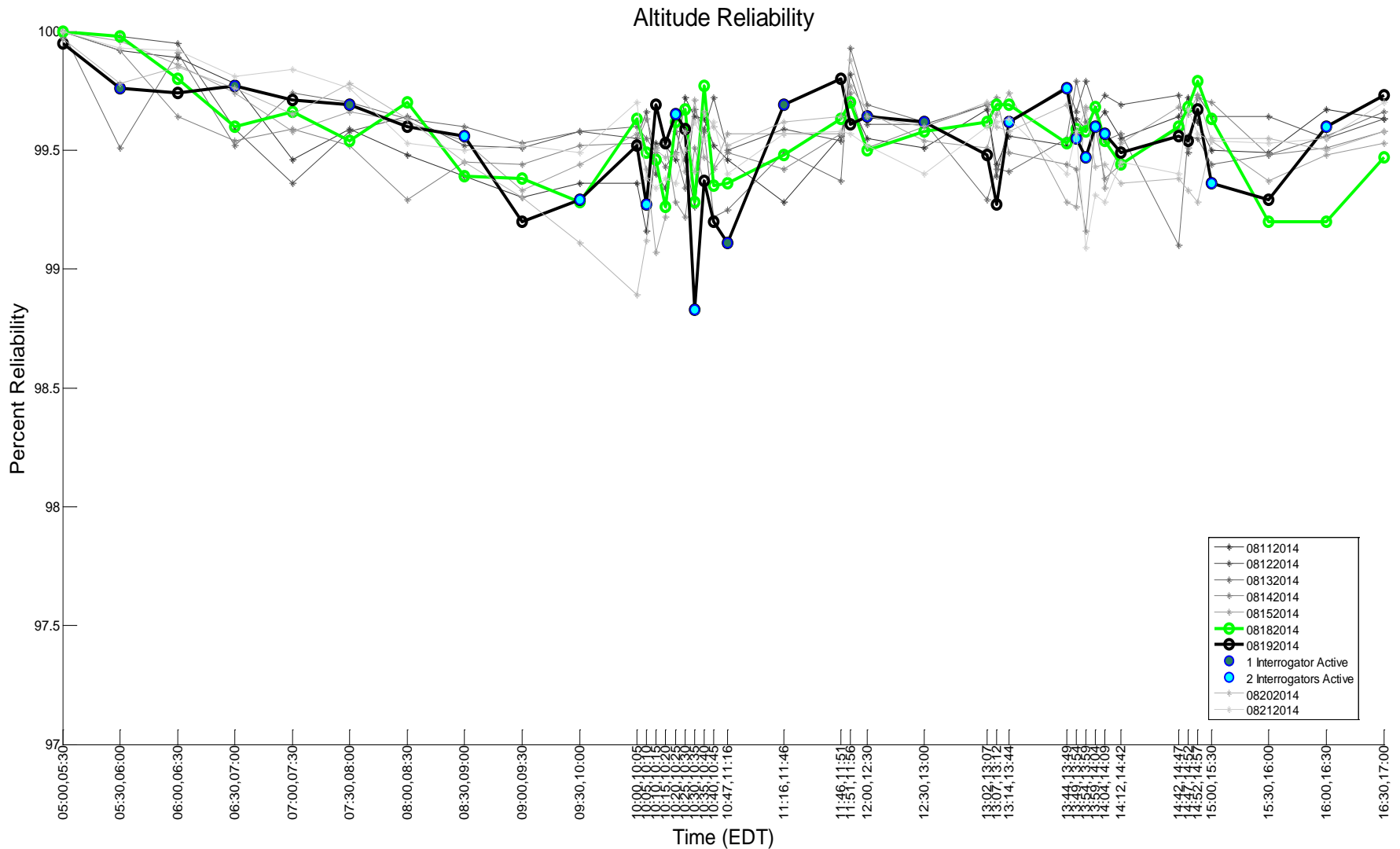
# Identity (3/A) Confidence – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

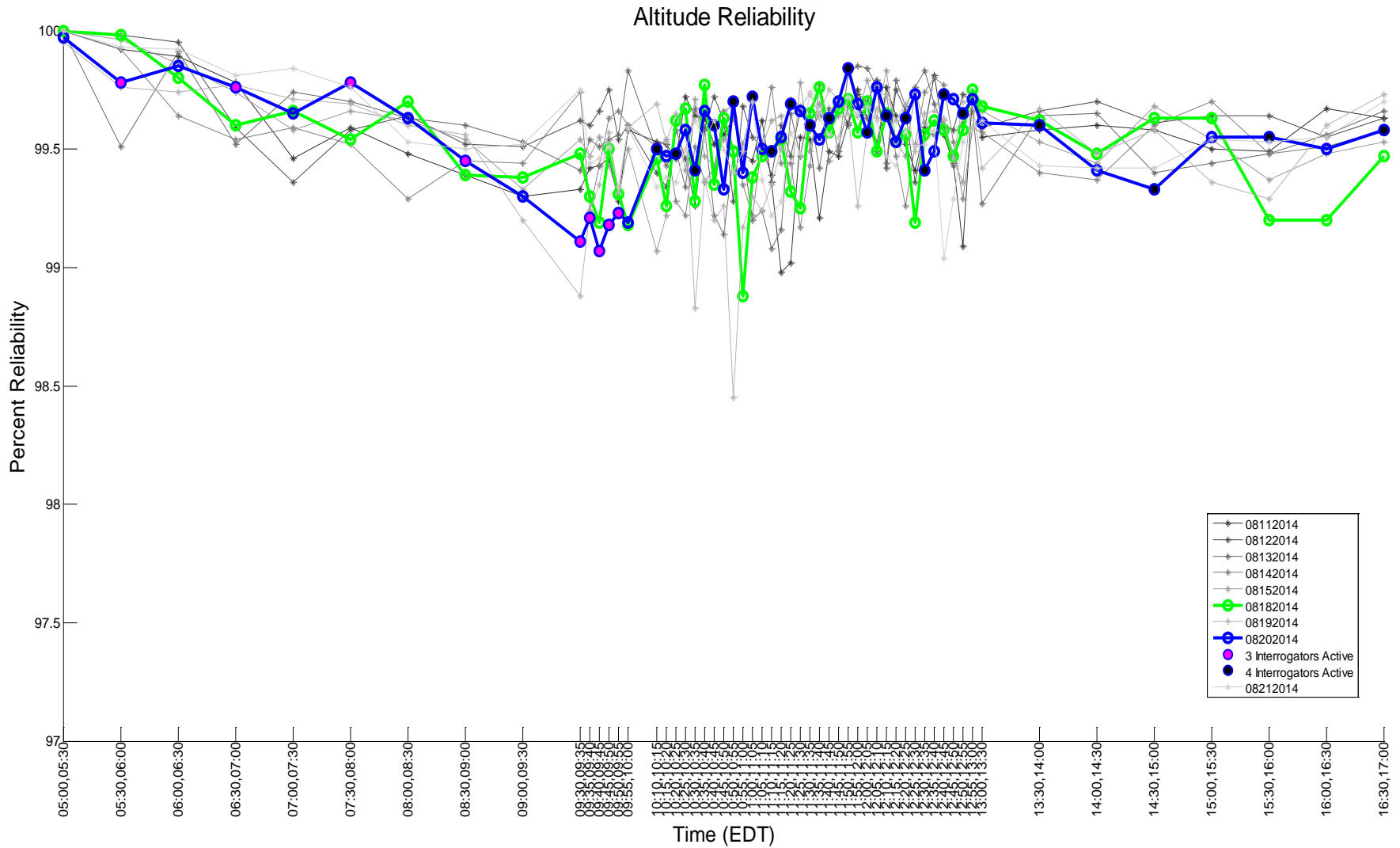
# Altitude (C) Reliability – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

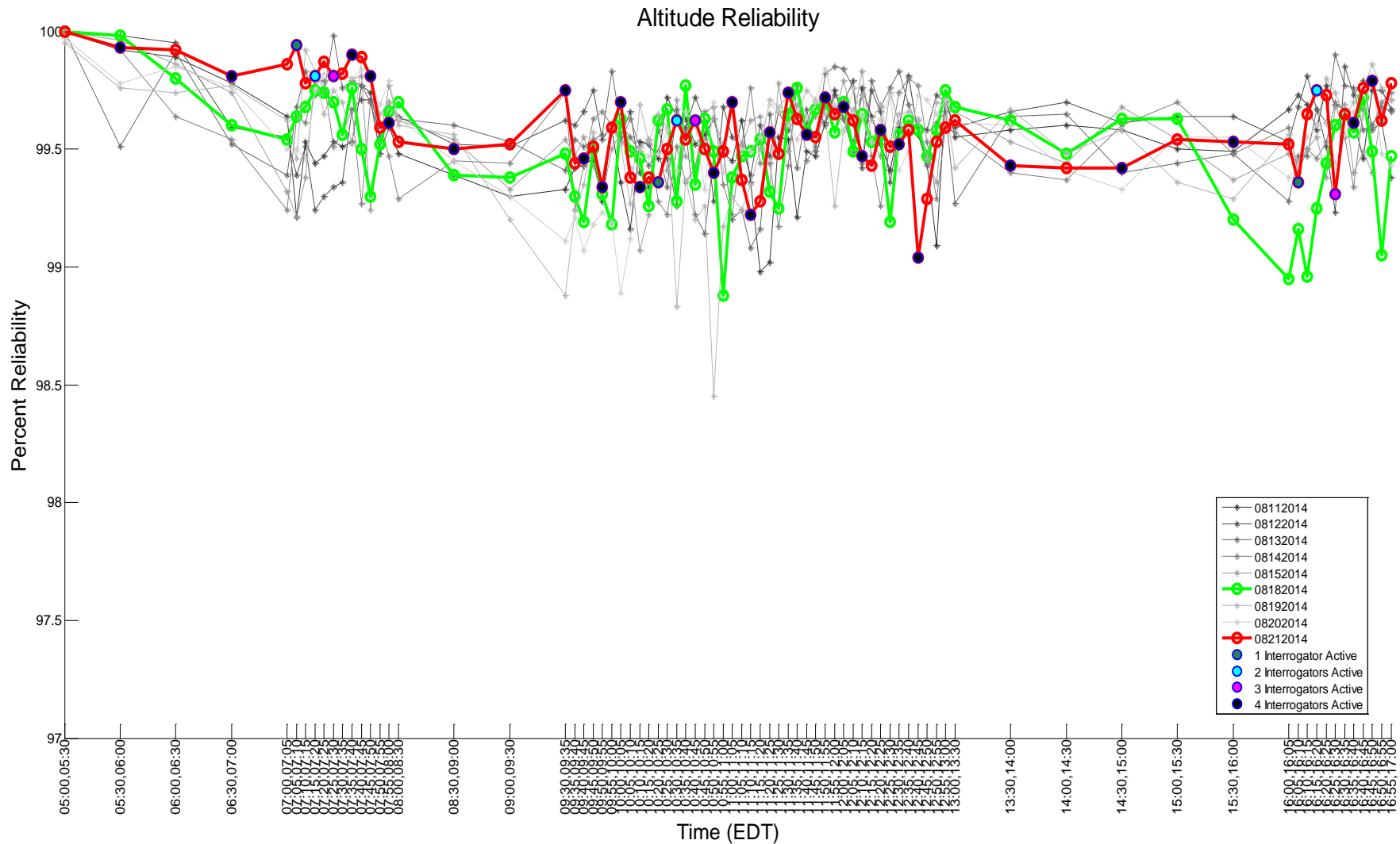
# Altitude (C) Reliability – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

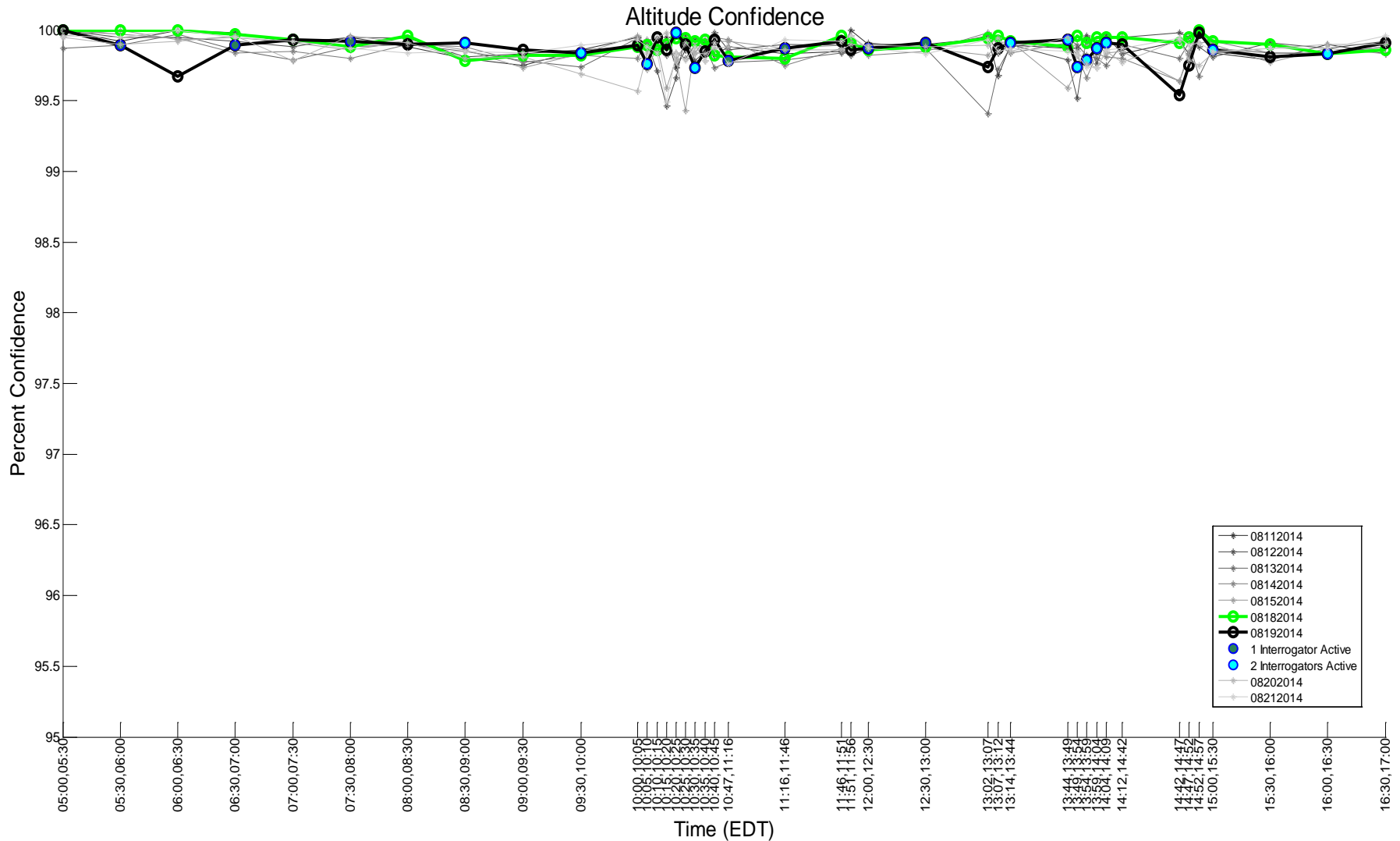
# Altitude (C) Reliability – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

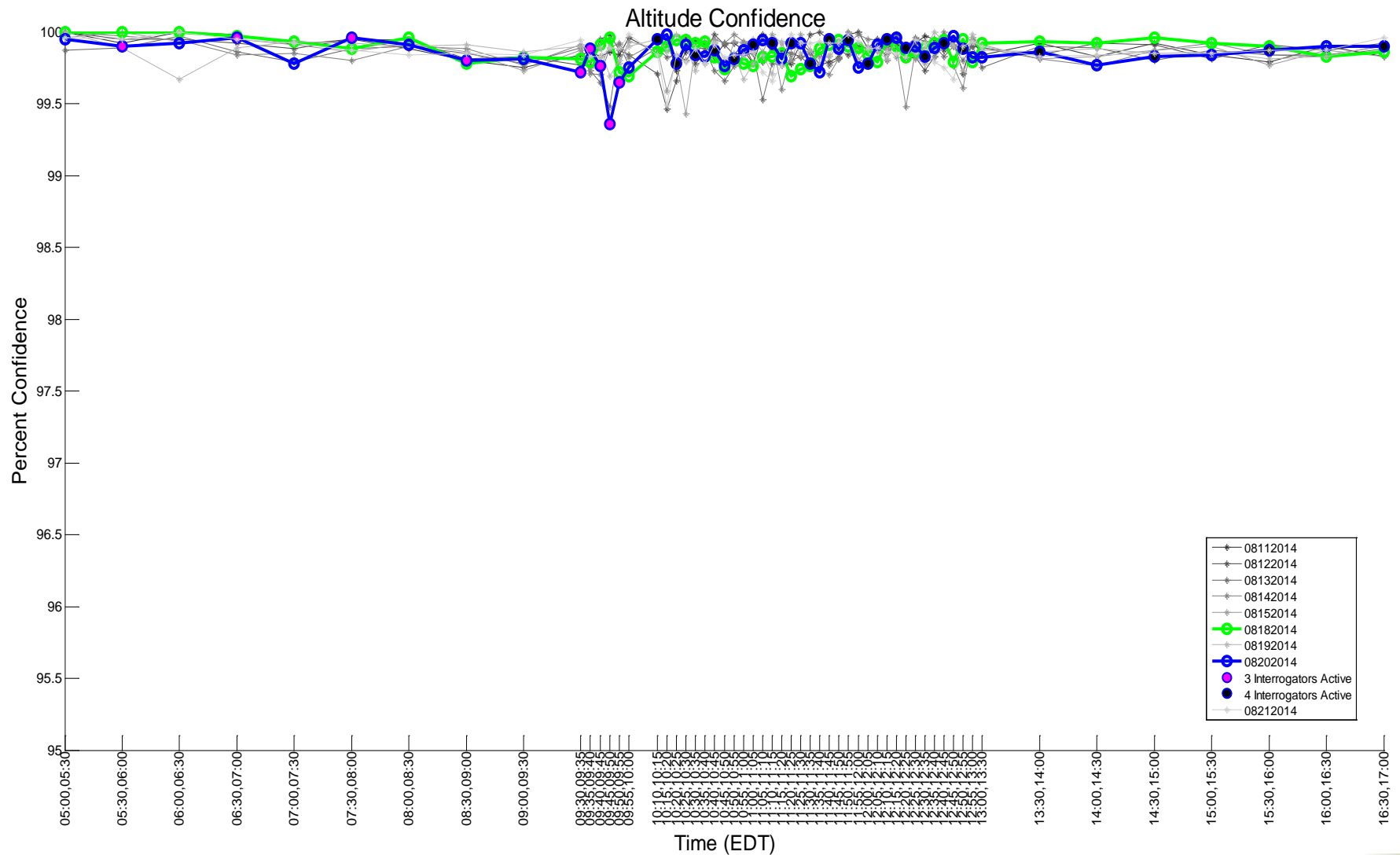
# Altitude (C) Confidence – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

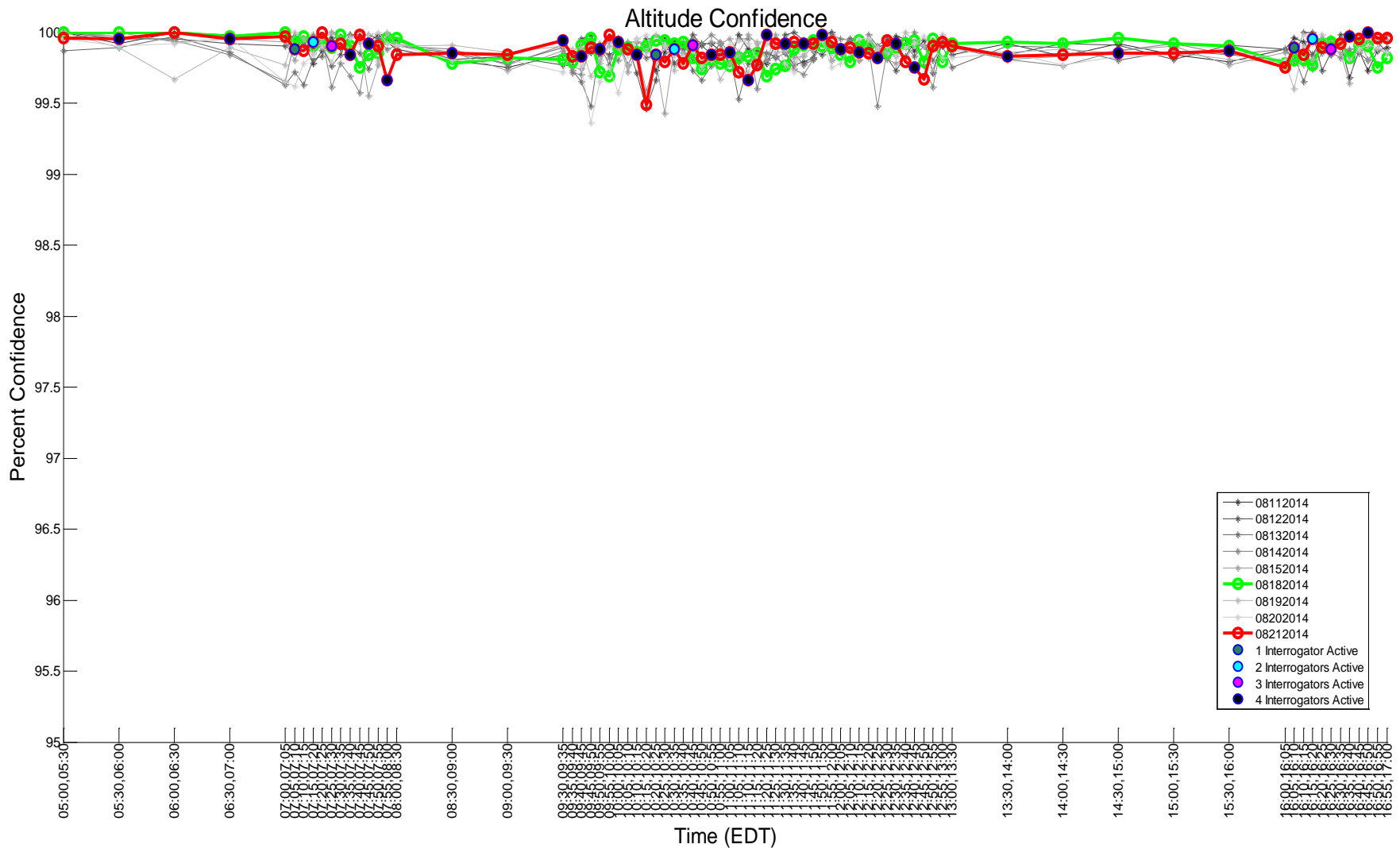
# Altitude (C) Confidence – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Altitude (C) Confidence – August 21<sup>st</sup>



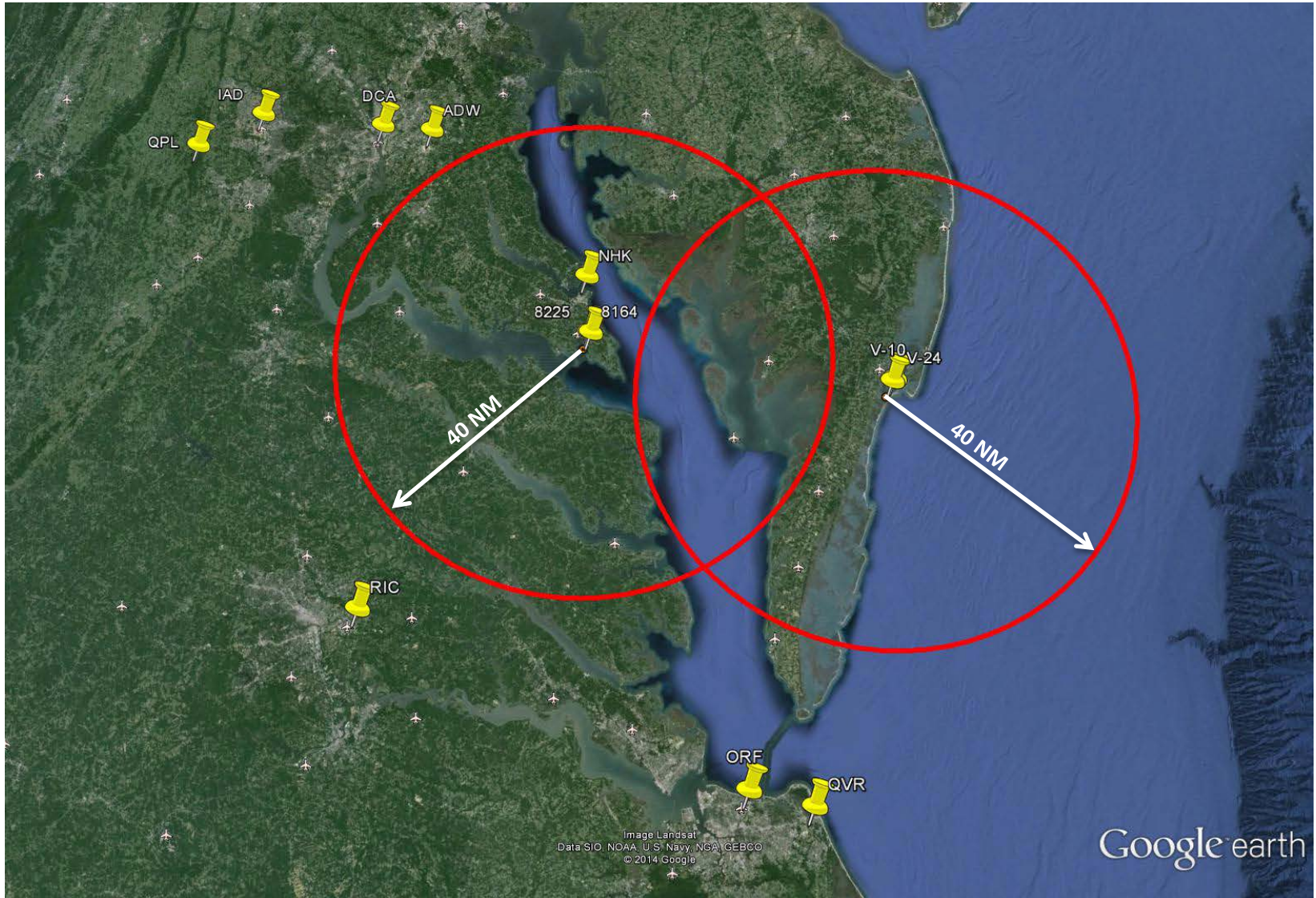
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

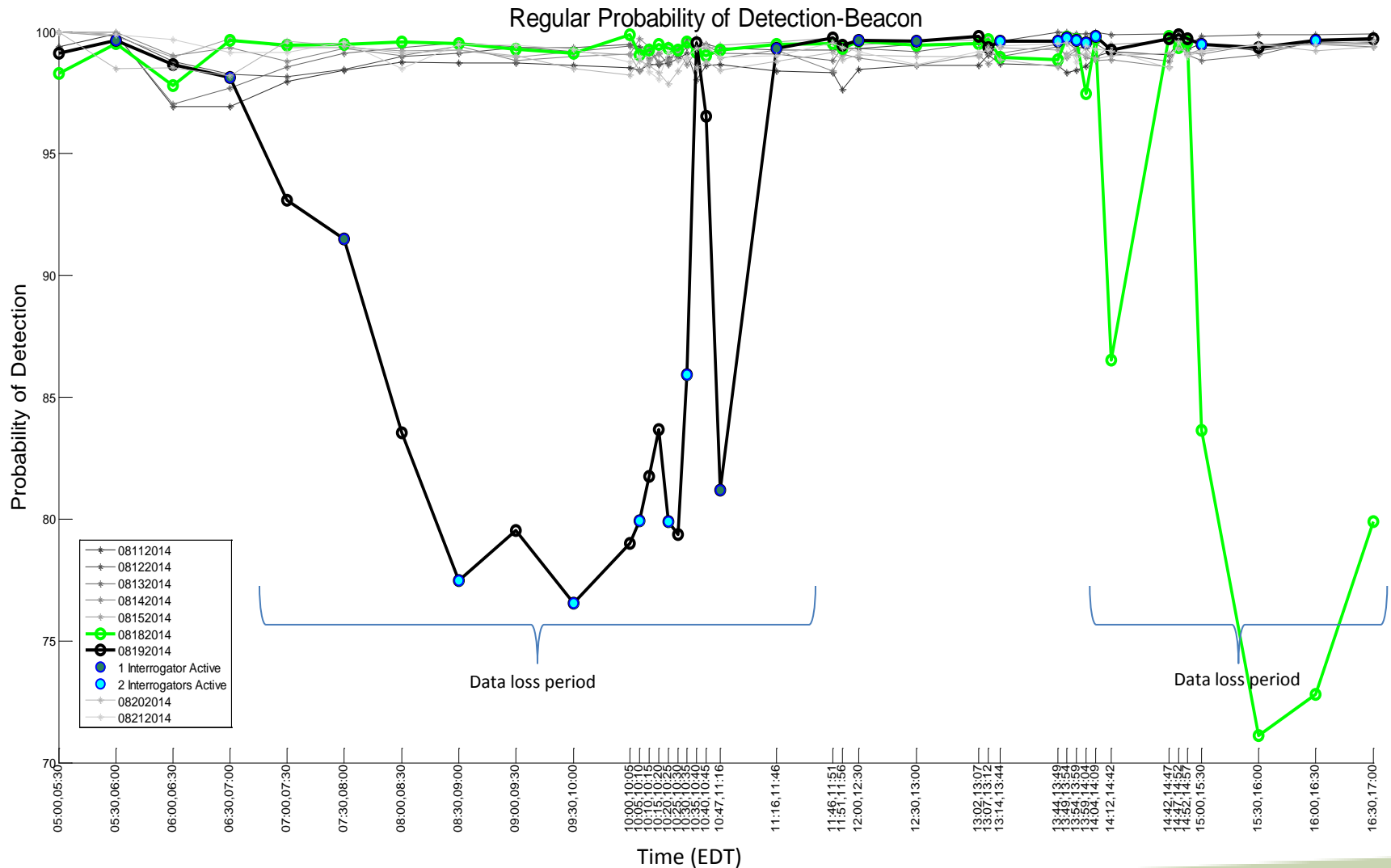
# Target Metrics within the Hotspot Region



# Hotspot Geography

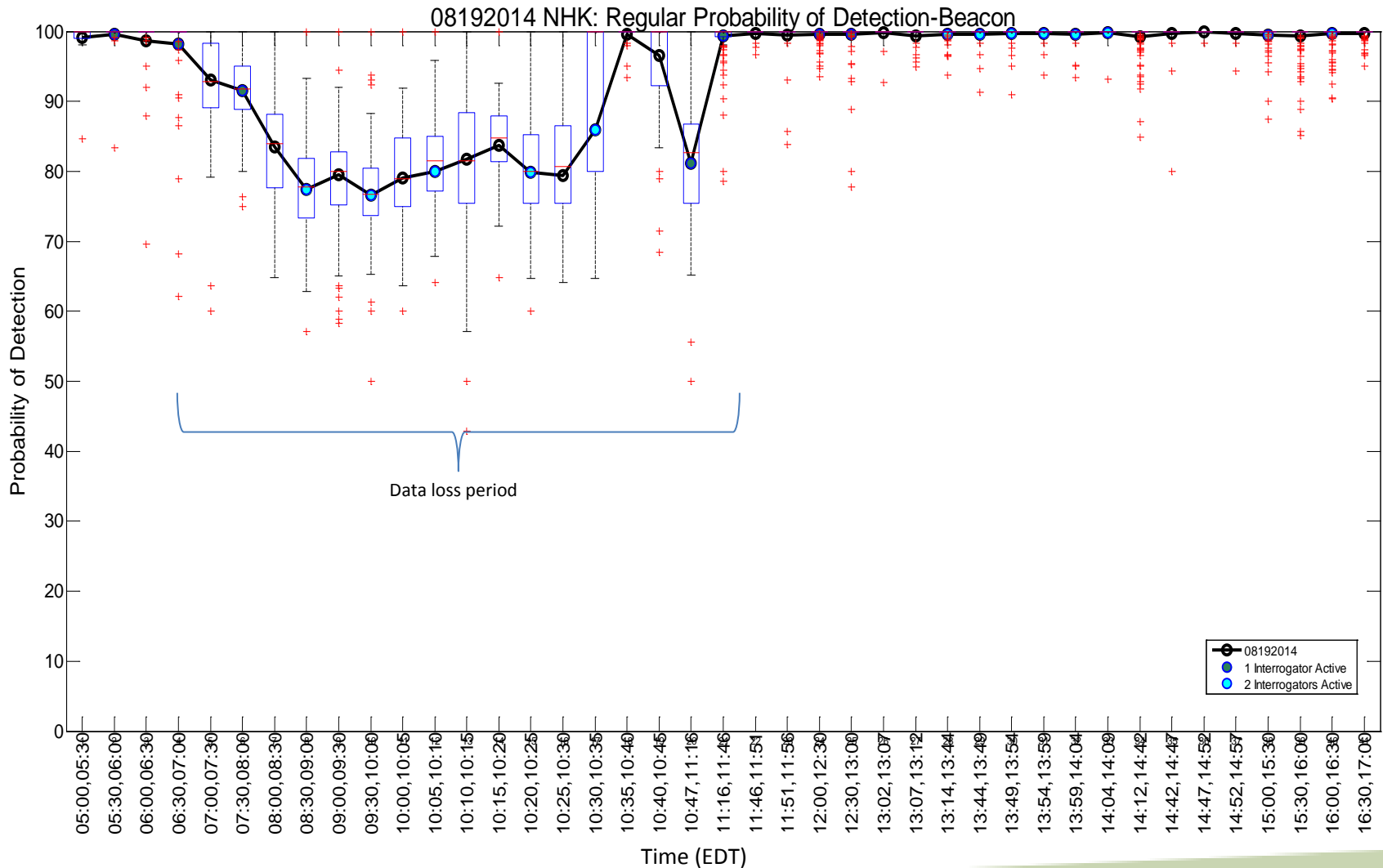


# Probability of Detection – All Days



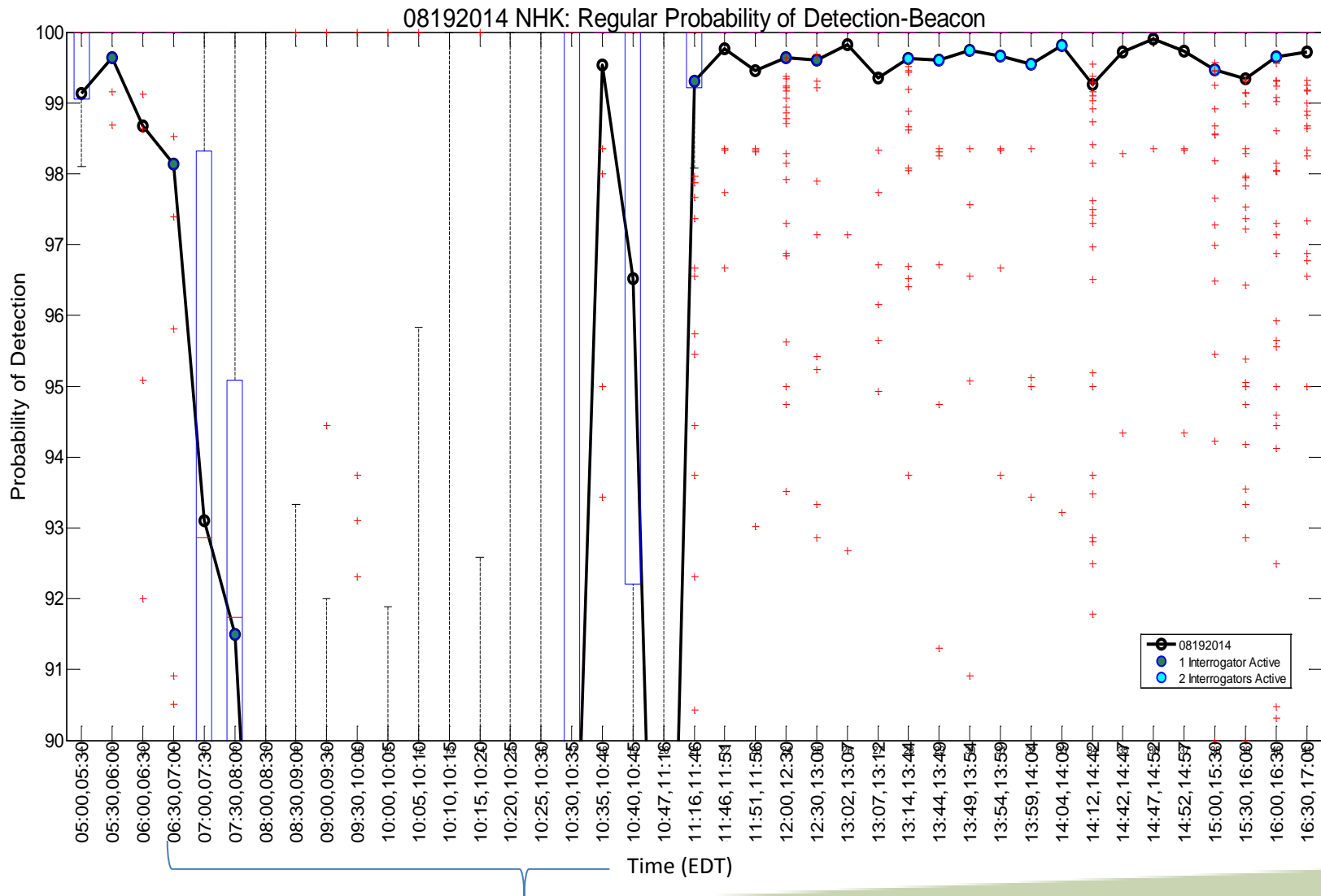
# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution



# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

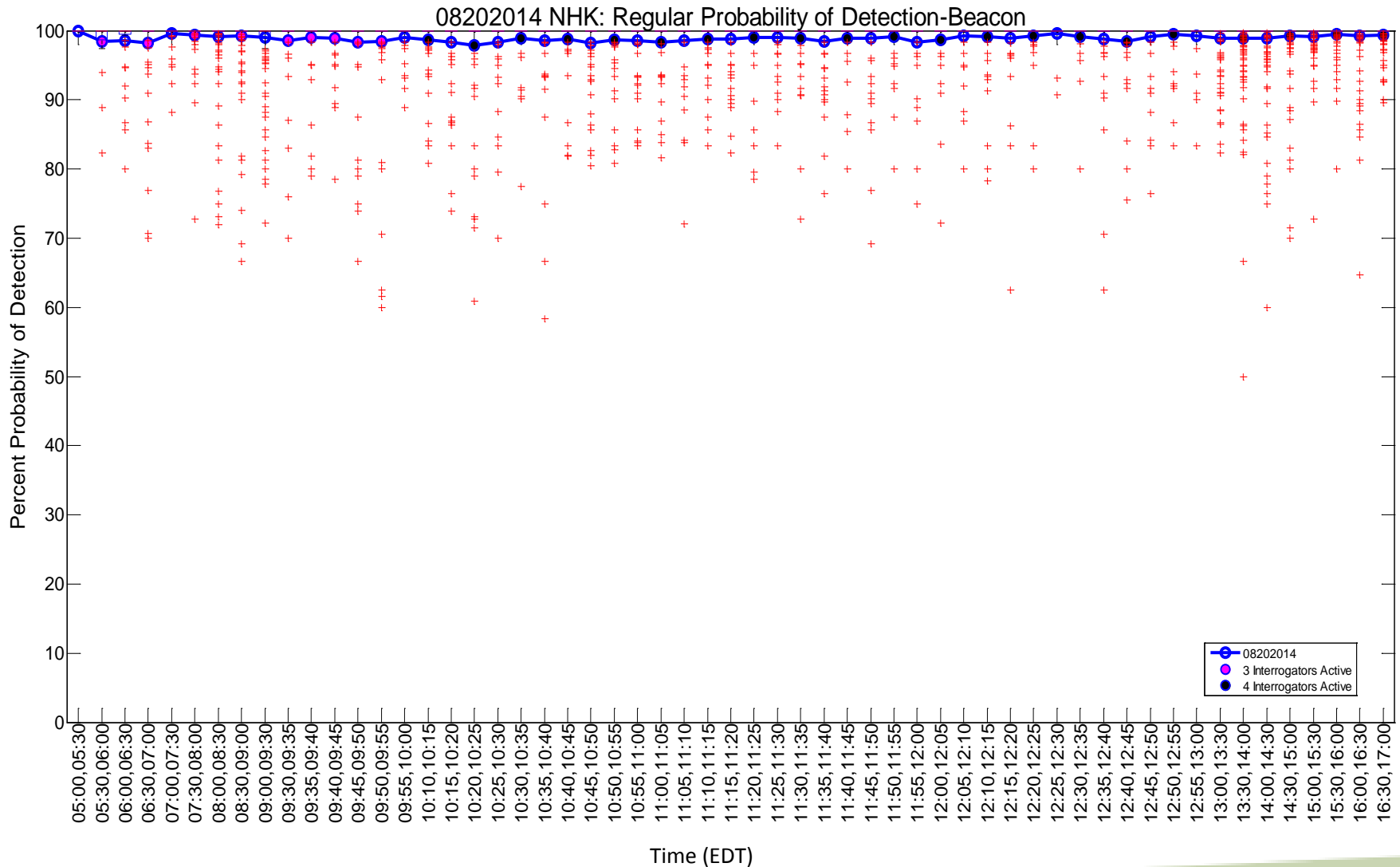


Geographic Filter: Hotspot Region  
 Target Filter: None

Data loss period

# Probability of Detection – August 20<sup>th</sup>

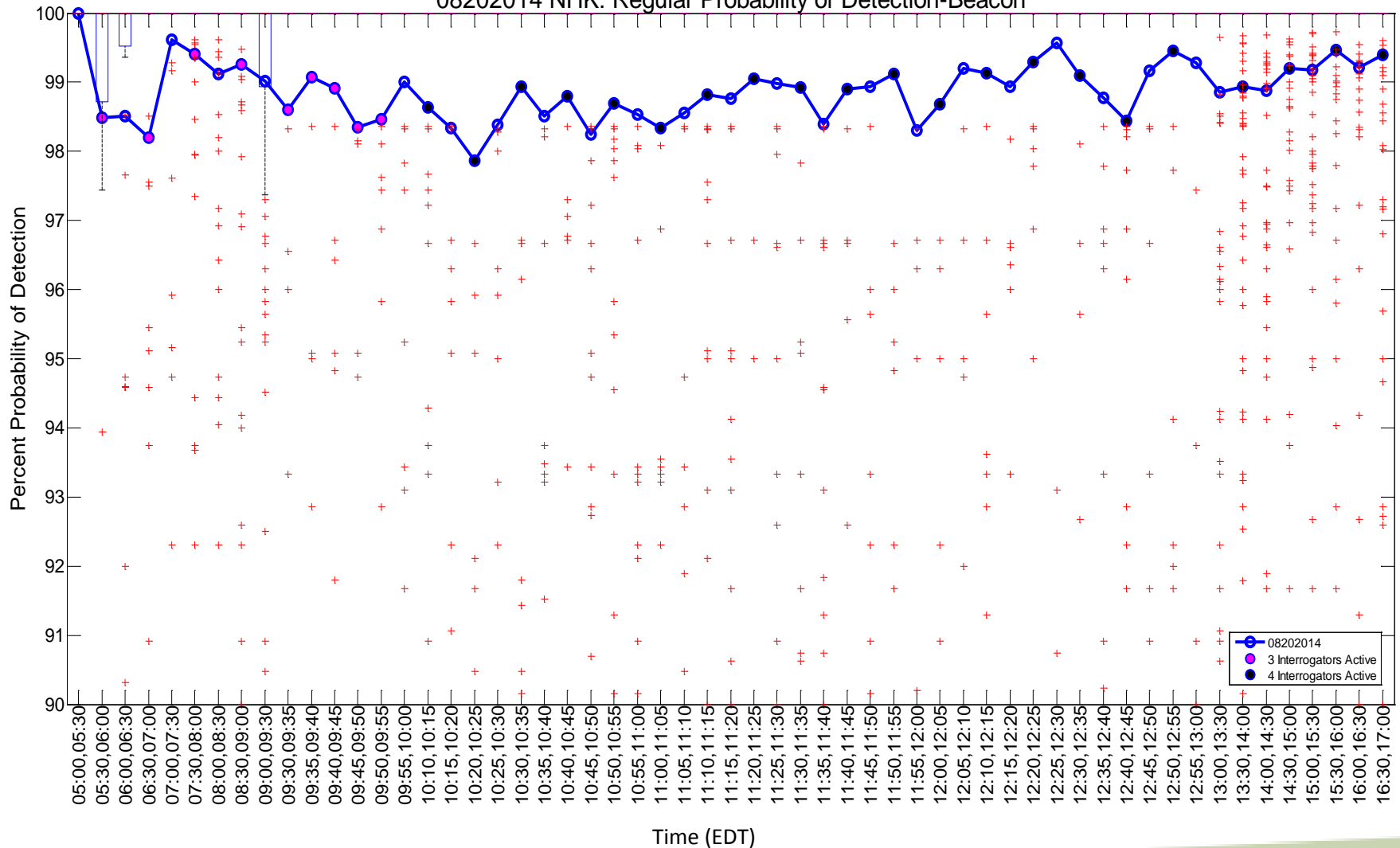
## Individual Aircraft Distribution



# Probability of Detection – August 20<sup>th</sup>

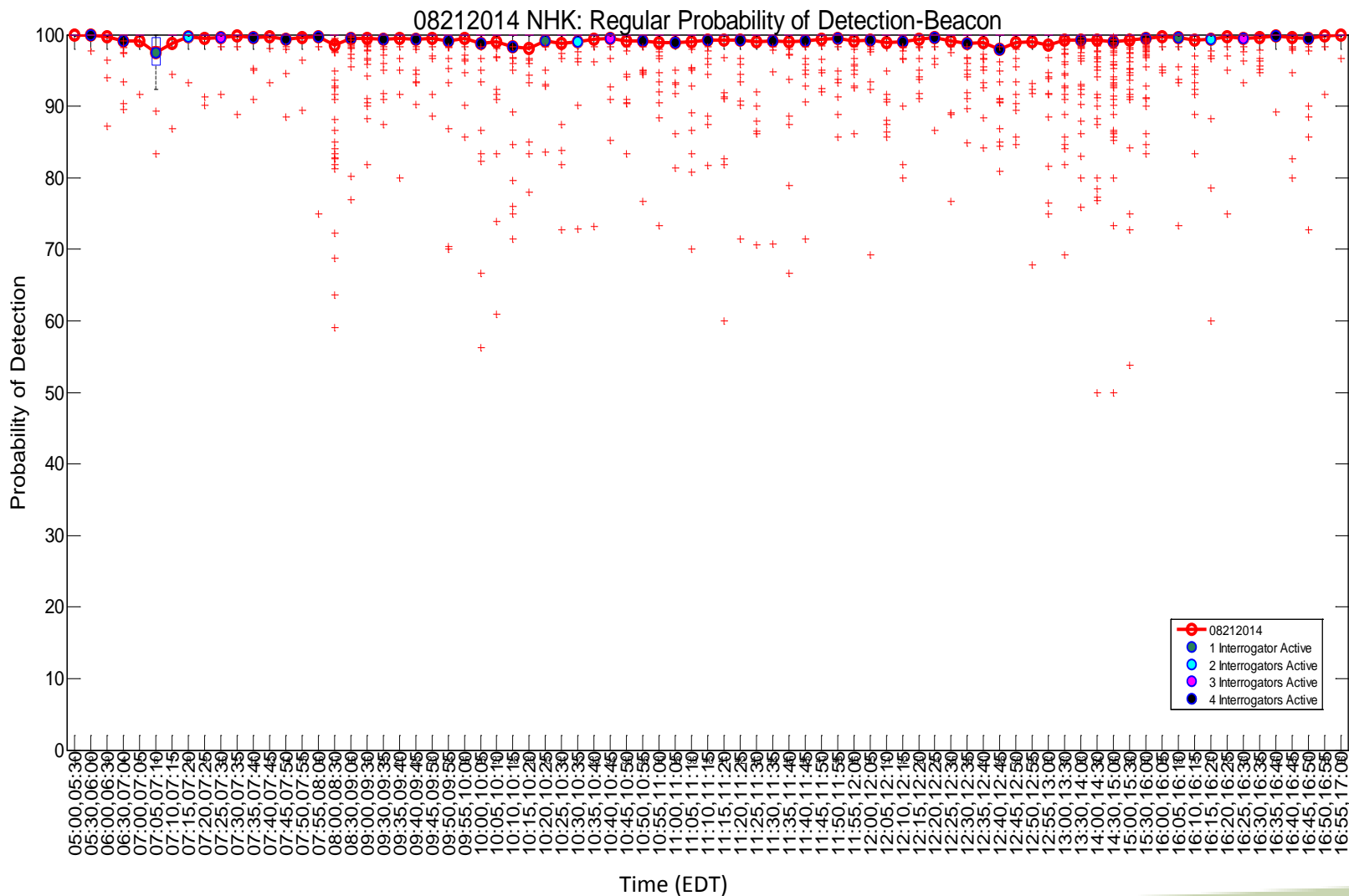
## Individual Aircraft Distribution (zoom-in)

08202014 NHK: Regular Probability of Detection-Beacon



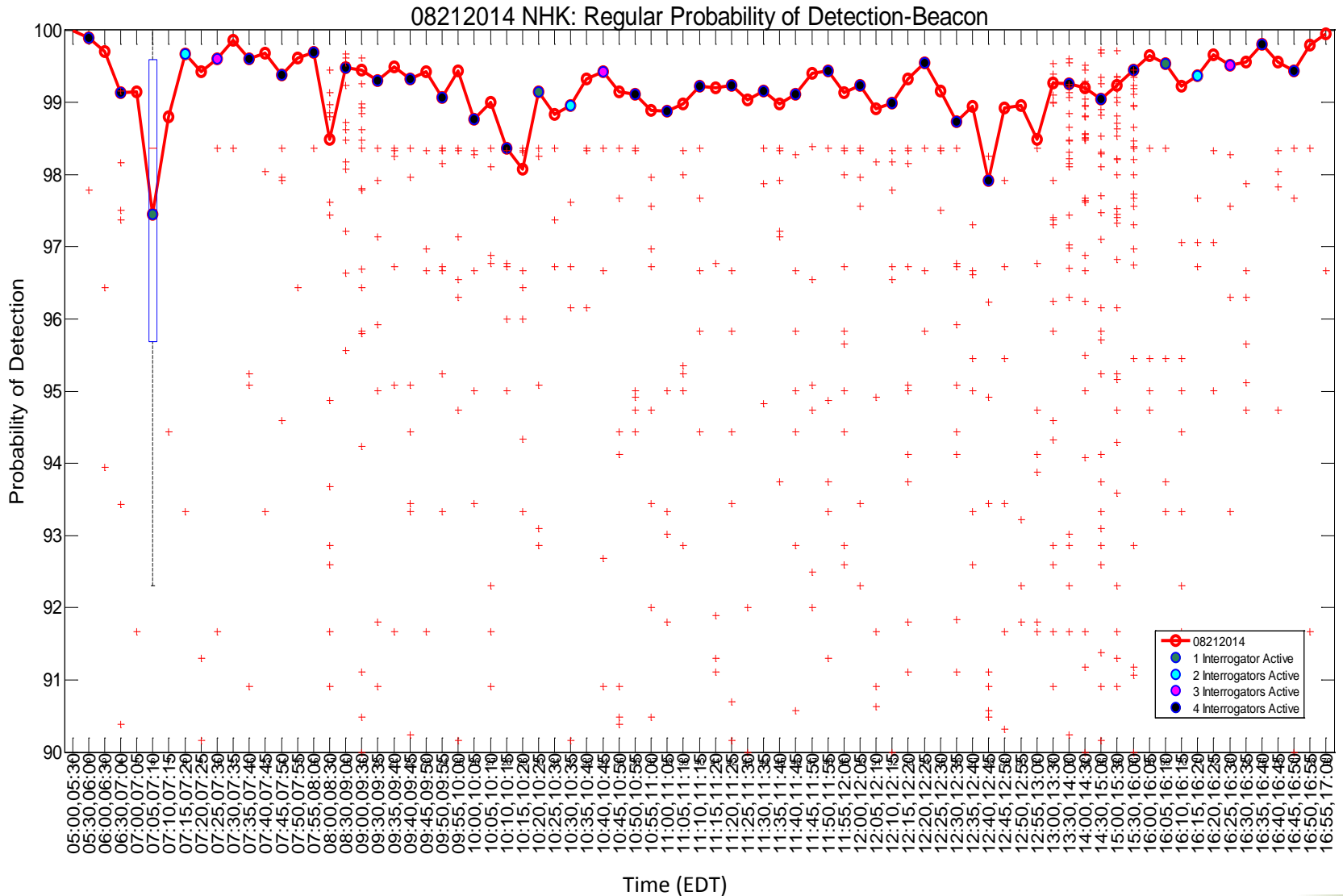
# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)



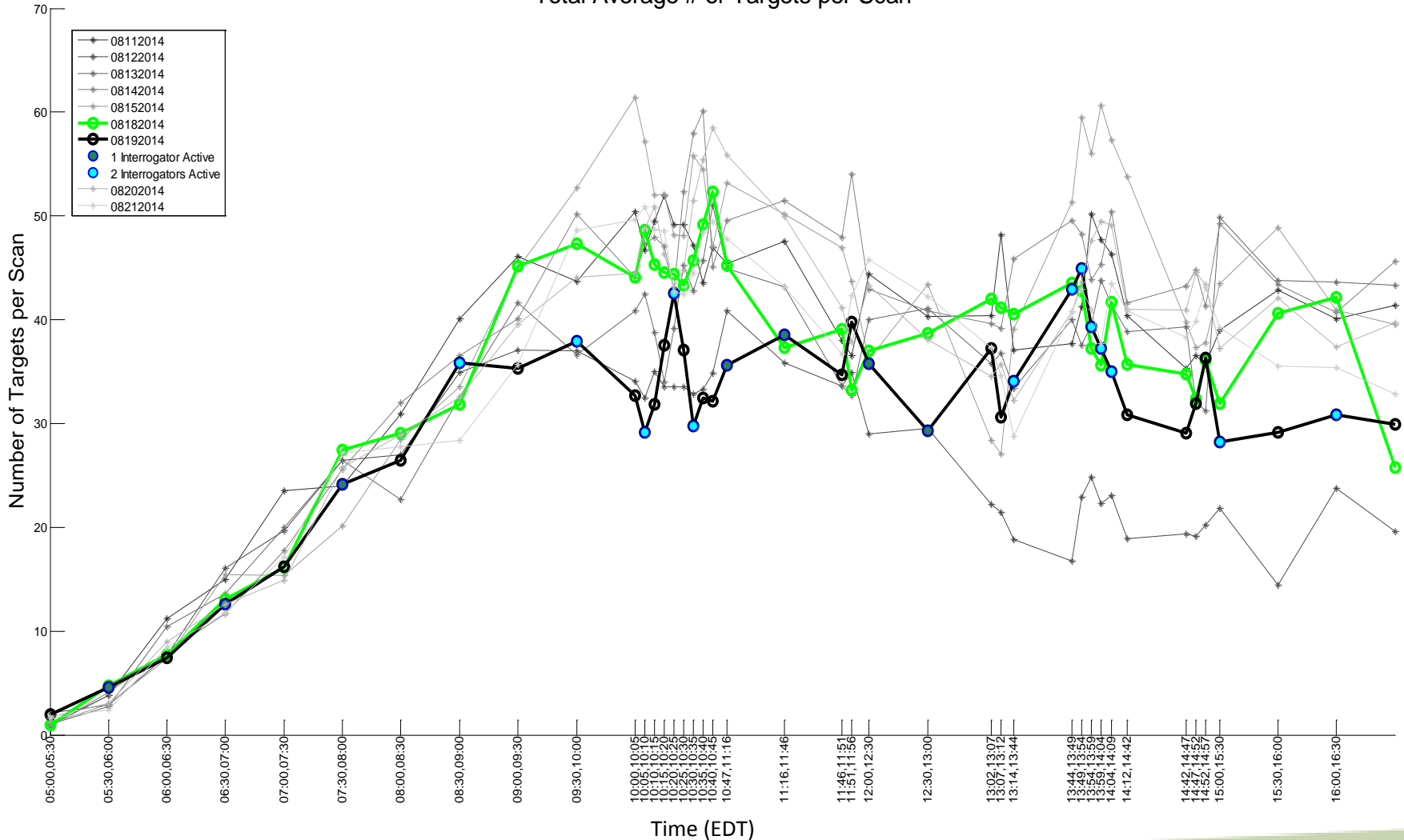
Geographic Filter: Hotspot Region

Target Filter: None



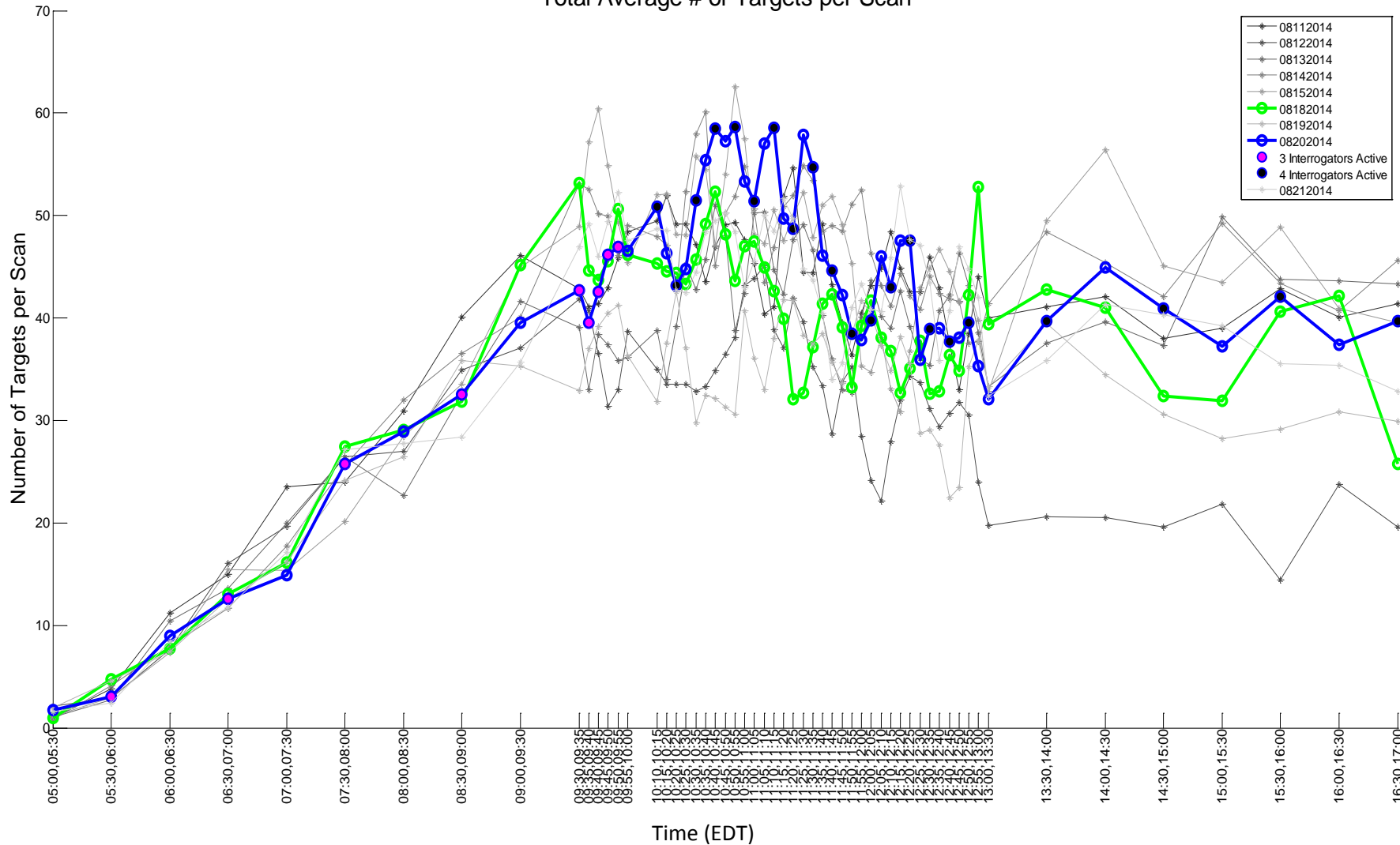
# Targets per Scan – August 19<sup>th</sup>

Total Average # of Targets per Scan



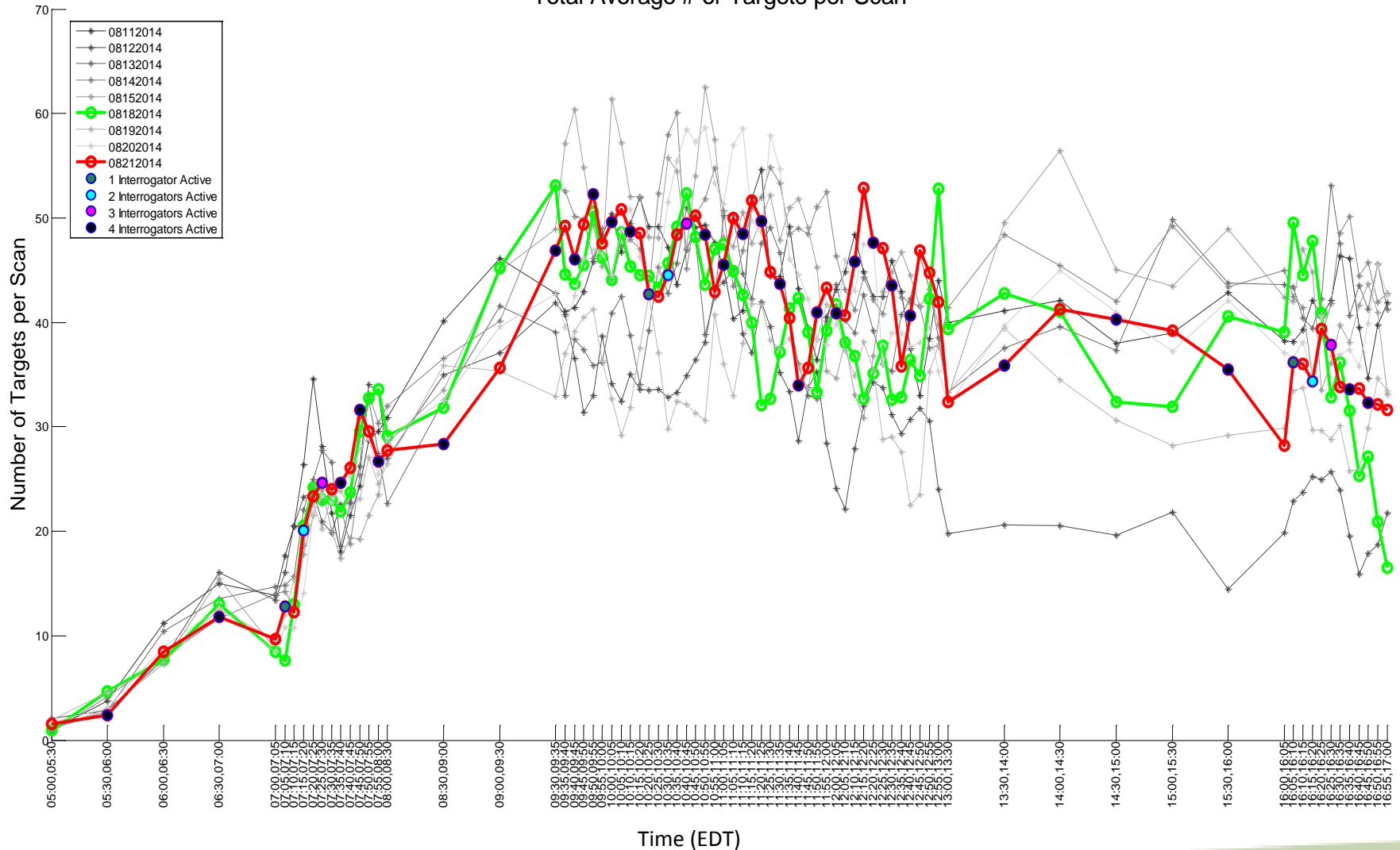
# Targets per Scan – August 20<sup>th</sup>

Total Average # of Targets per Scan

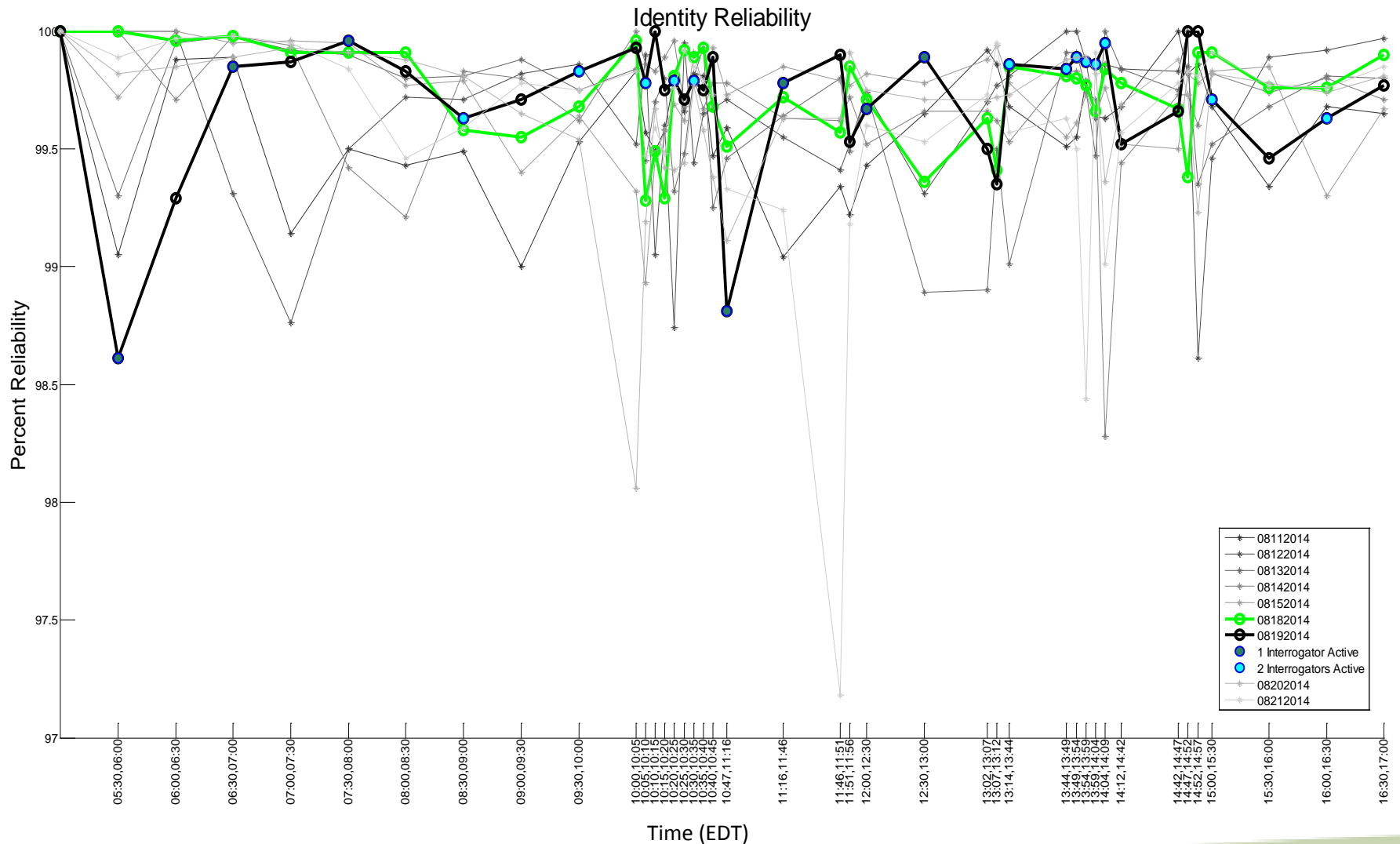


# Targets per Scan – August 21<sup>st</sup>

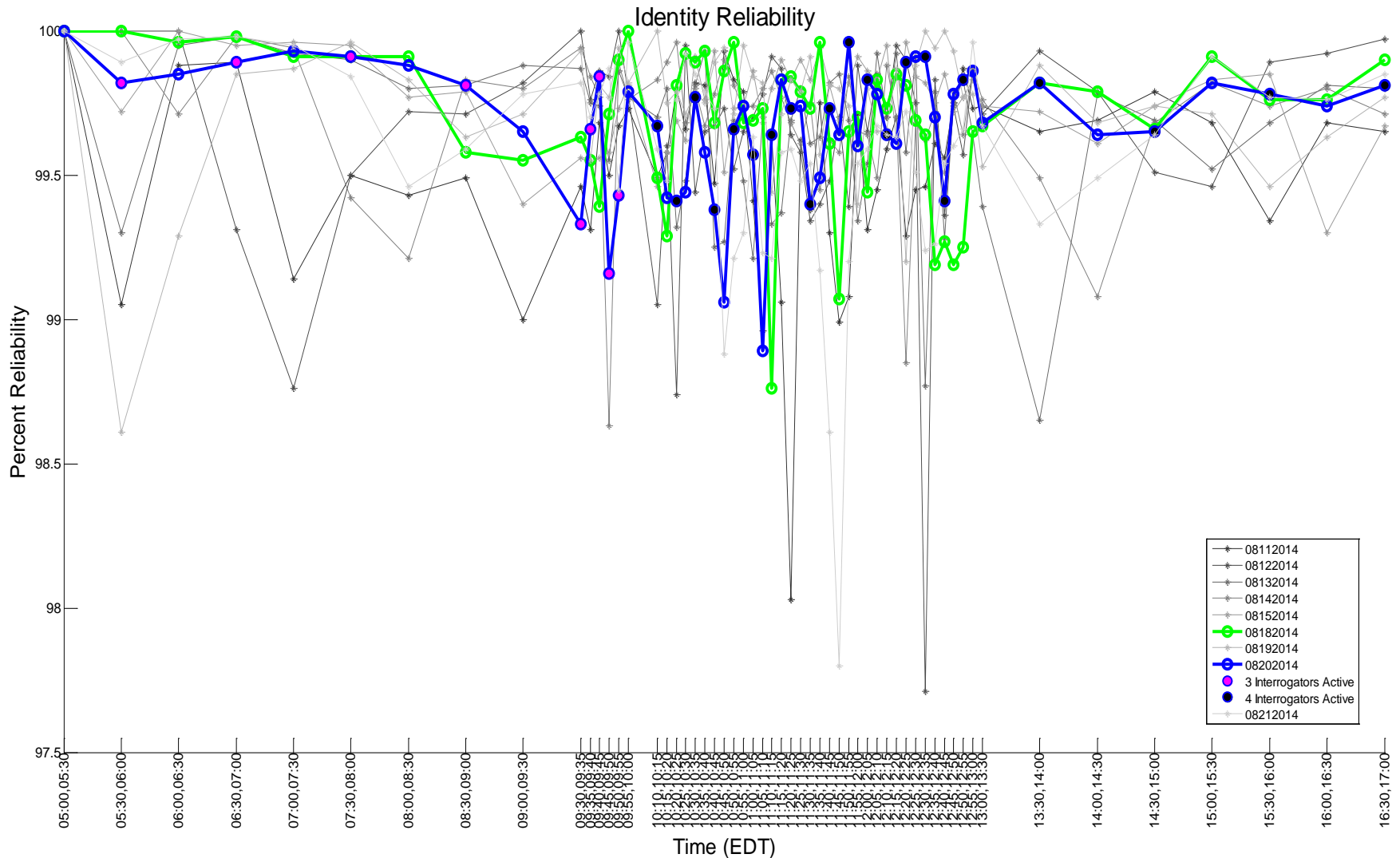
Total Average # of Targets per Scan



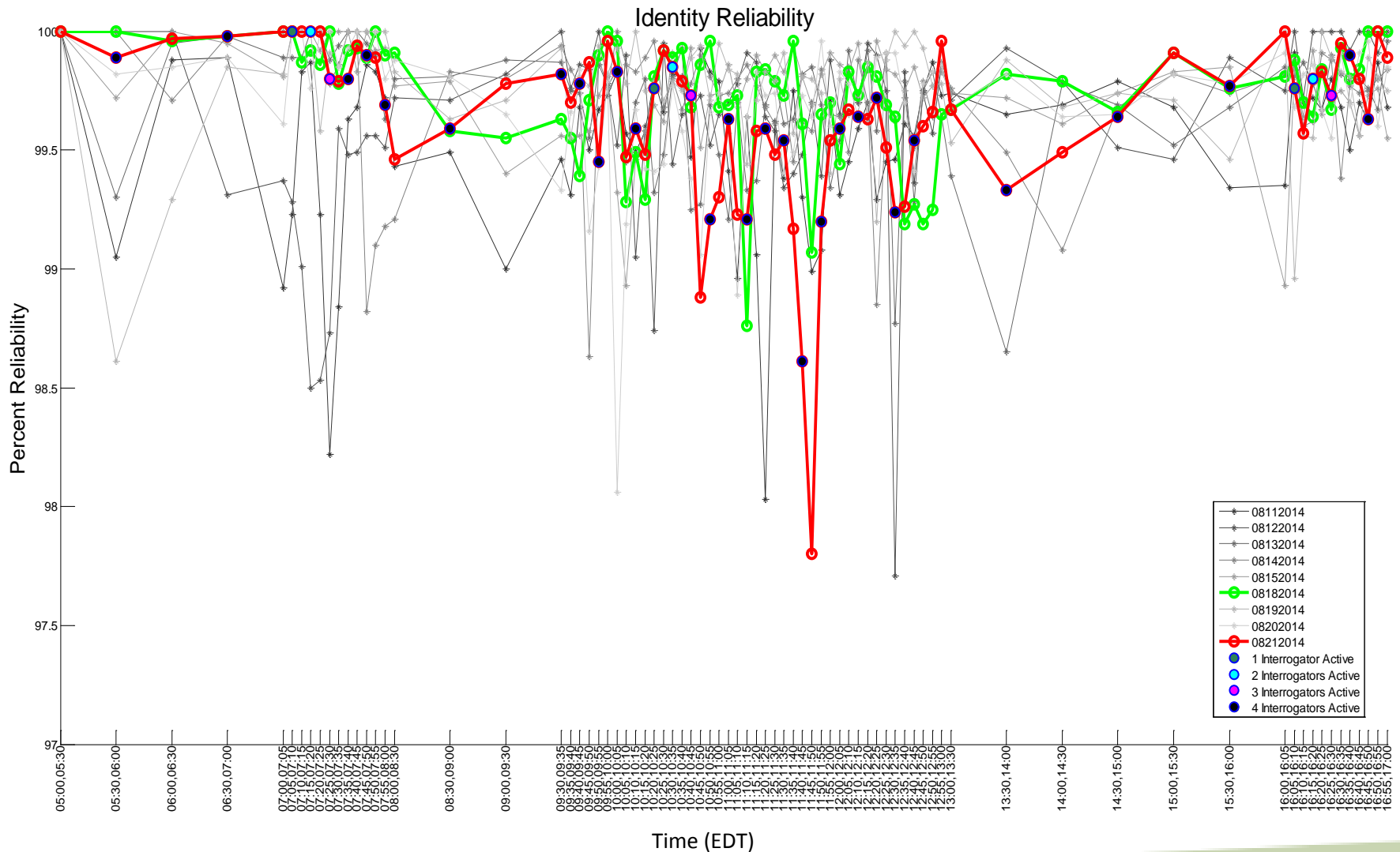
# Identity (3/A) Reliability – August 19<sup>th</sup>



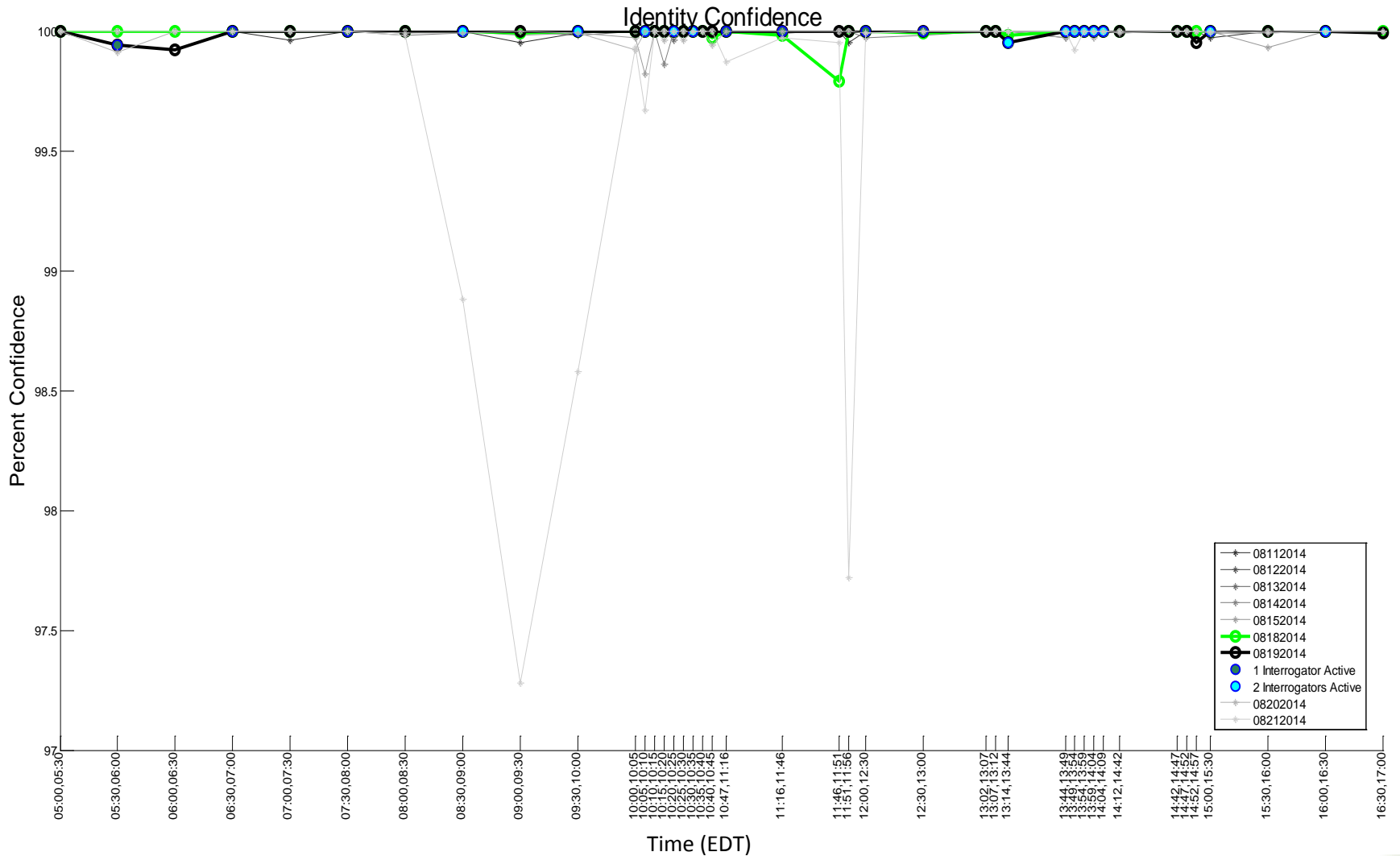
# Identity (3/A) Reliability – August 20<sup>th</sup>



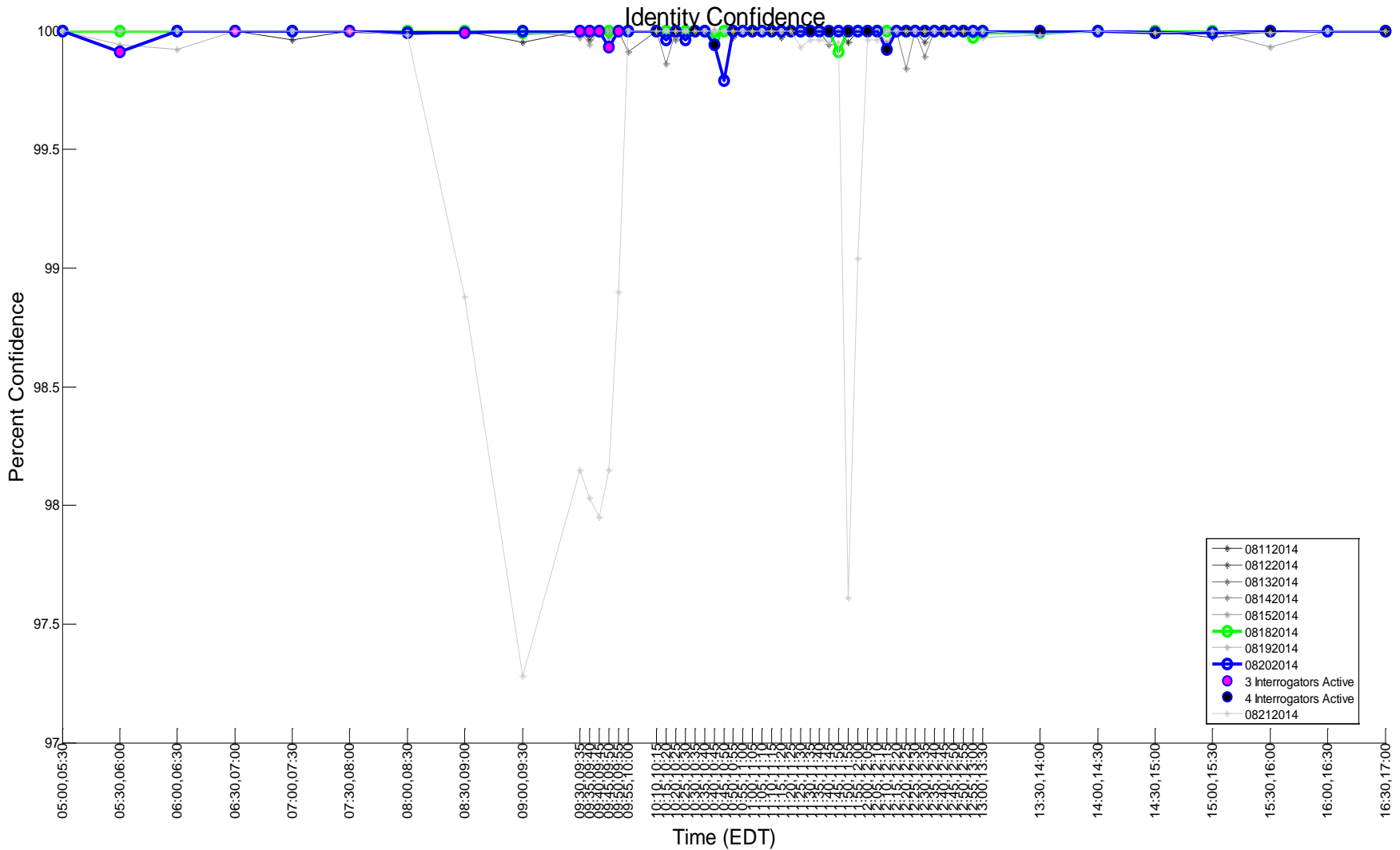
# Identity (3/A) Reliability – August 21<sup>st</sup>



# Identity (3/A) Confidence – August 19<sup>th</sup>

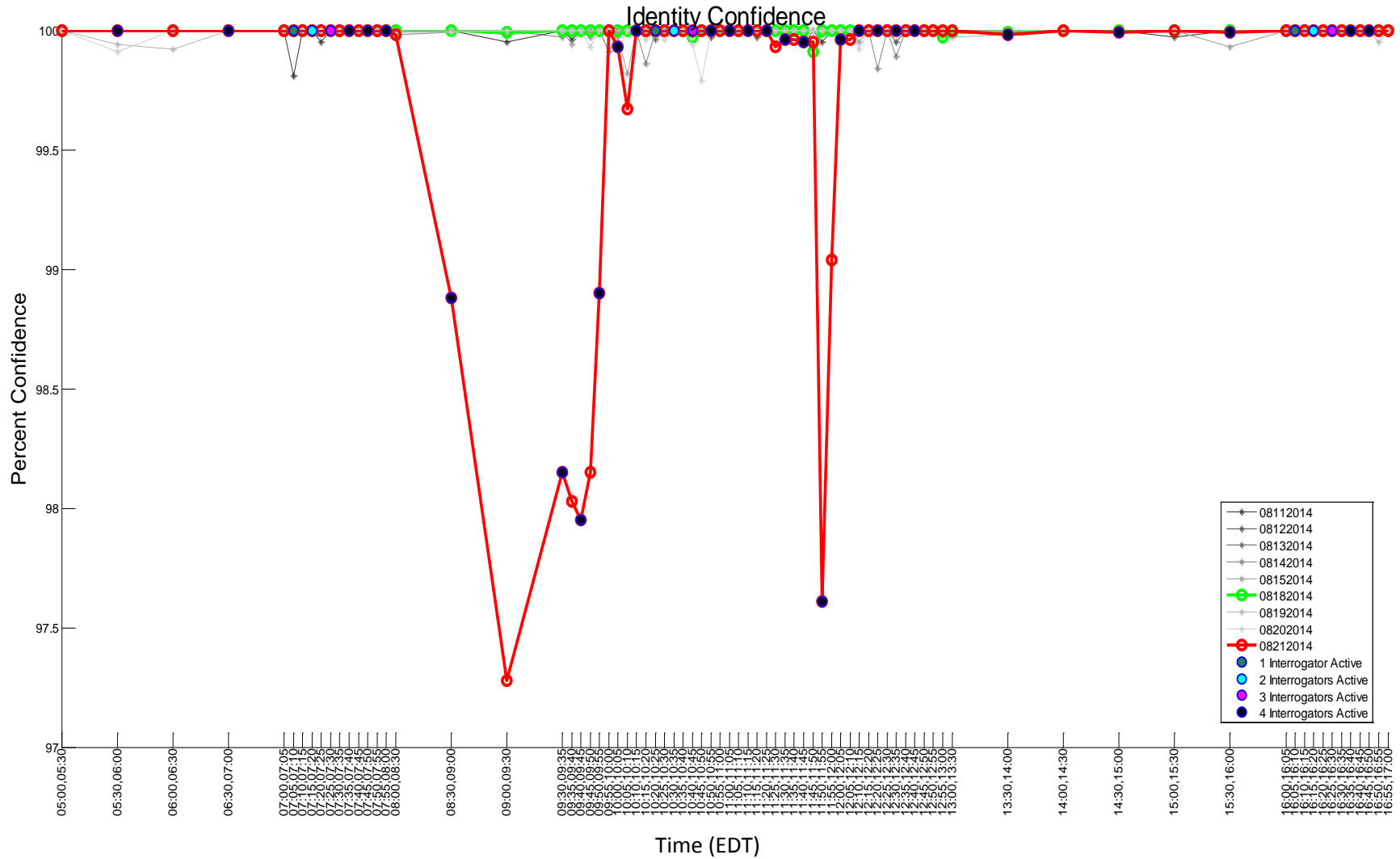


# Identity (3/A) Confidence – August 20<sup>th</sup>

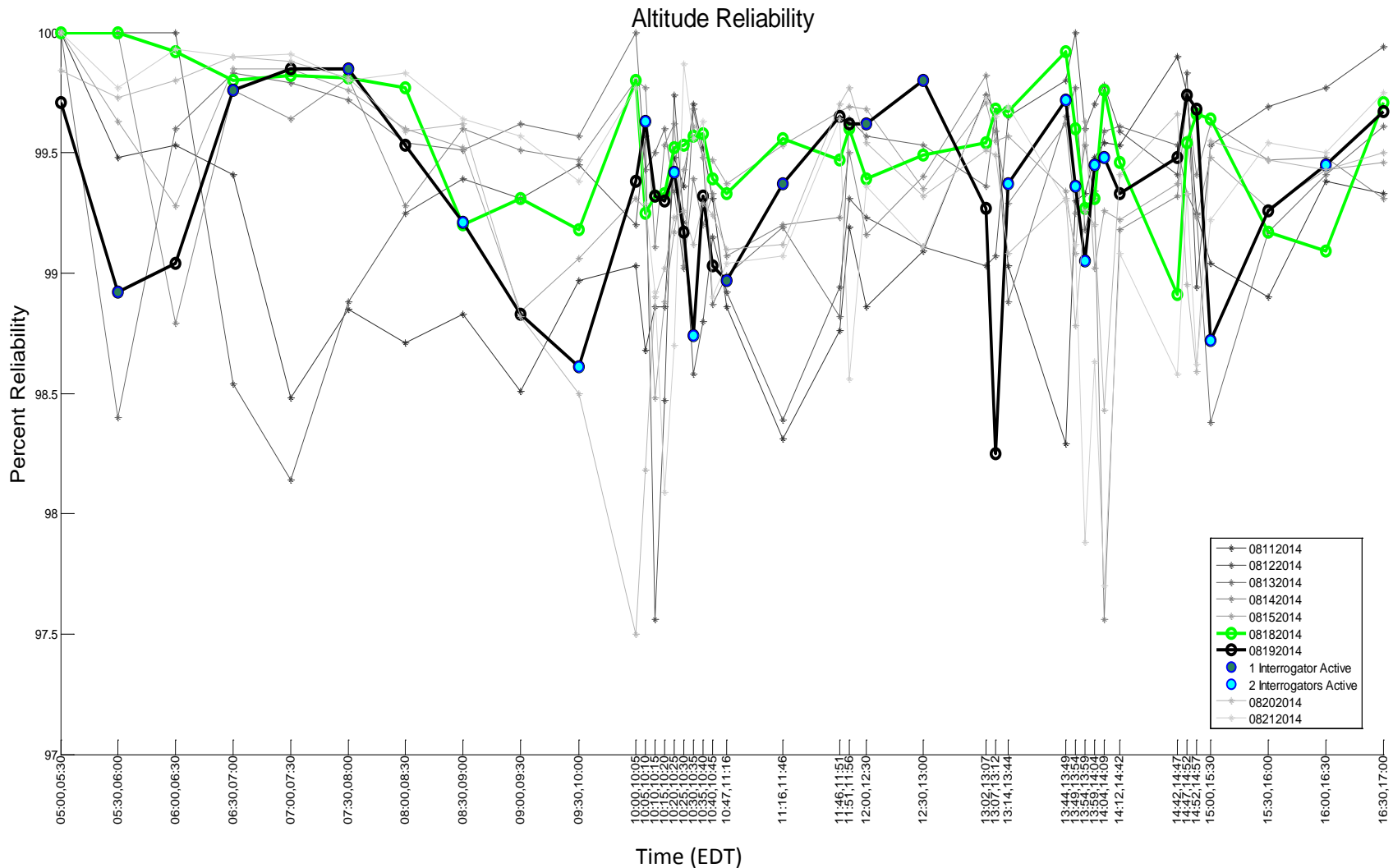




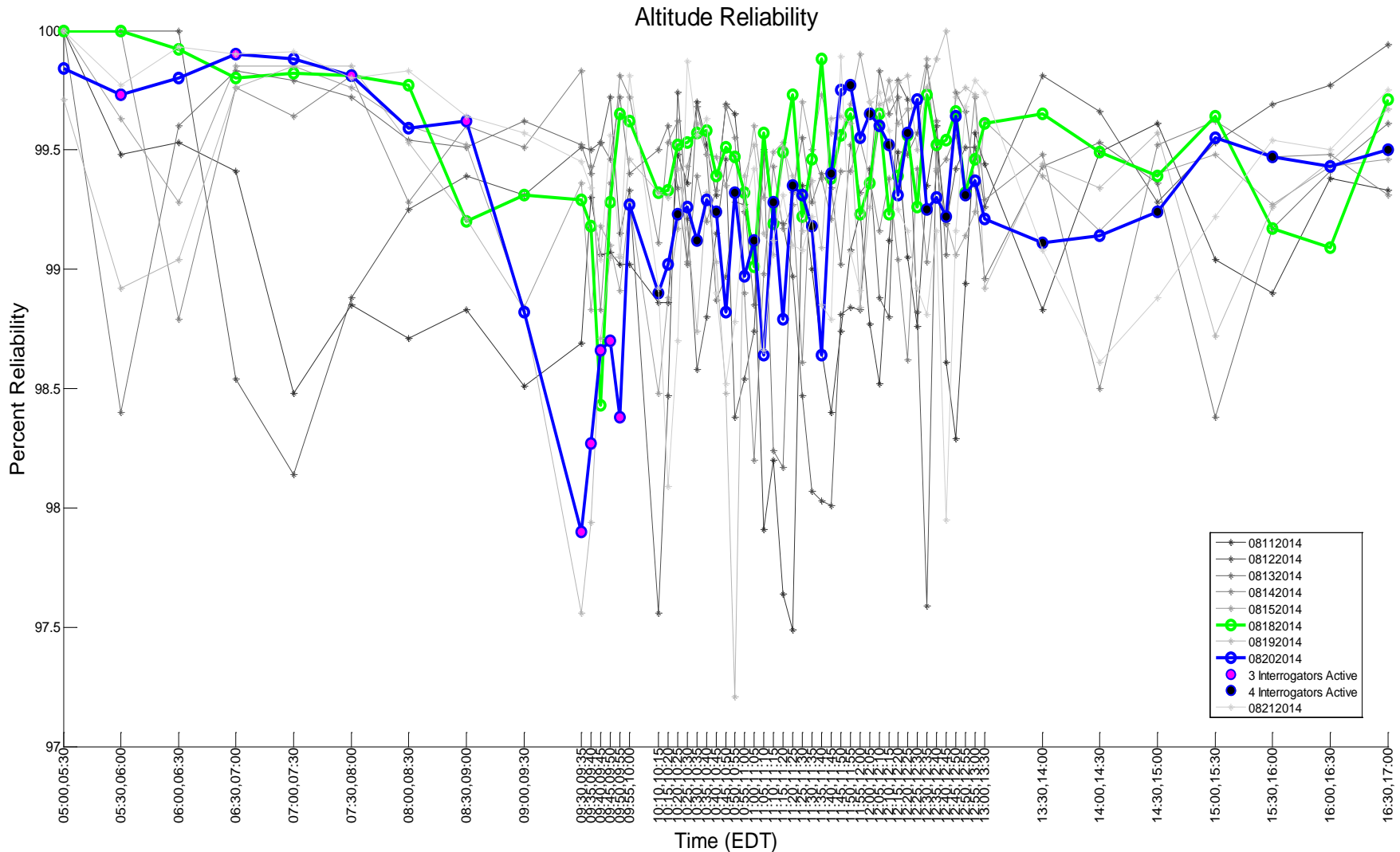
# Identity (3/A) Confidence – August 21<sup>st</sup>



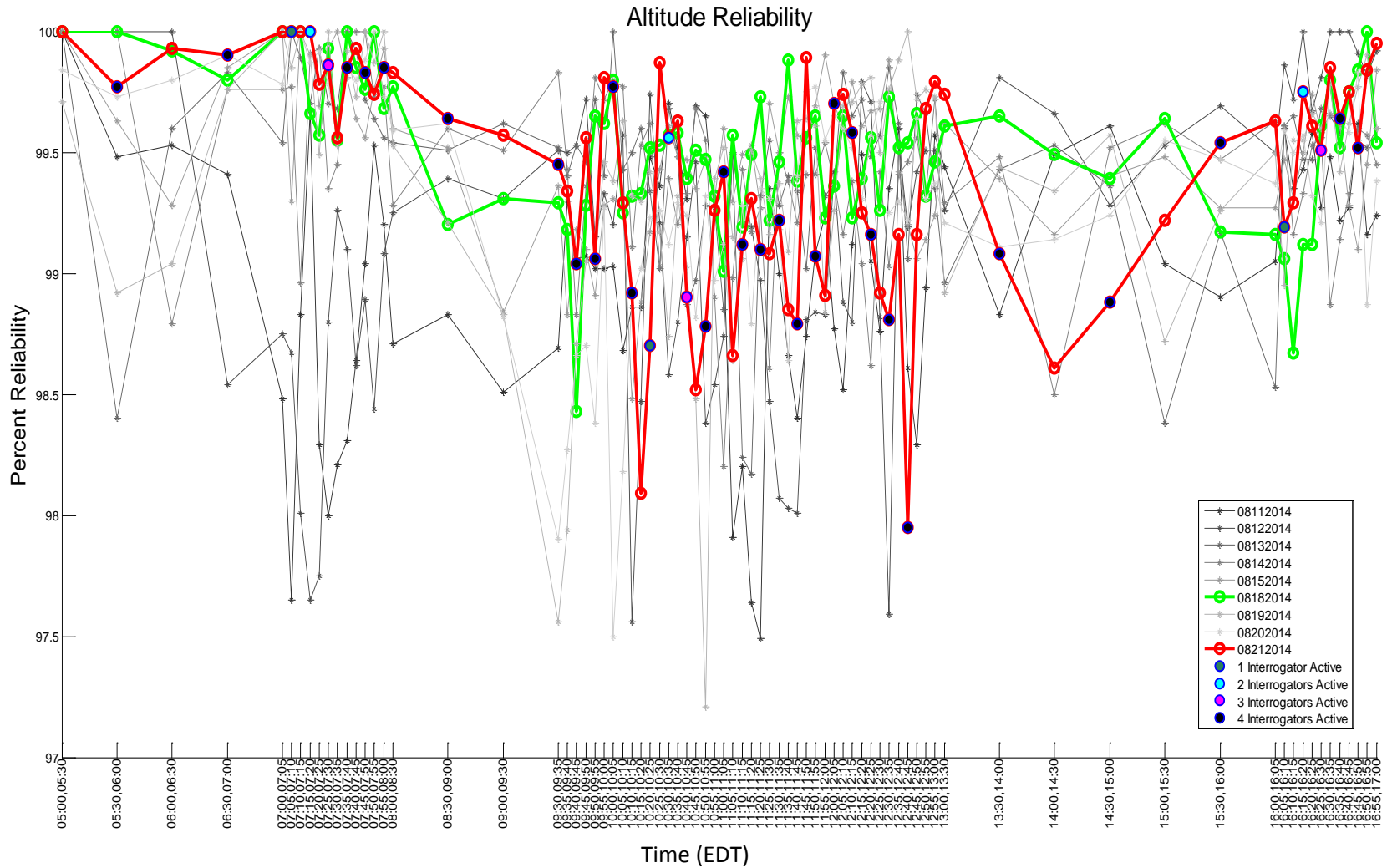
# Altitude (C) Reliability – August 19<sup>th</sup>



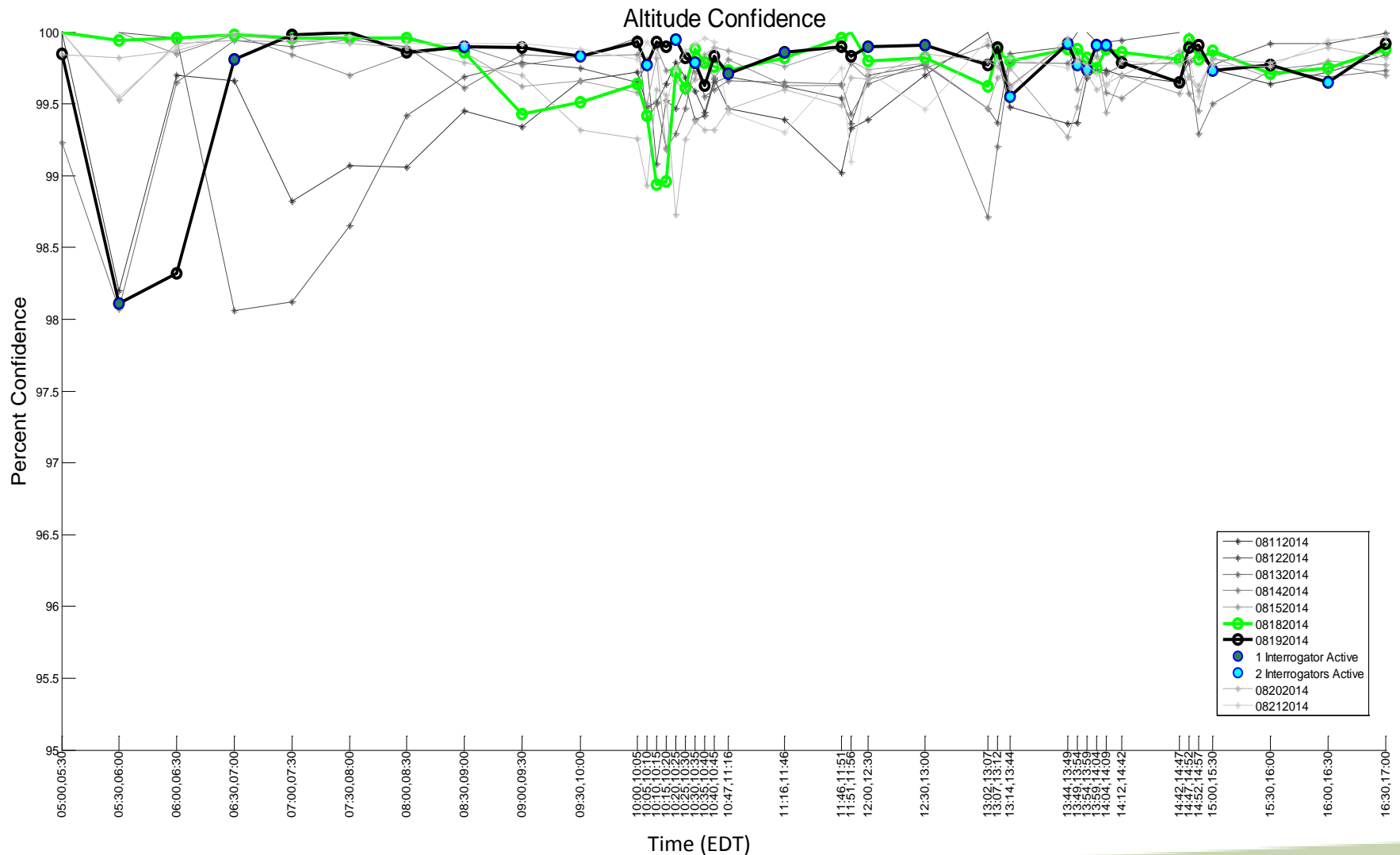
# Altitude (C) Reliability – August 20<sup>th</sup>



# Altitude (C) Reliability – August 21<sup>st</sup>

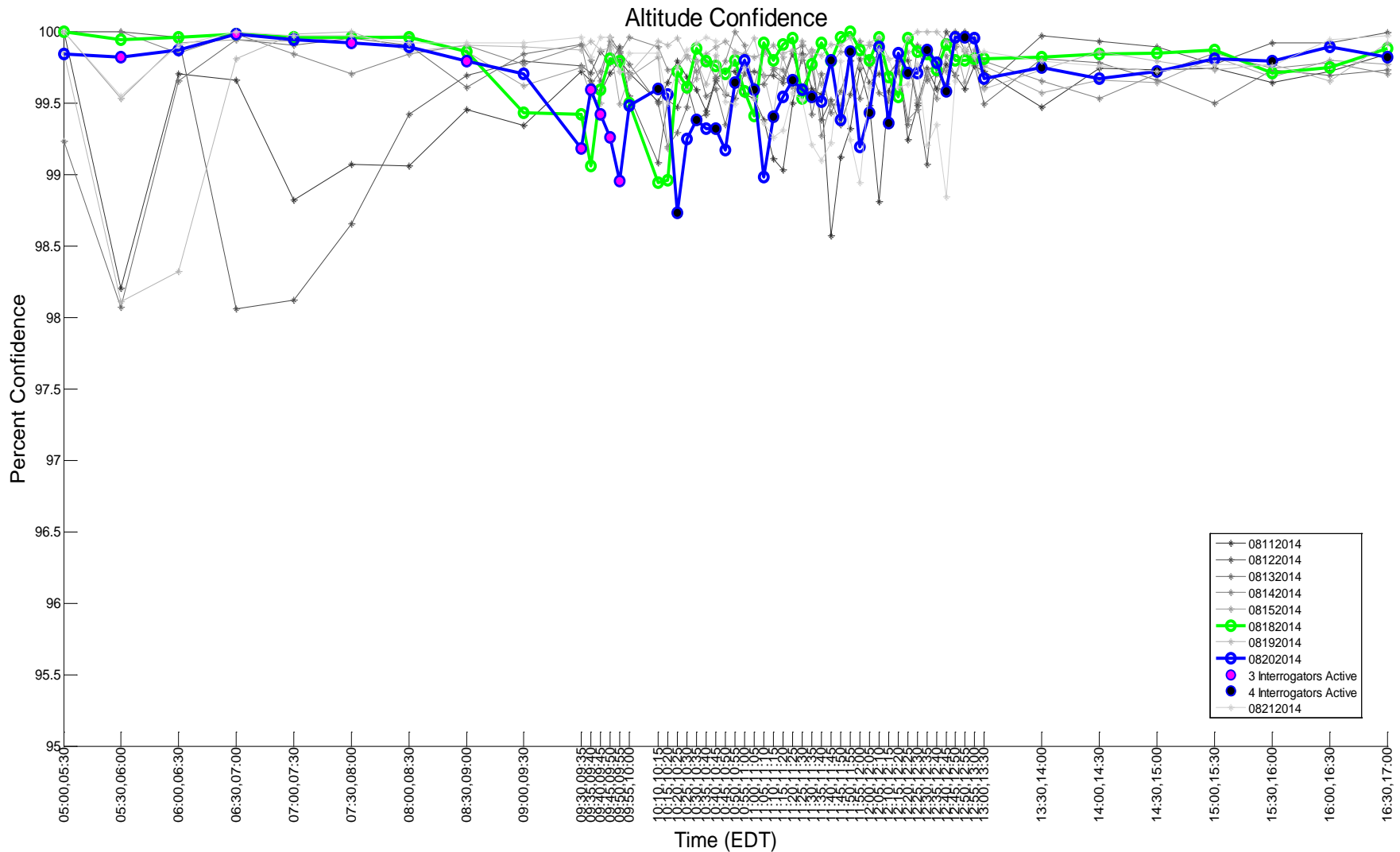


# Altitude (C) Confidence – August 19<sup>th</sup>

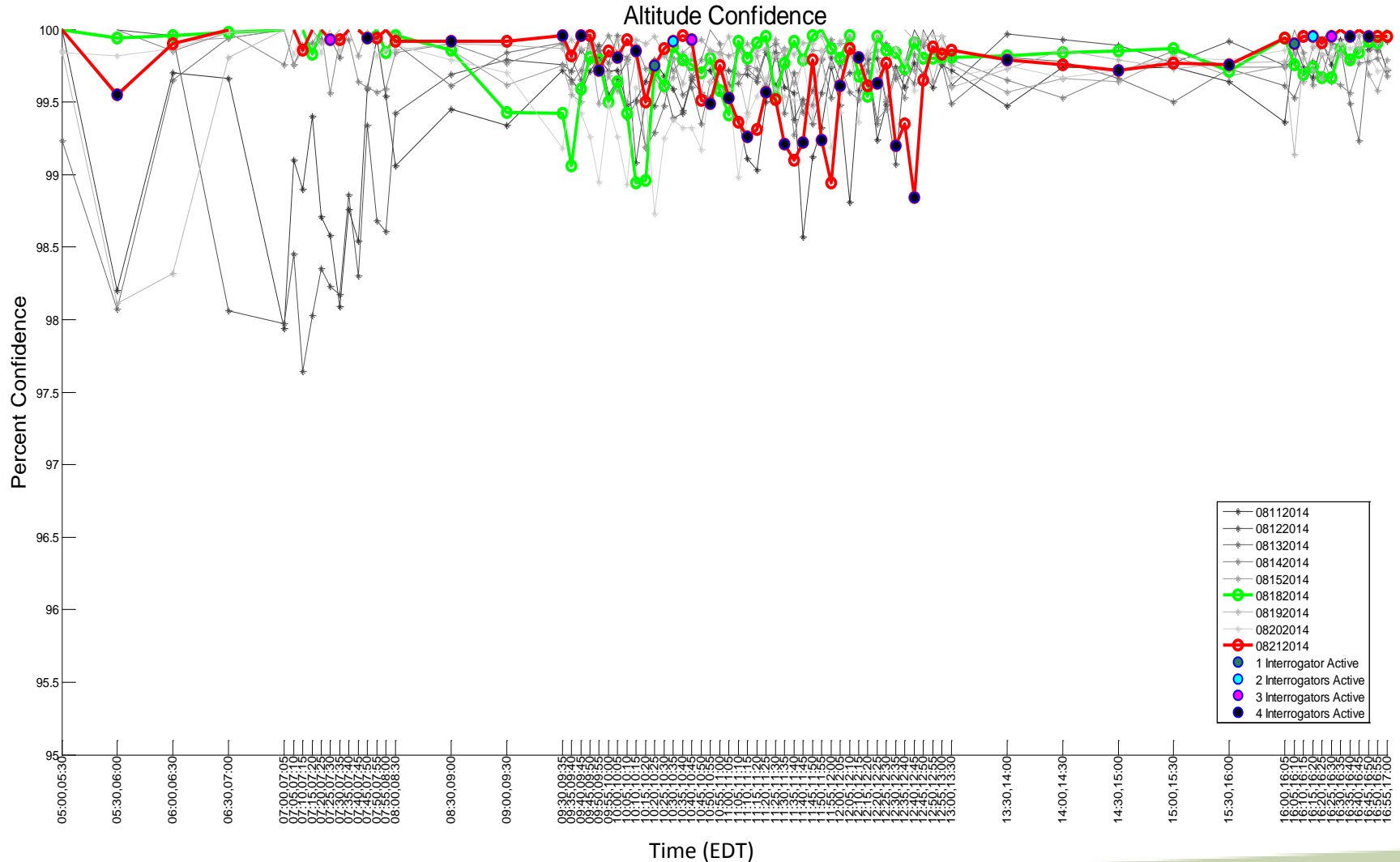


Geographic Filter: Hotspot Region  
Target Filter: None

# Altitude (C) Confidence – August 20<sup>th</sup>



# Altitude (C) Confidence – August 21<sup>st</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

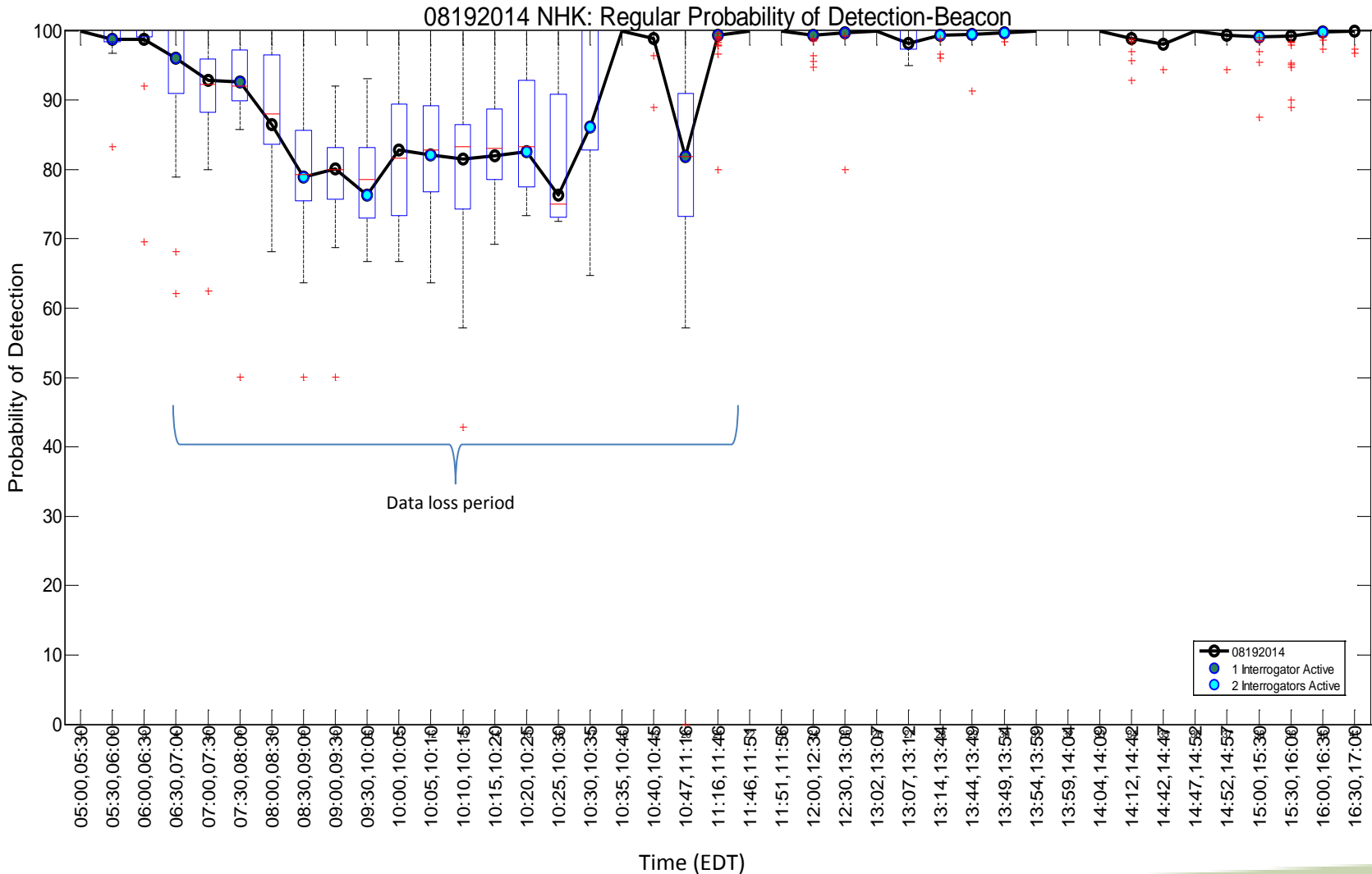
# Target Metrics in the Hotspot Region with Range greater than 50 NM from SSR

*\* Number of Targets Unavailable*



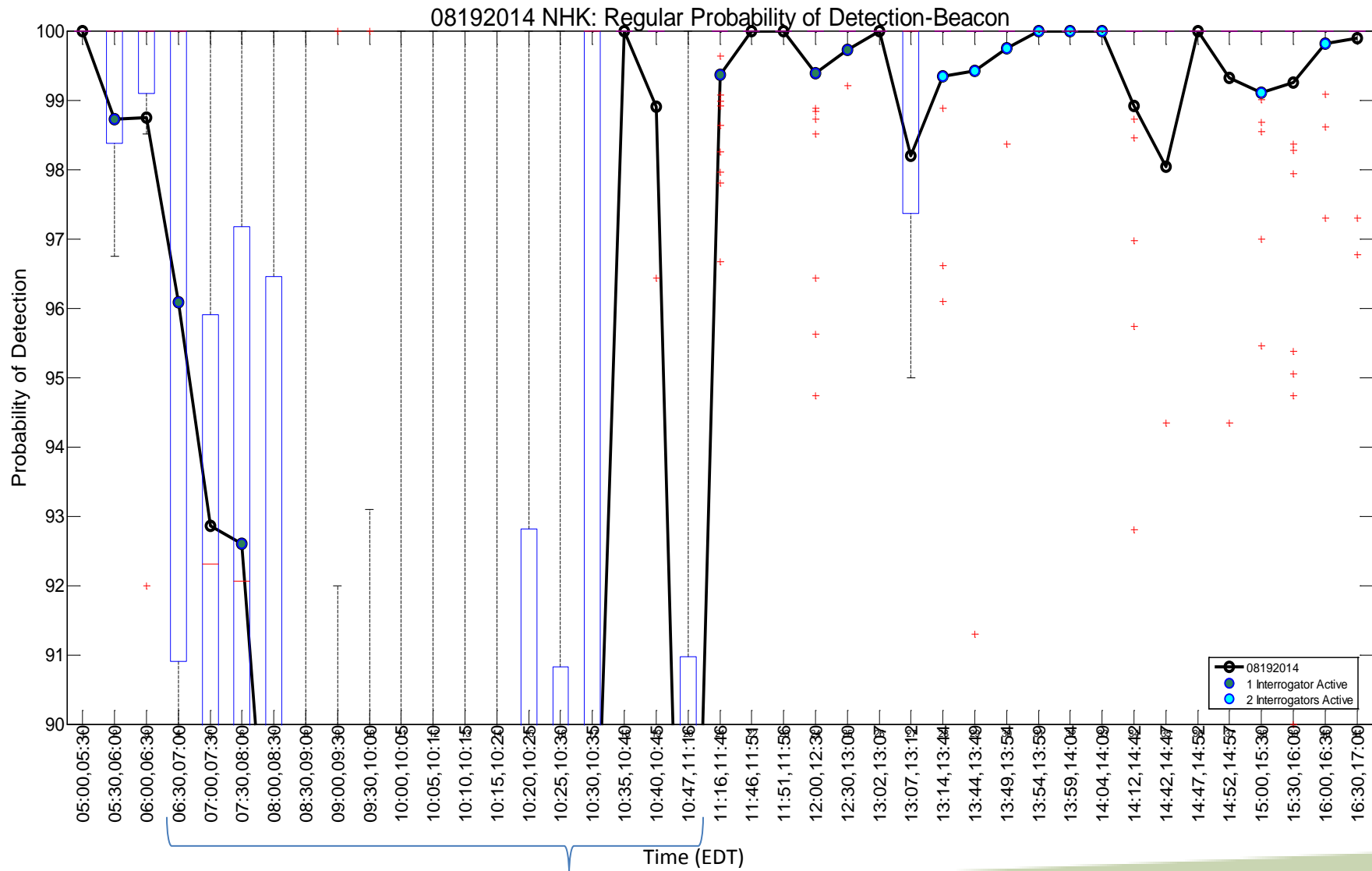
# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution



# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)



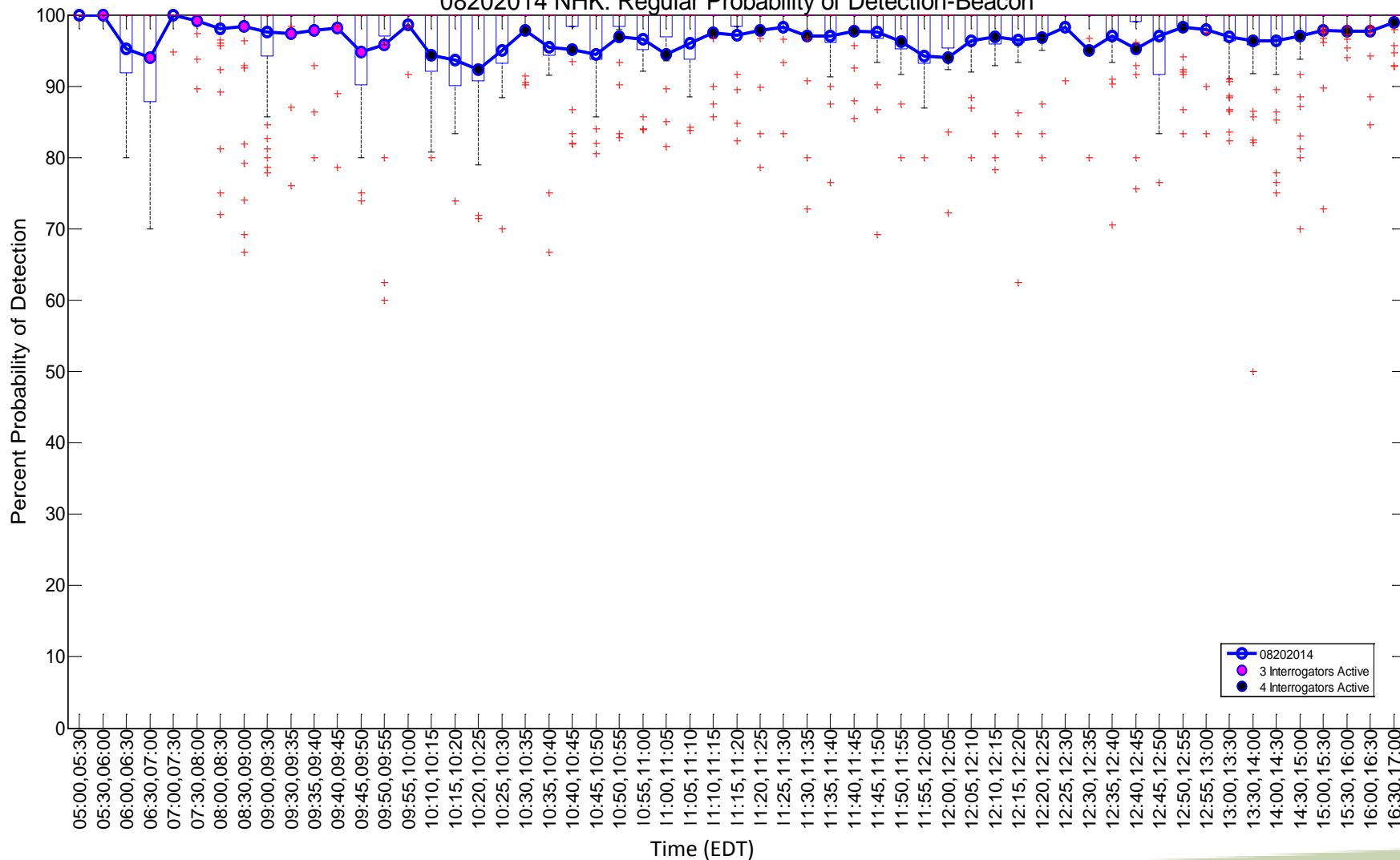
Geographic Filter: Hotspot Region  
 Target Filter: Exclude Targets < 50 NM

Data loss period

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

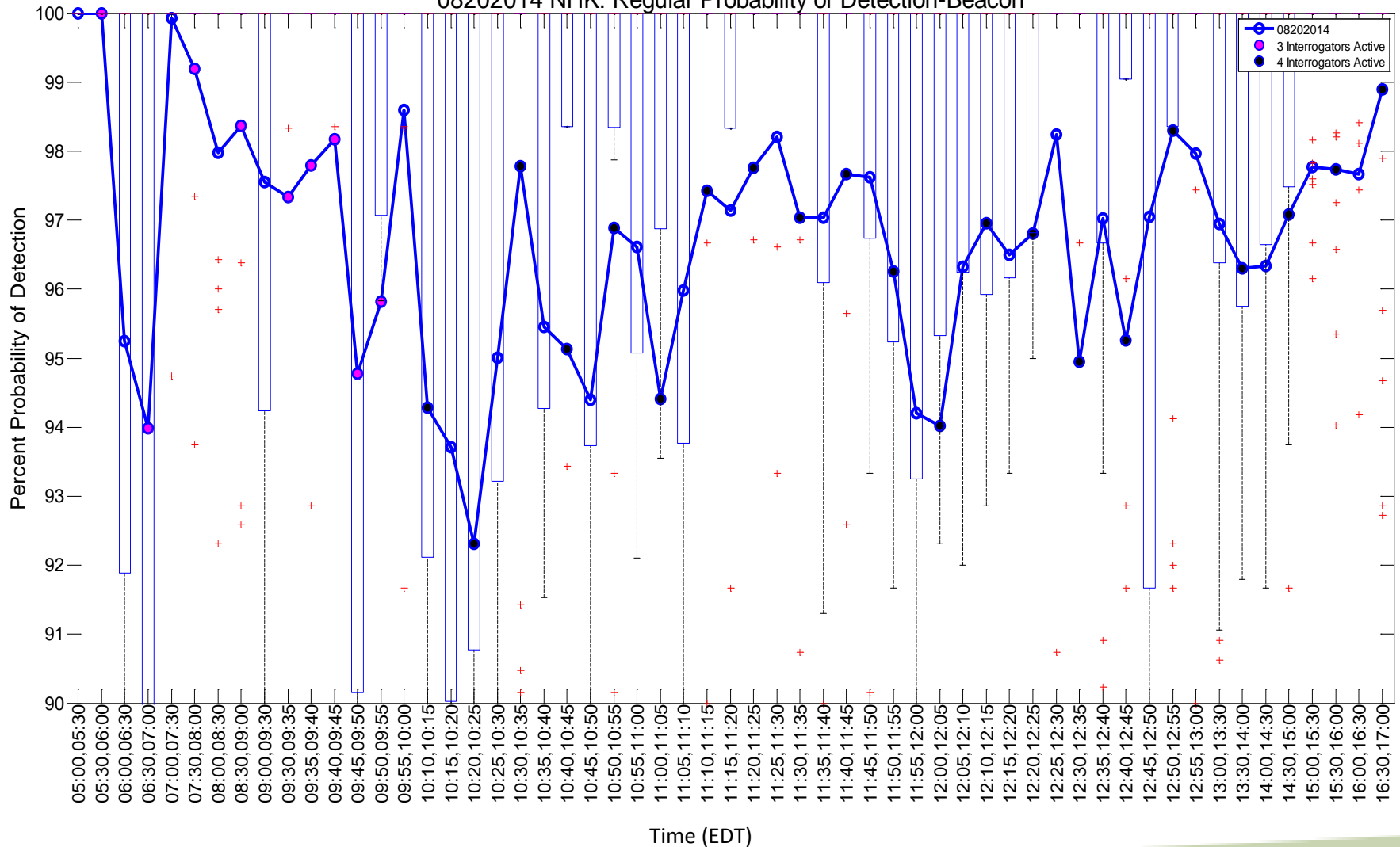
08202014 NHK: Regular Probability of Detection-Beacon



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

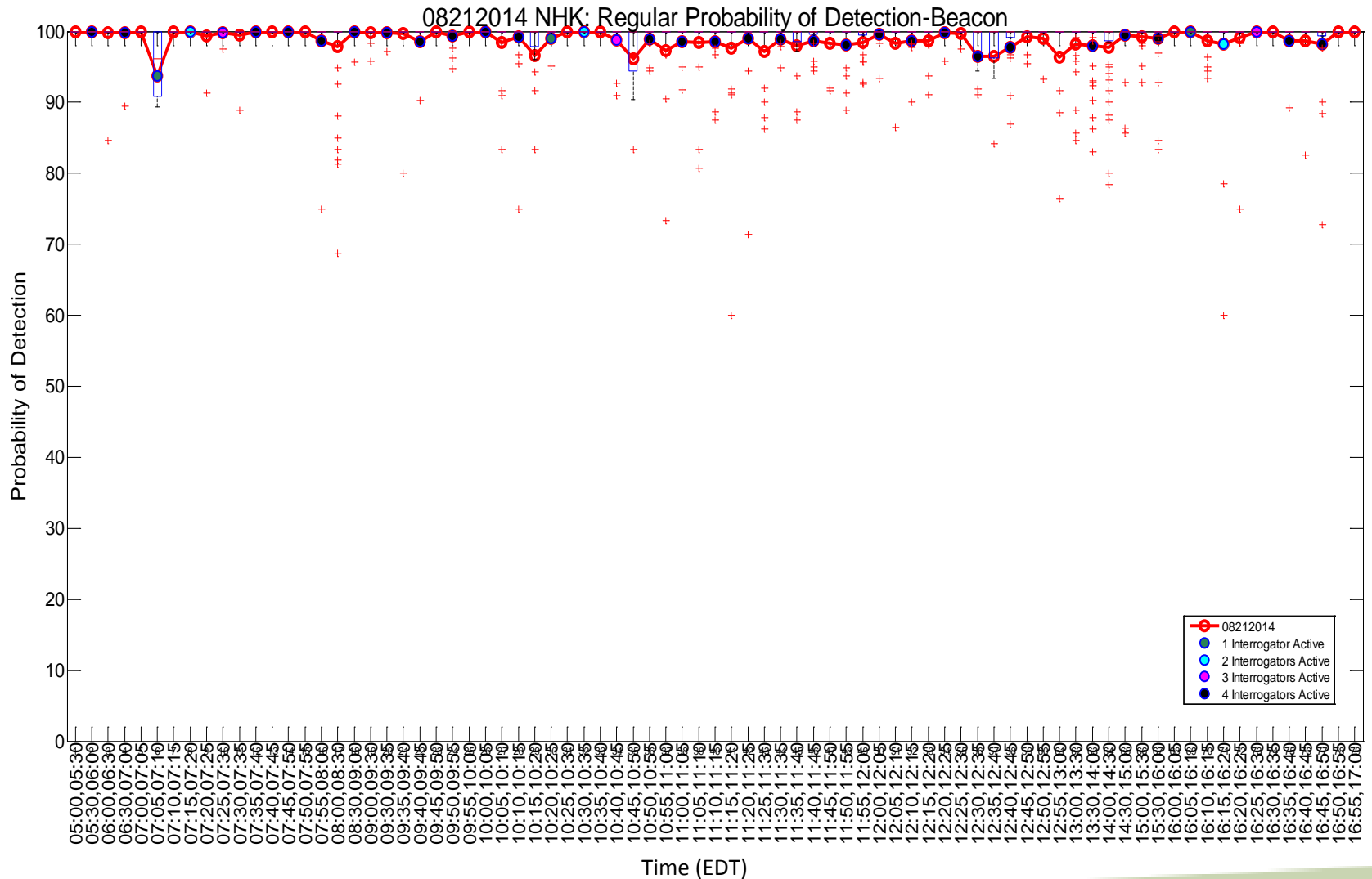
08202014 NHK: Regular Probability of Detection-Beacon



Geographic Filter: Hotspot Region  
 Target Filter: Exclude Targets < 50 NM

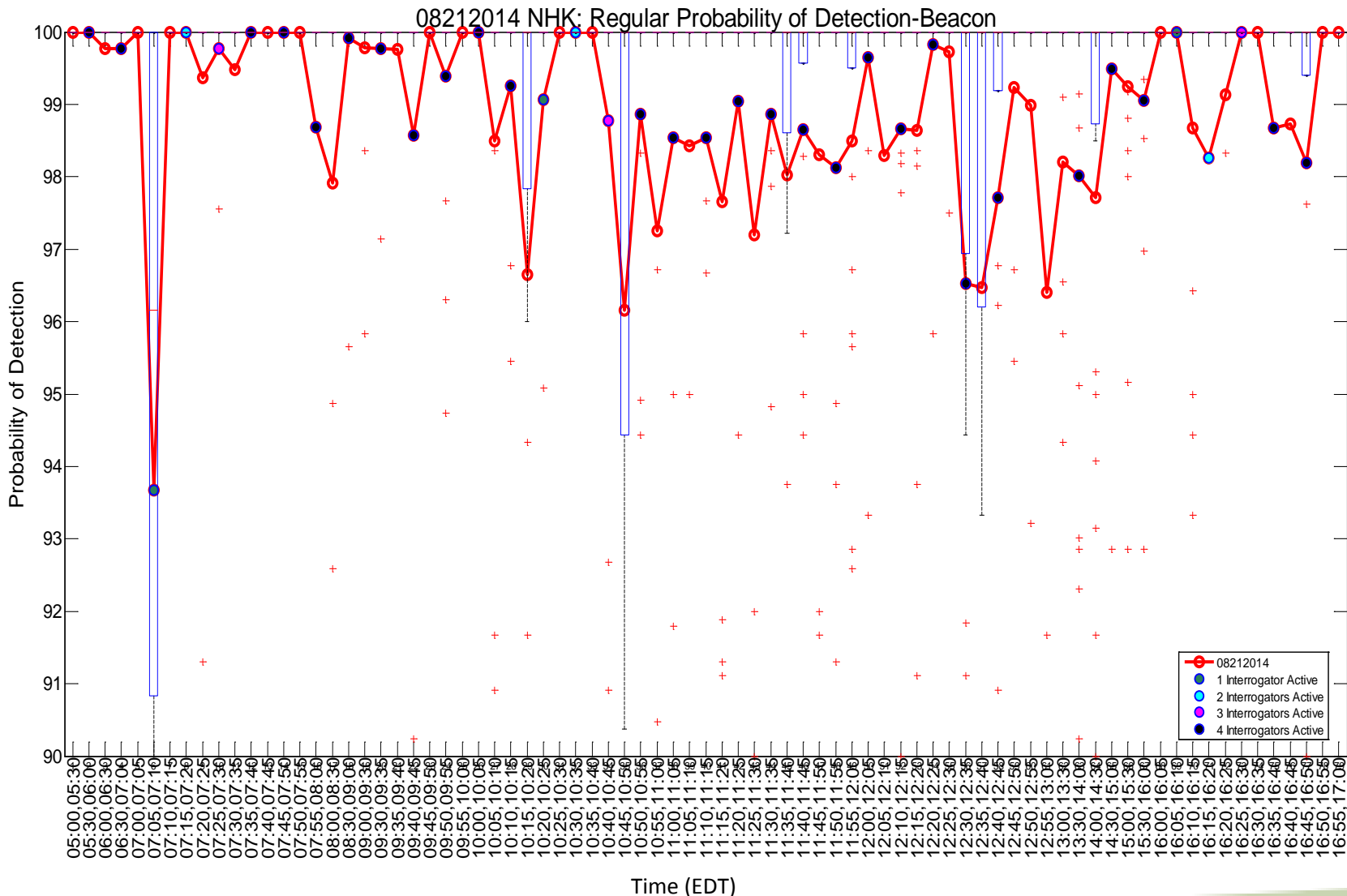
# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution



# Probability of Detection – August 21<sup>st</sup>

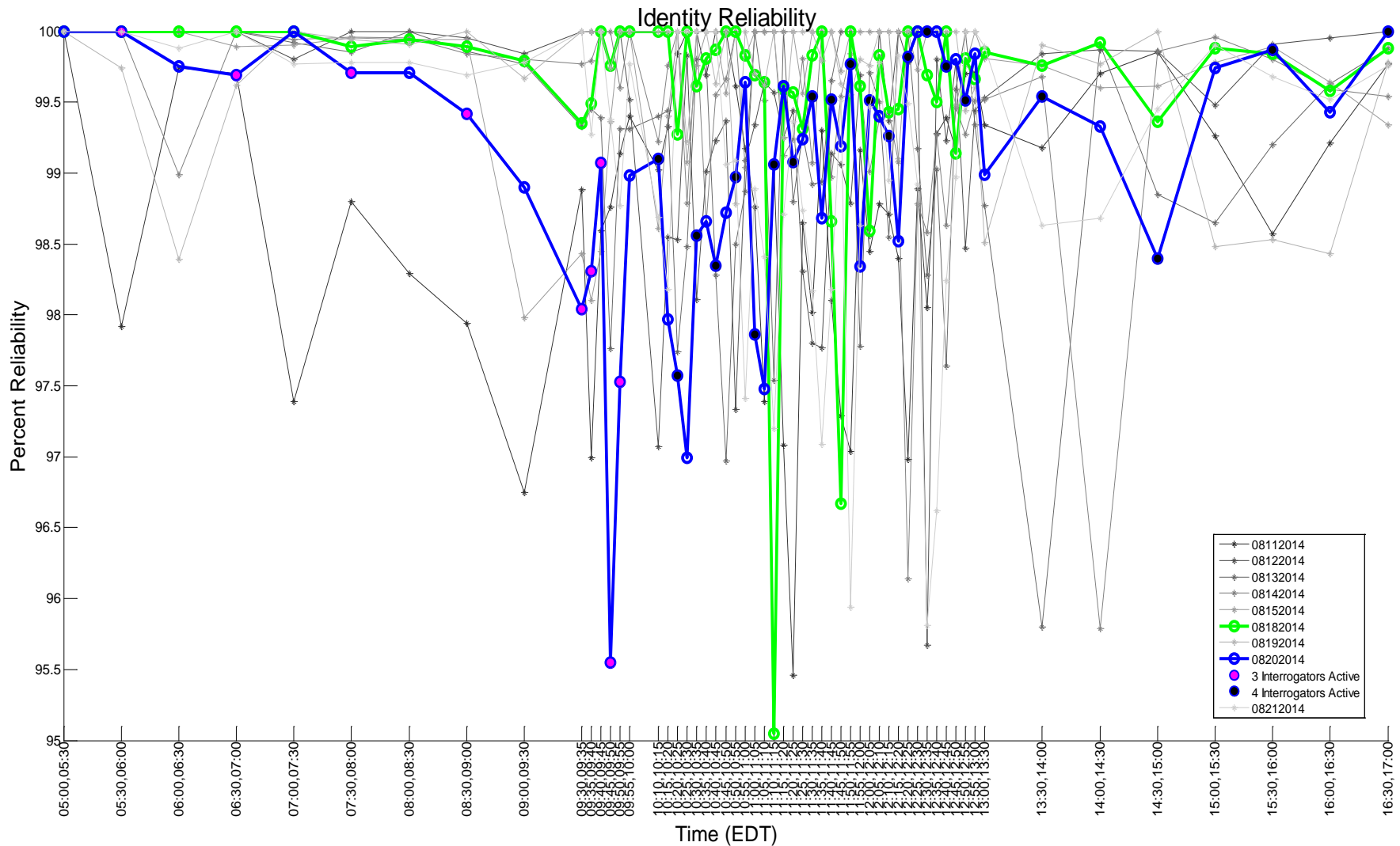
## Individual Aircraft Distribution (zoom-in)



Geographic Filter: Hotspot Region  
Target Filter: Exclude Targets < 50 NM



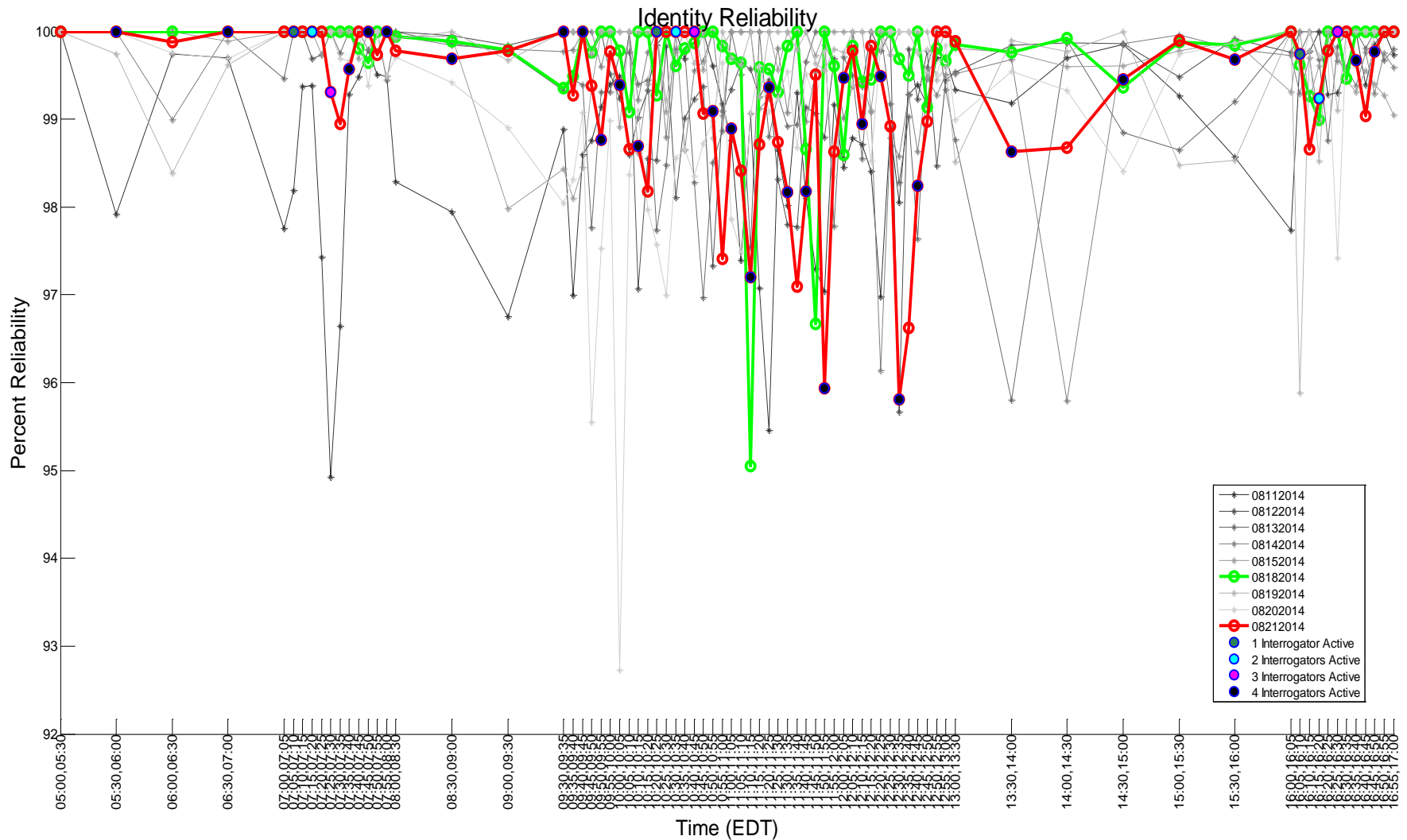
# Identity (3/A) Reliability – August 20<sup>th</sup>



Geographic Filter: Hotspot Region  
Target Filter: Exclude Targets < 50 NM

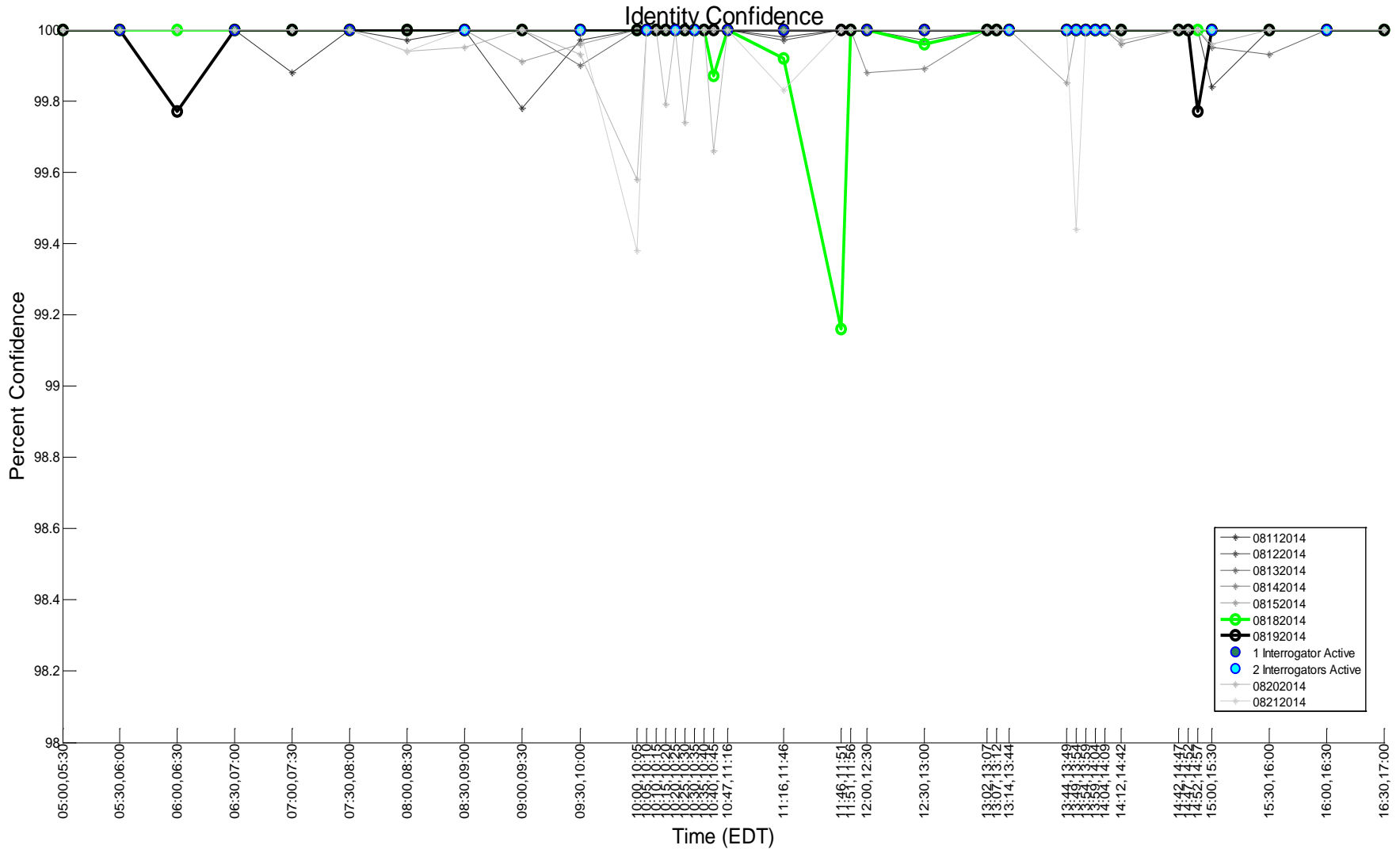


# Identity (3/A) Reliability – August 21<sup>st</sup>



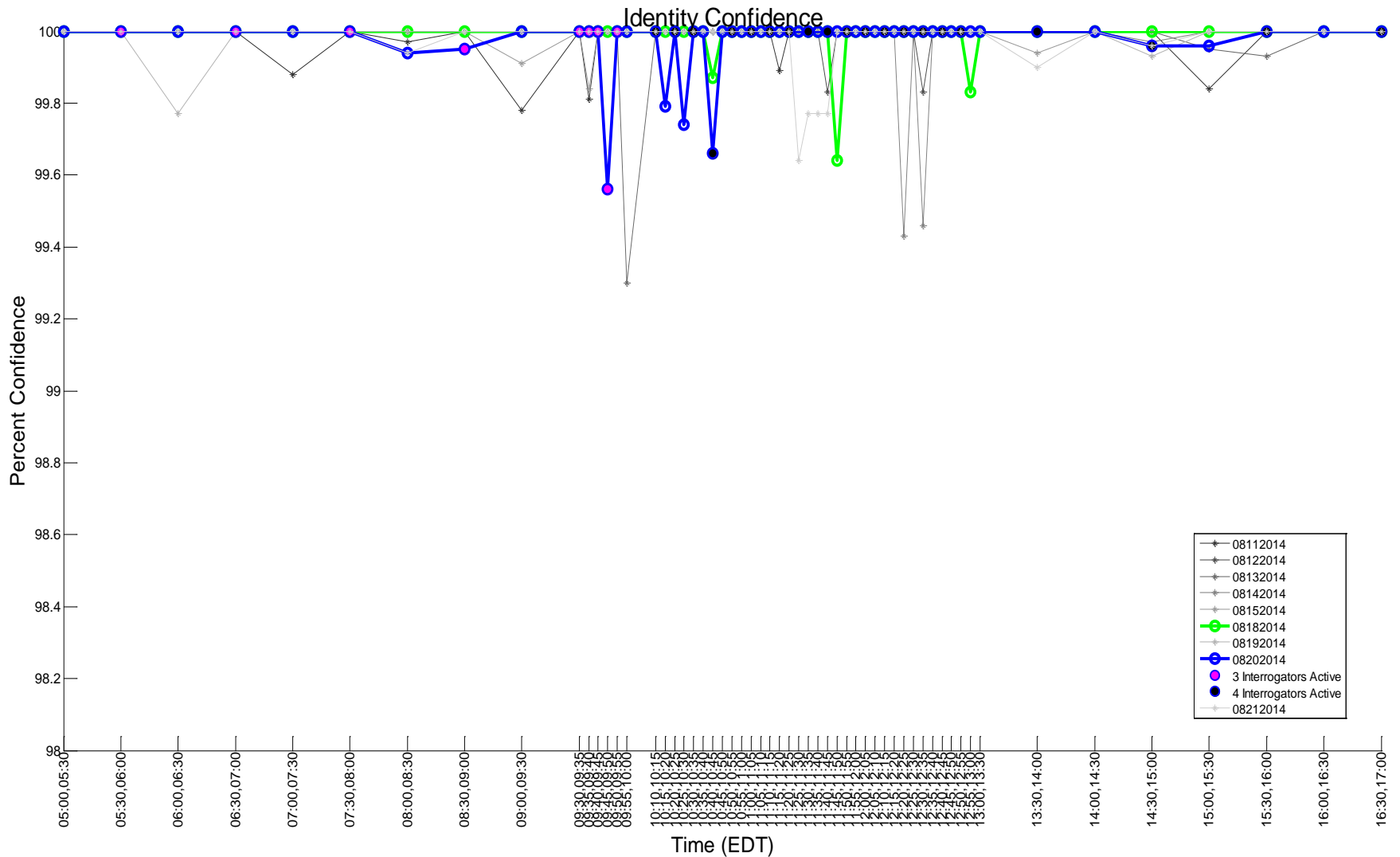
Geographic Filter: Hotspot Region  
Target Filter: Exclude Targets < 50 NM

# Identity (3/A) Confidence – August 19<sup>th</sup>

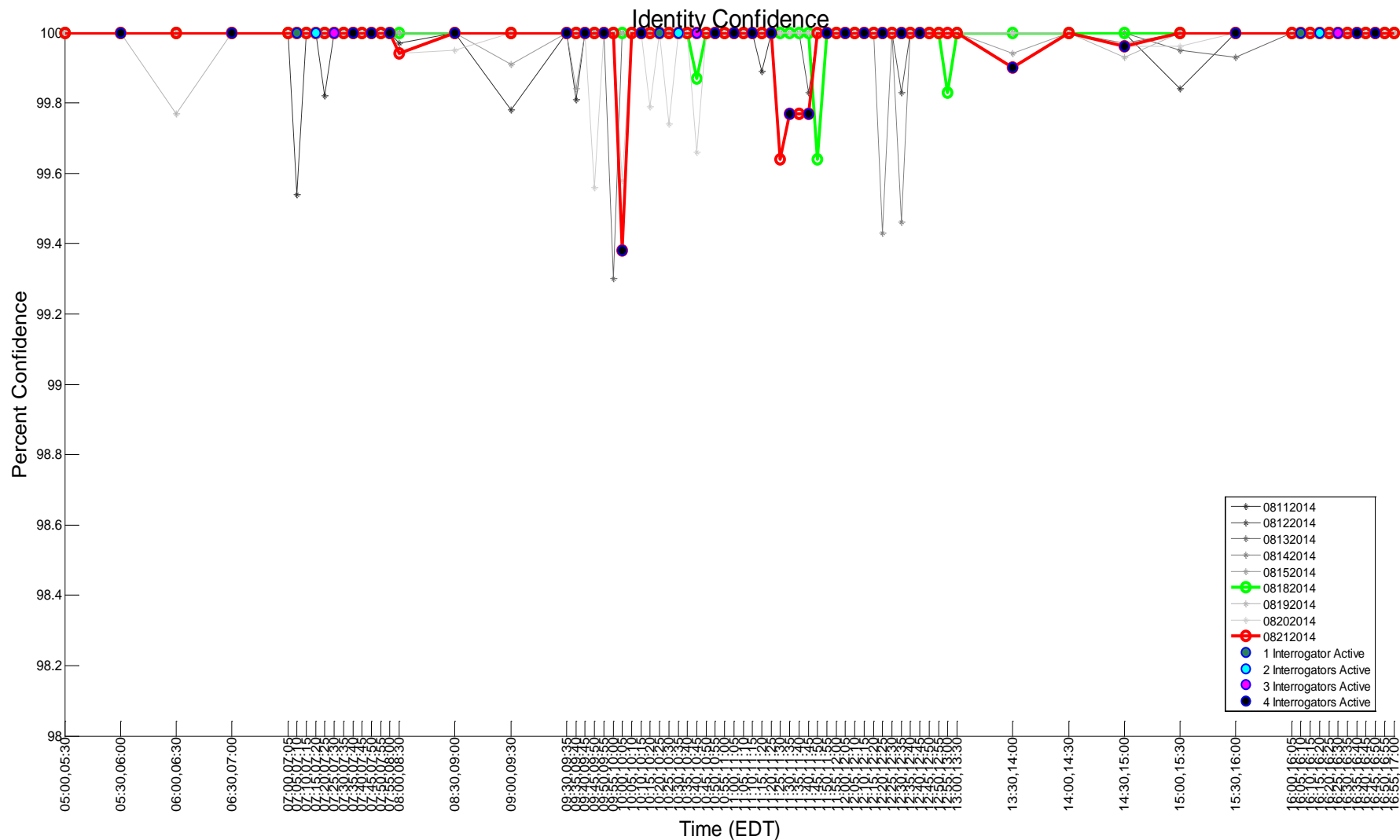


Geographic Filter: Hotspot Region  
 Target Filter: Exclude Targets < 50 NM

# Identity (3/A) Confidence – August 20<sup>th</sup>

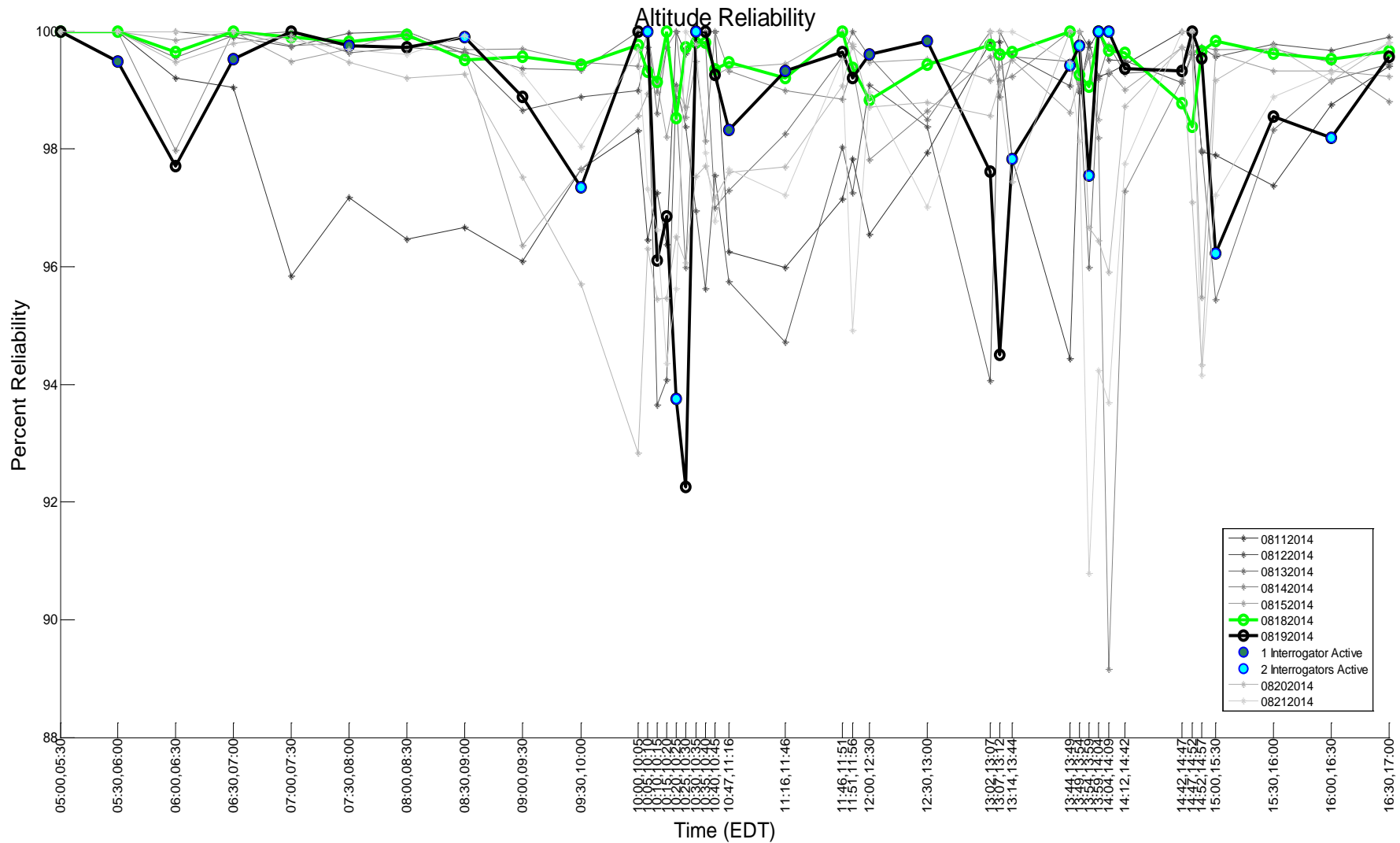


# Identity (3/A) Confidence – August 21<sup>st</sup>



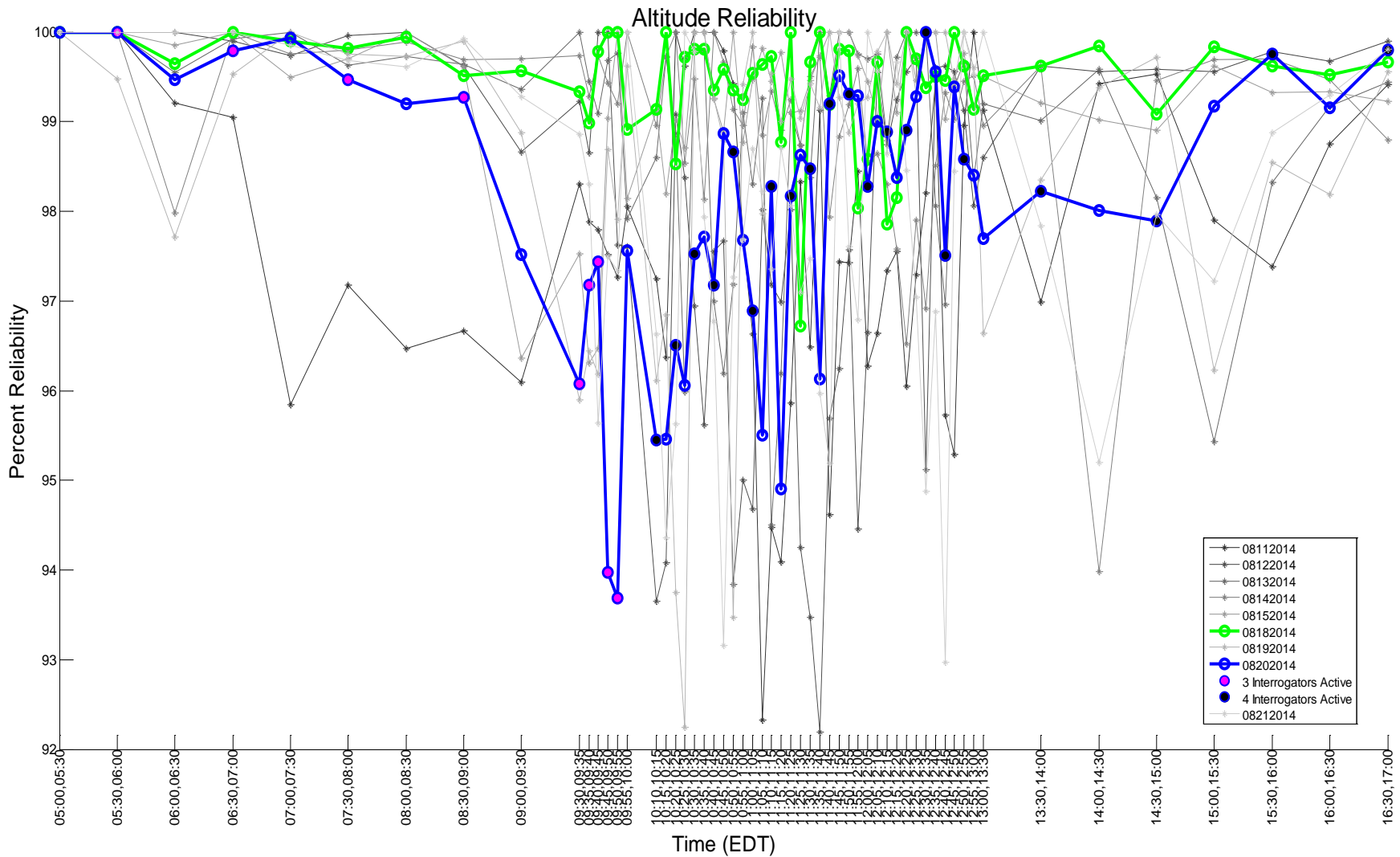
Geographic Filter: Hotspot Region  
Target Filter: Exclude Targets < 50 NM

# Altitude (C) Reliability – August 19<sup>th</sup>



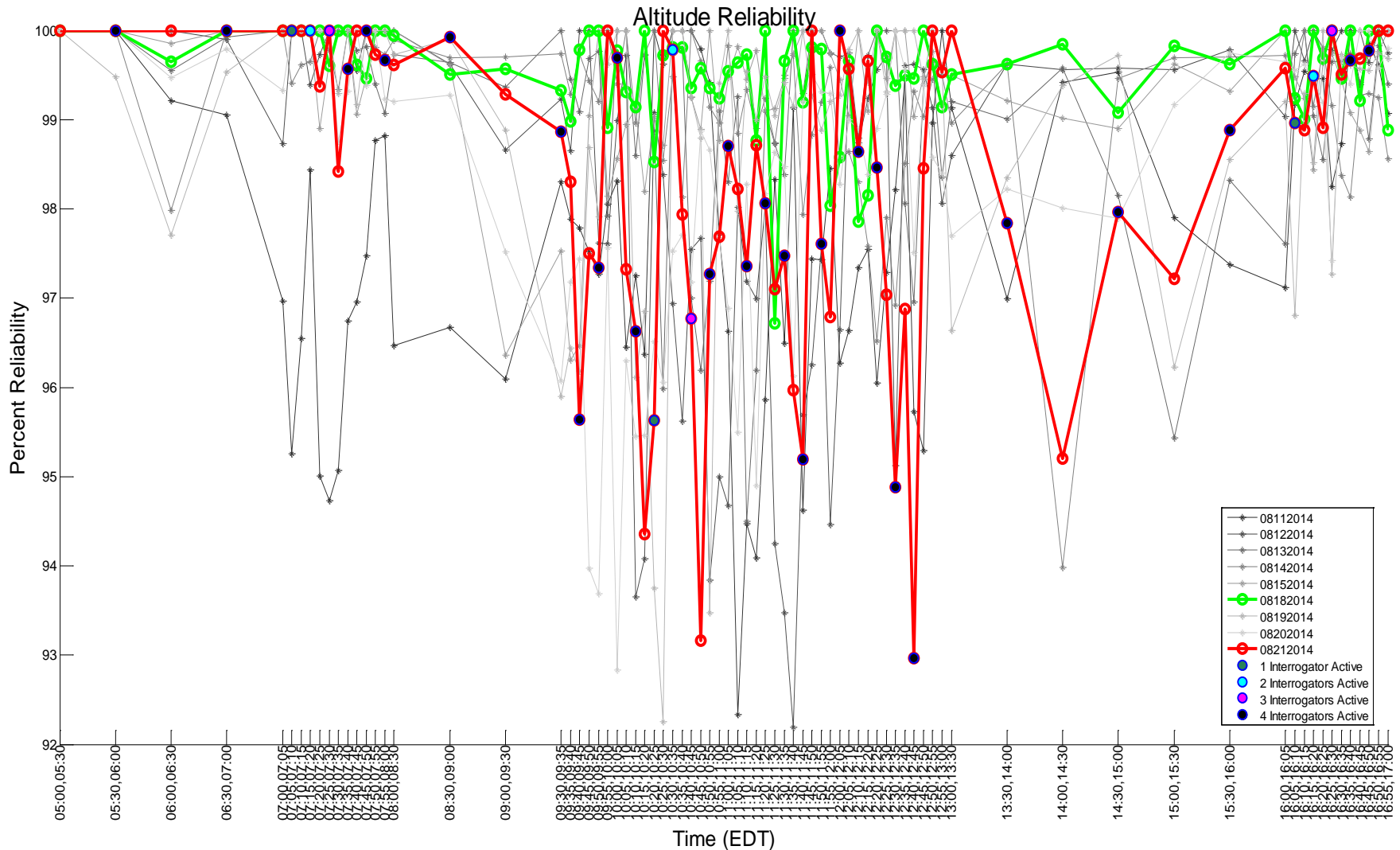
Geographic Filter: Hotspot Region  
Target Filter: Exclude Targets < 50 NM

# Altitude (C) Reliability – August 20<sup>th</sup>



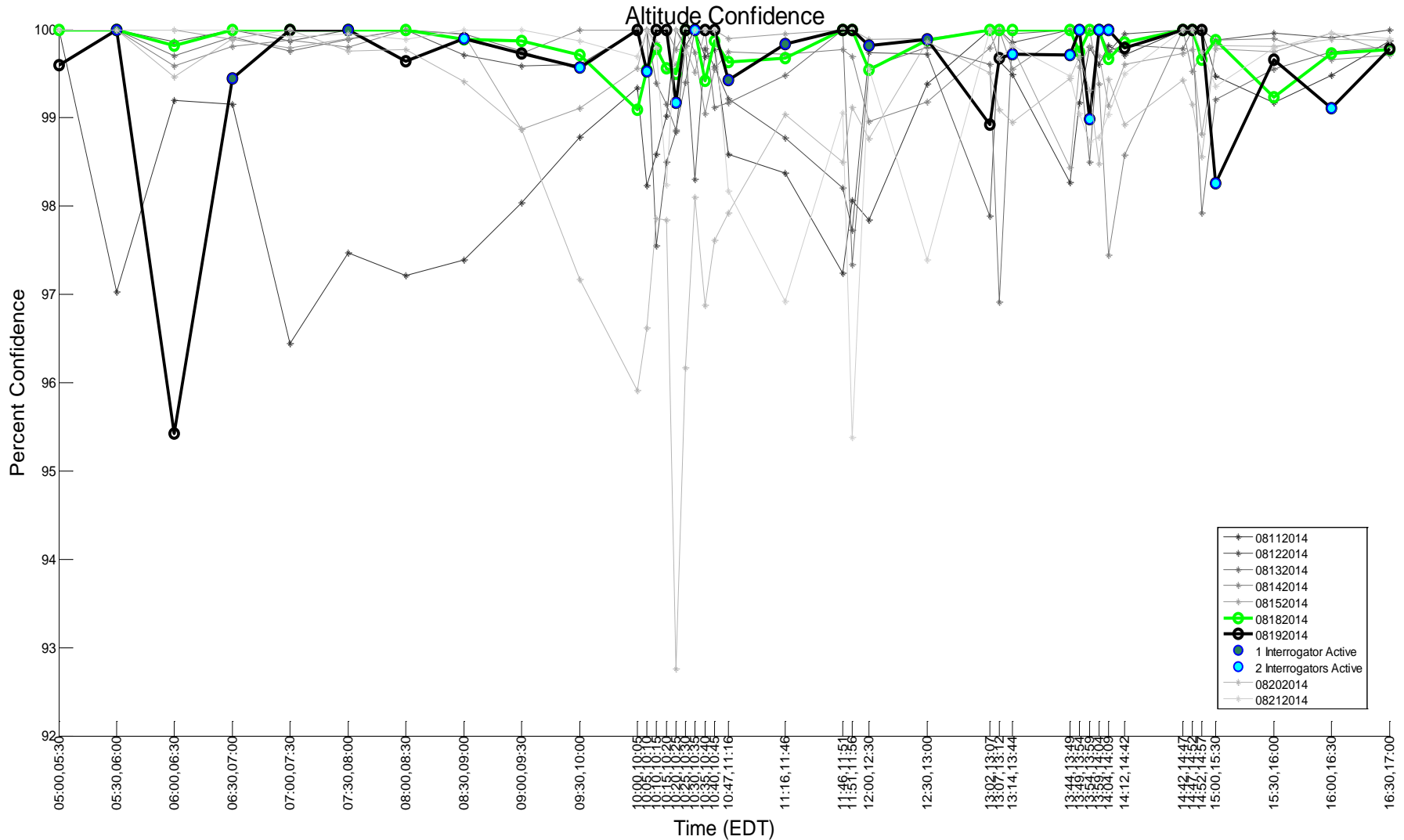
Geographic Filter: Hotspot Region  
Target Filter: Exclude Targets < 50 NM

# Altitude (C) Reliability – August 21<sup>st</sup>



Geographic Filter: Hotspot Region  
Target Filter: Exclude Targets < 50 NM

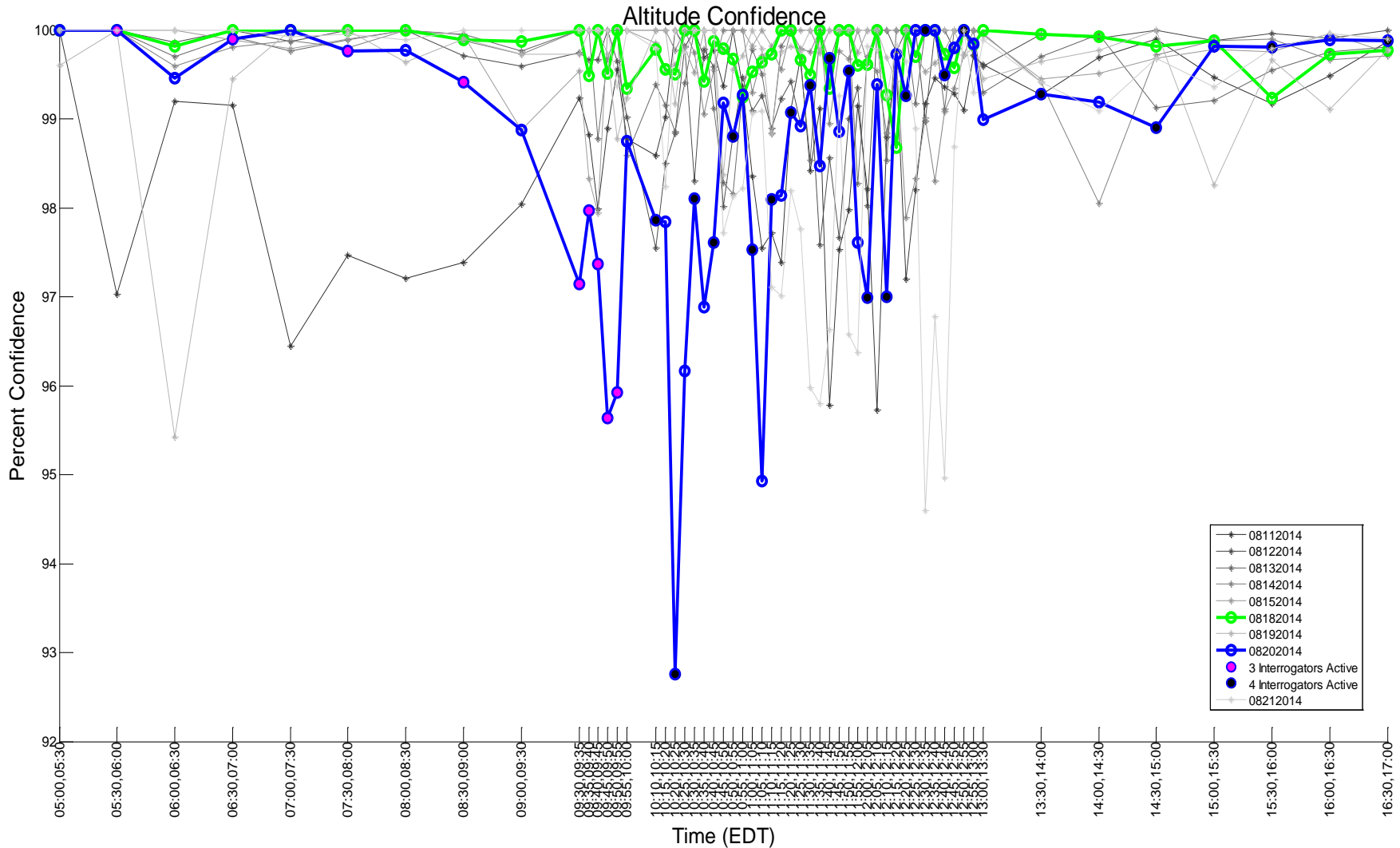
# Altitude (C) Confidence – August 19<sup>th</sup>



Geographic Filter: Hotspot Region  
 Target Filter: Exclude Targets < 50 NM

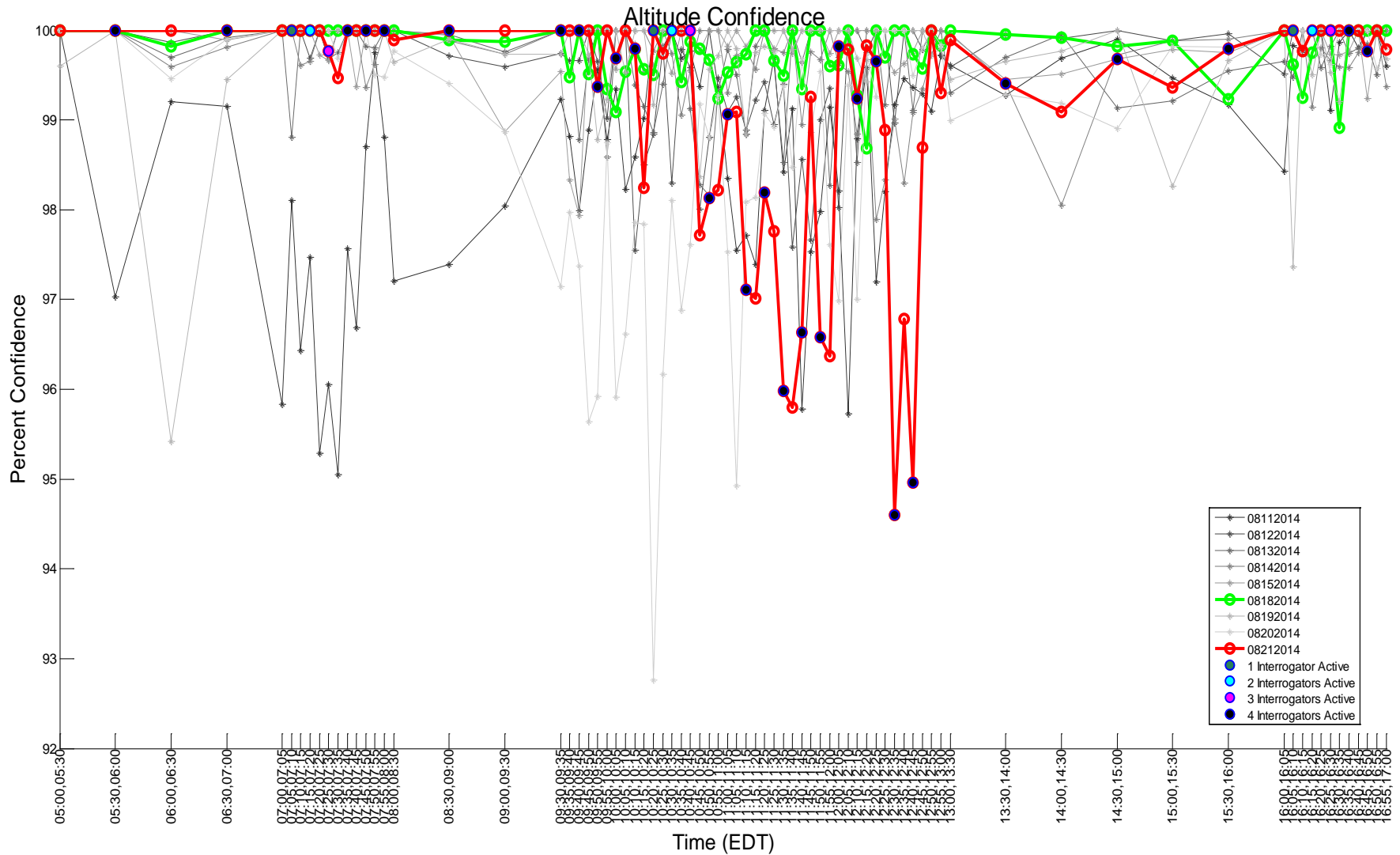


# Altitude (C) Confidence – August 20<sup>th</sup>



Geographic Filter: Hotspot Region  
Target Filter: Exclude Targets < 50 NM

# Altitude (C) Confidence – August 21<sup>st</sup>



Geographic Filter: Hotspot Region  
 Target Filter: Exclude Targets < 50 NM



# Executive Summary

- ❑ The Probability of Detection, Identity Reliability and Confidence, Altitude Reliability and Confidence, False Targets, 0000 Codes, Hit Counts, and Targets per Scan exhibit no observable adverse trend with respect to periods of radiation by the AN/UPX-41(C) interrogator.
- ❑ During AN/UPX-41(C) interrogator radiation, the variations or volatility of the aforementioned metrics are within the bounds of the variations of the same metrics on non-test days (baseline).

# Background

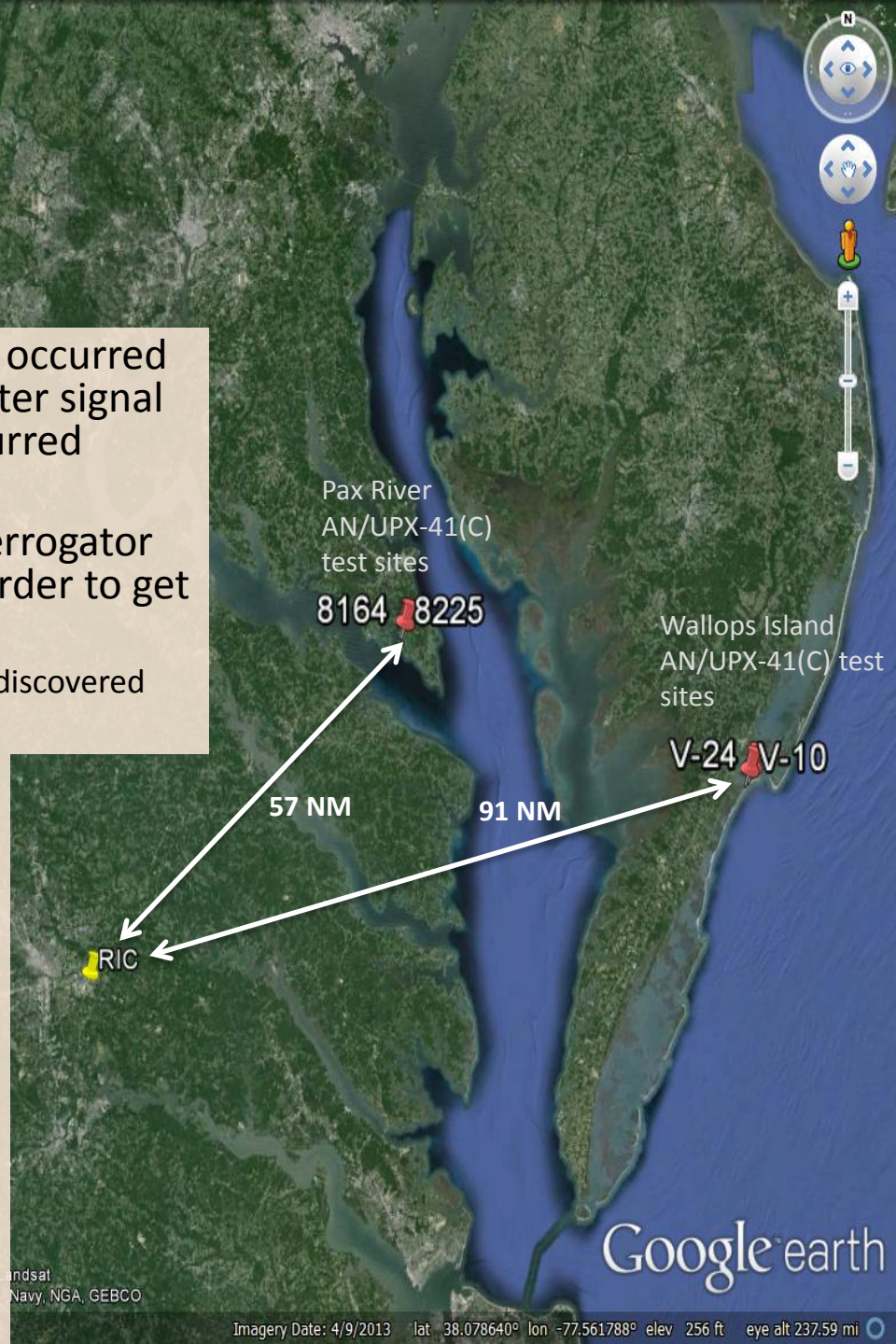
- ❑ The AN/UPX-41(C)\* Stage-4 operational transmit certification for AEGIS-Class ships was signed by NTIA on June 22, 2012 with geographic and platform number restrictions when operating in proximity to the NAS.†
- ❑ Additionally, the Stage-4 certification contained a requirement for a joint FAA-Navy test to validate the operational restrictions.
- ❑ The Volpe Center, in conjunction with the Navy, FAA Spectrum, and FAA aeronautical surveillance and collision avoidance systems (ASCAS) SMEs created a test plan to validate the operational restrictions.
- ❑ From August 18-21, 2014 the FAA and Navy conducted the above-mentioned joint test, under the management of the Volpe Center.
- ❑ Since the test, the Volpe Center has analyzed recorded data to look for instances of harmful interference that would affect ASCAS system performance.

\*AN/UPX-41(C) Digital Interrogator System when operated in conjunction with the OE-120 antenna, the AN/UPX-29(V) Identification Friend or Foe (IFF) system, and the AN/UPX-24 software interface Version 2.1.2, controlled by the Cooperative Engagement Capability (CEC), in Naval surface vessels

†See SPS-18778\_1 Navy AN-UPX-41 V5.5 St4

# Test Plan Refresher

- ❑ Cycling of AN/UPX-41(C) systems Active/OFF occurred every 30 minutes; however, if N39 (Tech Center signal recording aircraft) was in the air, cycling occurred every 5 minutes
- ❑ During the test week, non-essential DoD interrogator platforms were scheduled to be inactive in order to get an accurate baseline of civil ASCAS activity
  - This did not occur. Non-test platform radiation was discovered through flight test data.
- ❑ Baseline week: August 11<sup>th</sup> – 15<sup>th</sup>
  - Baseline recording of data from 5 AM – 5 PM
    - No AN/UPX-41(C) systems Active
- ❑ Test week: August 18<sup>th</sup> – 21<sup>st</sup>
  - August 18<sup>th</sup> – Baseline recording of data from 5 AM – 5 PM
    - No AN/UPX-41(C) systems Active
  - August 19<sup>th</sup> – Record data from 5 AM – 5 PM
    - Cycle 1 and 2 AN/UPX-41(C) systems Active and OFF
  - August 20<sup>th</sup> – Record data from 5 AM – 5 PM
    - Cycle 3 and 4 AN/UPX-41(C) systems Active and OFF
  - August 21<sup>st</sup> – Record data from 5 AM – 5 PM
    - Cycle 1, 2, 3, and 4 AN/UPX-41(C) systems Active and OFF



# Data Recording

- ❑ During the August test, Enroute Common Gateway (ECG) data was recorded at the Tech Center from the RIC site.
- ❑ The Radar Beacon Analysis Tool (RBAT) was used to analyze ECG data to produce statistics for the following list of parameters:
  - Targets per Scan
  - Probability of Detection
  - Identity Reliability
  - Identity Confidence
  - Altitude Reliability
  - Altitude Confidence
  - Hit Counts
  - False Target Percentage
  - 0000 Code Percentage

# Data Analysis Methodology

- ❑ Applied time bins that corresponded to the AN/UPX-41(C) Active/OFF periods from test days (August 19<sup>th</sup>-21<sup>st</sup>) to baseline days to produce baseline statistics
- ❑ Data was first analyzed without any geographic or target filters
  - In analyzing possible cases of interference, it was determined that targets at low elevation angles exhibited relatively low probabilities of detection regardless of Active/OFF period
  - This behavior was not conducive to pinpointing interference events
- ❑ Analysis of targets at elevation angles greater than 2° was prepared
  - Interference events would be easier to see if targets that were already behaving poorly were excluded from the analysis
- ❑ Targets that were beyond 50 NM from the SSR site were analyzed
  - Replies from targets at the edge of the coverage area are more likely to be lost to overpowering FRUIT
- ❑ Data was analyzed using a geographic filter that represented the area of AN/UPX-41(C) systems' sidelobes (subsequently referred to as the Hotspot area) – the area where transponder occupancy due to AN/UPX-41(C) would be the greatest
  - Assumption: AN/UPX-41(C) sidelobes extend 40 NM
  - Recent developments from flight test data show that P2 pulse can be seen up to 40 NM; however, only caused N39 ownship transponder suppressions up to 20 NM
- ❑ Produced hit count statistics for the Tech Center Aircraft (N39) as it flew within the SSRs LOS
  - Focused on possible interference during mainbeam overlap with V10, 8164, and 8225 sites



# Analysis Limitations

- ❑ The theoretical or textbook definition of probability of detection is a function of interrogation/reply round reliability.
- ❑ However, probability of detection in RBAT is the percentage of target updates versus total number of beam dwells over all targets.
- ❑ Therefore, the ability for probability of detection calculated by RBAT to properly represent theoretical probability of detection is minimized as the sample size decreases (either through geographical or time constraints) since it no longer reliably reflects the target population mean.
- ❑ Example: A target population of two where both targets miss one update out of ten scans (approximately 50 seconds) results in a probability of detection of 90%. While this is unacceptable by QARS blip/scan minimums, we have no knowledge of the updates that occurred outside of the given time constraint . If both targets received ten out of ten updates for the previous as well as the next 10 scans, the probability of detection is now 96.7%.

# Analysis Objective

- ❑ We are attempting to observe distinct patterns of change in the metrics of interest between times when the AN/UPX-41(C) systems are OFF and when they are Active.
- ❑ While geographic and time filters reduces target update sample sizes such that a small sample size itself influences the metric of interest, it is more important to focus on the change from Off to Active since both the Off and Active periods have the same constraints applied.

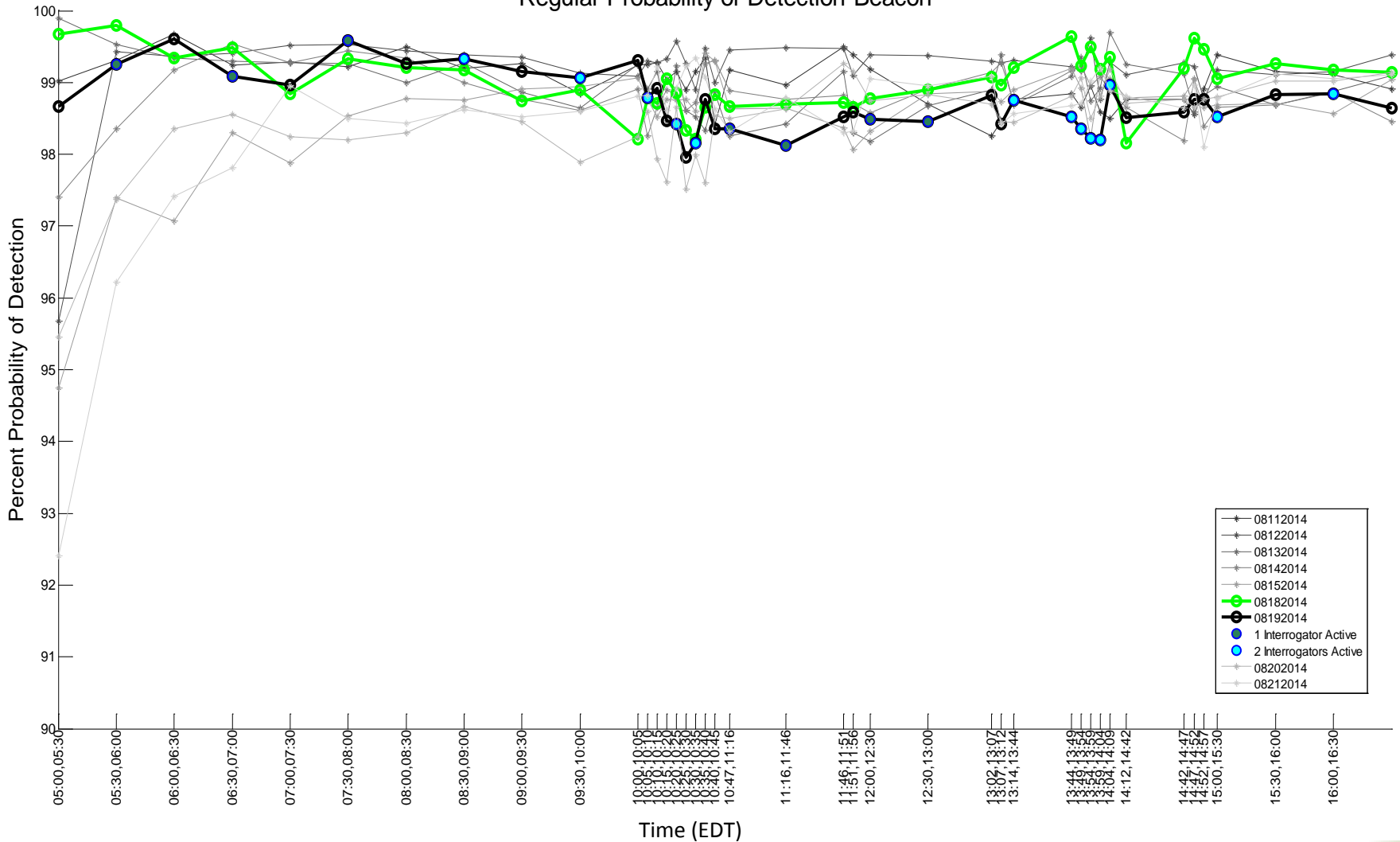
# Plot Guide

- ❑ There are four sets of plots that correspond to the data analysis methodology discussed previously
  1. No filters
  2. Filter on targets with elevation angle greater than 2 degrees
  3. Filter on targets with range greater than 50 NM from SSR
  4. Filter on targets within Hotspot
- ❑ Plots with multiple days of data utilize the time filters from the Active/Off periods for the date given in the slide's title
- ❑ Plots that use boxplots
  - The edges of the box are the 25<sup>th</sup> and 75<sup>th</sup> percentiles. The maximum whisker length represents approximately 2.7 sigma (99.3%). Points in red are shown as outliers.
  - For five minute time bins, there are only 65 RIC scans and, if you miss one target update, Pd will automatically drop to 98.4% (64 out of 65 possible target reports).
  - Horizontal axis 30-min and 5-min time bins are not scaled according to duration

# Target Metrics with No Filter

# Probability of Detection – August 19<sup>th</sup>

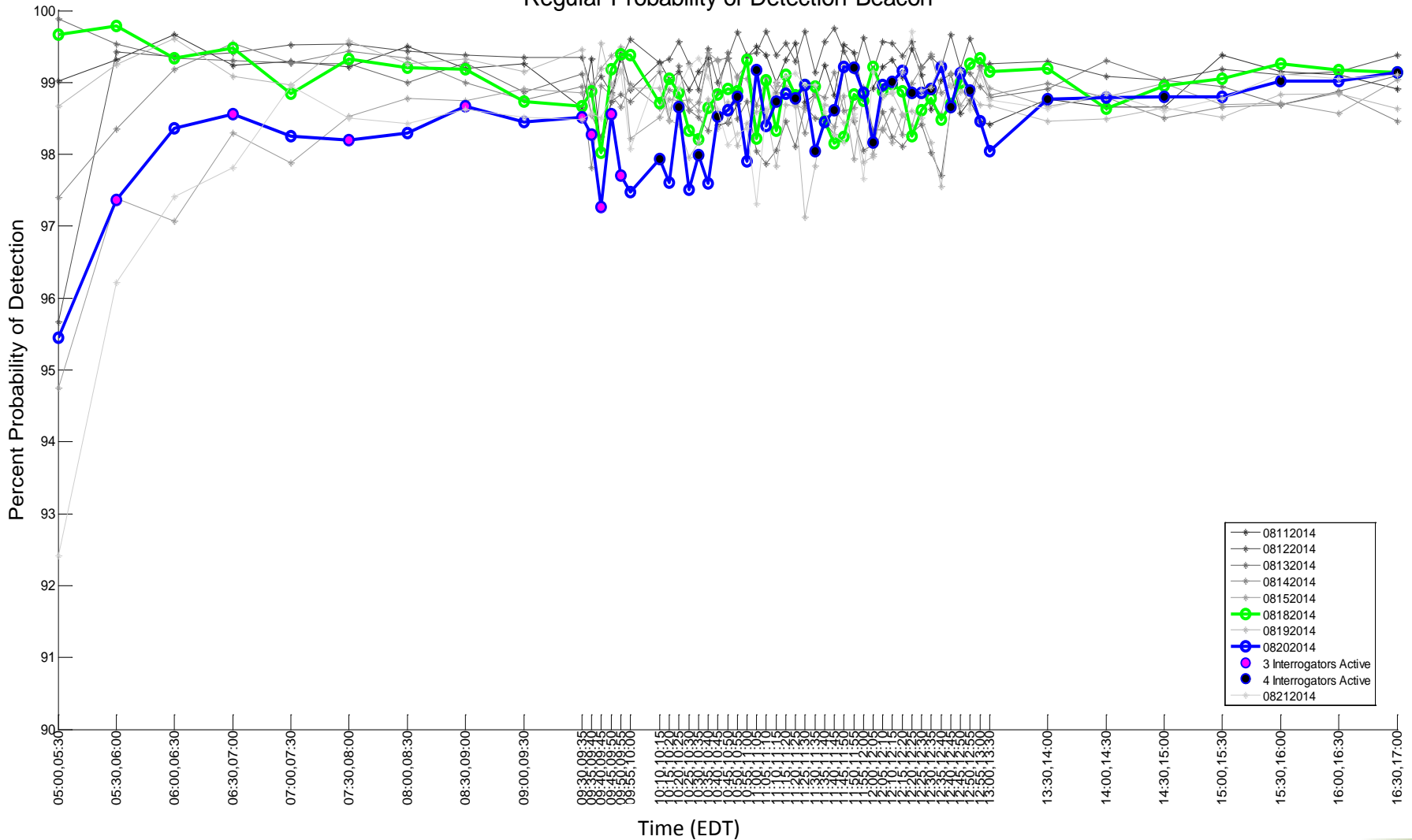
Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

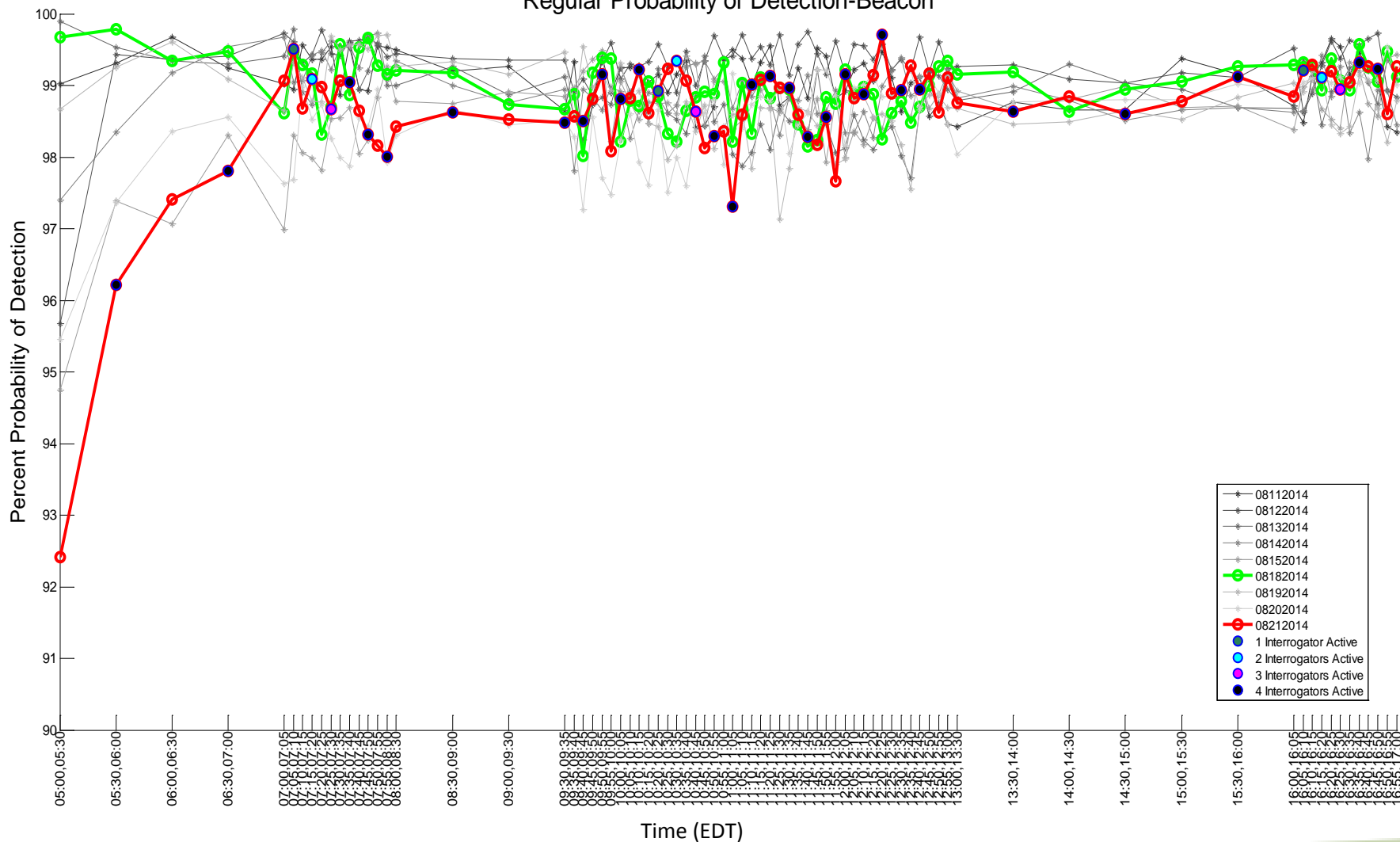
Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

Regular Probability of Detection-Beacon

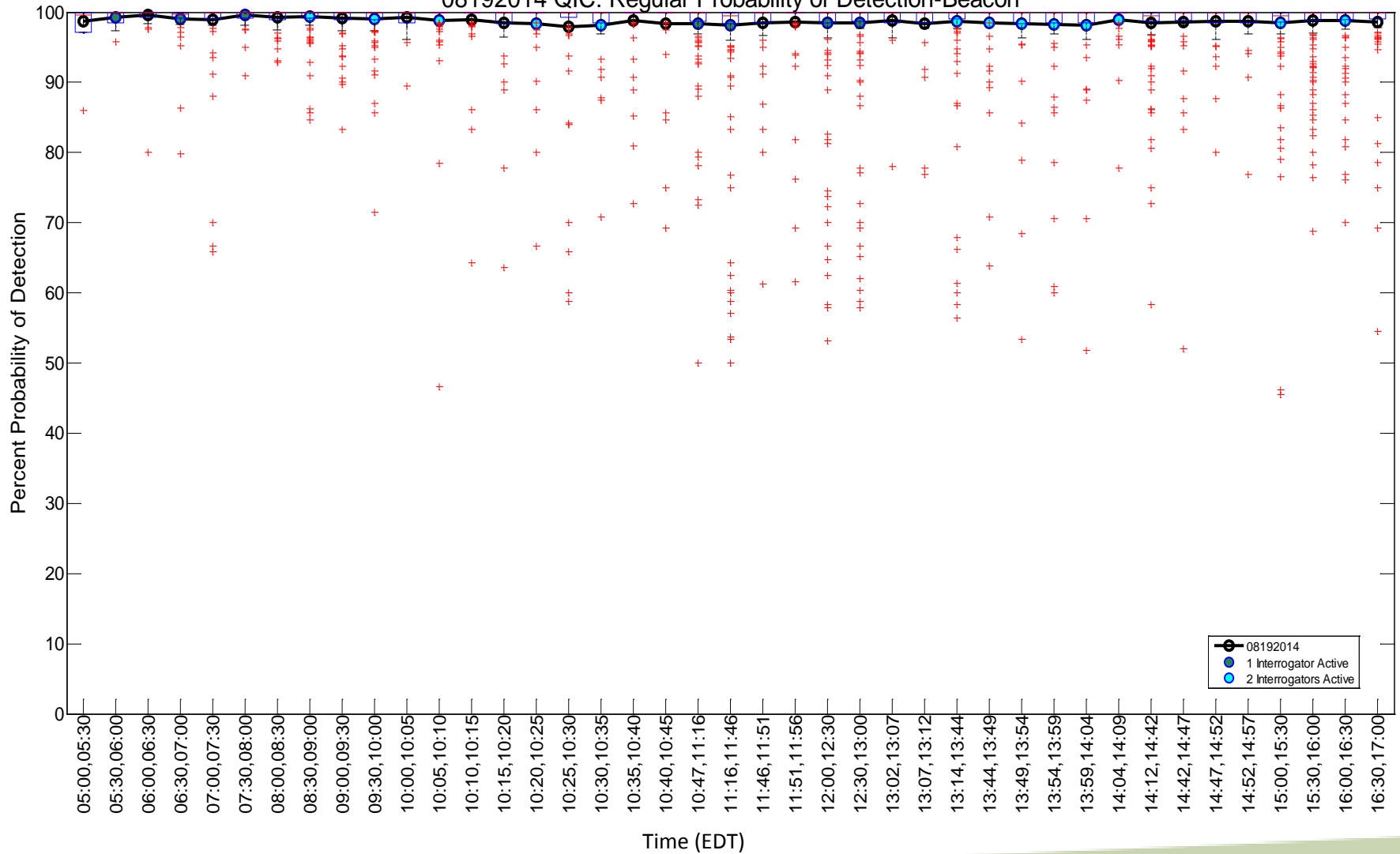


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution

08192014 QIC: Regular Probability of Detection-Beacon



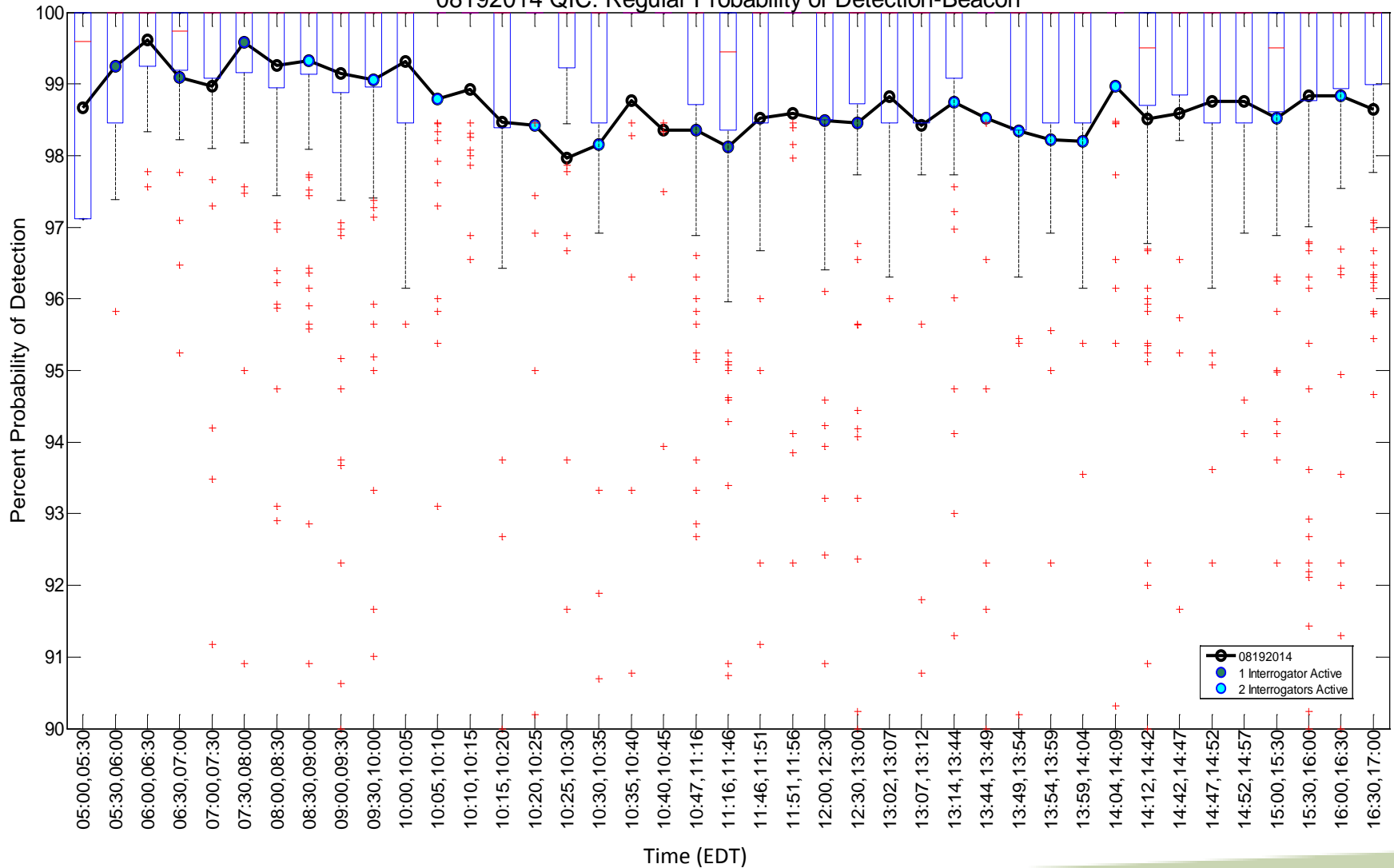
Geographic Filter: None  
Target Filter: None



# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08192014 QIC: Regular Probability of Detection-Beacon

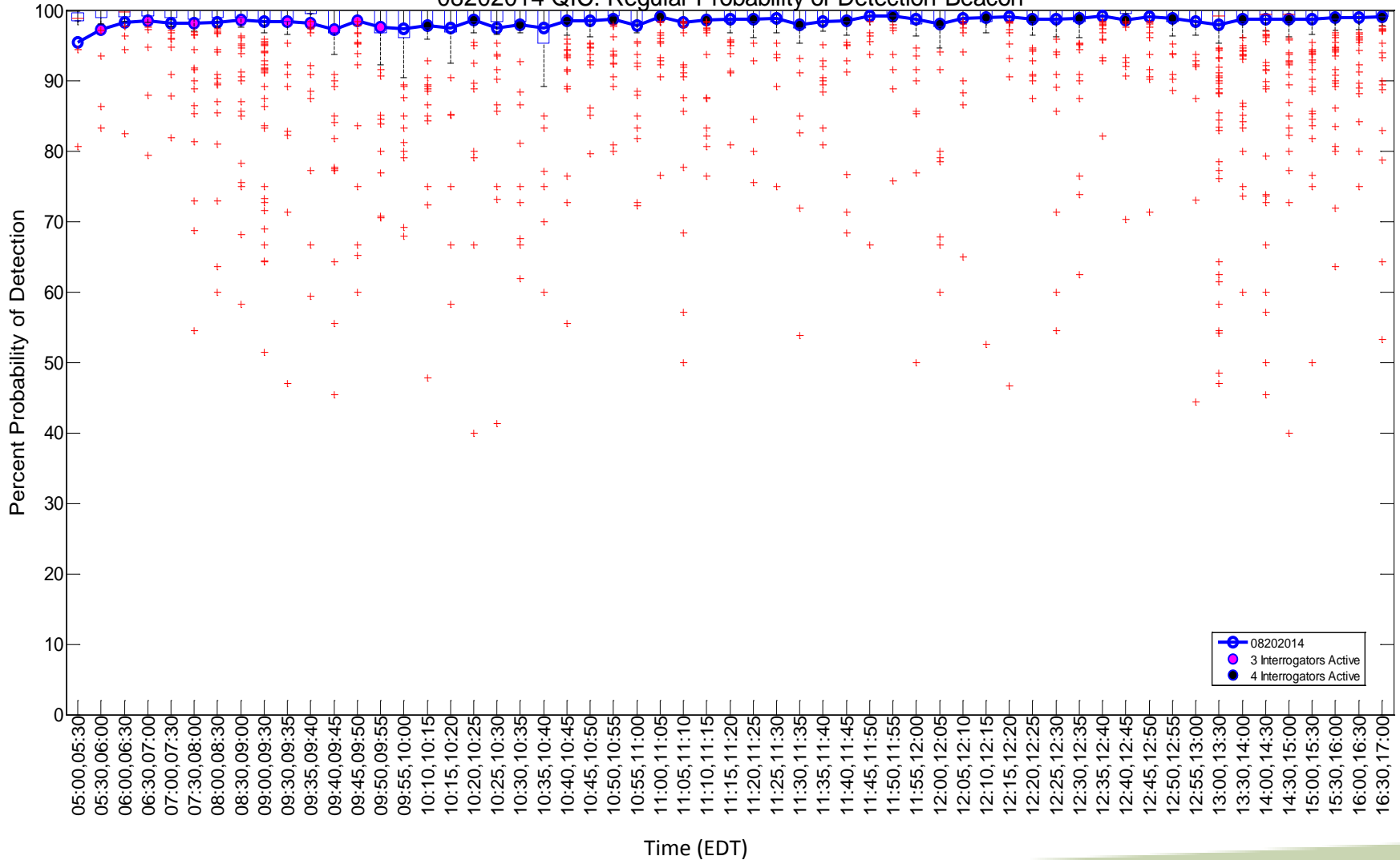


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

08202014 QIC: Regular Probability of Detection-Beacon

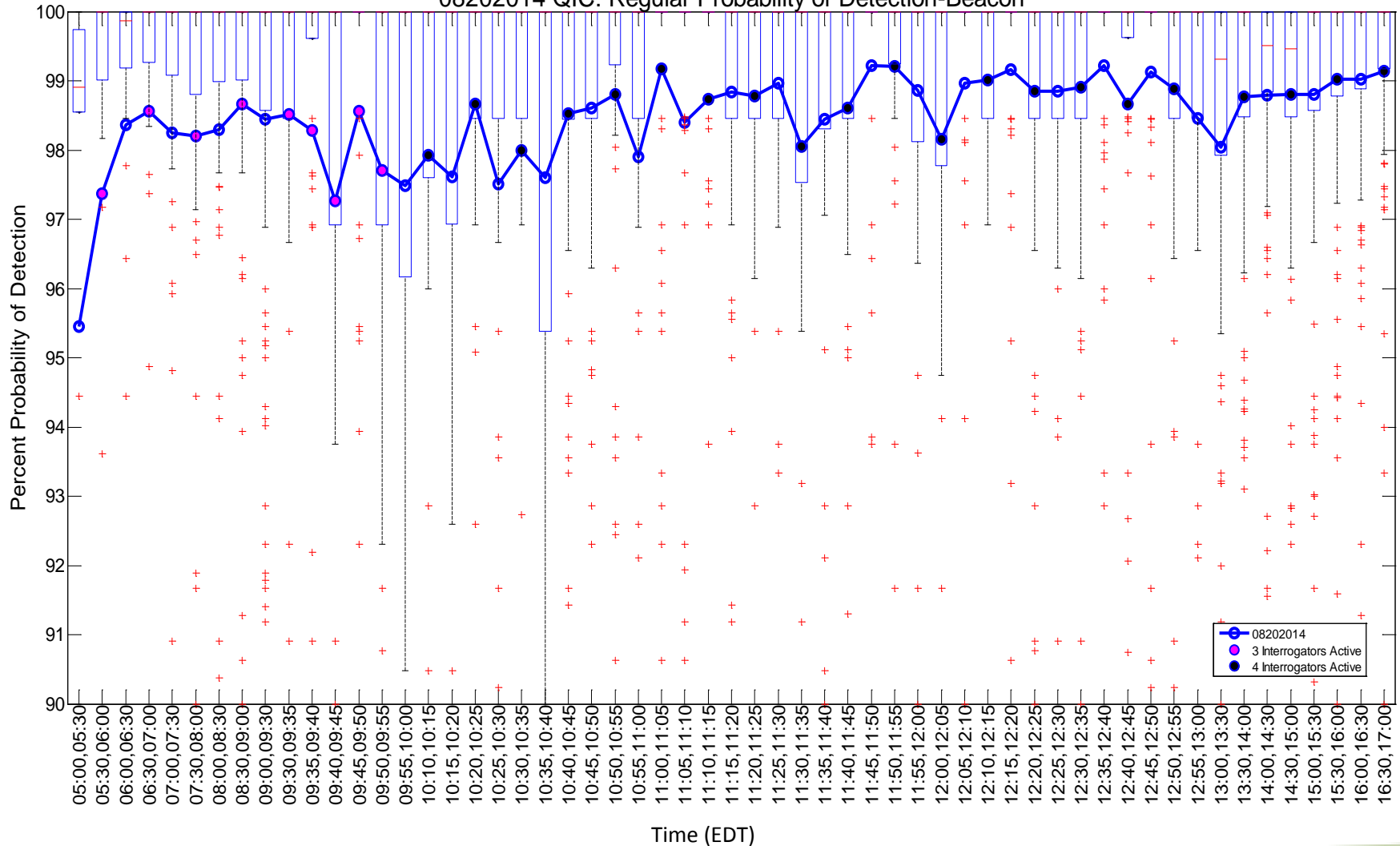


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

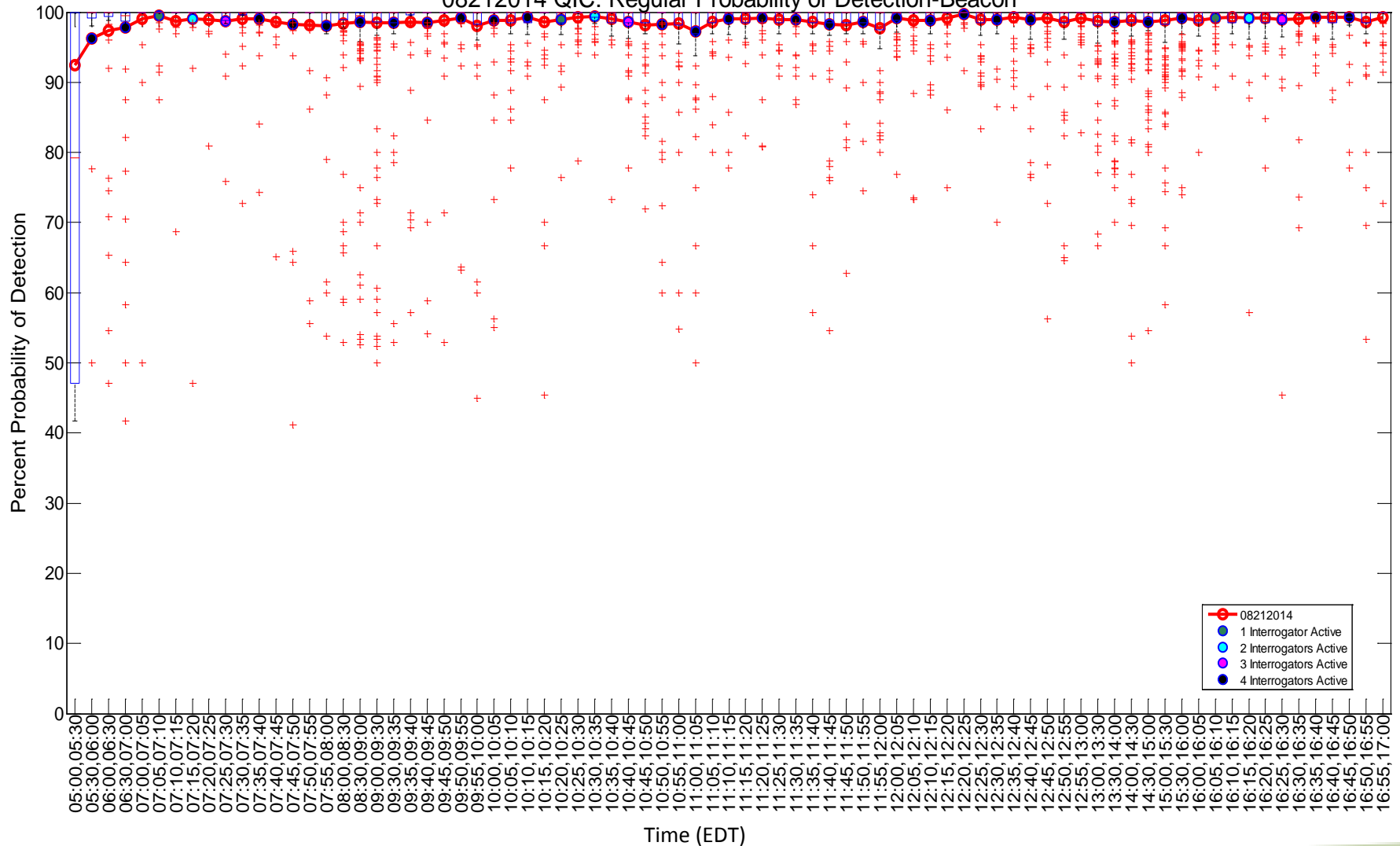
08202014 QIC: Regular Probability of Detection-Beacon



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

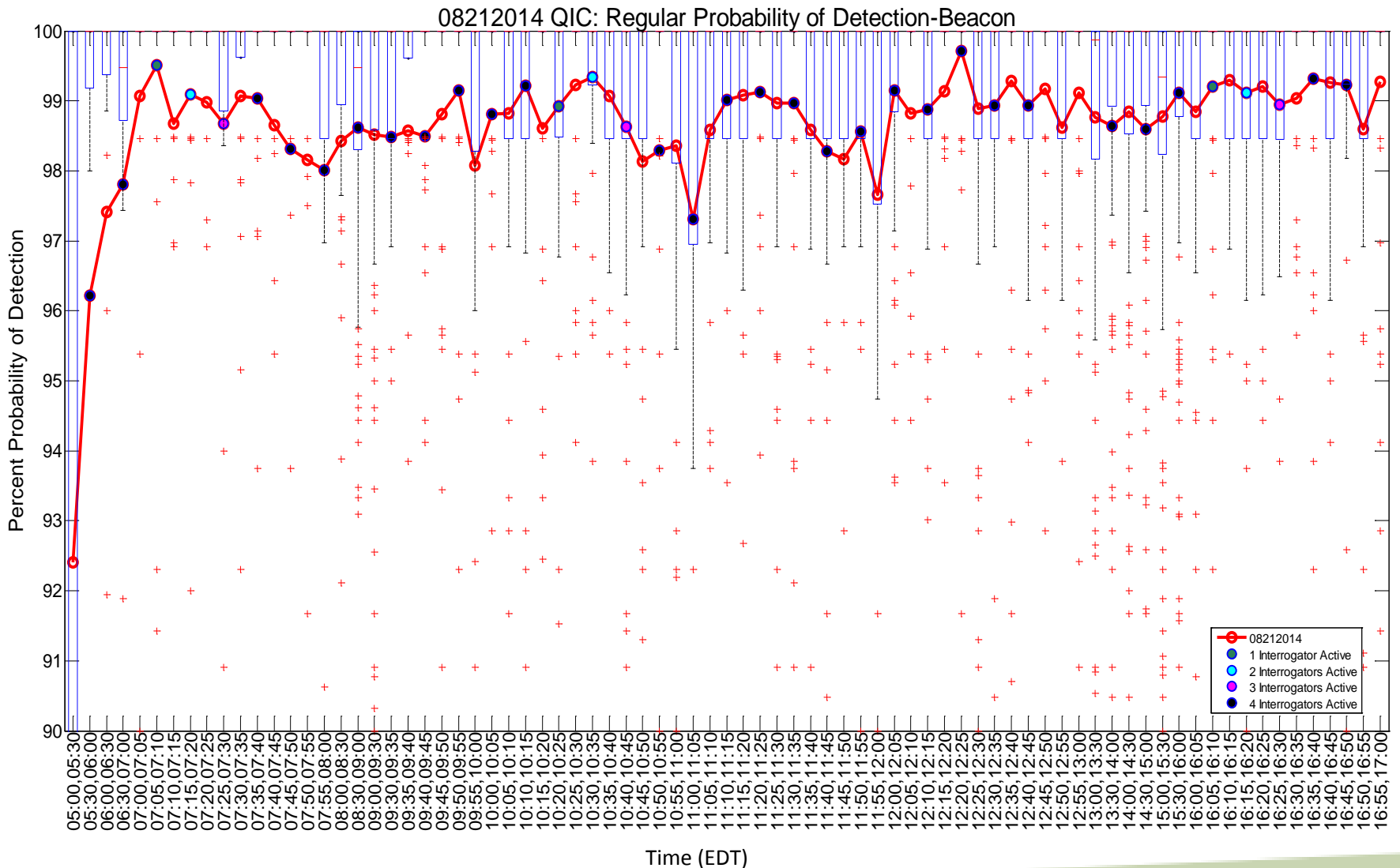
08212014 QIC: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

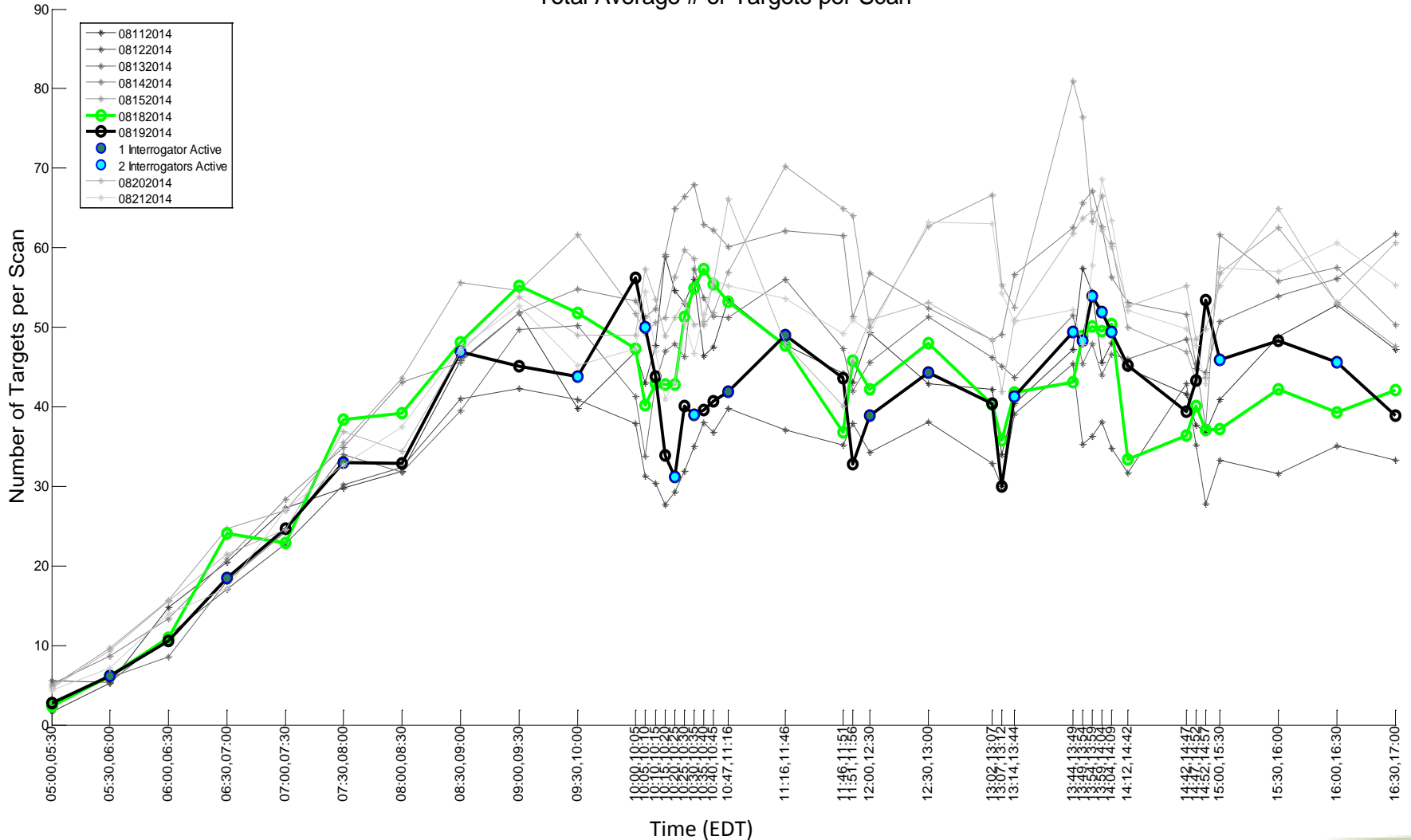
## Individual Aircraft Distribution (zoom-in)



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 19<sup>th</sup>

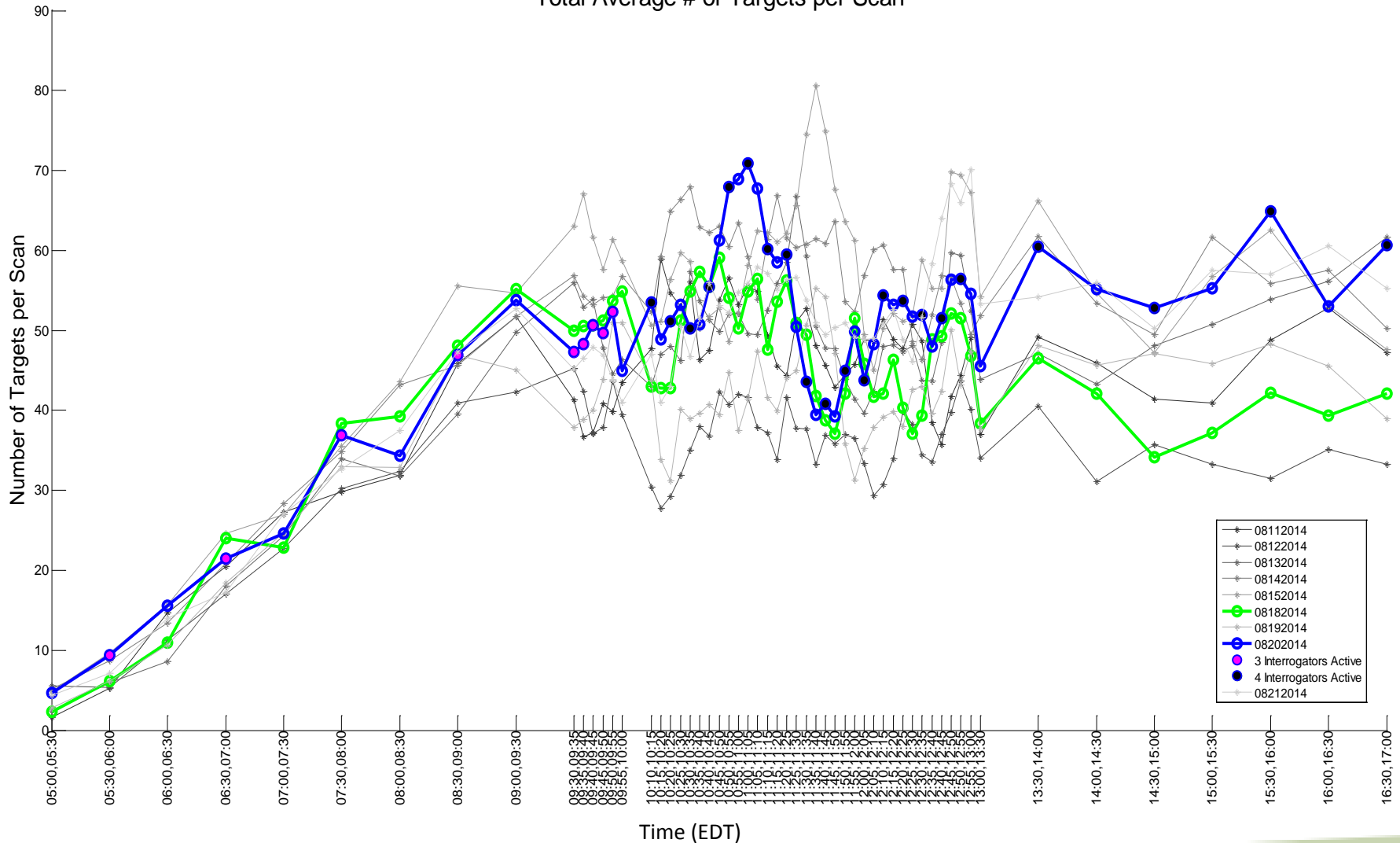
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 20<sup>th</sup>

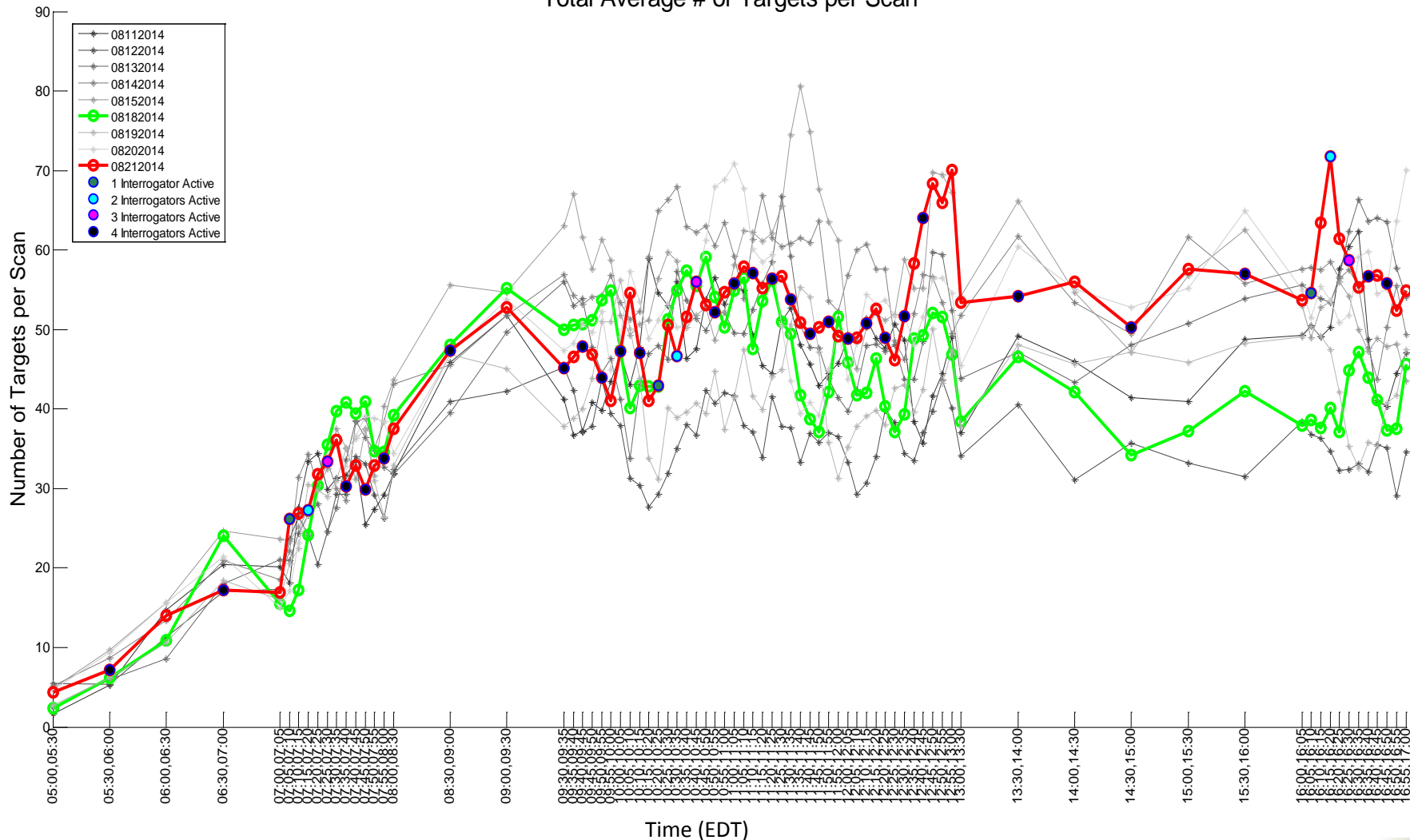
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 21<sup>st</sup>

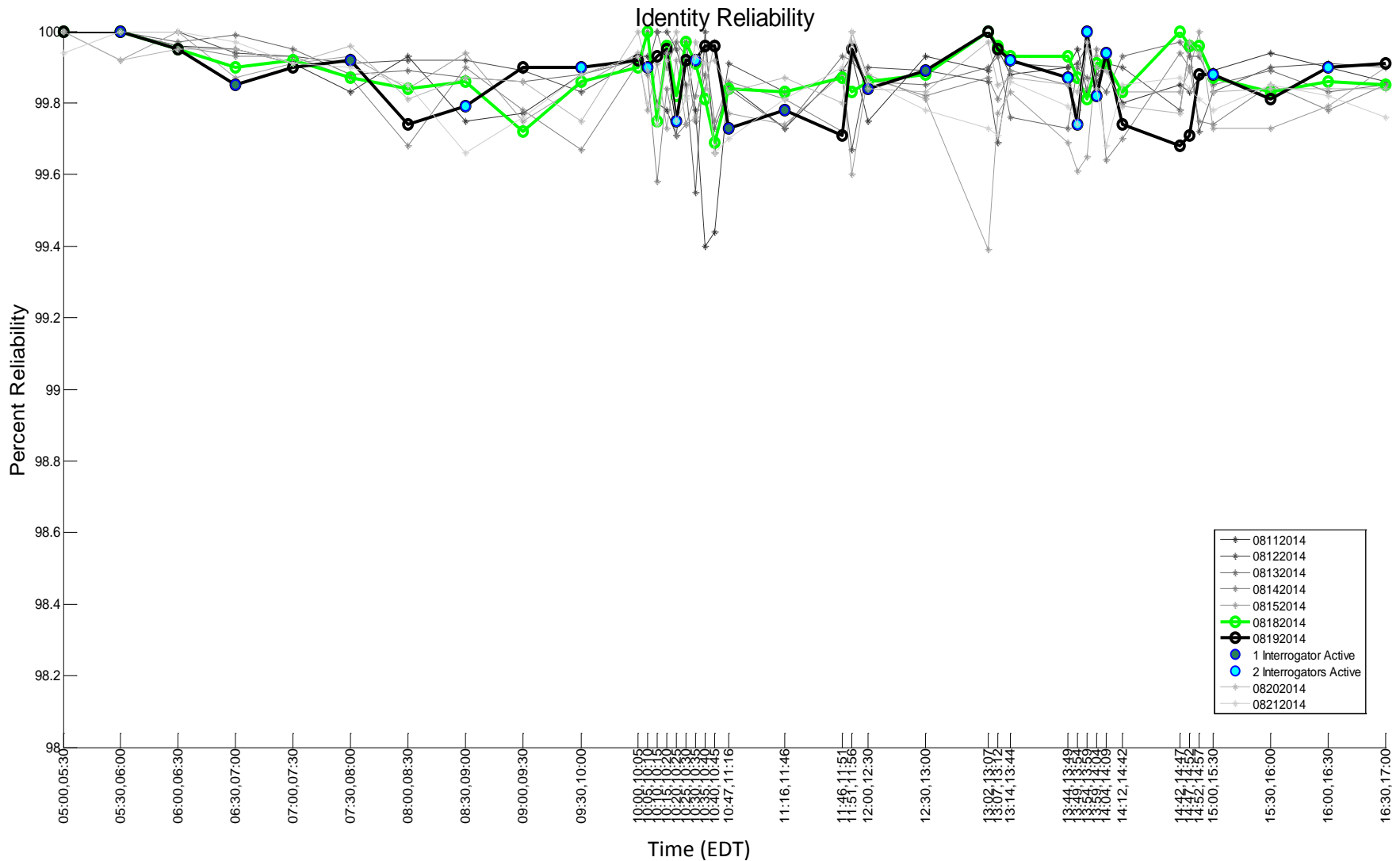
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

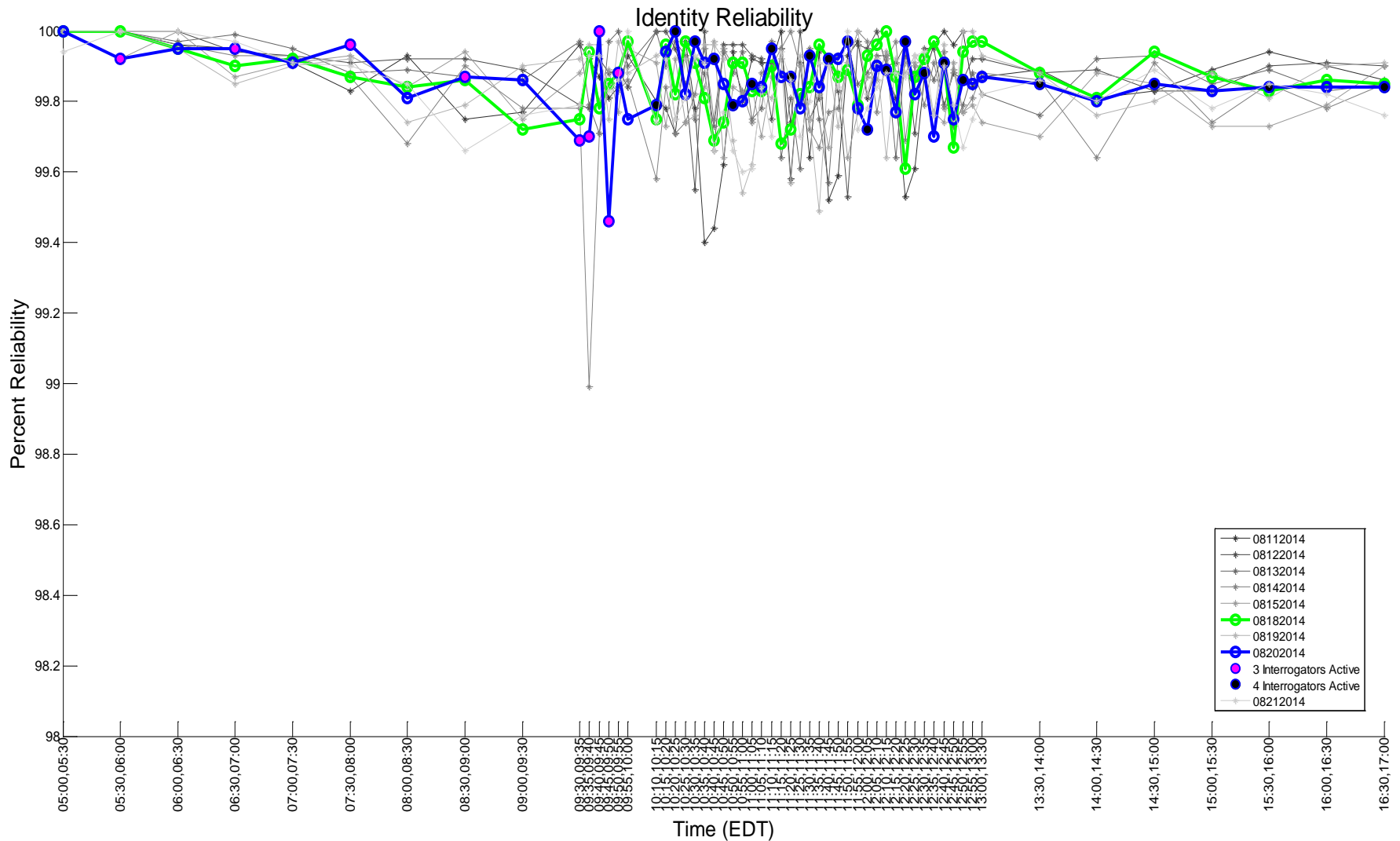


# Identity (3/A) Reliability – August 19th



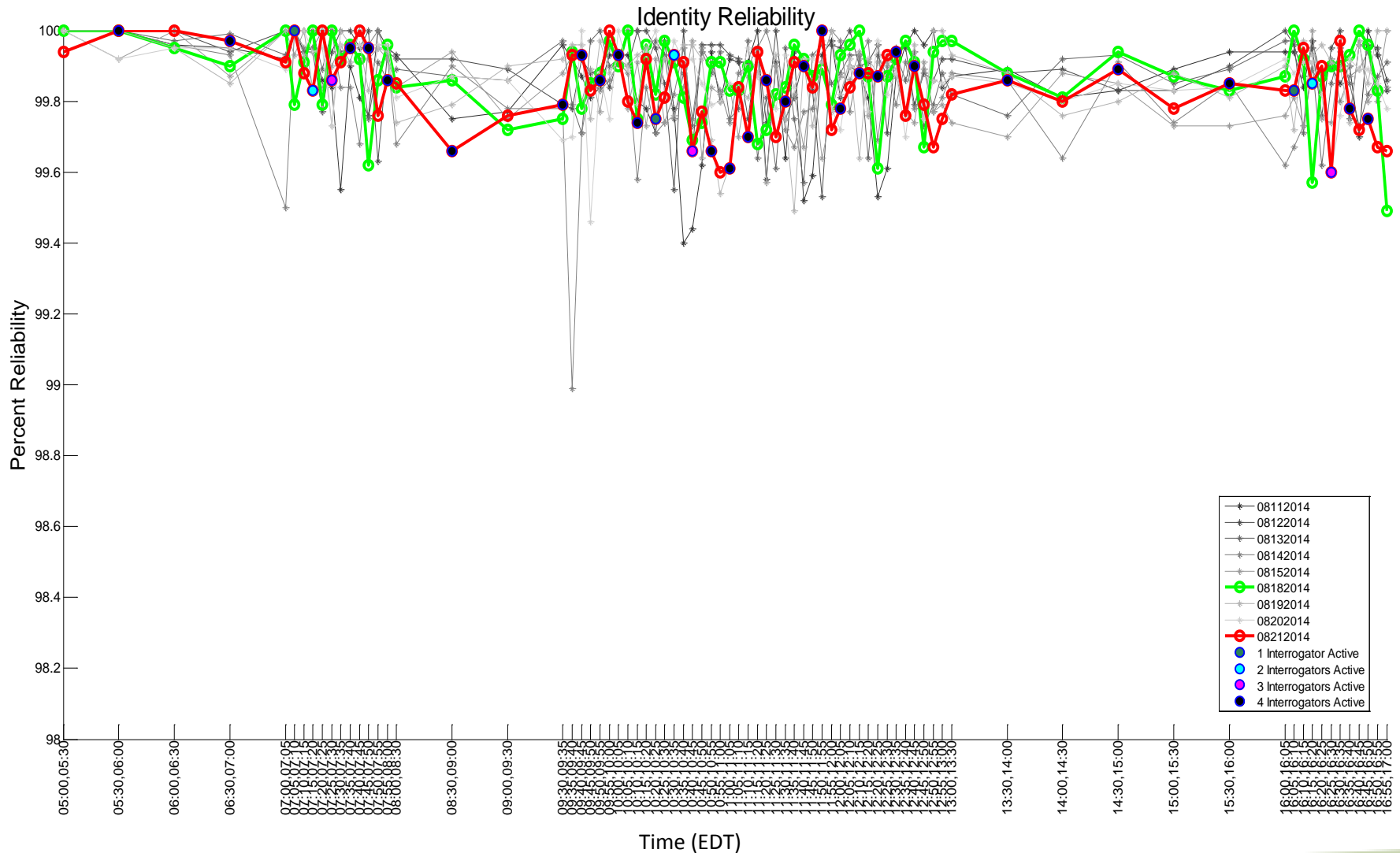
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 20<sup>th</sup>



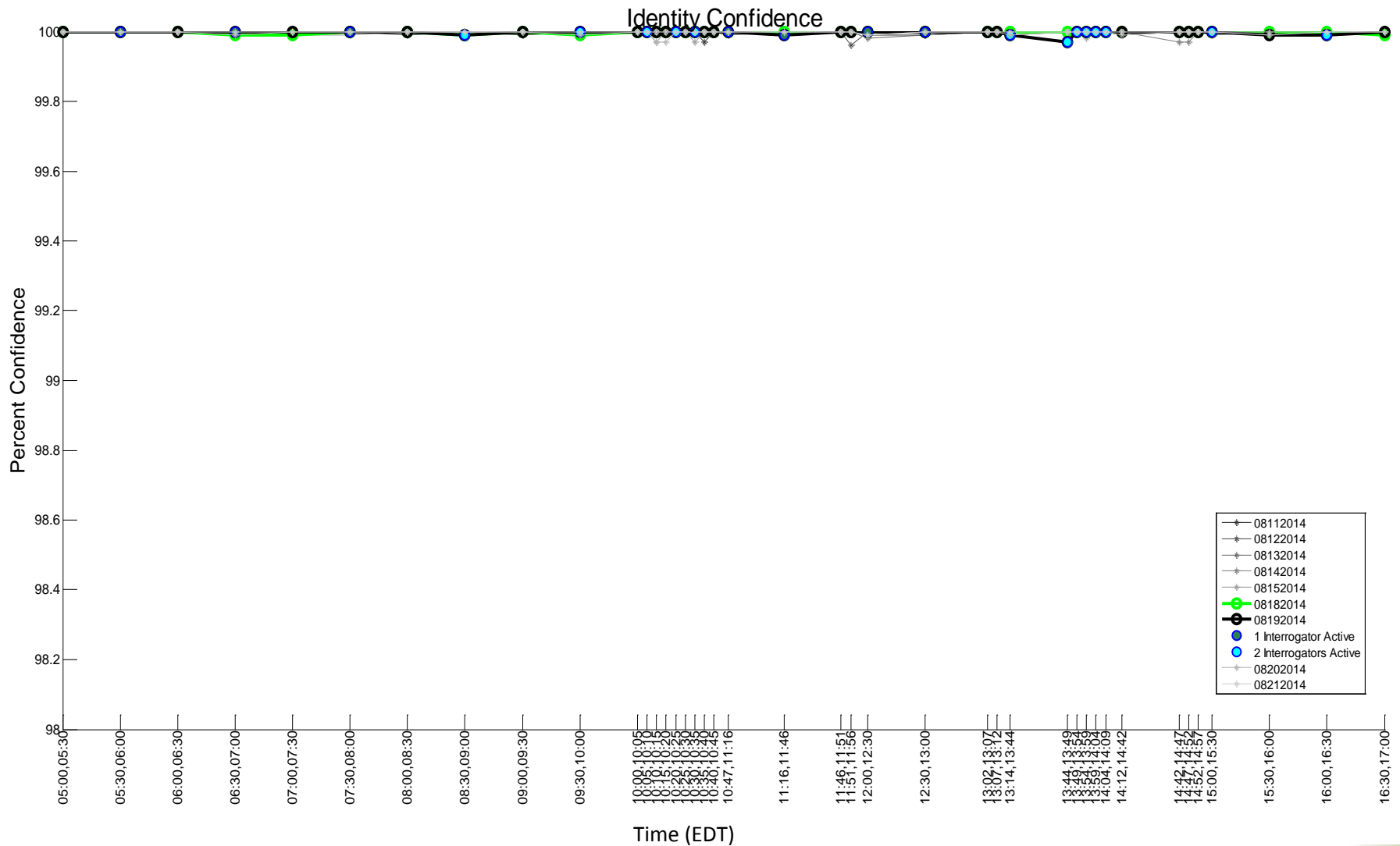
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 21<sup>st</sup>



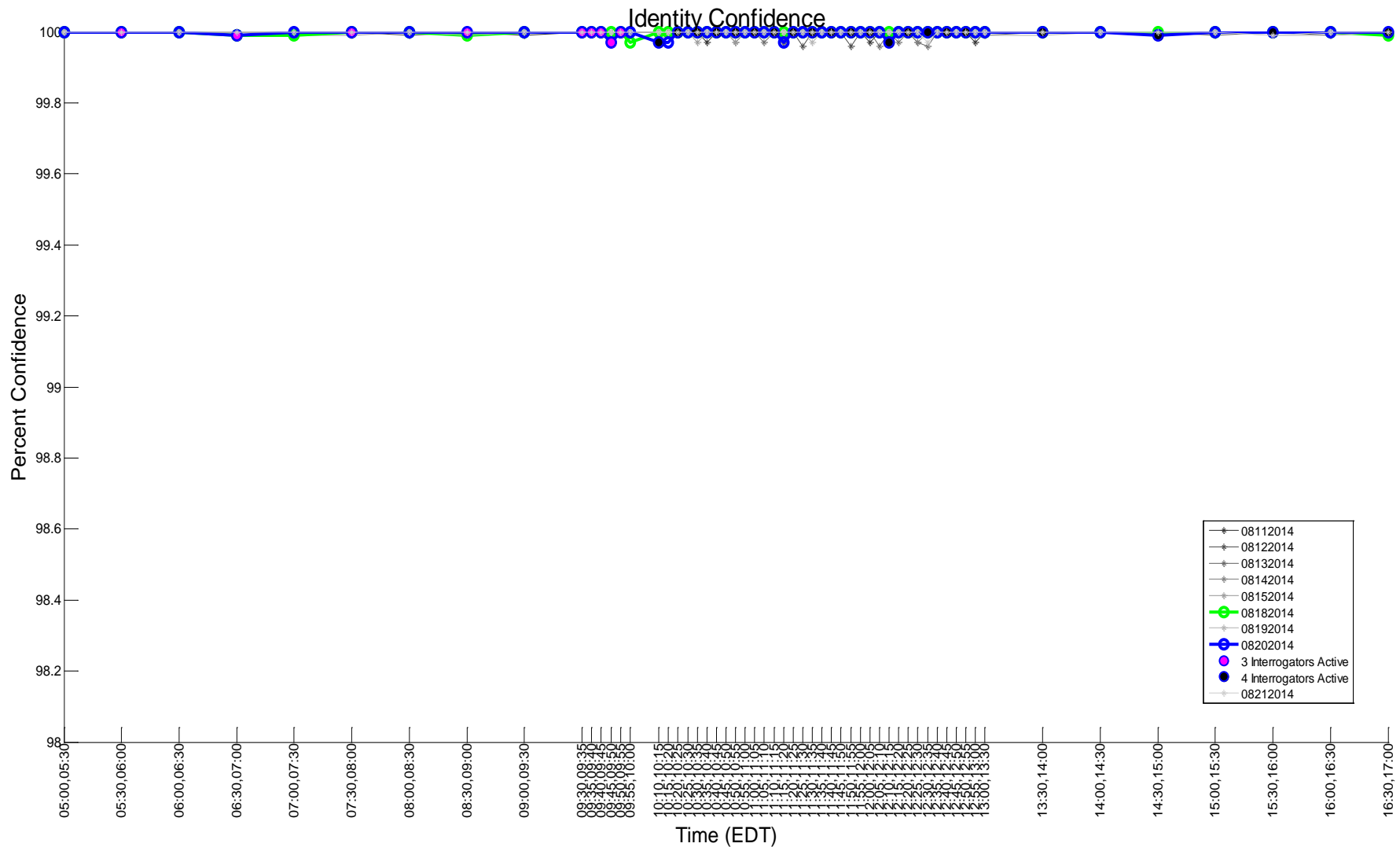
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 19th



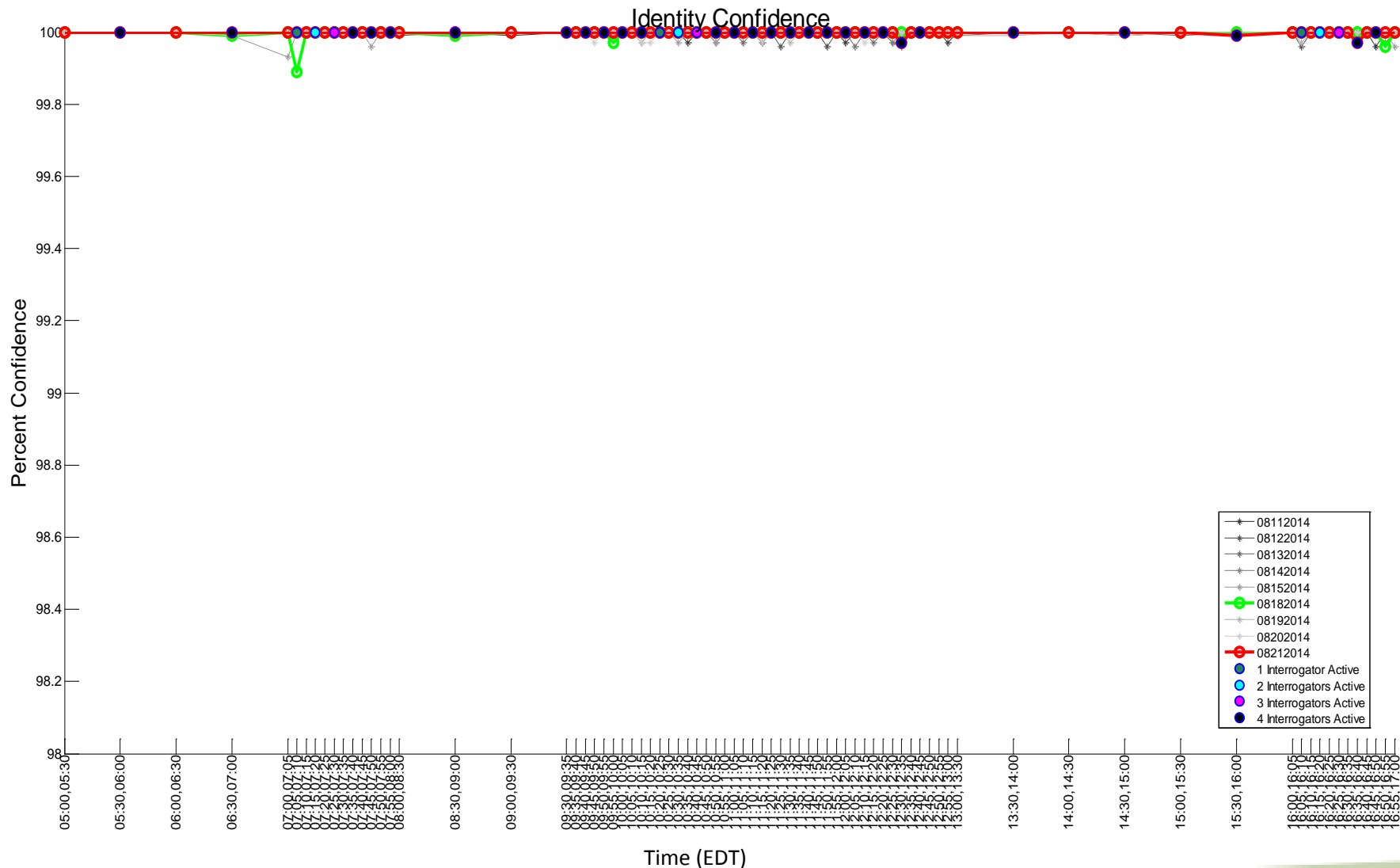
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 20<sup>th</sup>



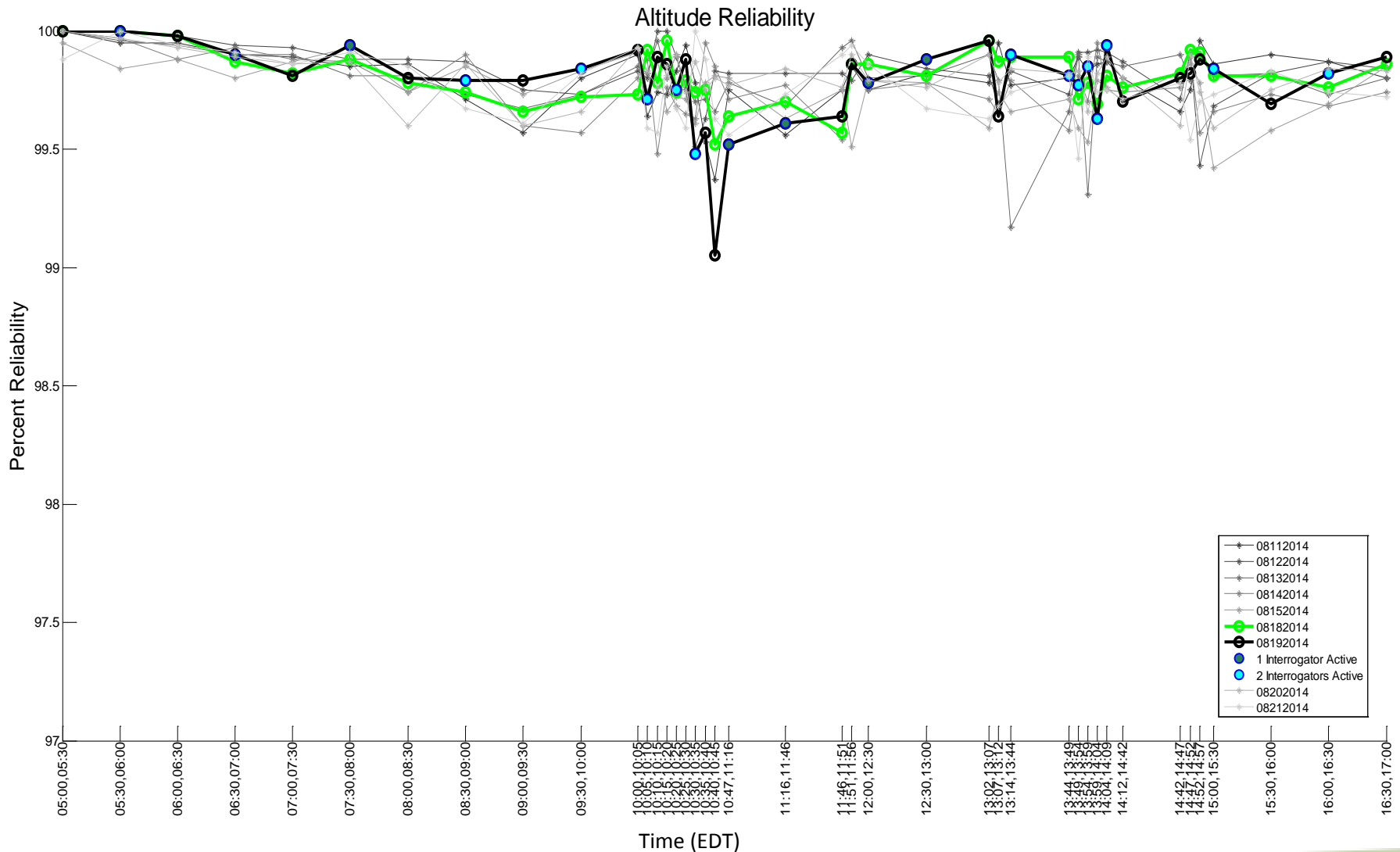
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 21<sup>st</sup>



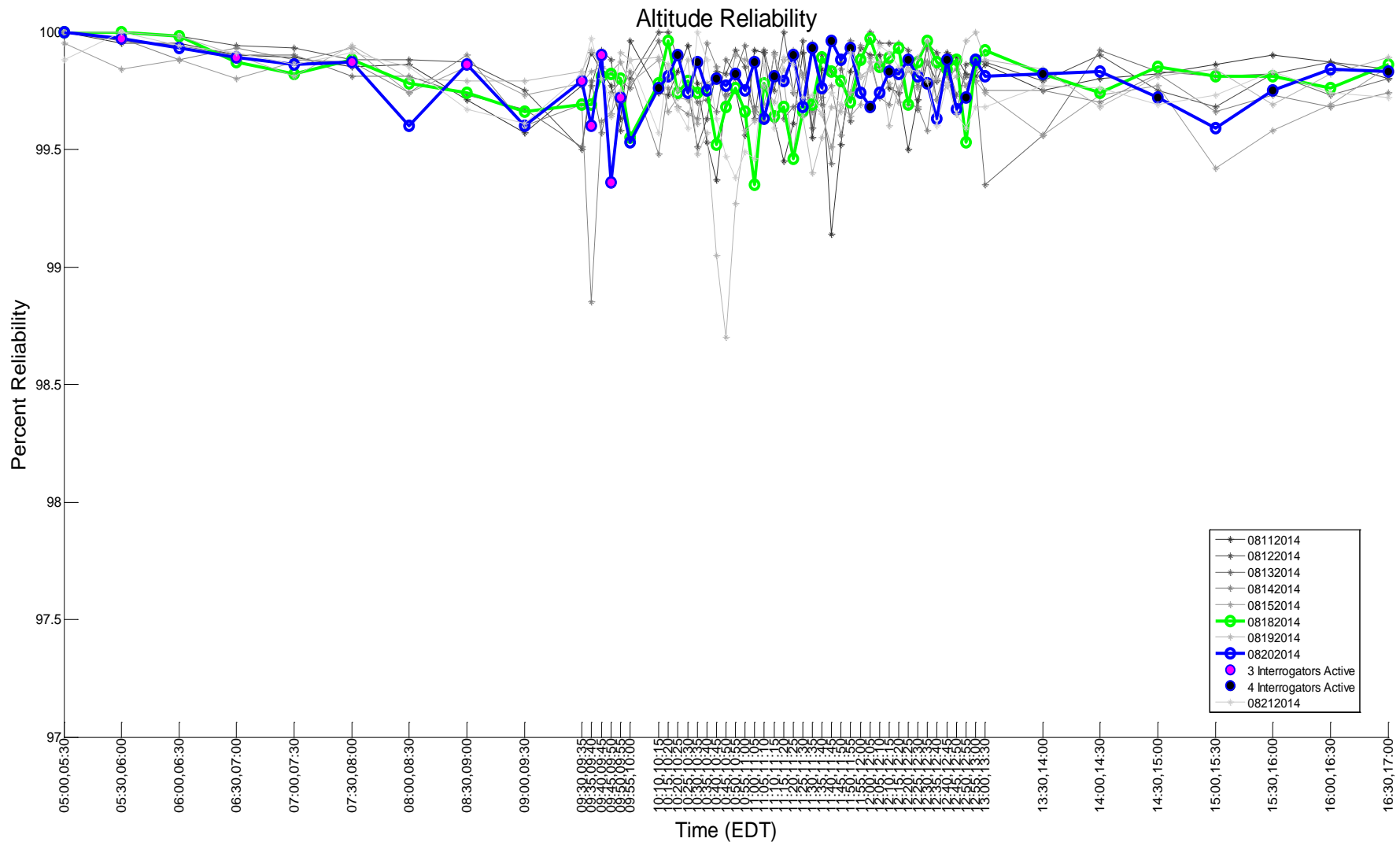
Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 19th



Geographic Filter: None  
Target Filter: None

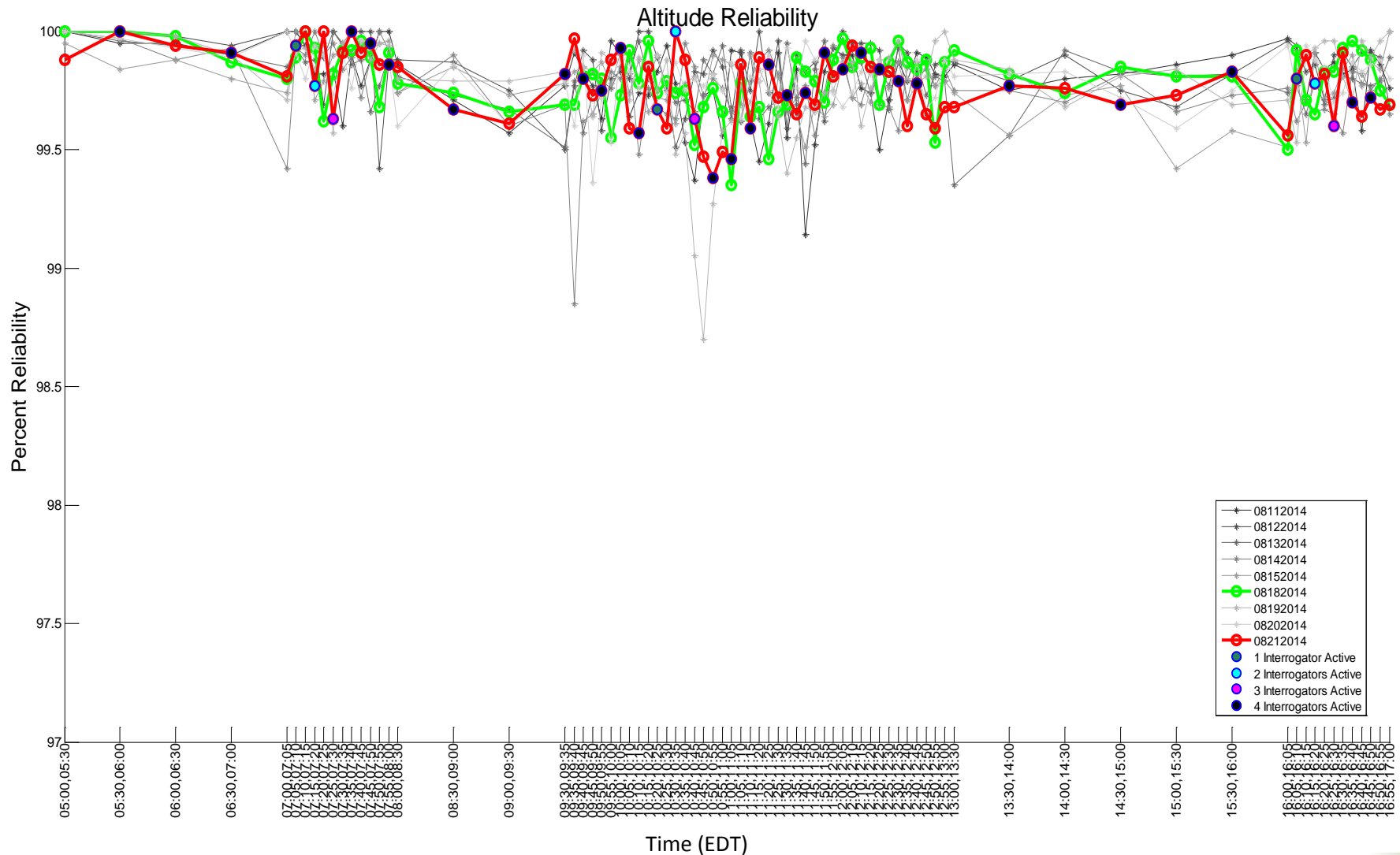
# Altitude (C) Reliability – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

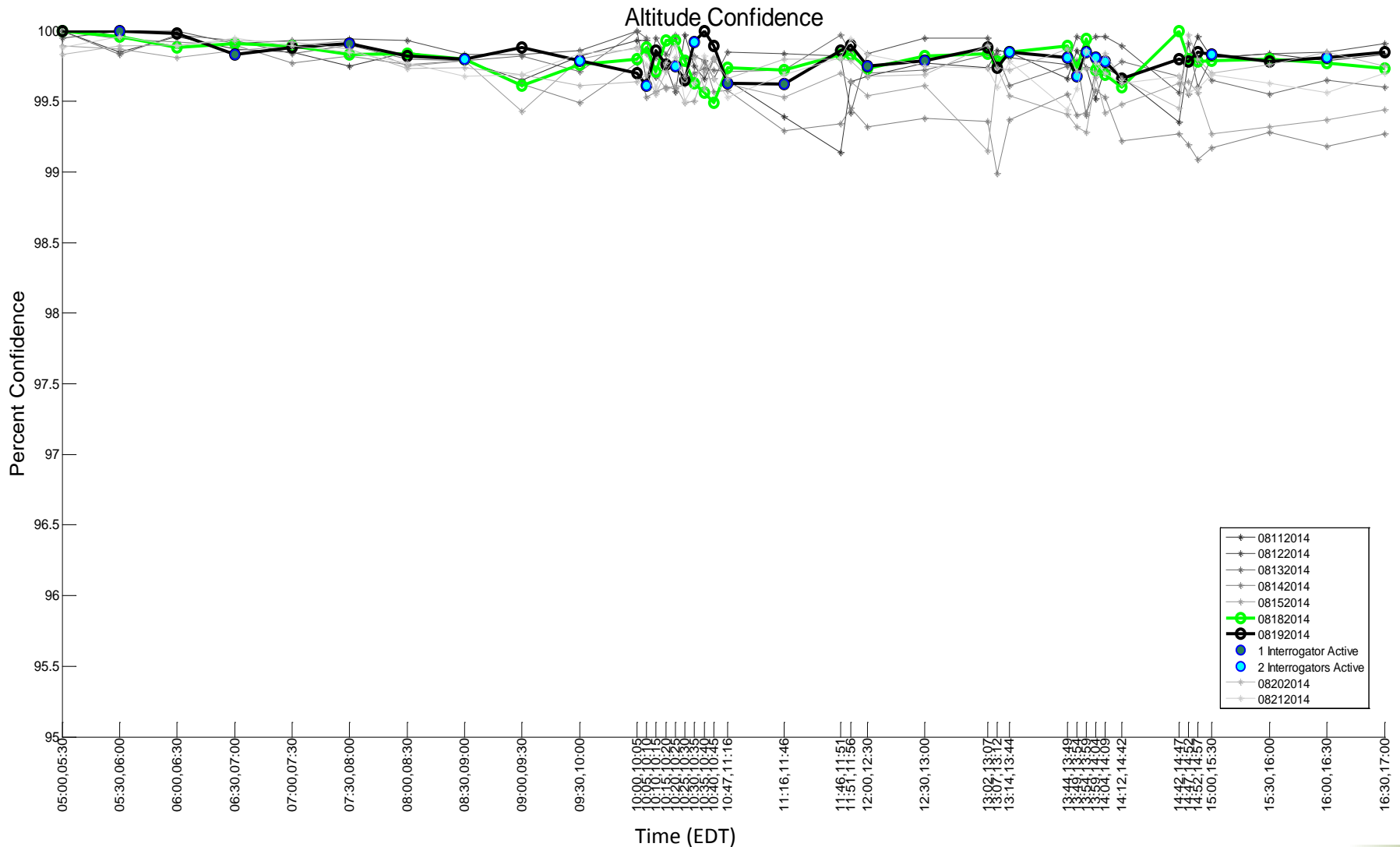


# Altitude (C) Reliability – August 21<sup>st</sup>



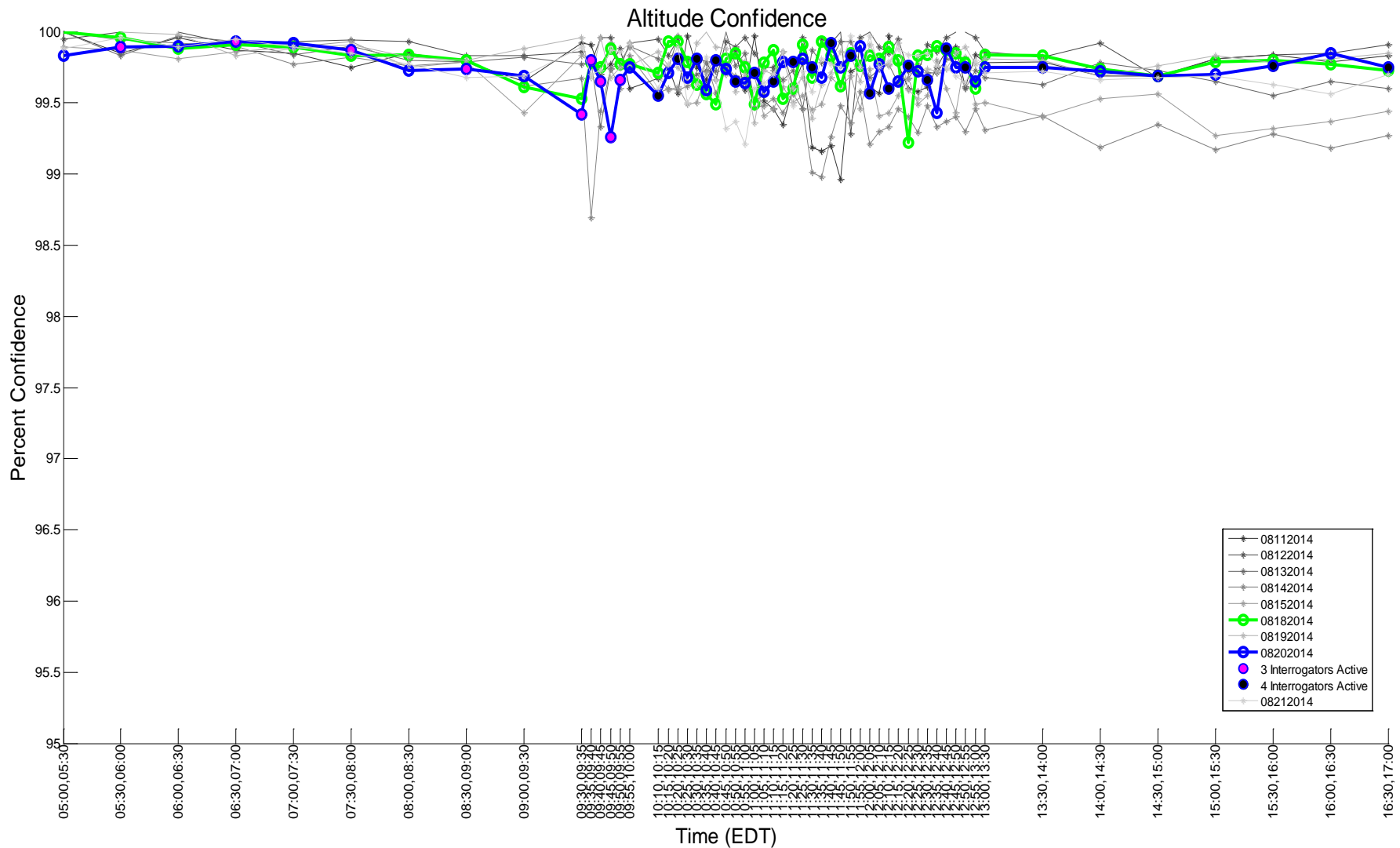
Geographic Filter: None  
Target Filter: None

# Altitude (C) Confidence – August 19th



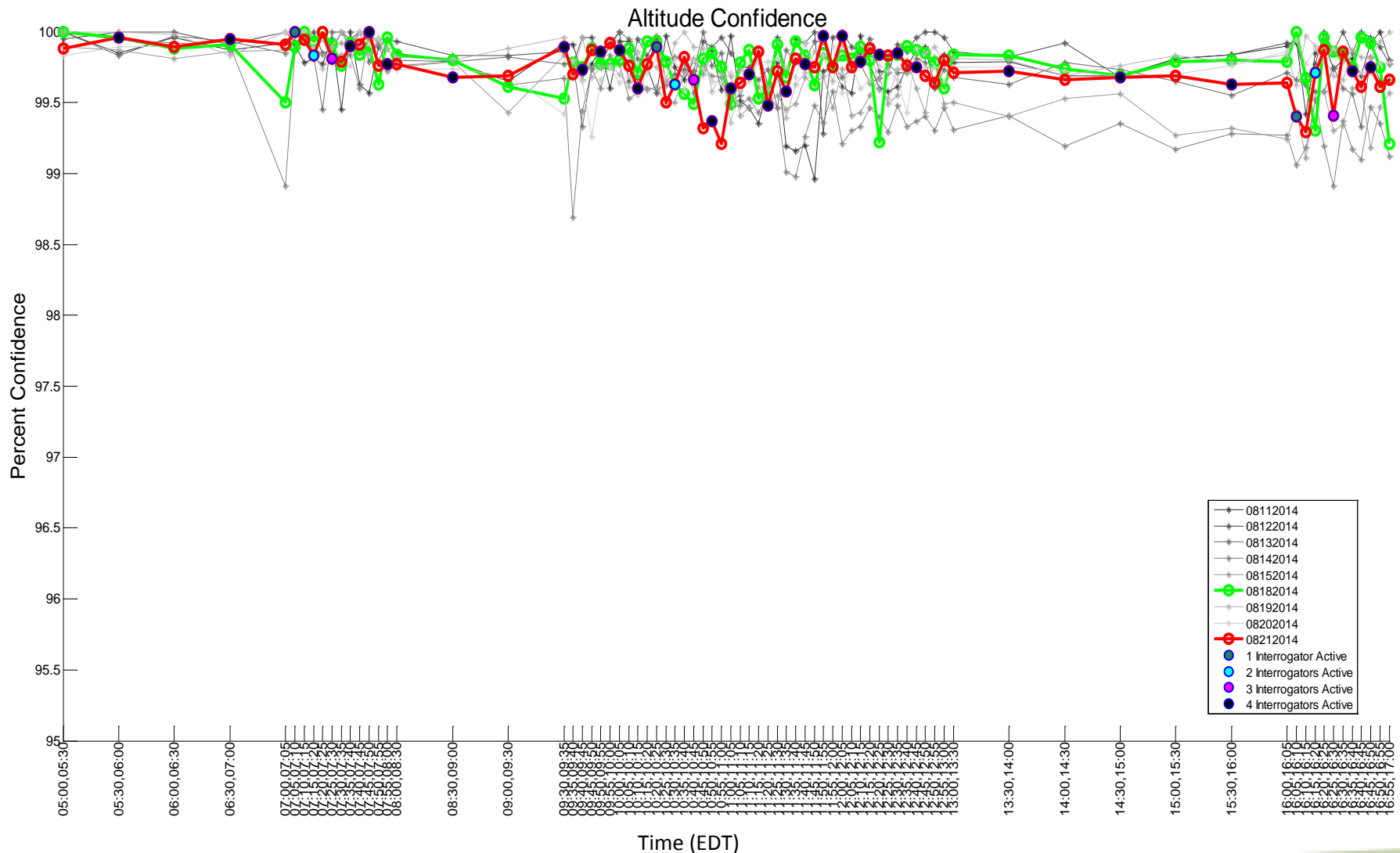
Geographic Filter: None  
Target Filter: None

# Altitude (C) Confidence – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

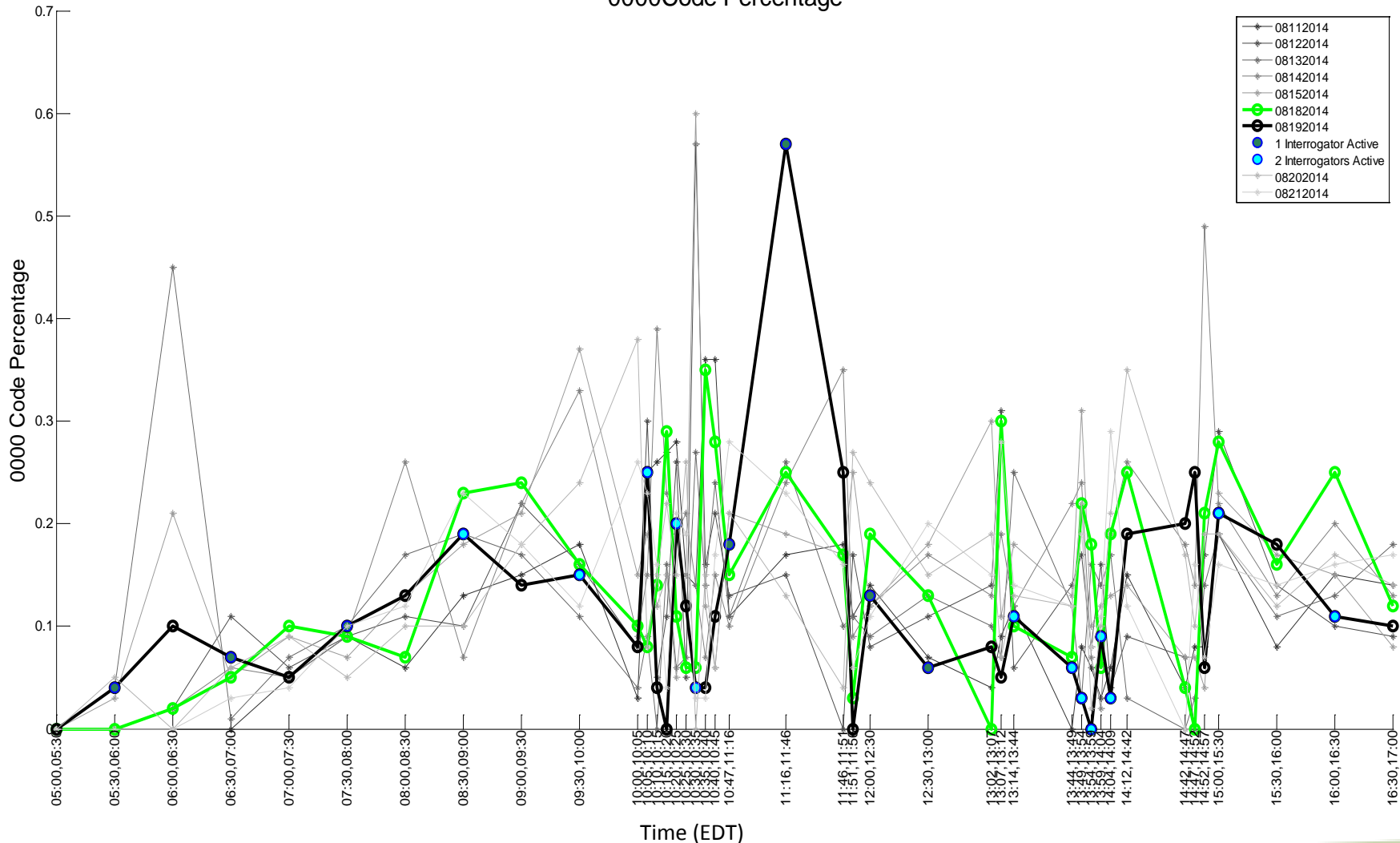
# Altitude (C) Confidence – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 19th

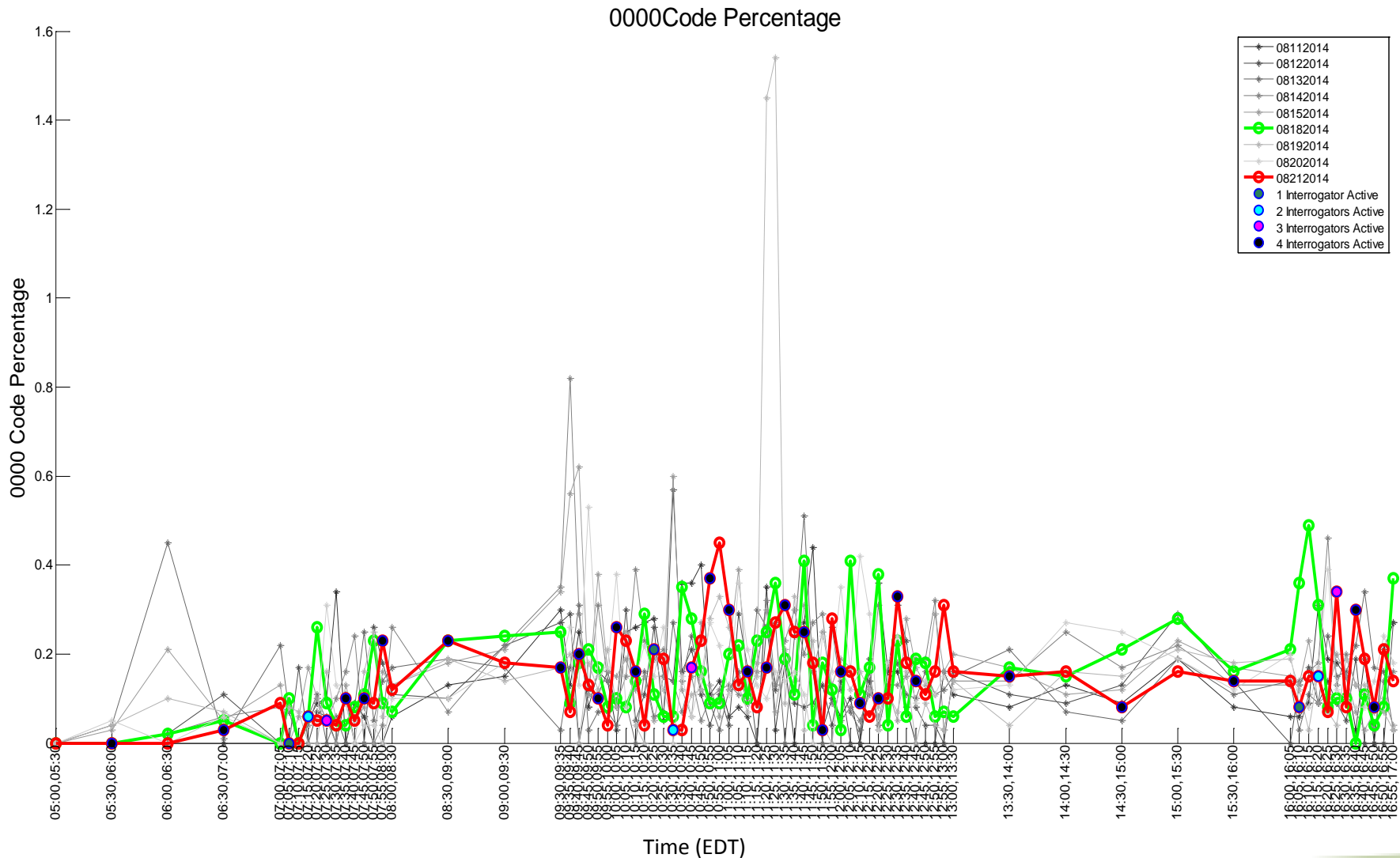
0000Code Percentage



Geographic Filter: None  
Target Filter: None



# 0000 Codes – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

# False Targets – August 19th

Total False Target Rate



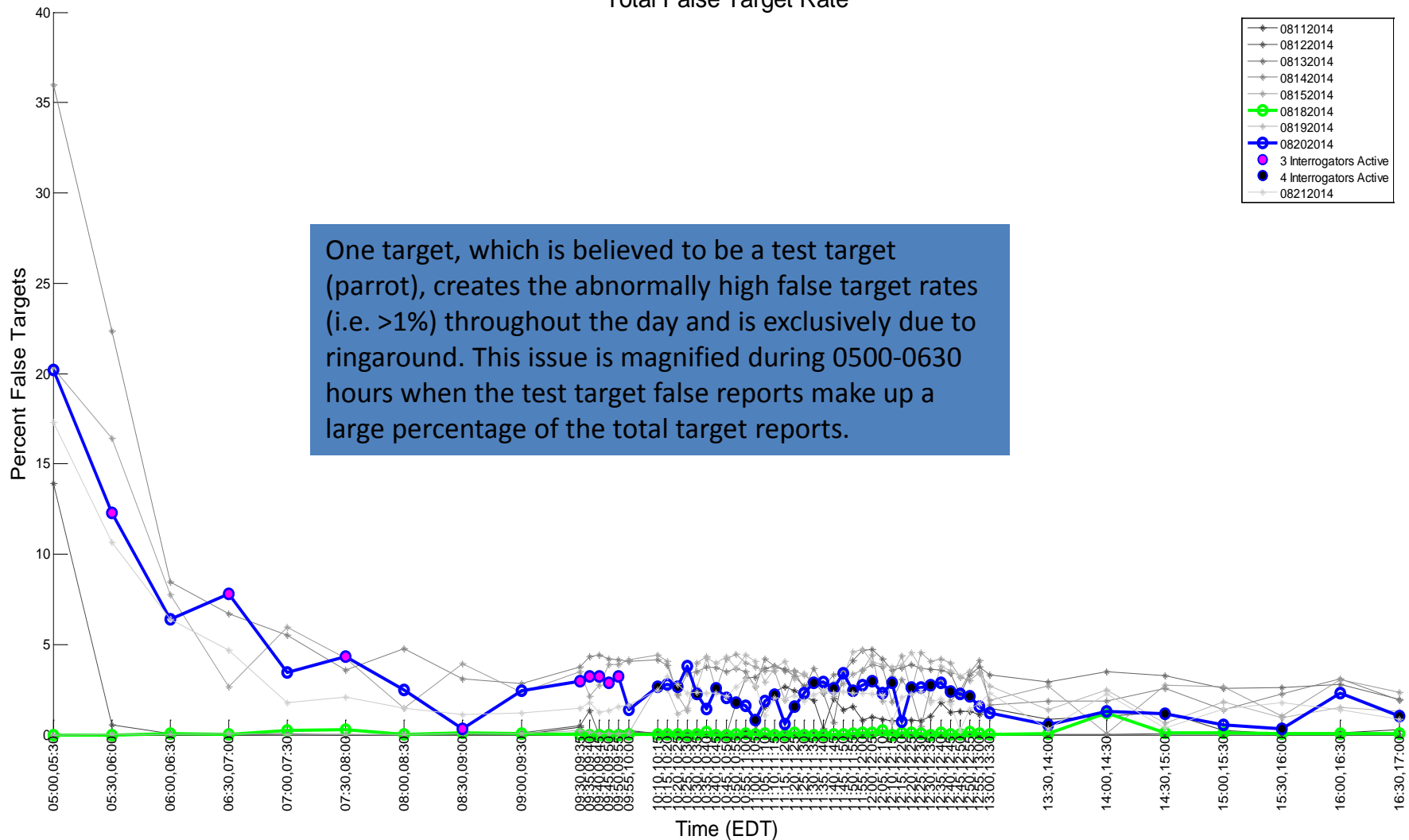
One target, which is believed to be a test target (parrot), creates the abnormally high false target rates (i.e. >1%) throughout the day and is exclusively due to ringaround. This issue is magnified during 0500-0630 hours when the test target false reports make up a large percentage of the total target reports.

Geographic Filter: None  
Target Filter: None



# False Targets – August 20<sup>th</sup>

Total False Target Rate



Geographic Filter: None  
Target Filter: None

# False Targets – August 21<sup>st</sup>

Total False Target Rate



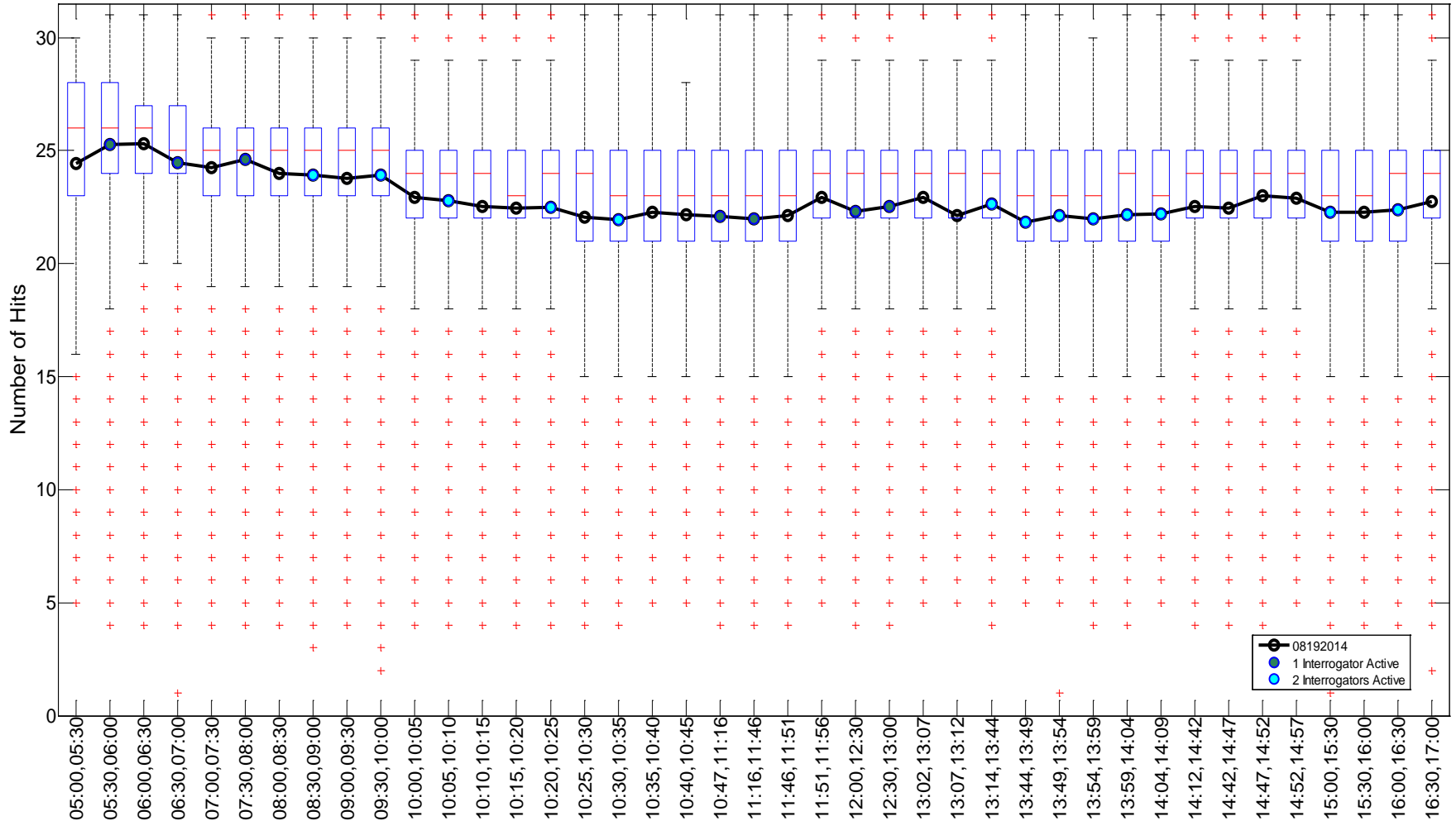
Geographic Filter: None  
Target Filter: None



# Hit Count – August 19<sup>th</sup>

## Individual Aircraft Distribution

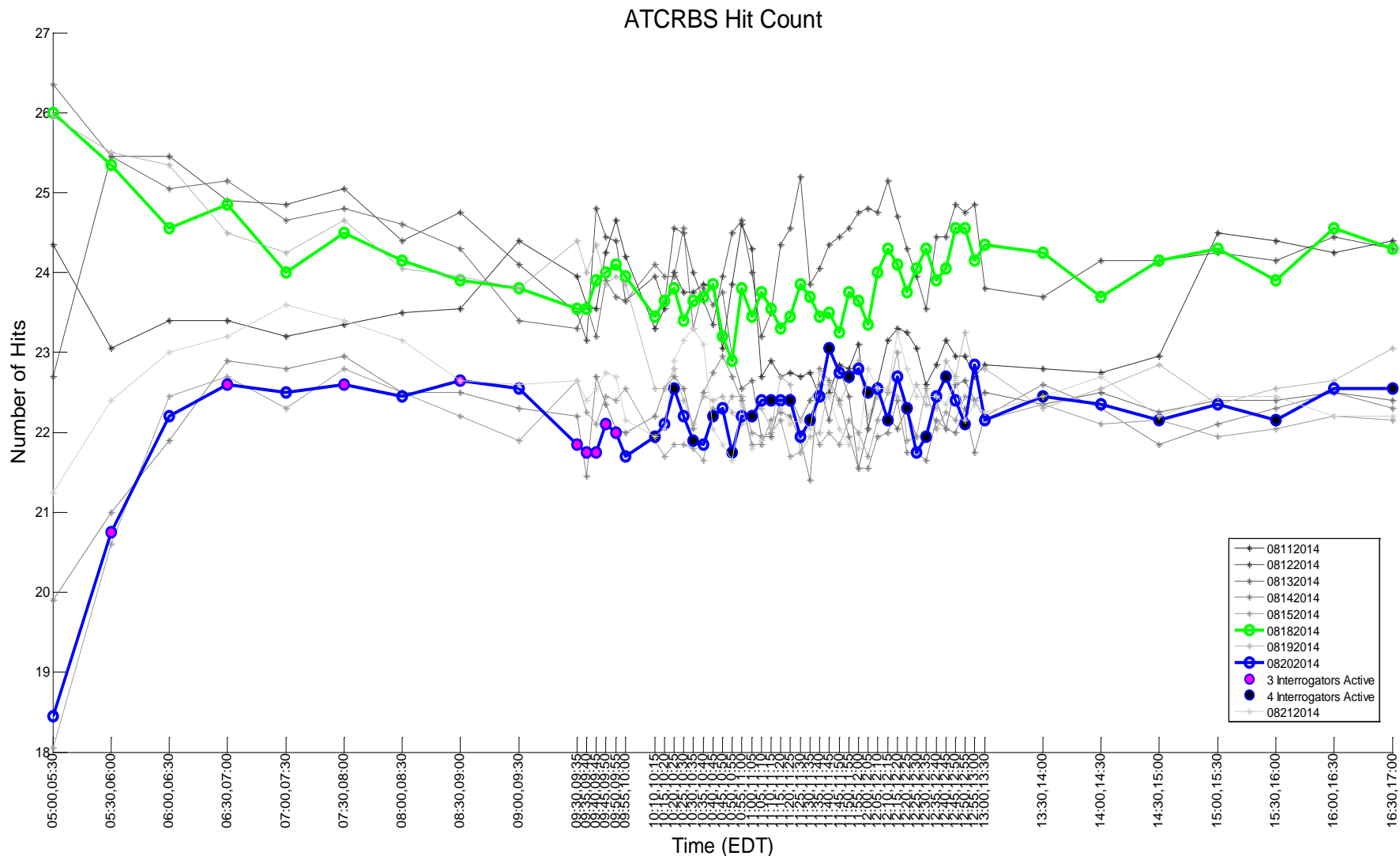
08192014 QIC: Number of Hits



Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

Geographic Filter: None  
Target Filter: None

# Hit Count – August 20<sup>th</sup>

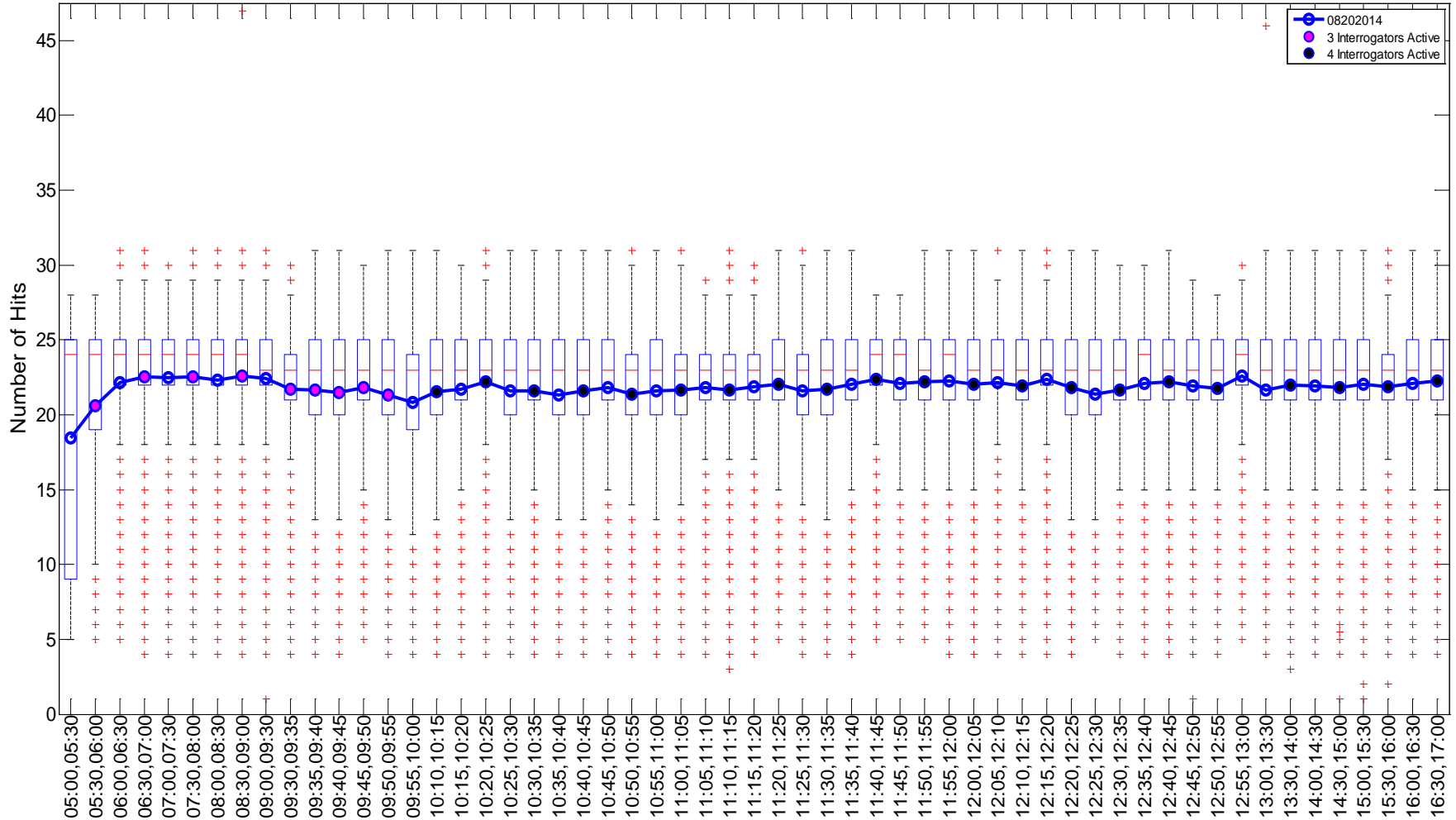


Geographic Filter: None  
Target Filter: None

# Hit Count – August 20<sup>th</sup>

## Individual Aircraft Distribution

08202014 QIC: Number of Hits

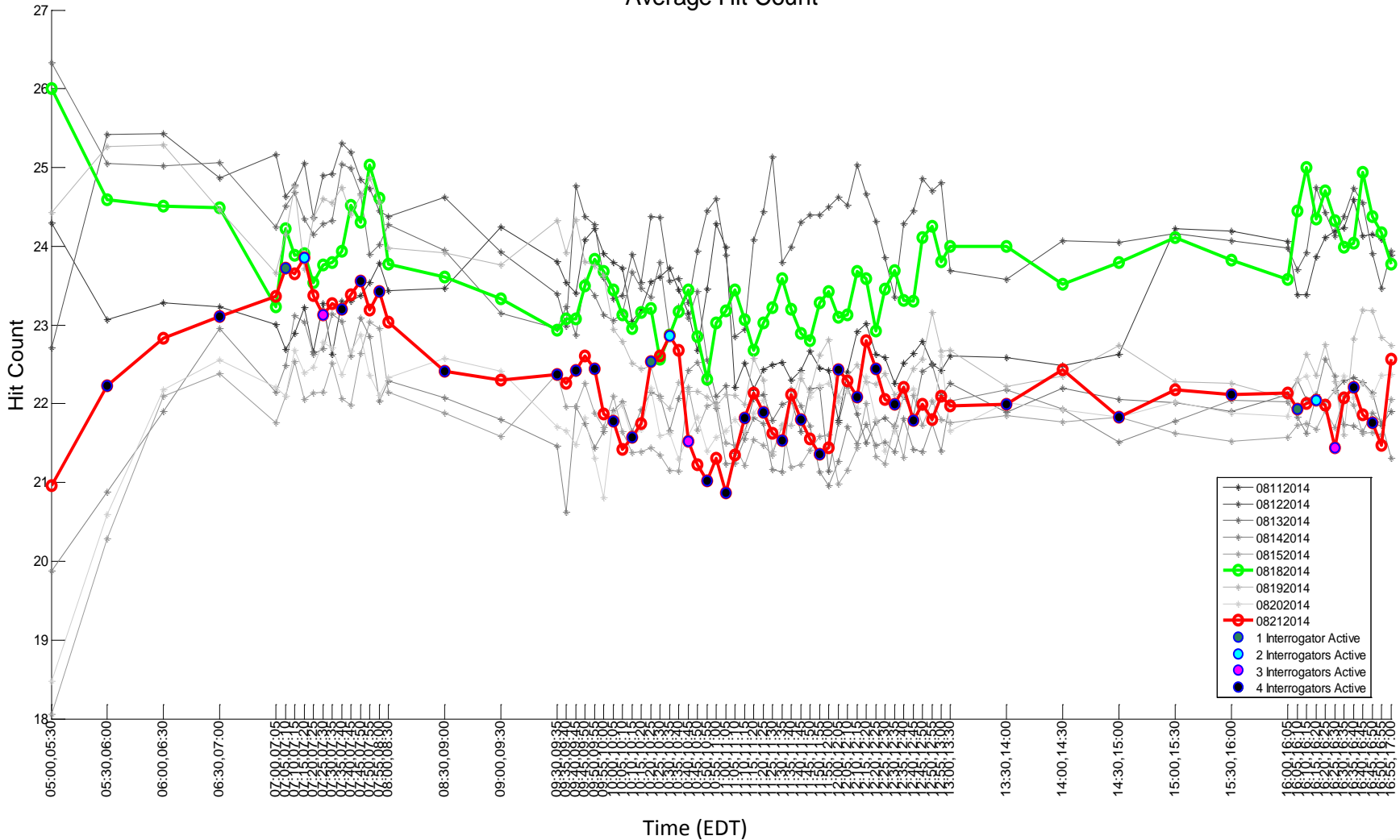


Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

Geographic Filter: None  
Target Filter: None

# Hit Count – August 21<sup>st</sup>

Average Hit Count

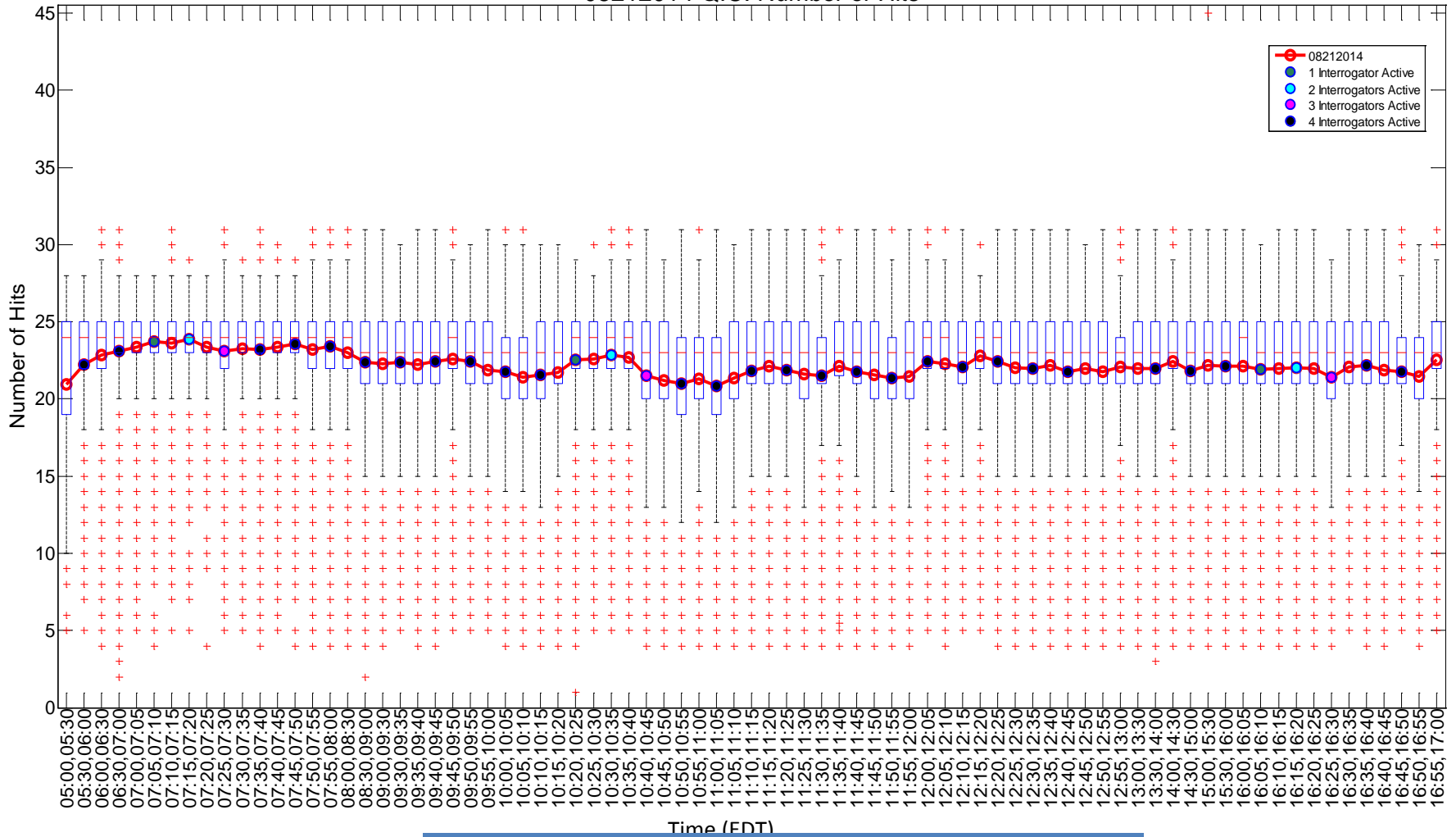


Geographic Filter: None  
Target Filter: None

# Hit Count – August 21<sup>st</sup>

## Individual Aircraft Distribution

08212014 QIC: Number of Hits



Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

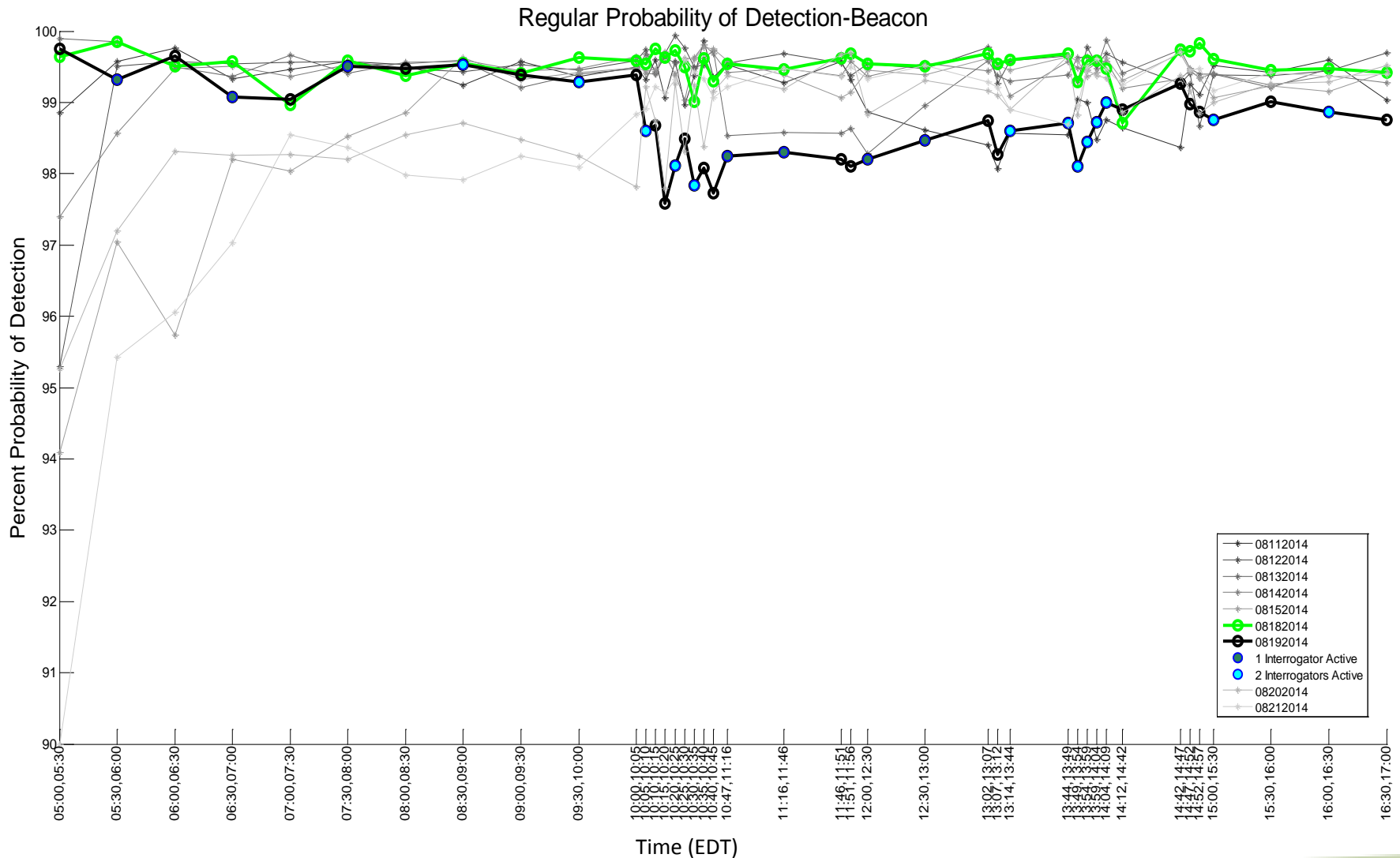
Geographic Filter: None  
Target Filter: None



# Target Metrics with Elevation Angle Greater than 2 Degrees

*\* Number of Targets Unavailable*

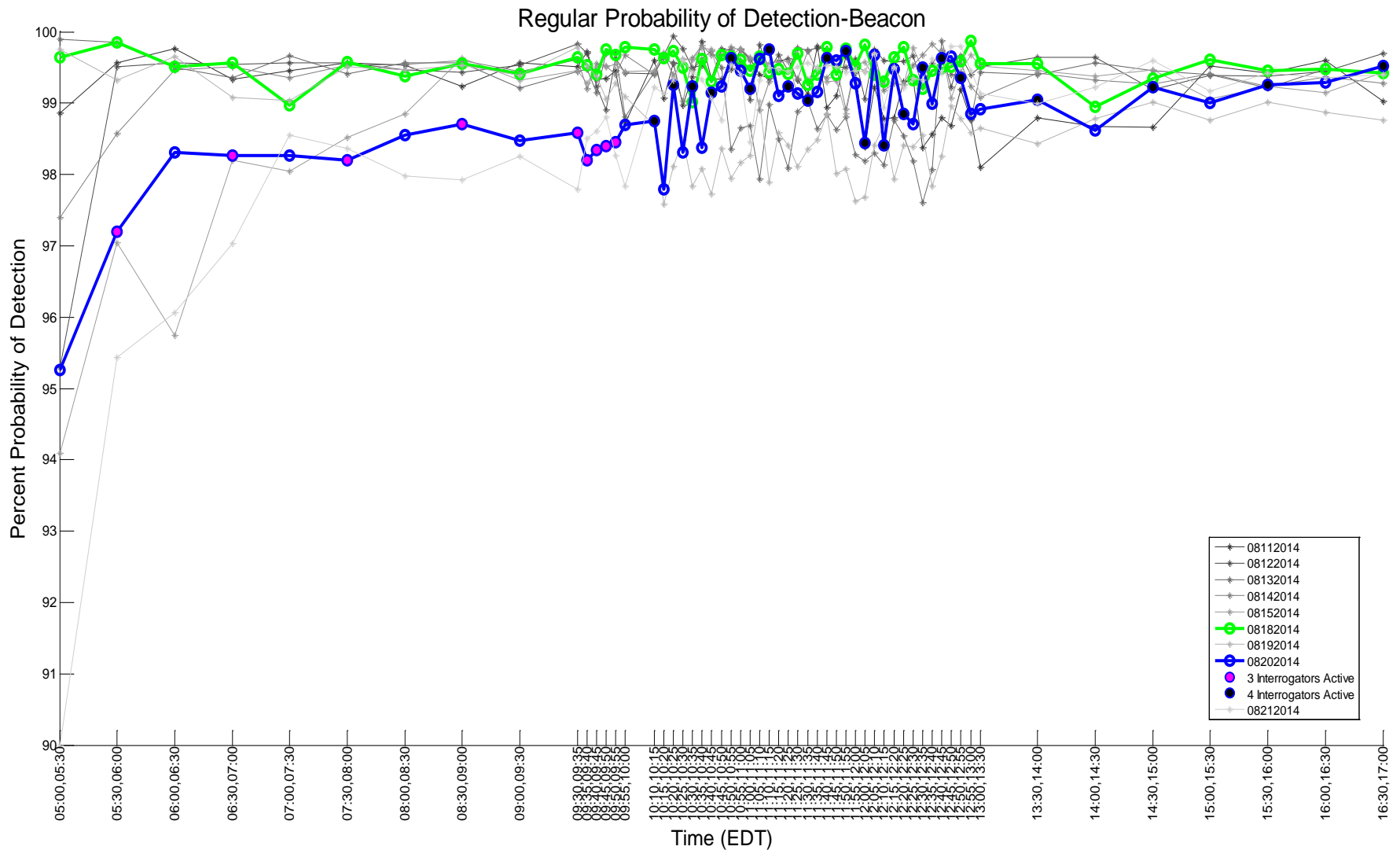
# Probability of Detection – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

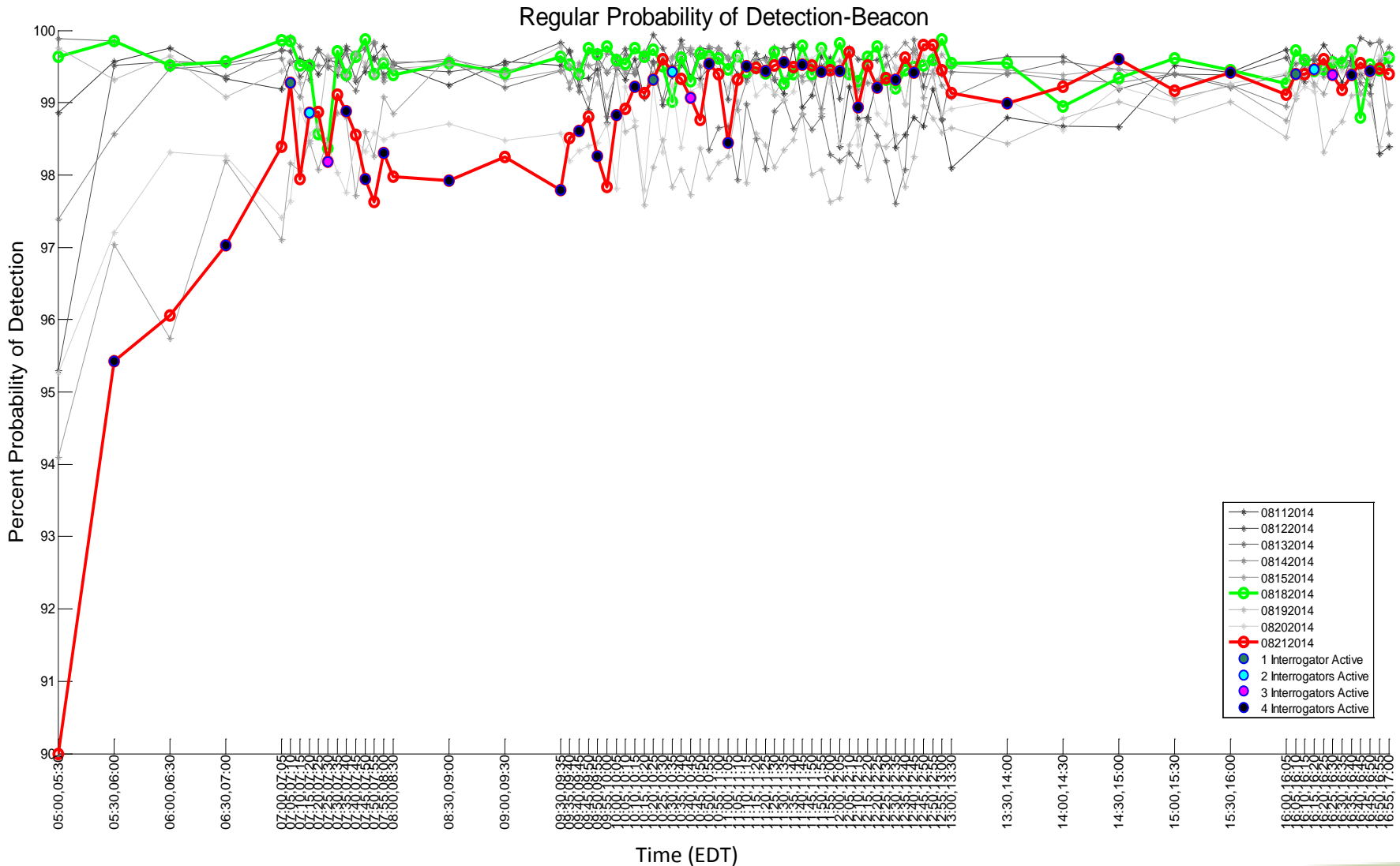
# Probability of Detection – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Probability of Detection – August 21<sup>st</sup>



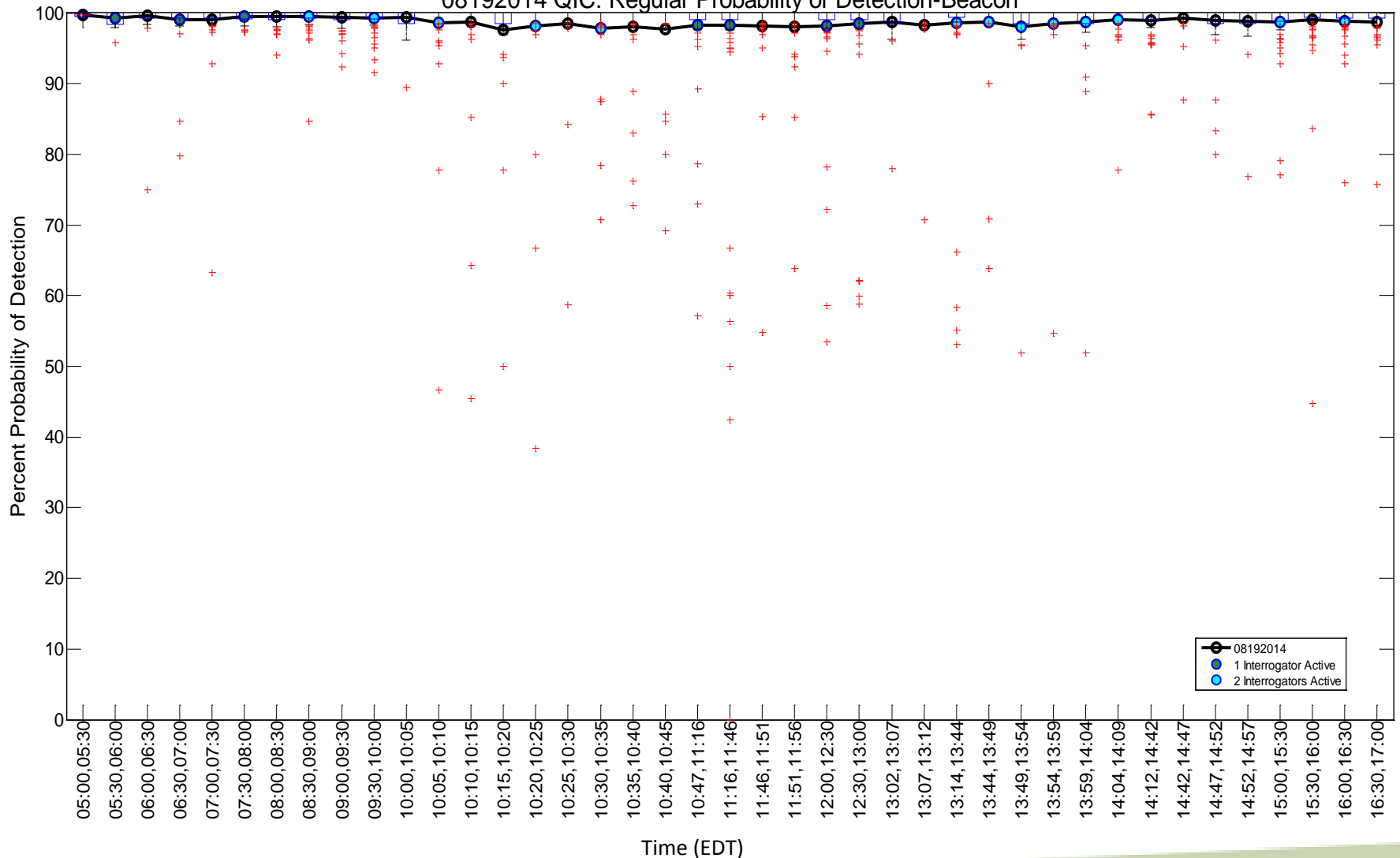
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution

08192014 QIC: Regular Probability of Detection-Beacon

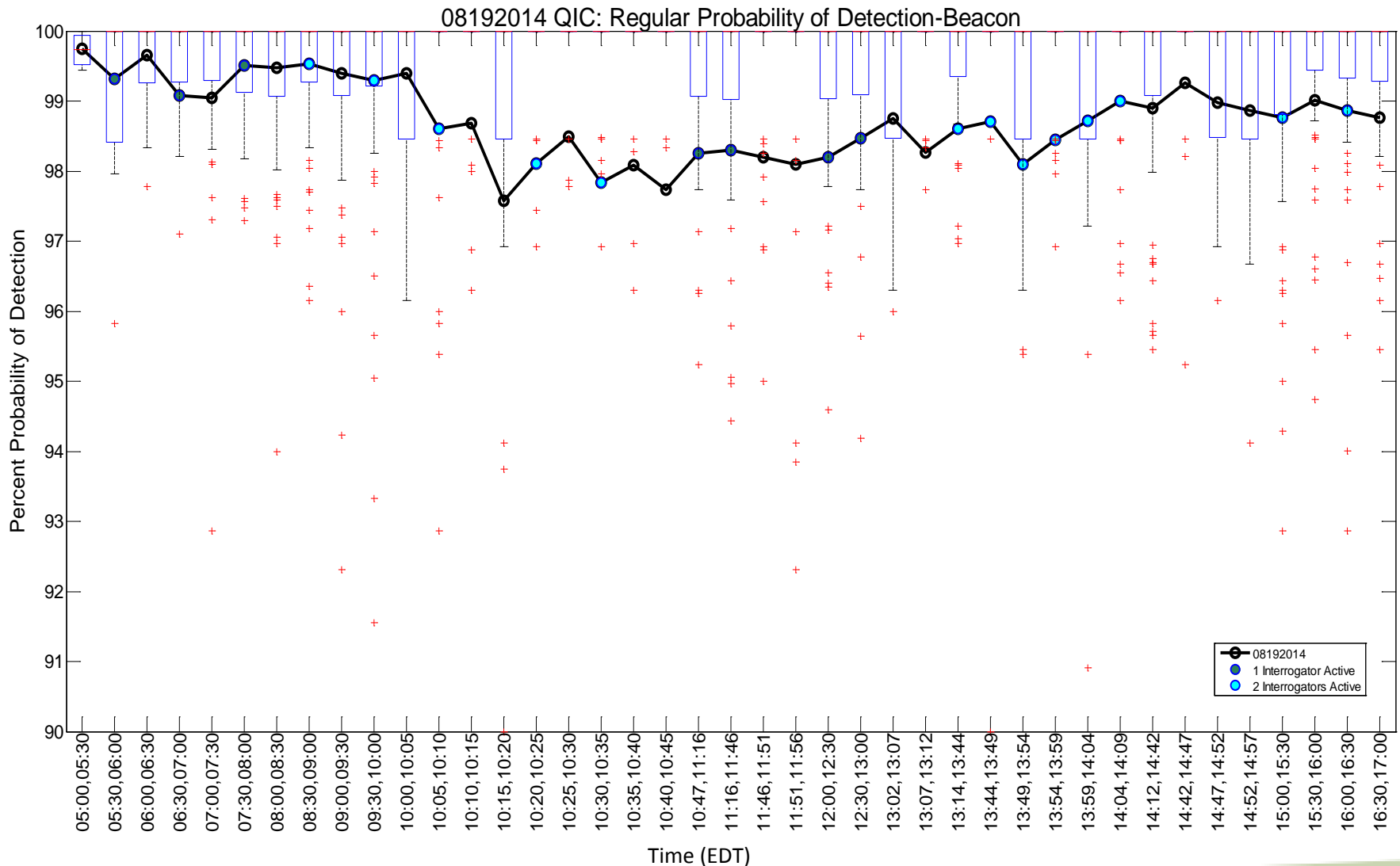


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

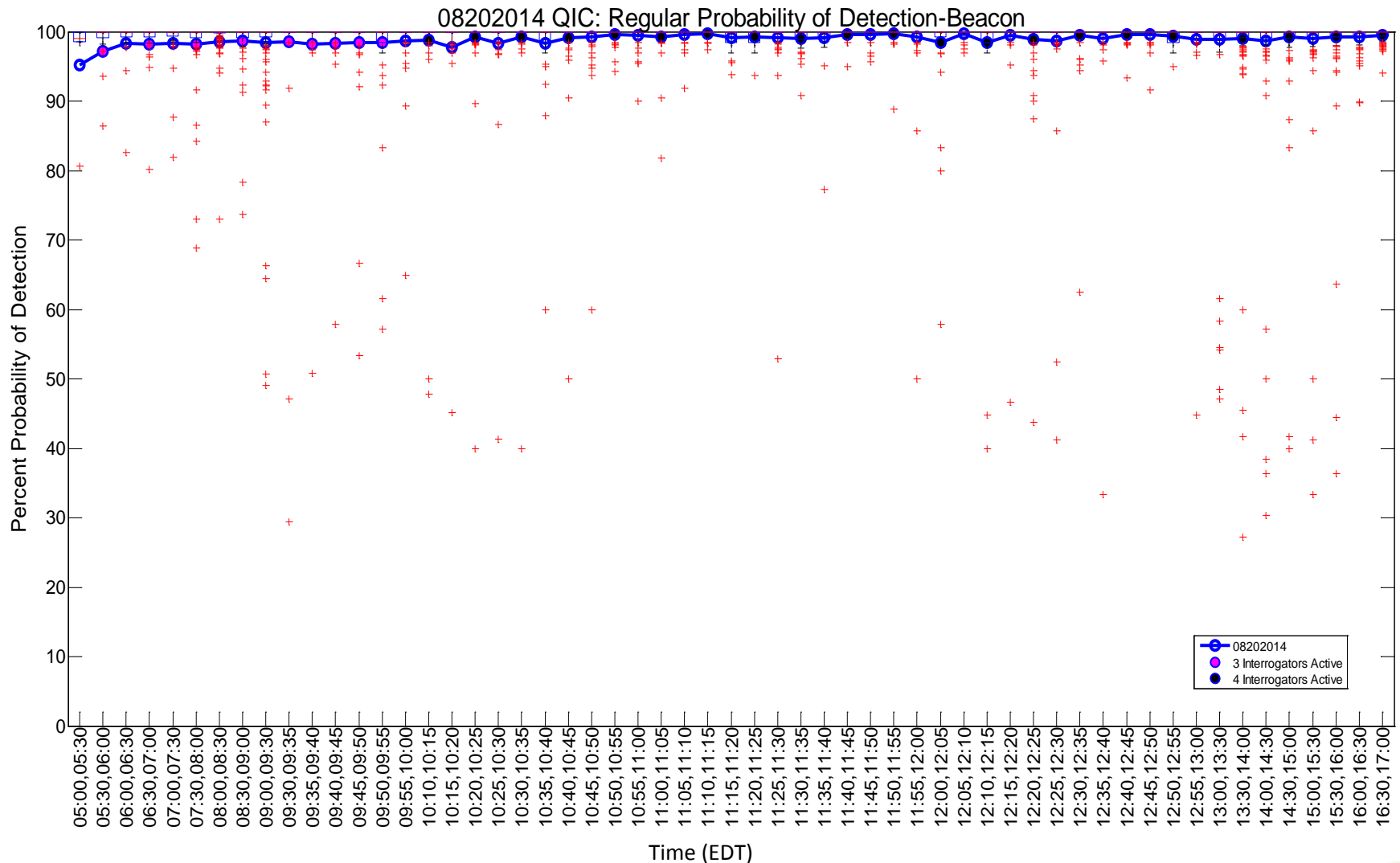


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution



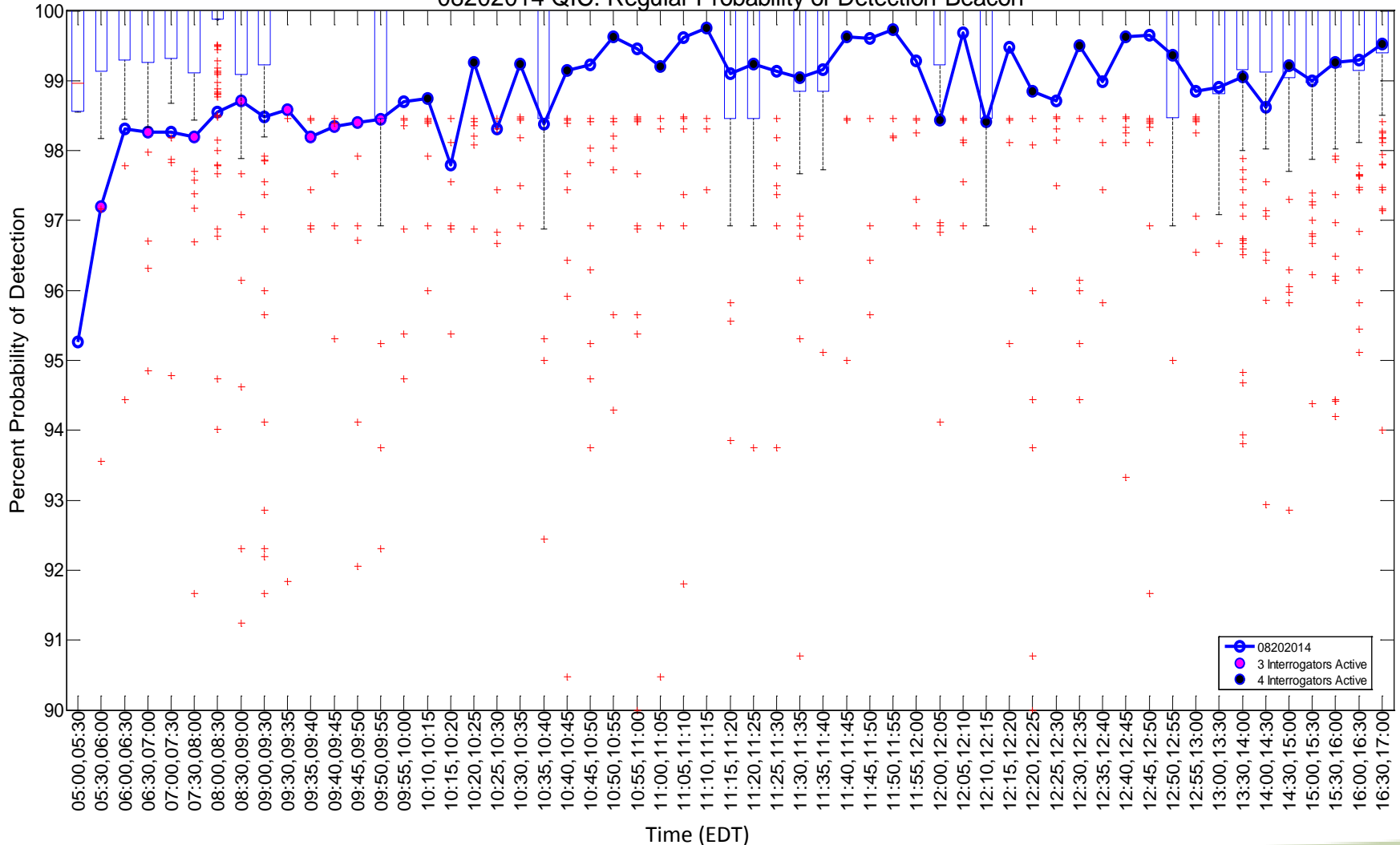
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08202014 QIC: Regular Probability of Detection-Beacon



Geographic Filter: None

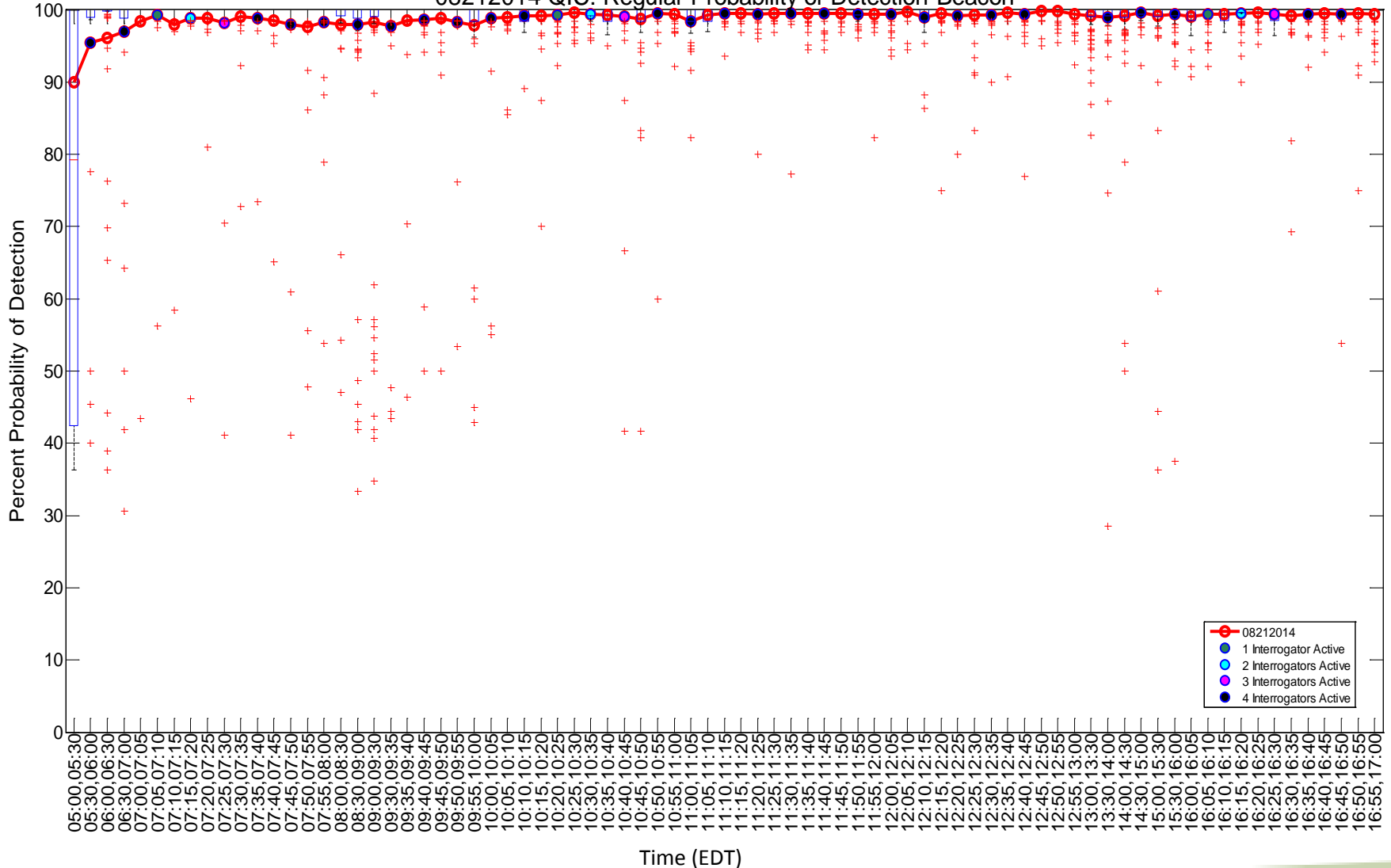
Target Filter: Exclude Targets with Elevation angle < 2°



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

08212014 QIC: Regular Probability of Detection-Beacon



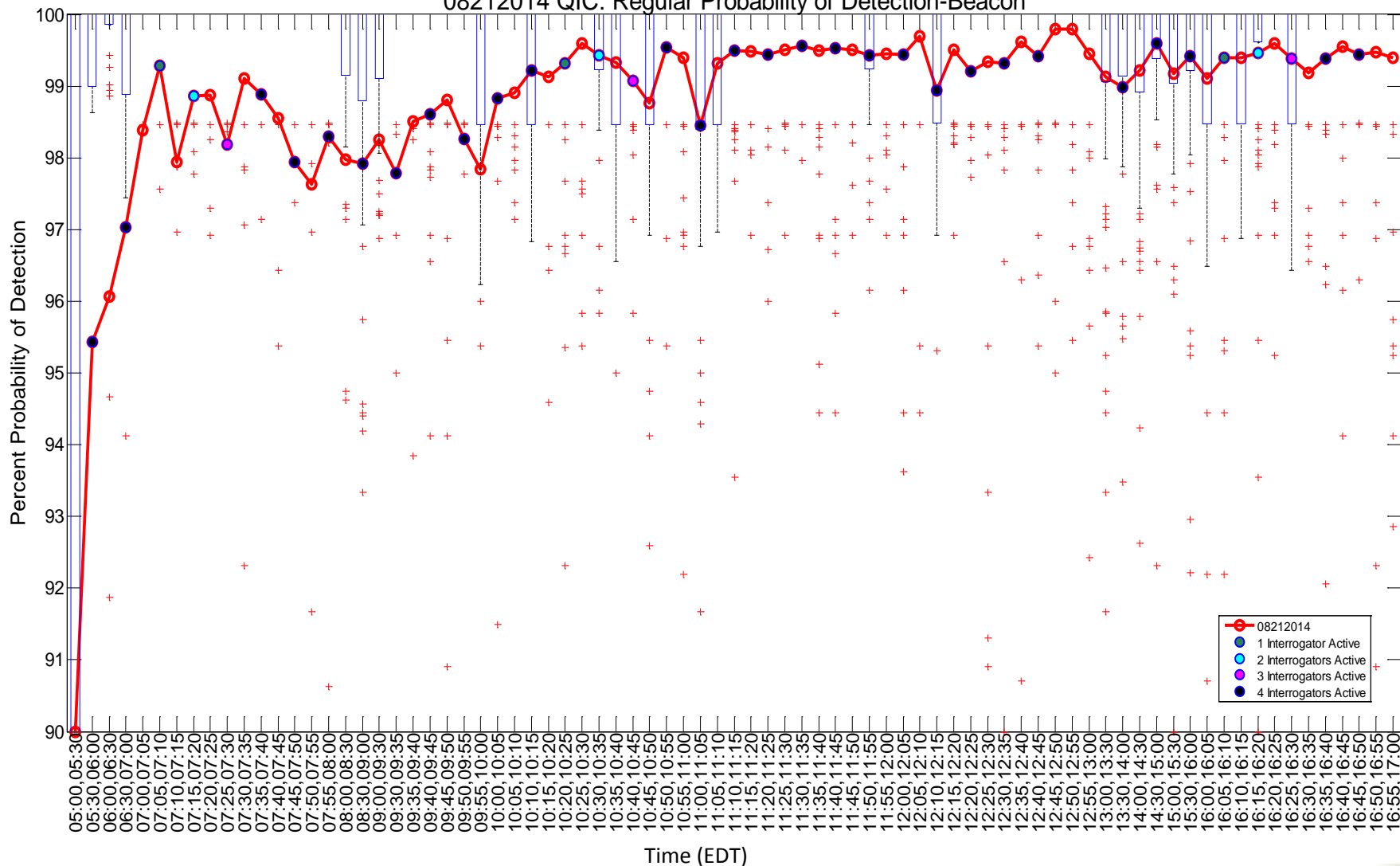
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)

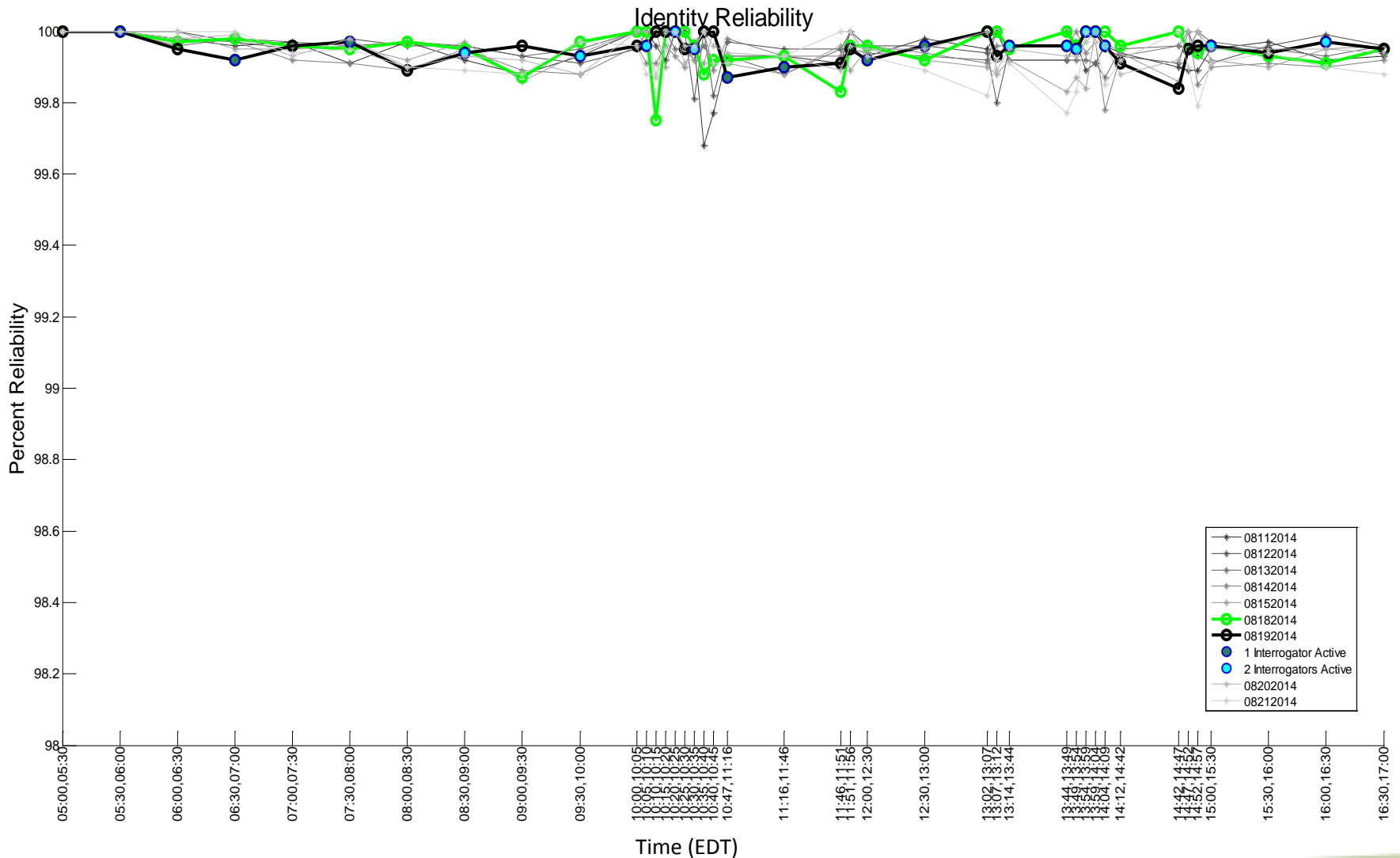
08212014 QIC: Regular Probability of Detection-Beacon



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

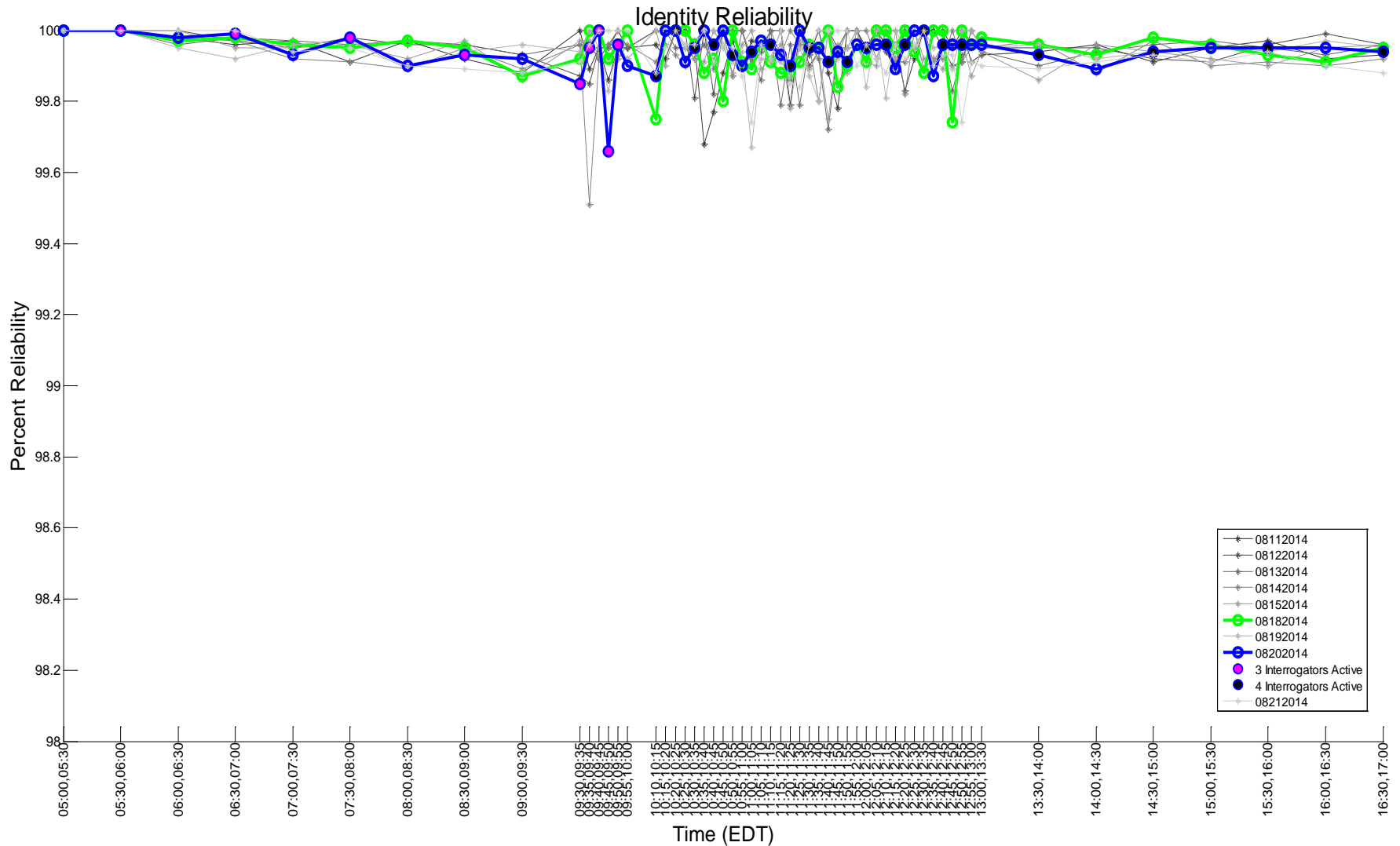
# Identity (3/A) Reliability – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

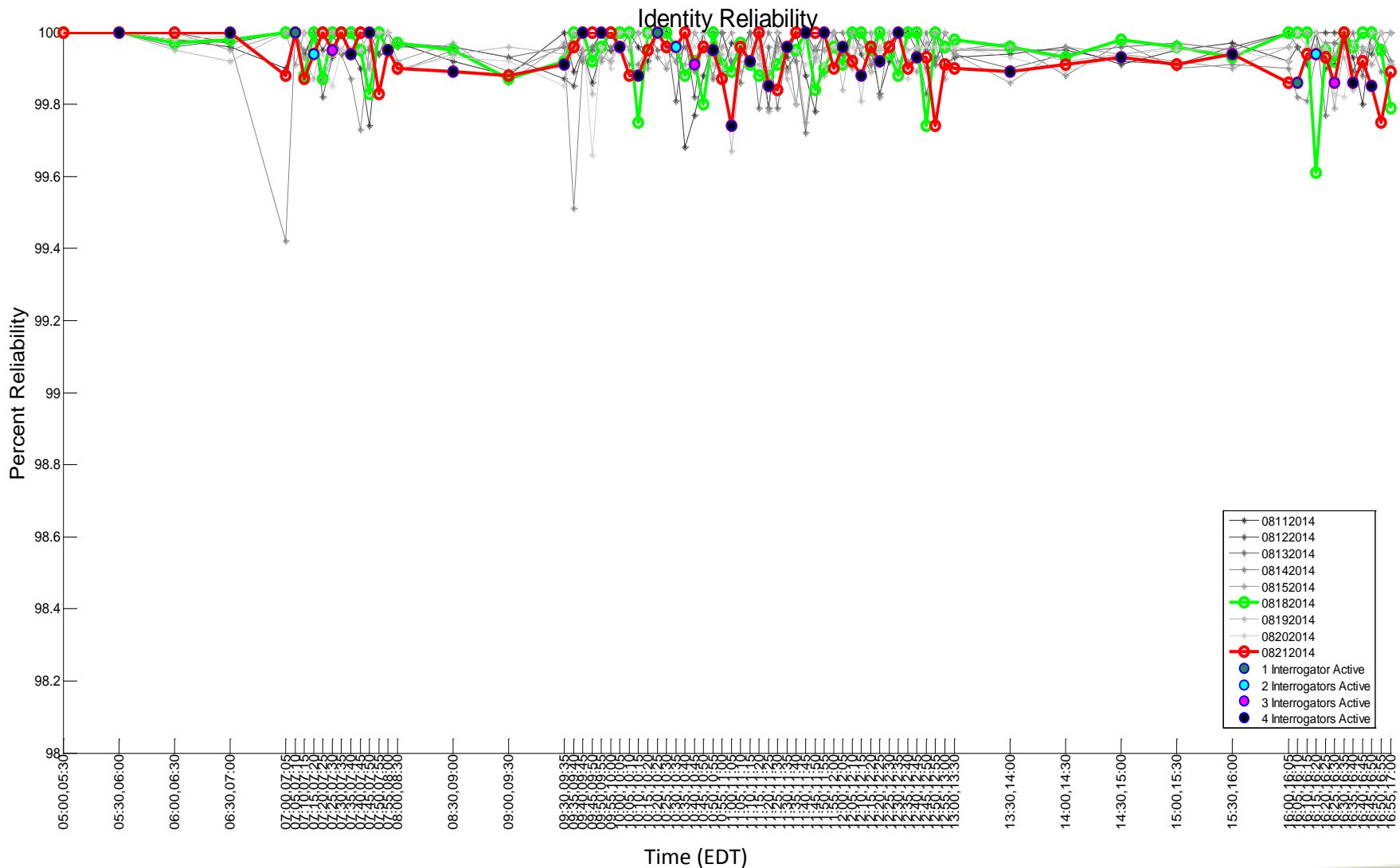
# Identity (3/A) Reliability – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

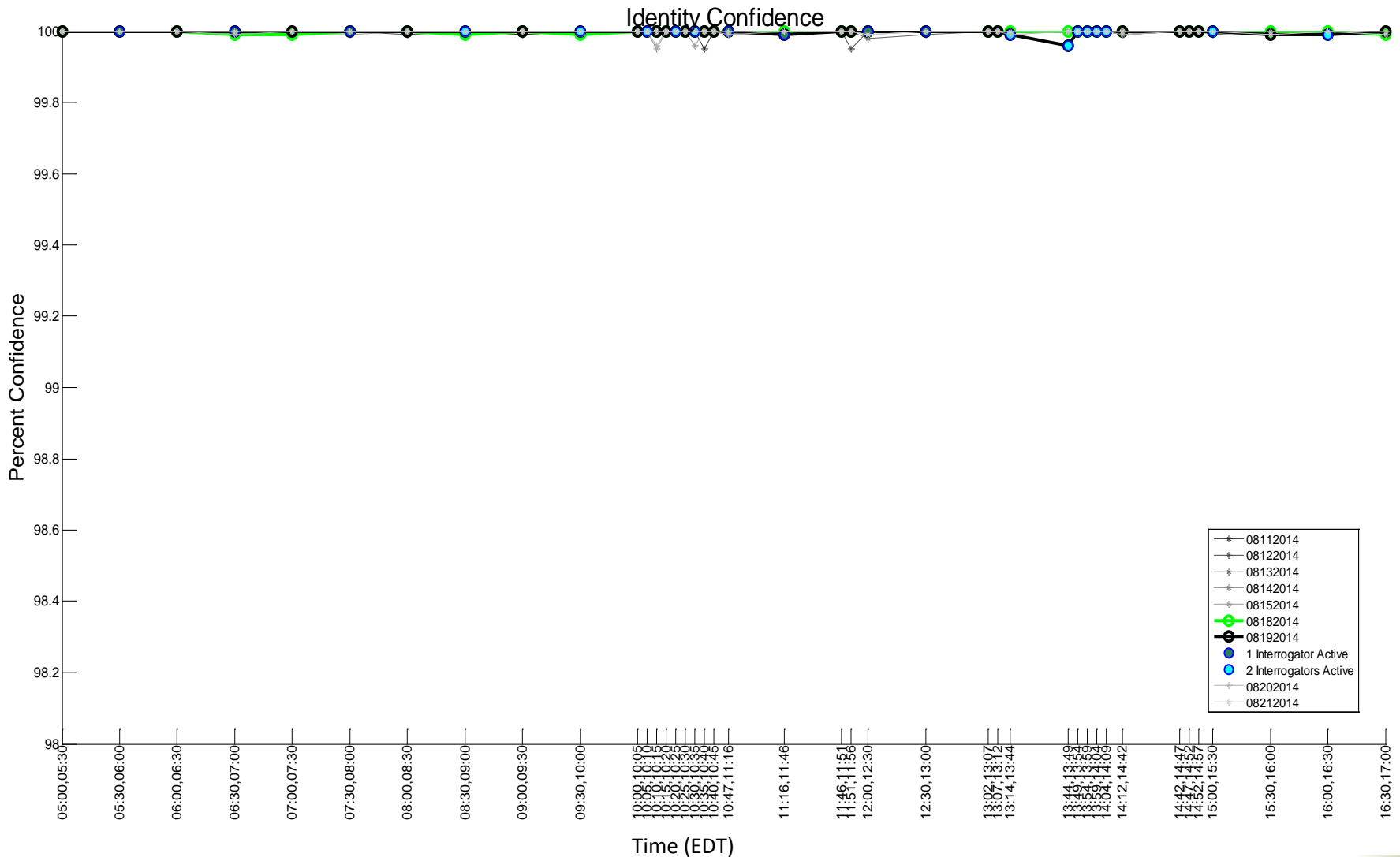
# Identity (3/A) Reliability – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

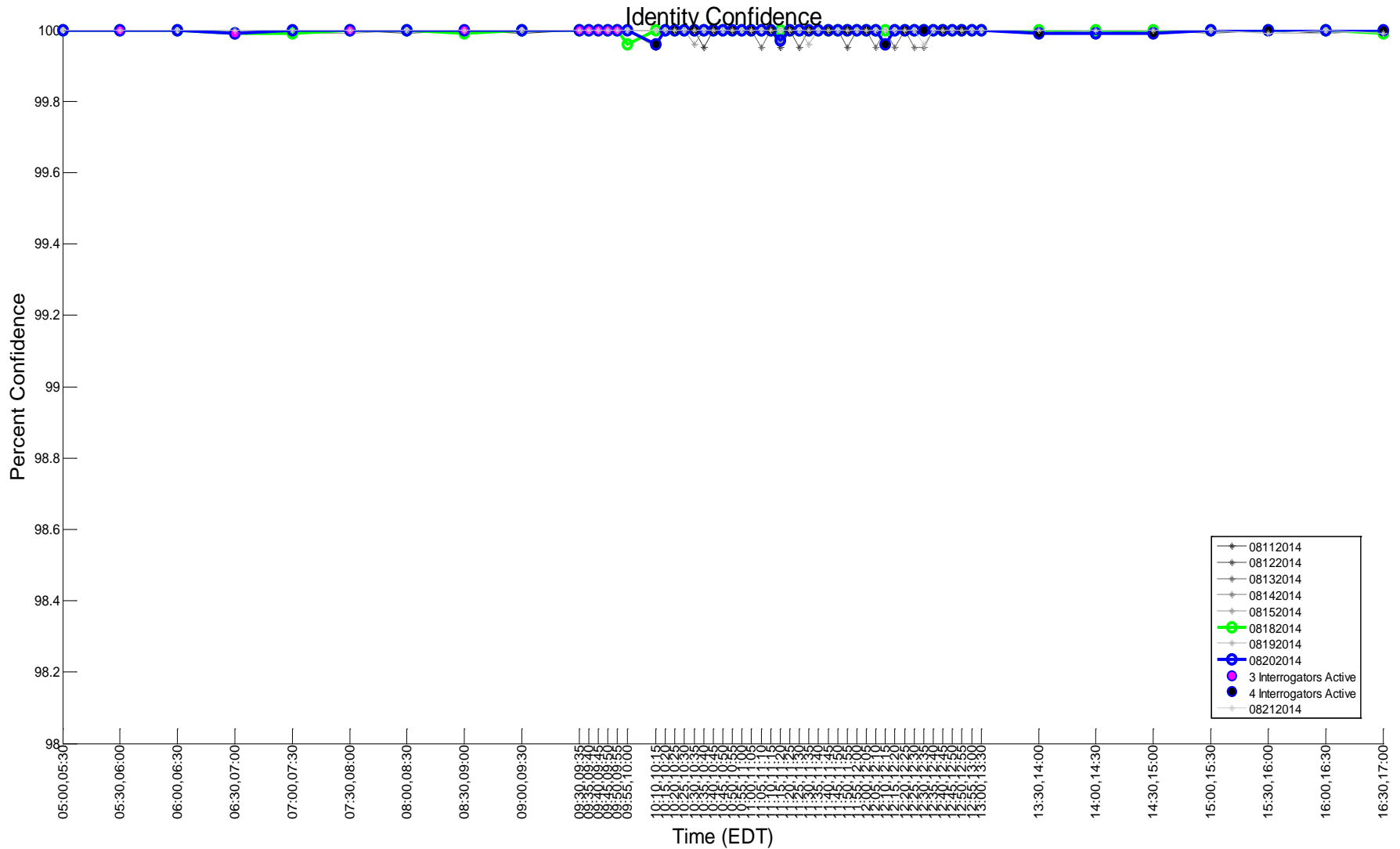
# Identity (3/A) Confidence – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

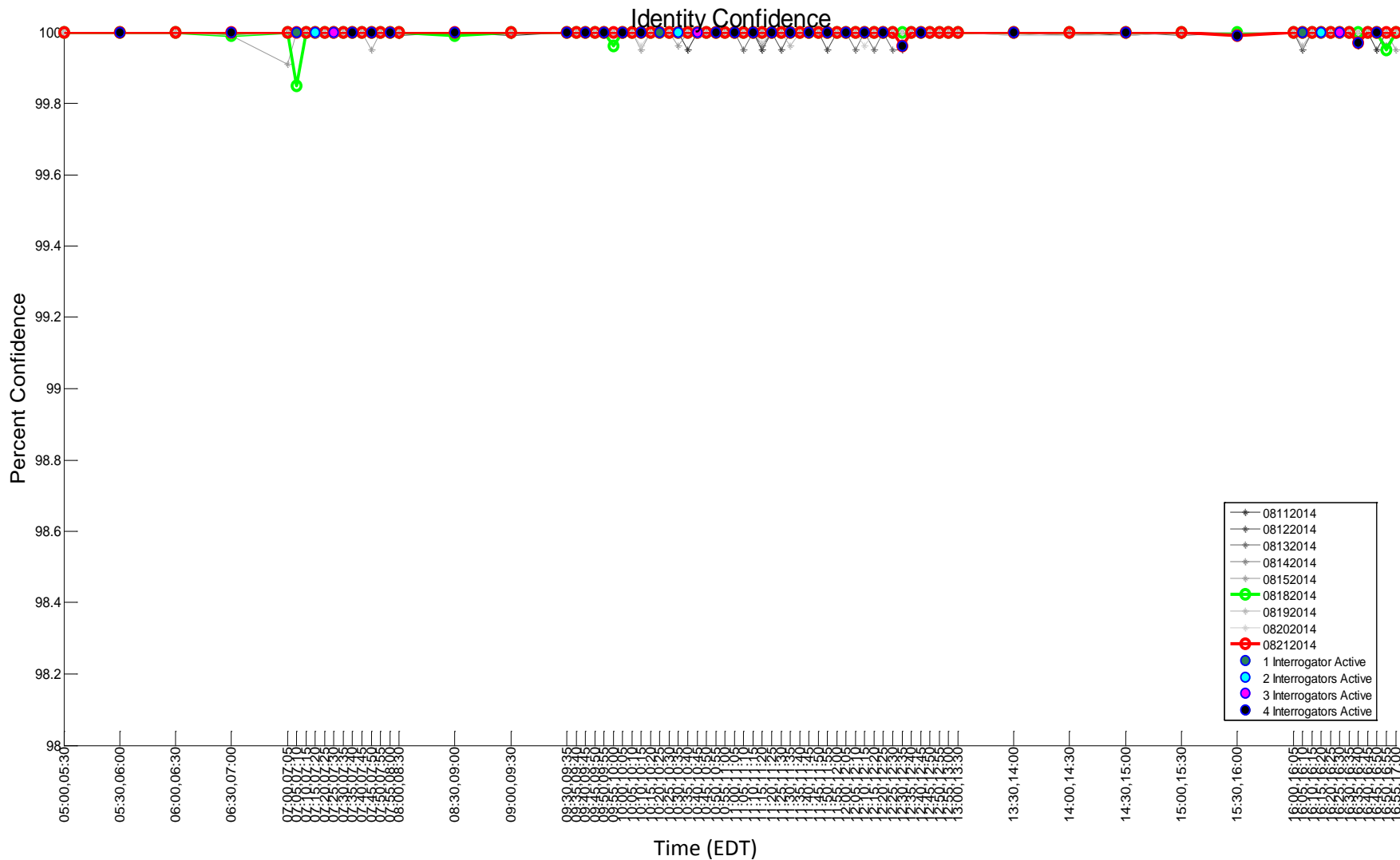
# Identity (3/A) Confidence – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Identity (3/A) Confidence – August 21<sup>st</sup>

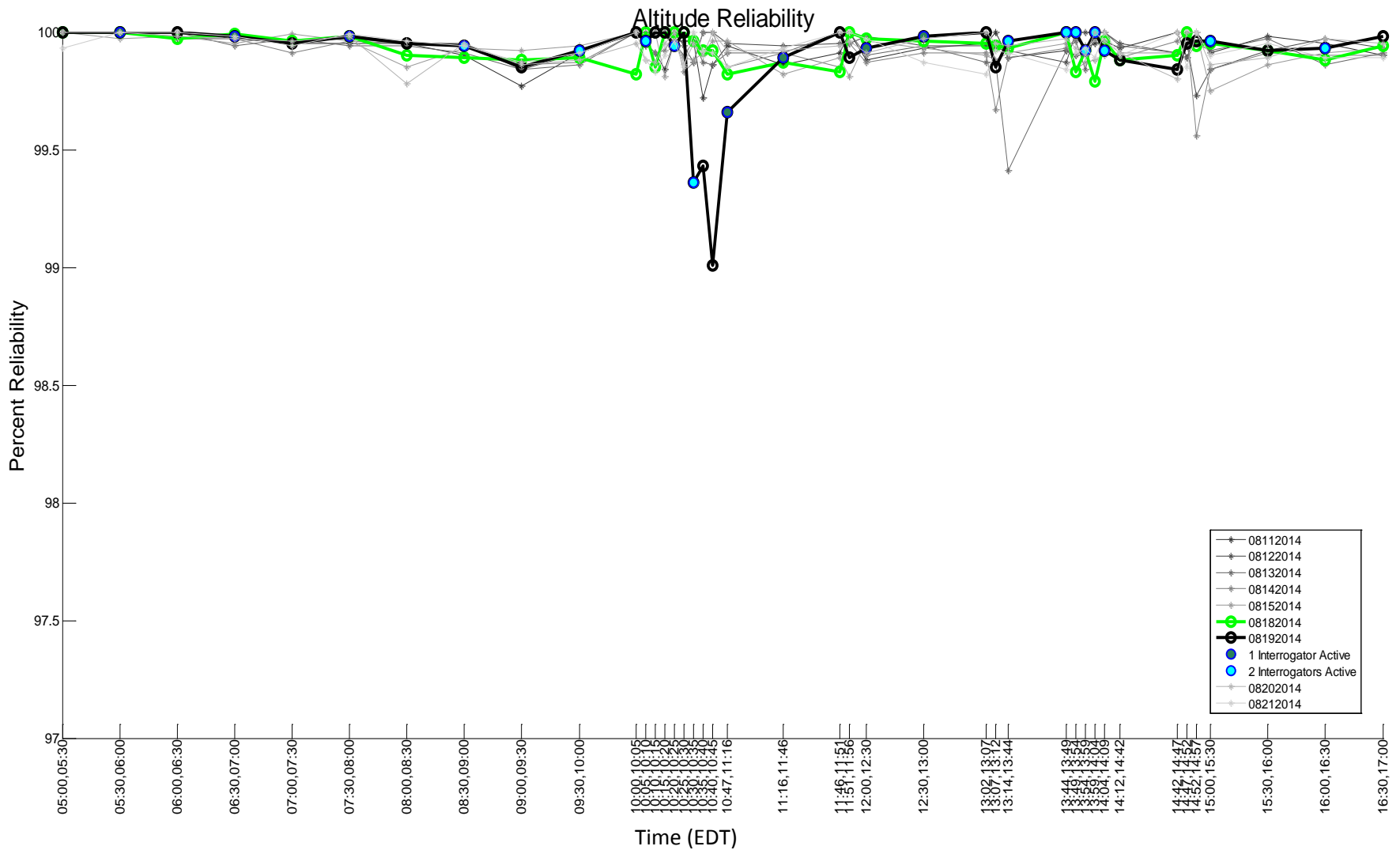


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°



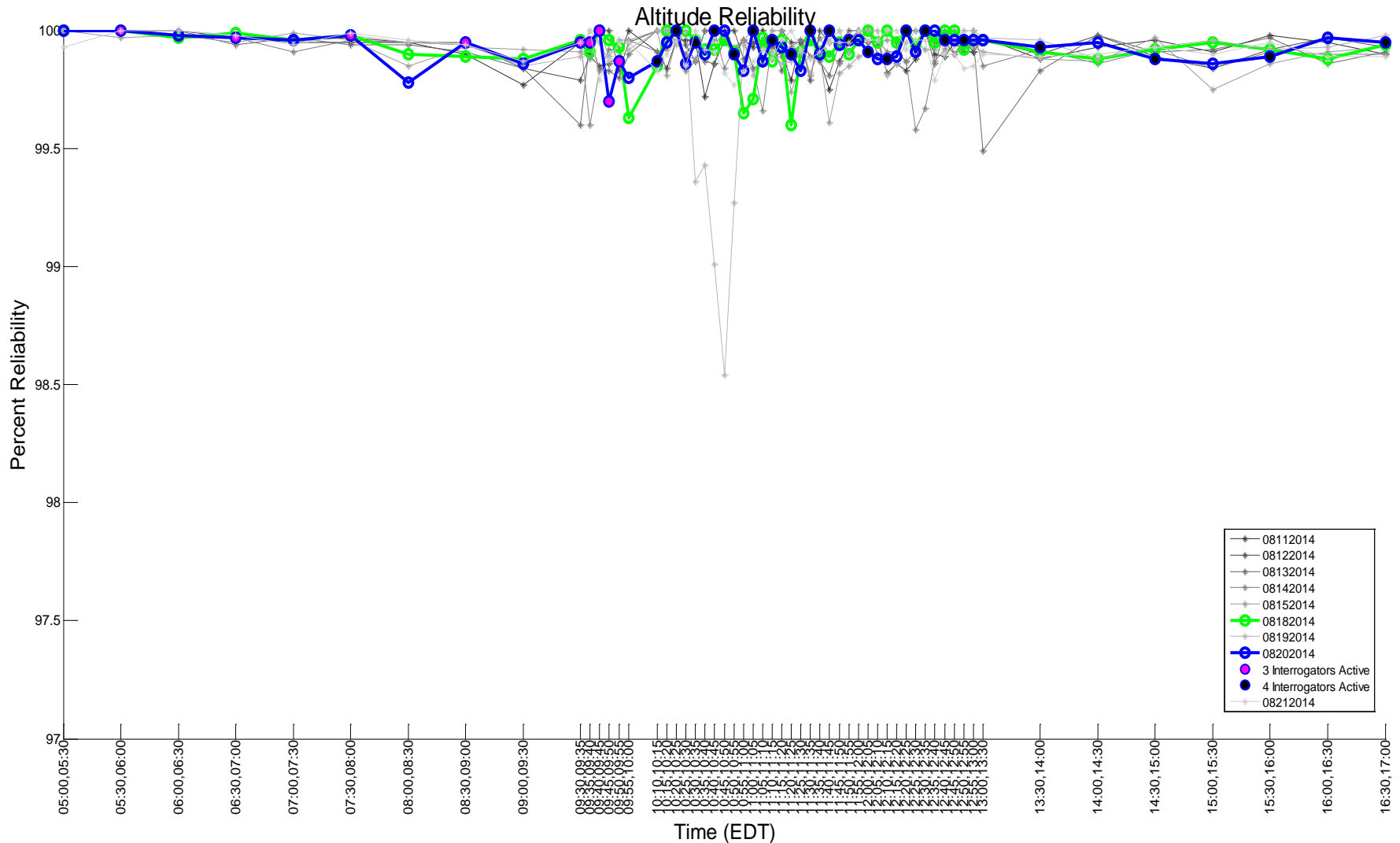
# Altitude (C) Reliability – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

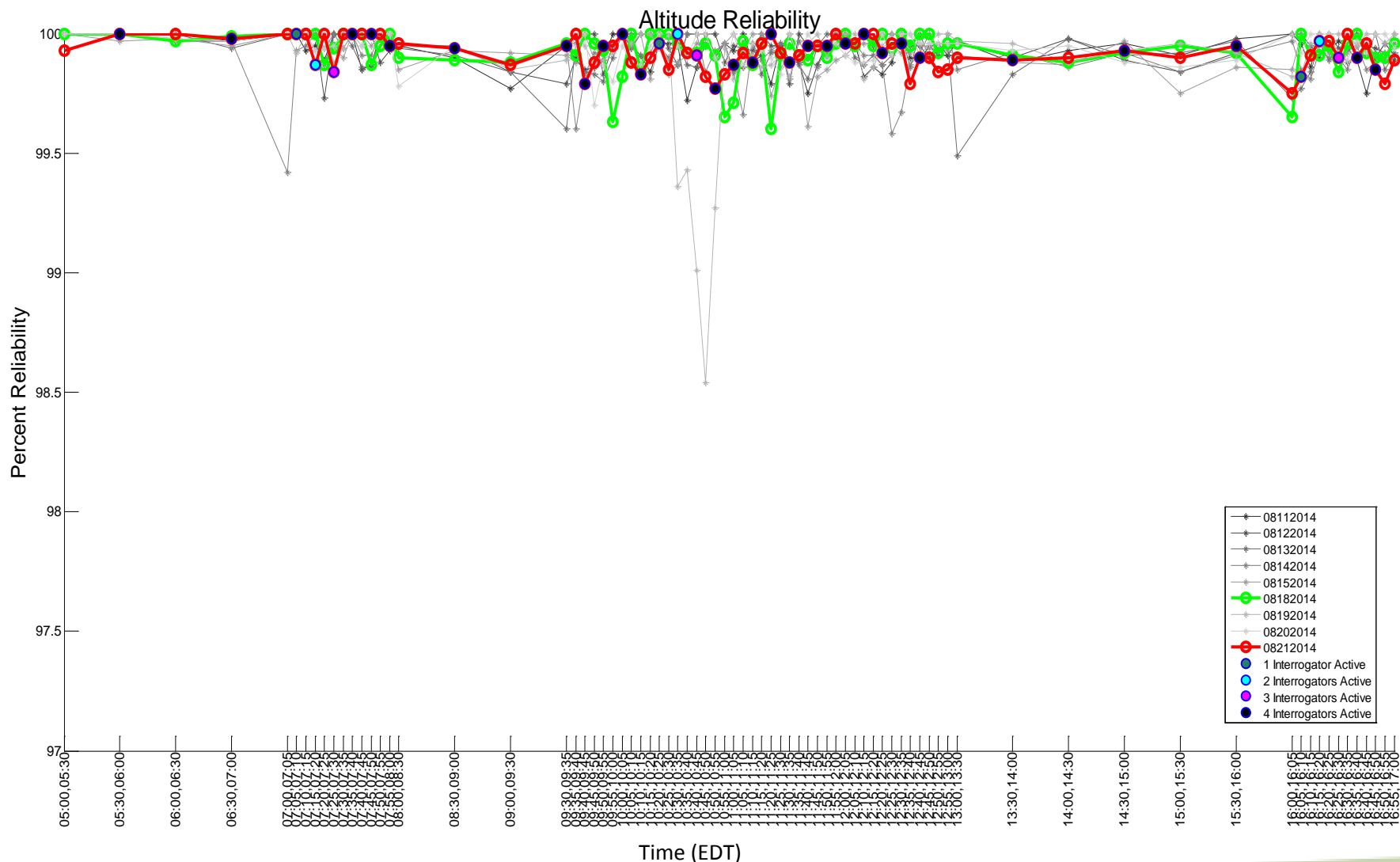
# Altitude (C) Reliability – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

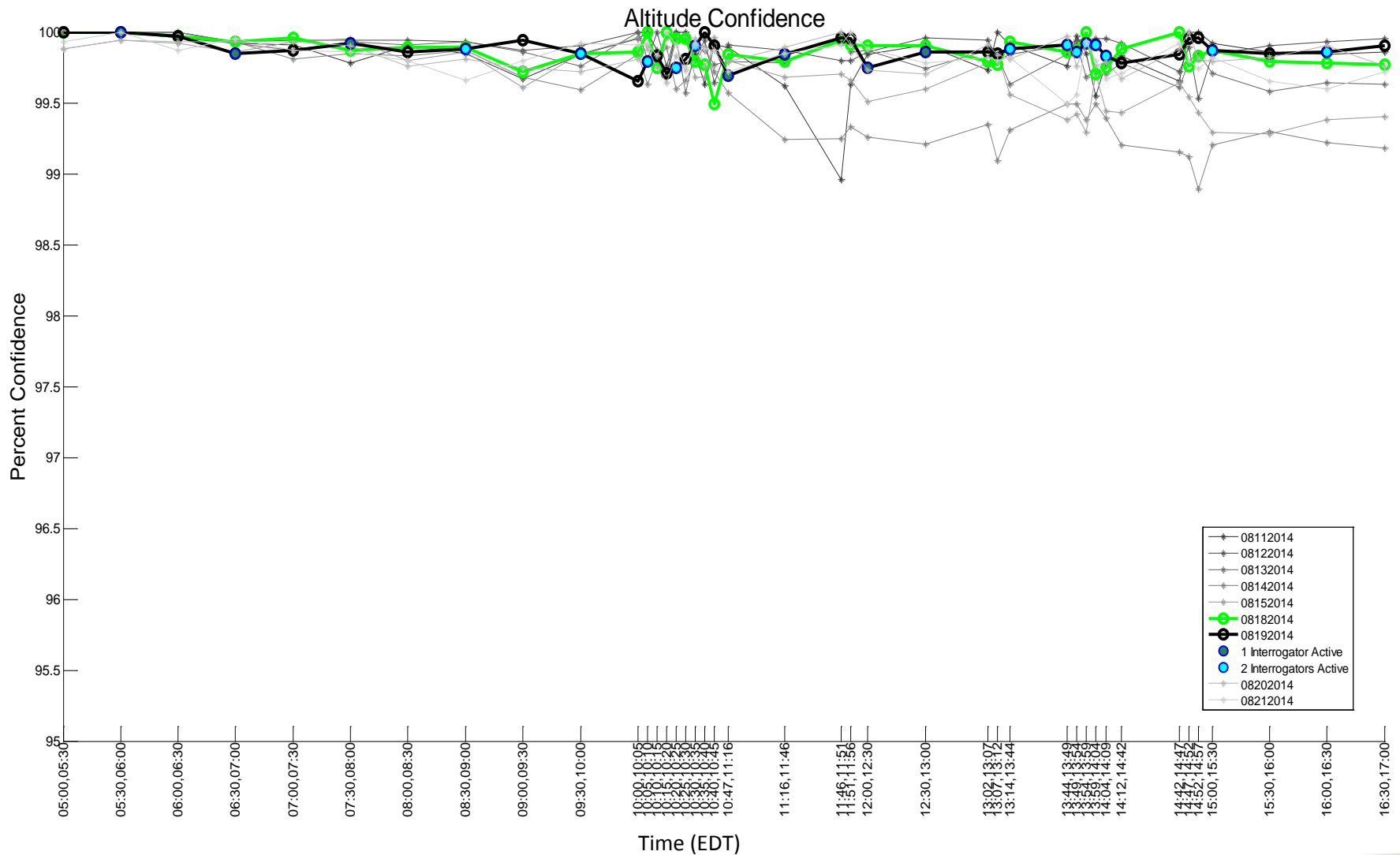
# Altitude (C) Reliability – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

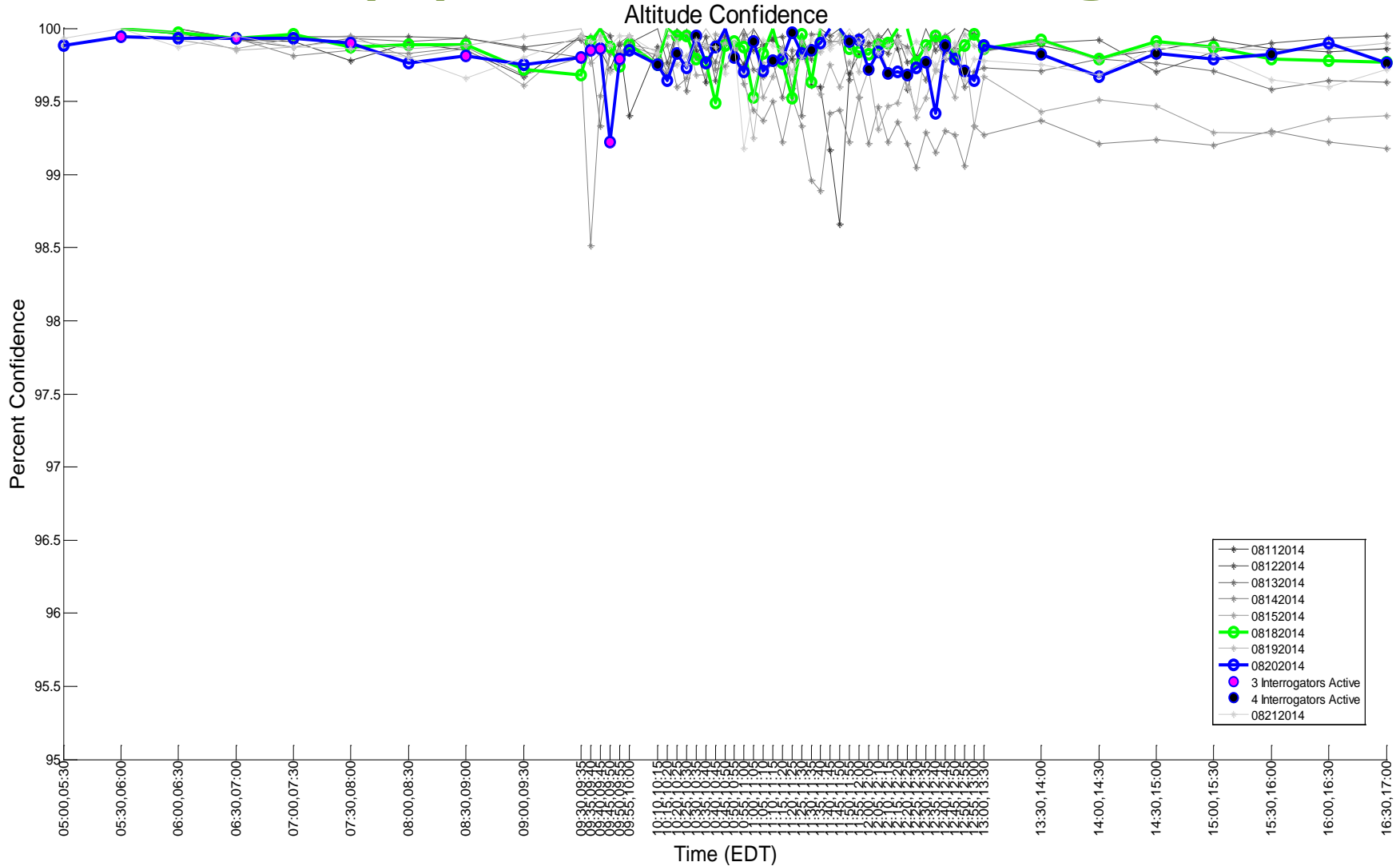
# Altitude (C) Confidence – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

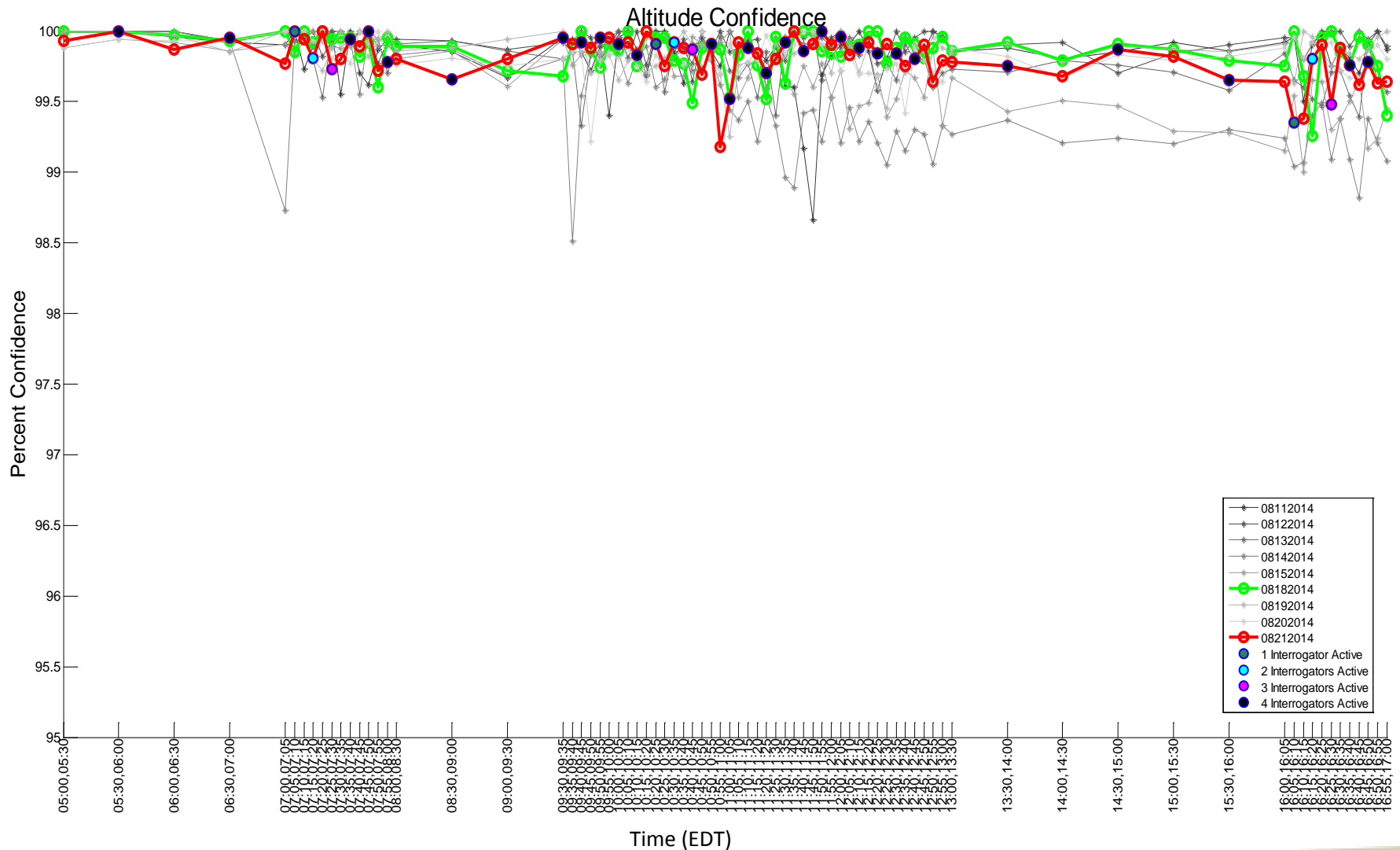
# Altitude (C) Confidence – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

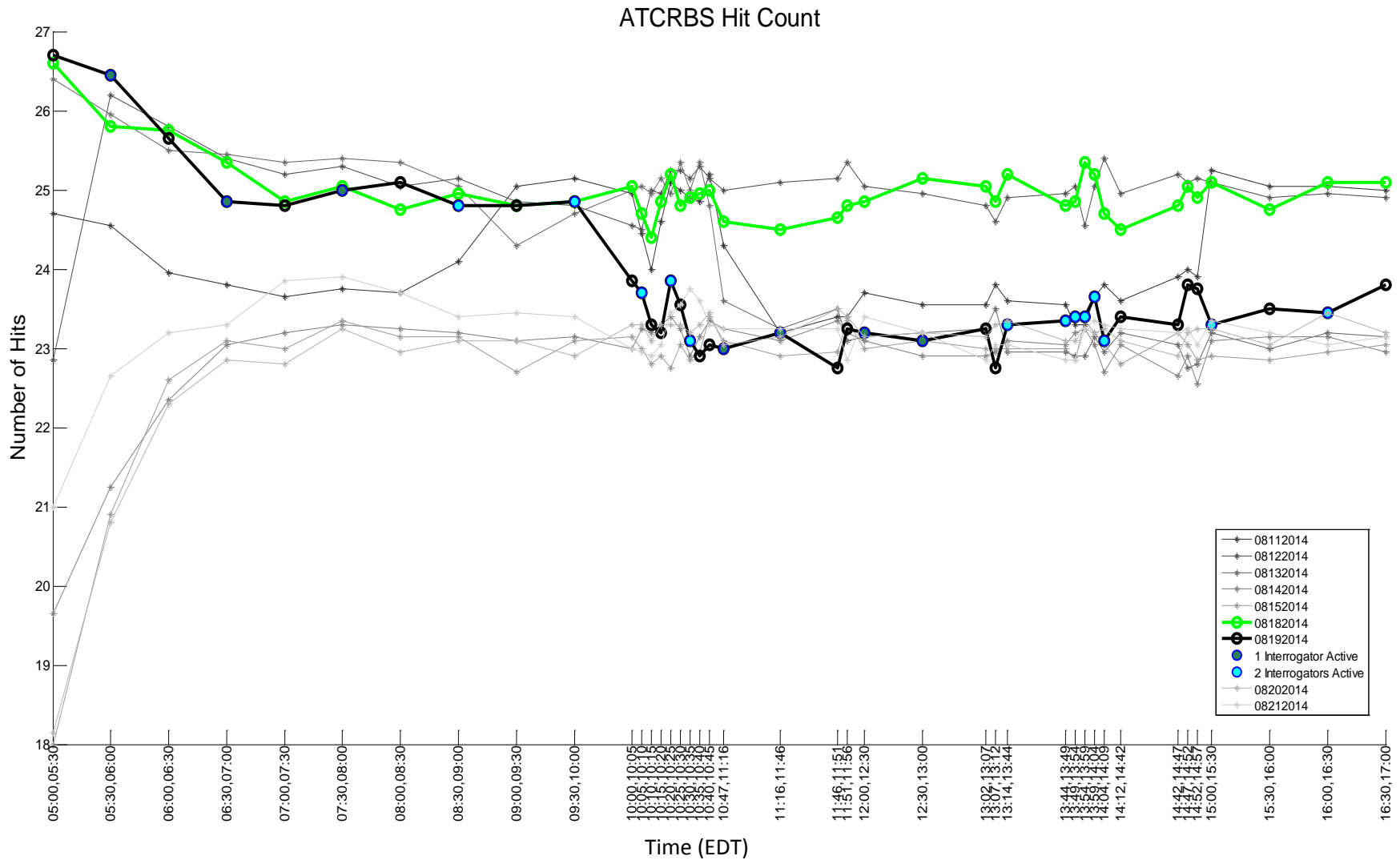
# Altitude (C) Confidence – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Hit Count – August 19th

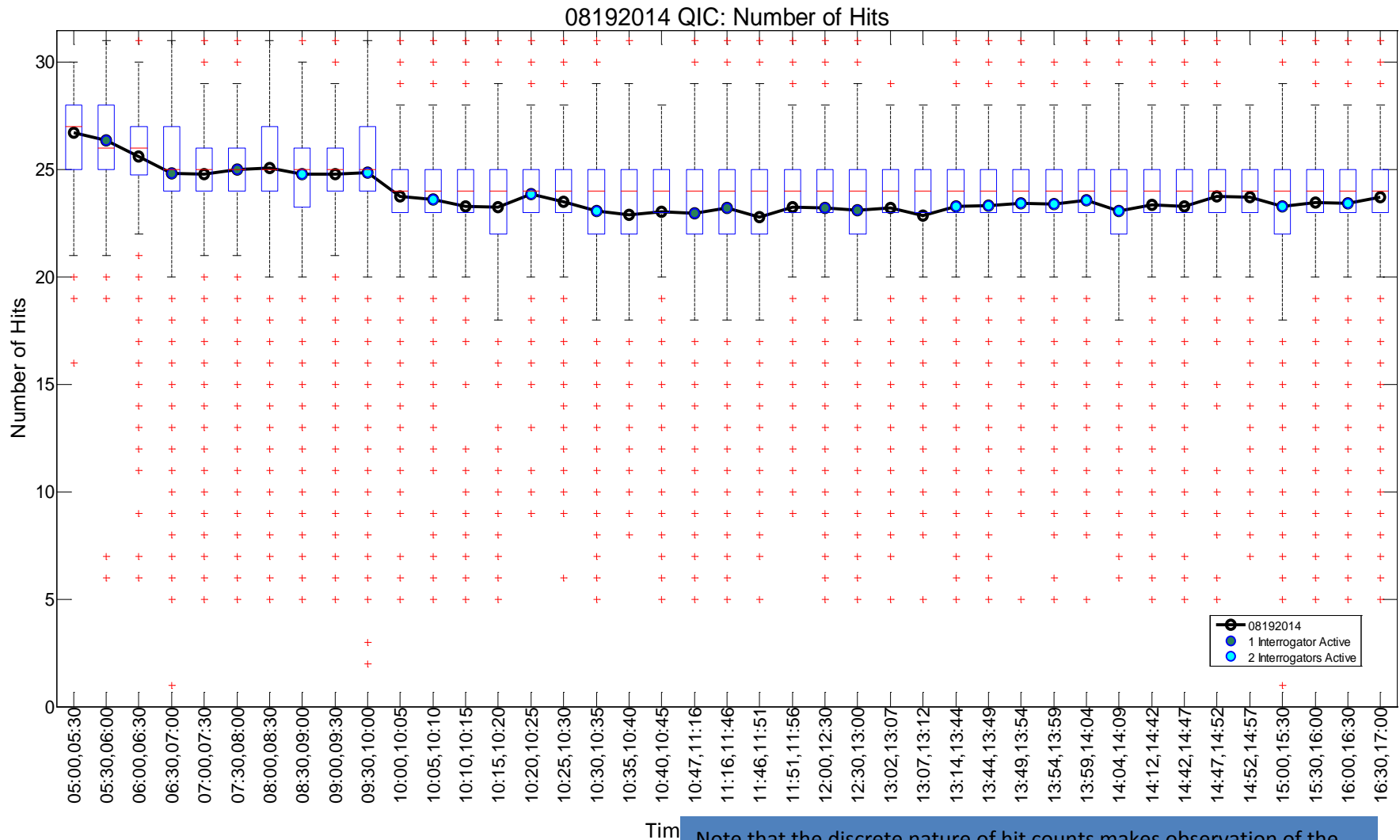


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Hit Count – August 19<sup>th</sup>

## Individual Aircraft Distribution

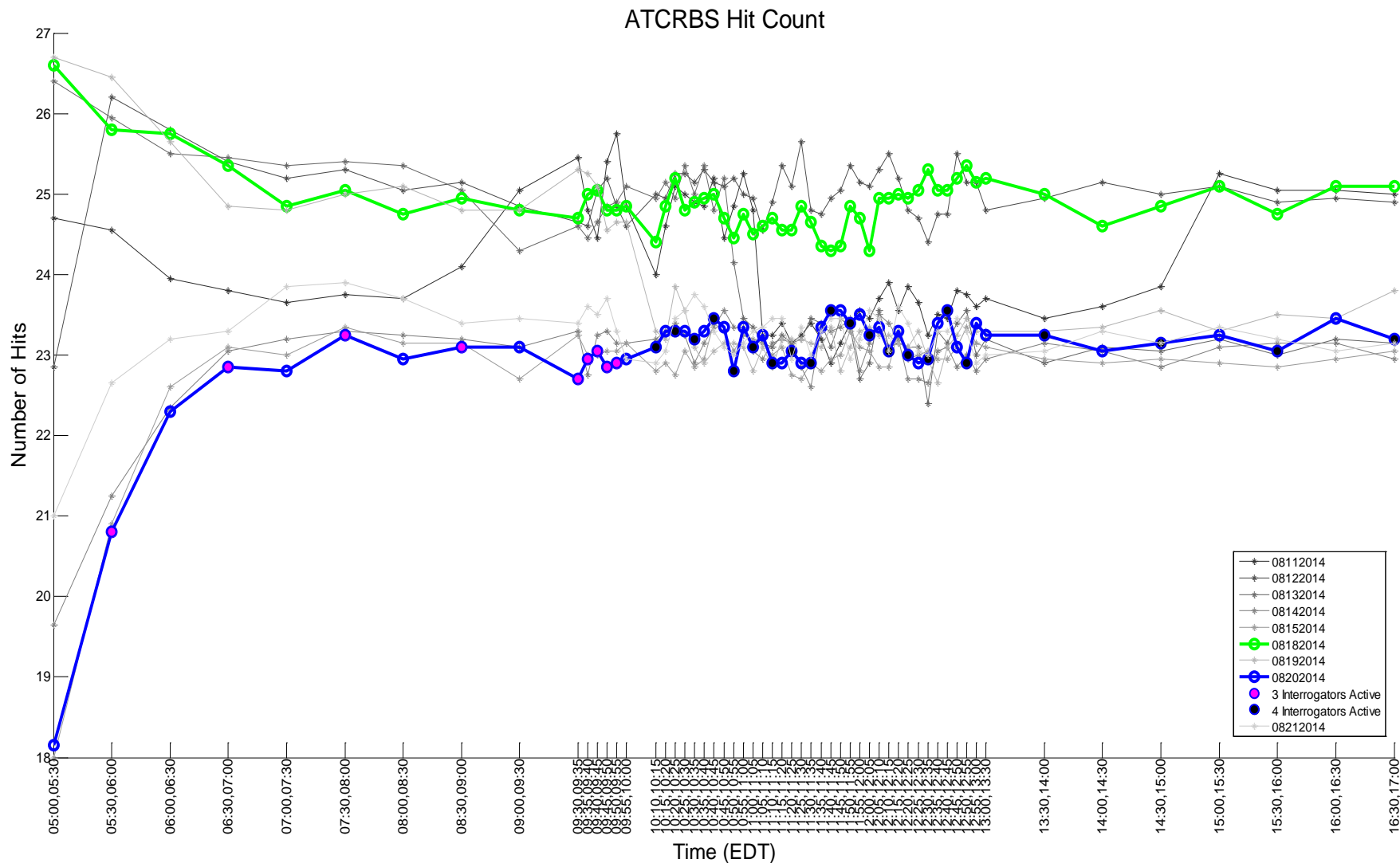


Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

Geographic Filter: None  
 Target Filter: Exclude Targets with Elevation angle < 2°



# Hit Count – August 20<sup>th</sup>



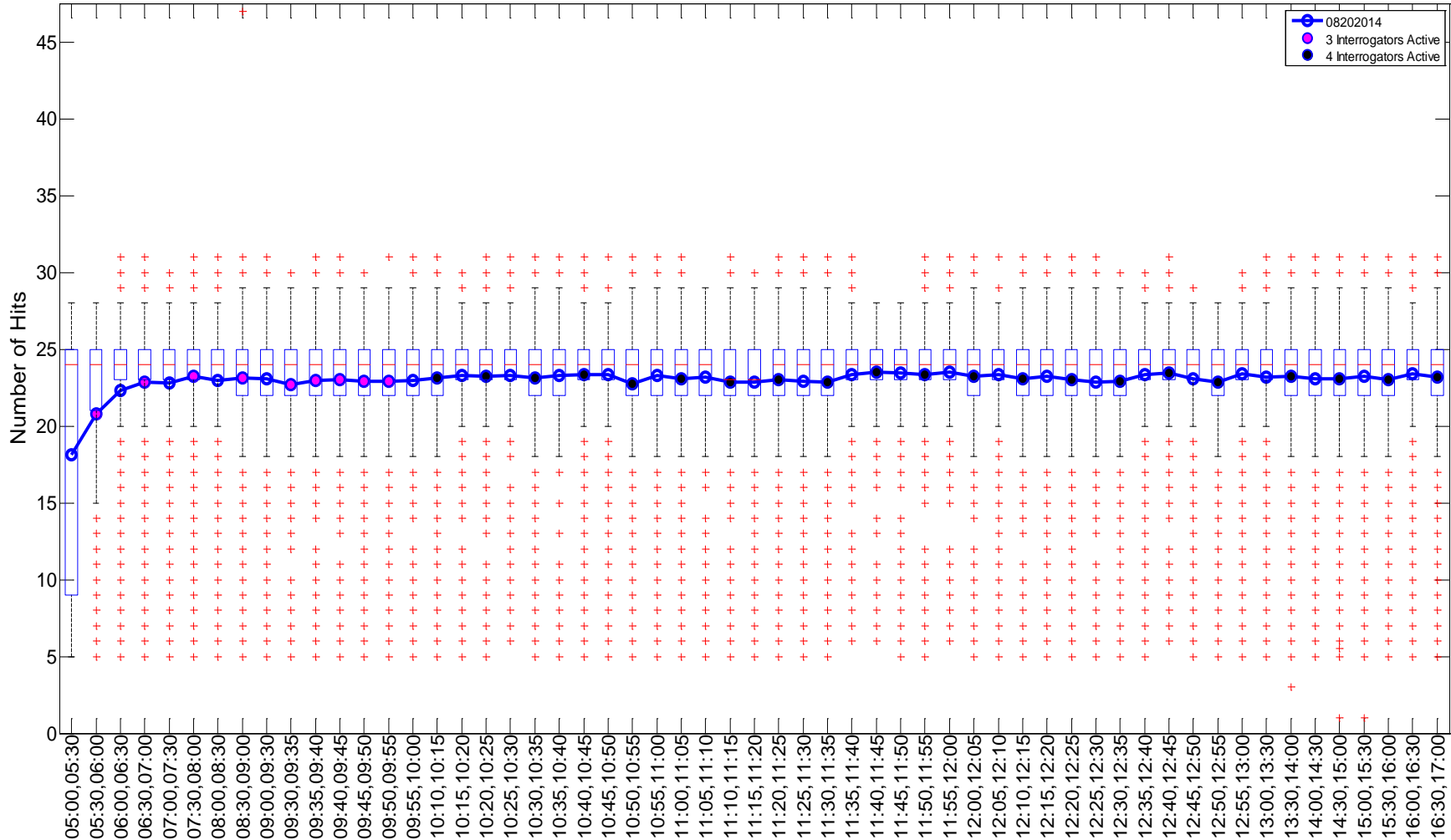
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Hit Count – August 20<sup>th</sup>

## Individual Aircraft Distribution

08202014 QIC: Number of Hits

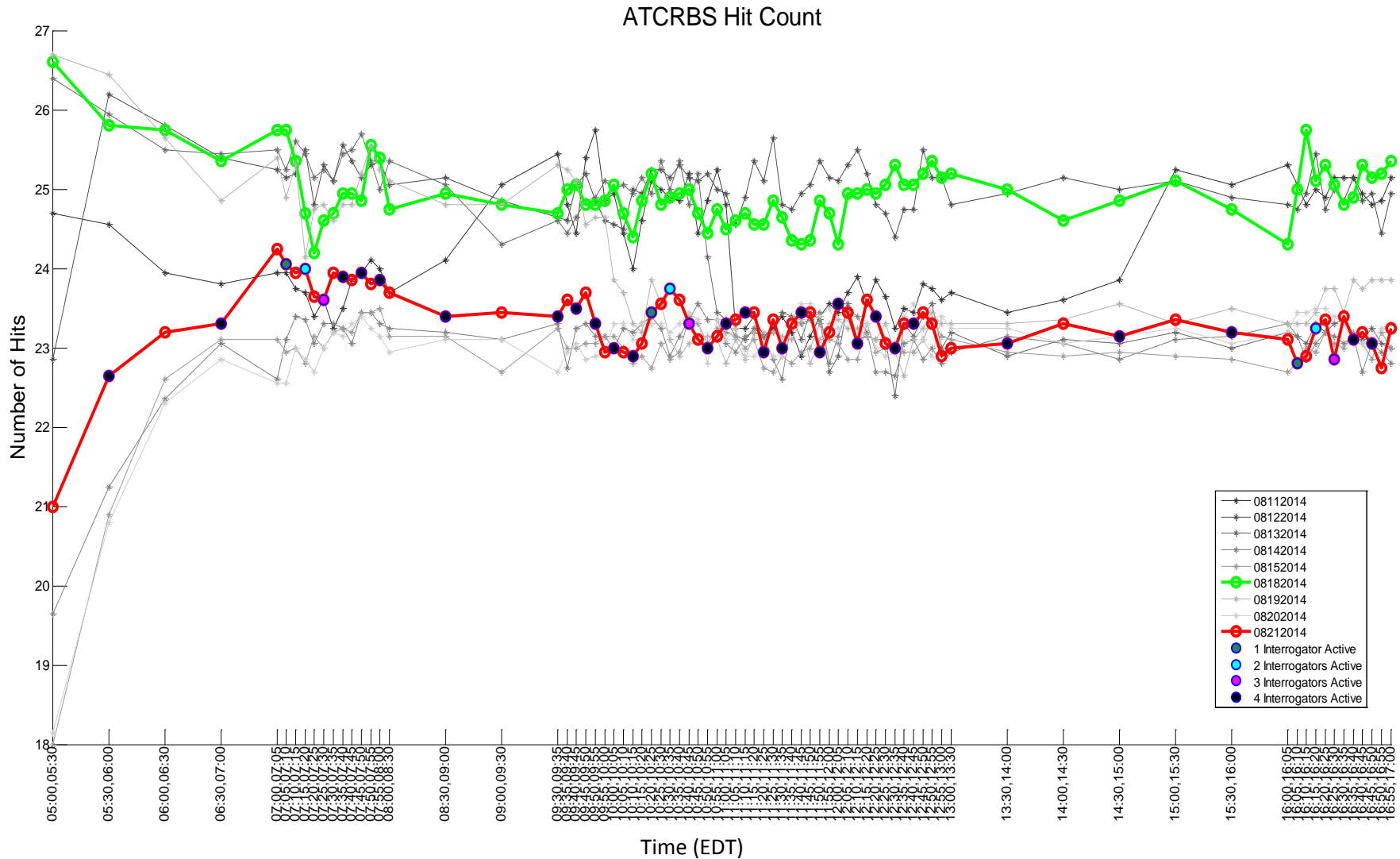


Time

Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

Geographic Filter: None  
 Target Filter: Exclude Targets with Elevation angle < 2°

# Hit Count – August 21<sup>st</sup>

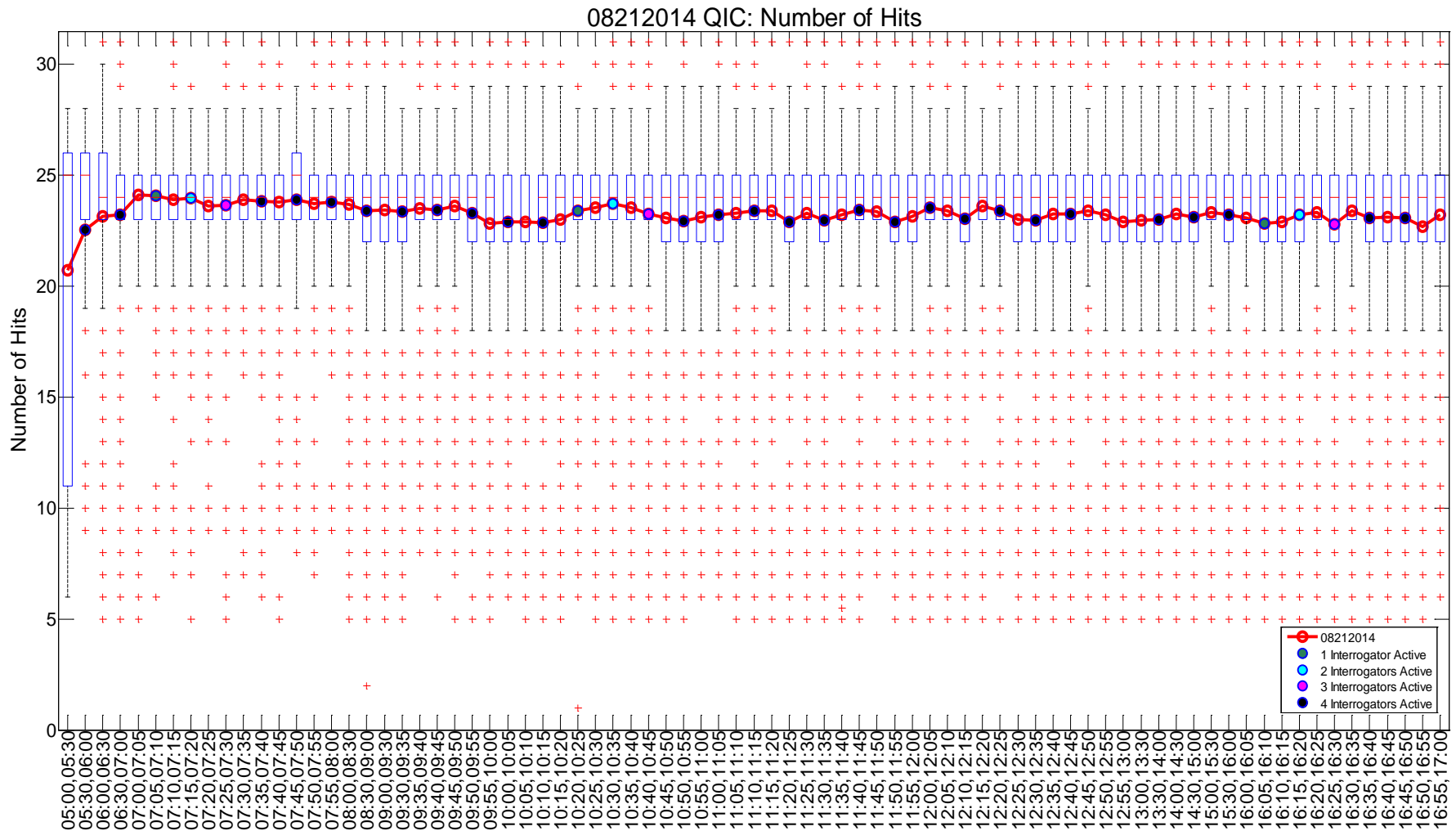


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 2°

# Hit Count – August 21<sup>st</sup>

## Individual Aircraft Distribution



Time Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

Geographic Filter: None

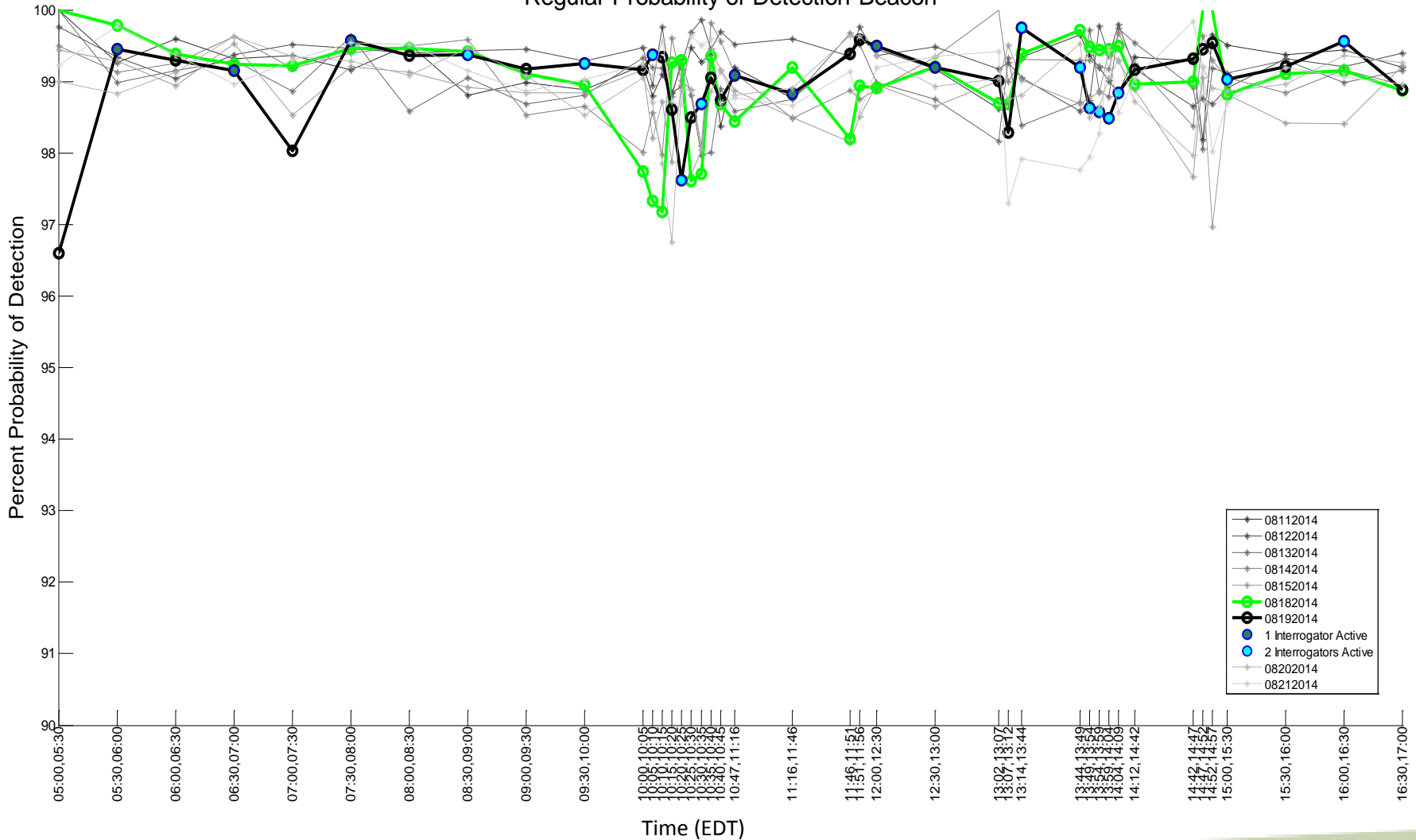
Target Filter: Exclude Targets with Elevation angle < 2°

# Target Metrics with Range greater than 50 NM from SSR

*\* Number of Targets Unavailable*

# Probability of Detection – August 19<sup>th</sup>

Regular Probability of Detection-Beacon

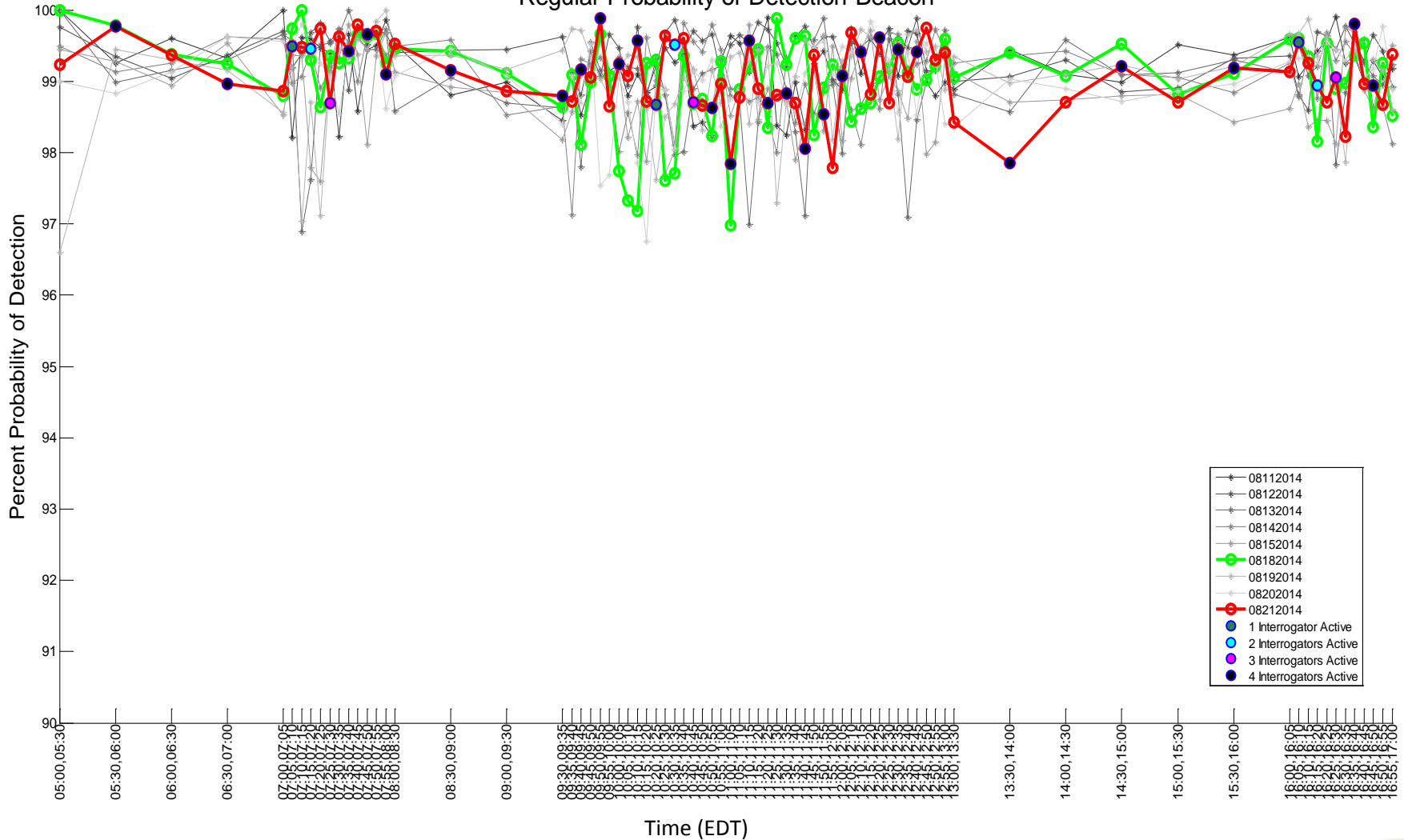


Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM



# Probability of Detection – August 21<sup>st</sup>

Regular Probability of Detection-Beacon

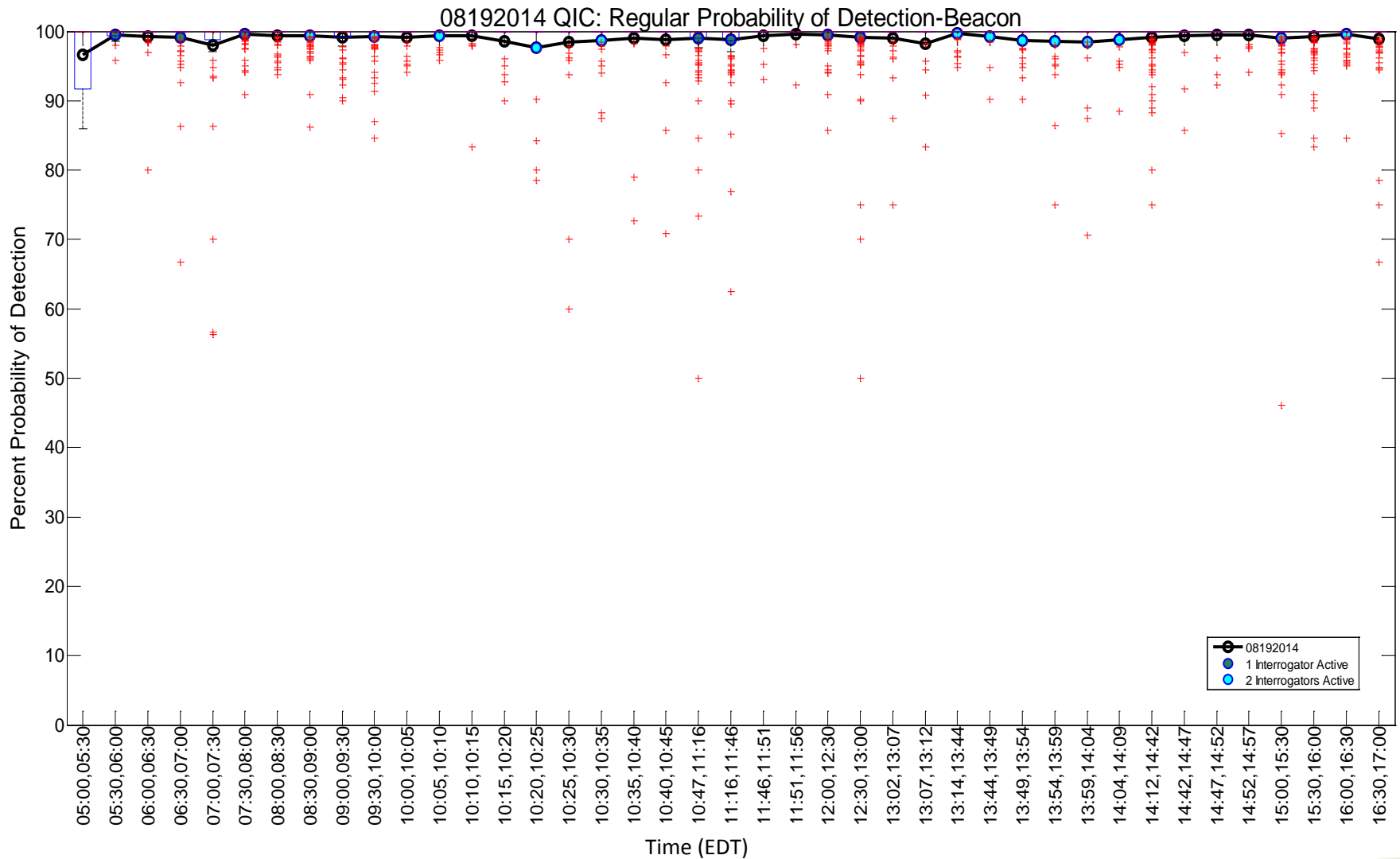


Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM



# Probability of Detection – August 19<sup>th</sup>

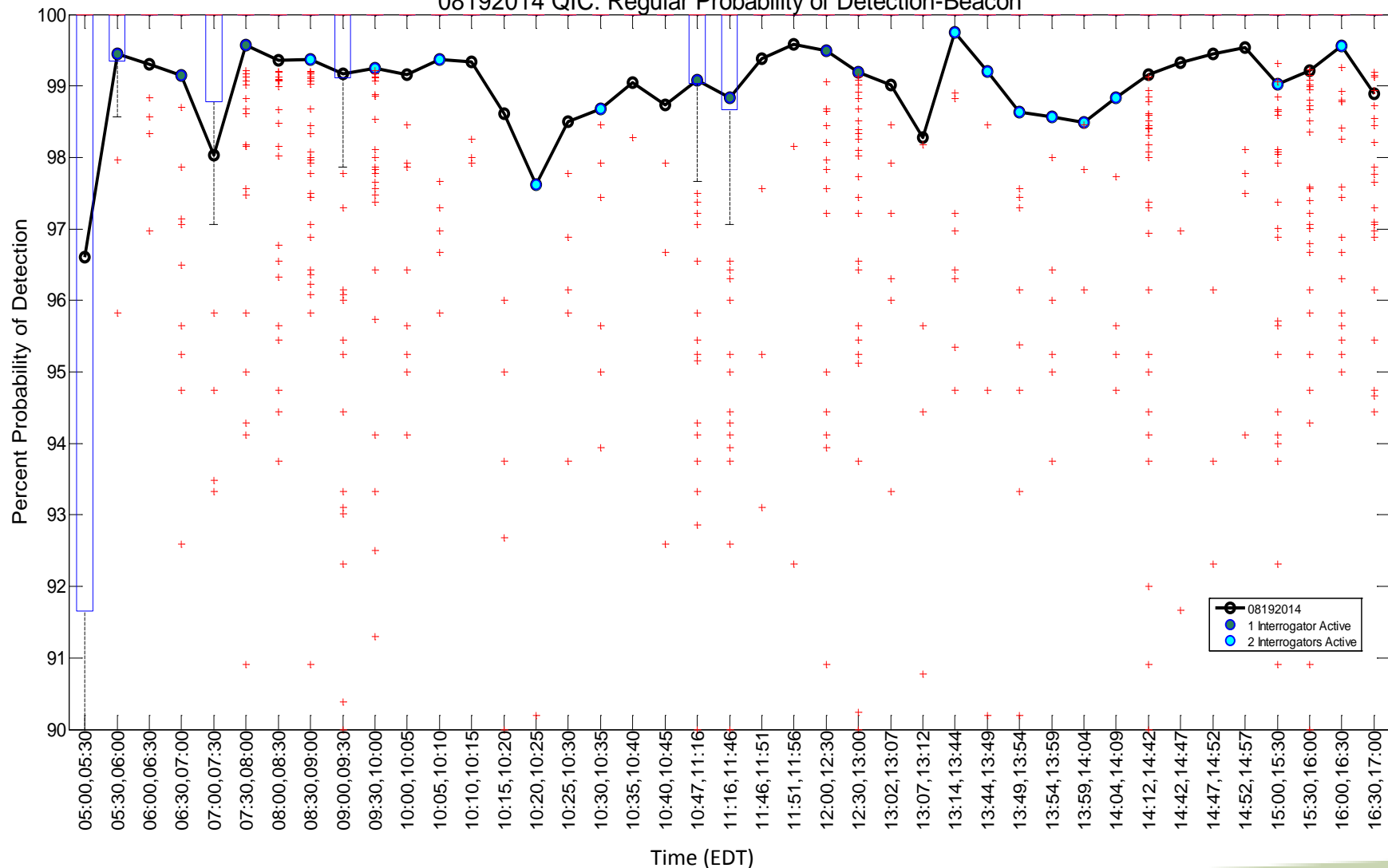
## Individual Aircraft Distribution



# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08192014 QIC: Regular Probability of Detection-Beacon

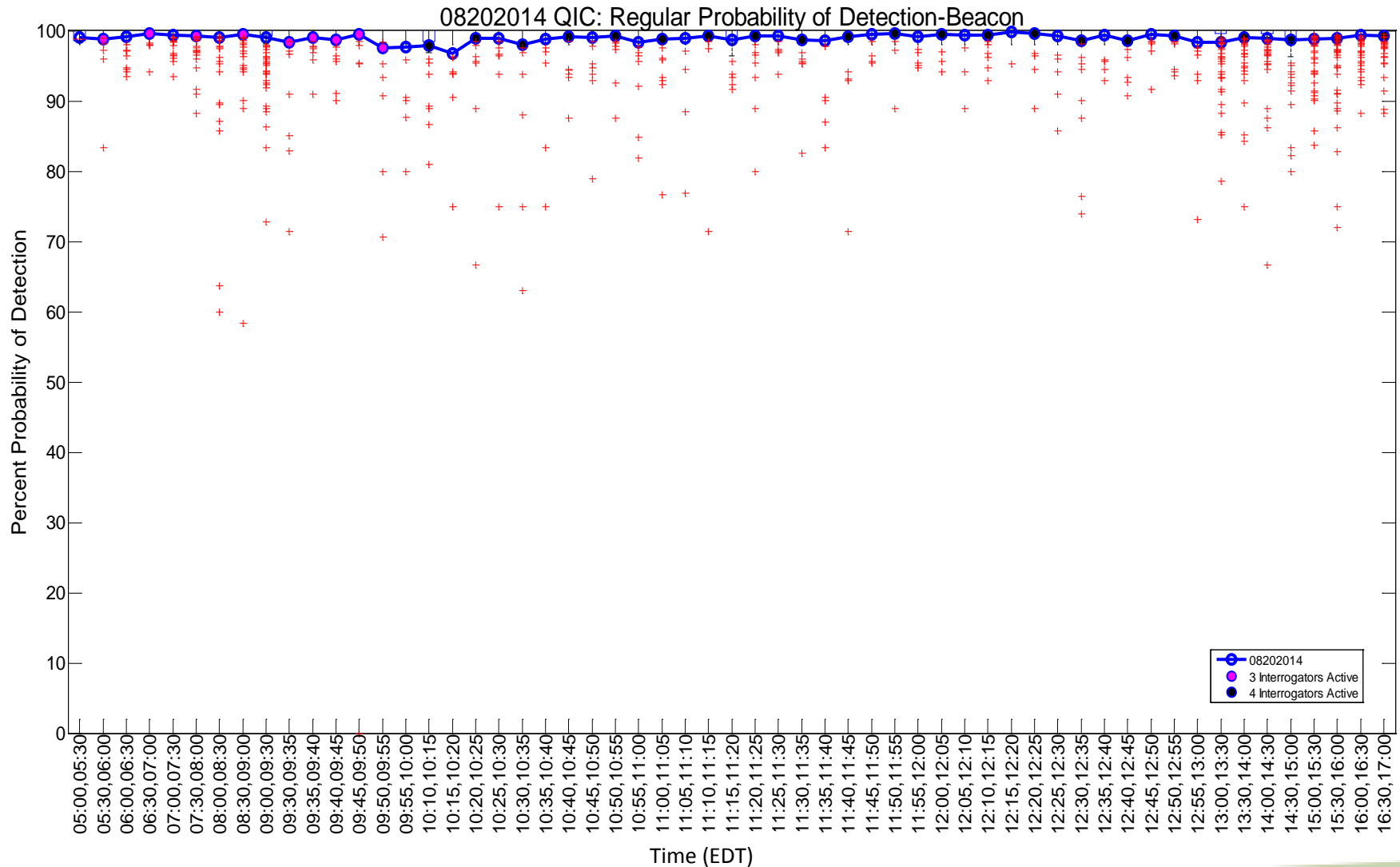


Geographic Filter: None

Target Filter: Exclude Targets < 50 NM

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

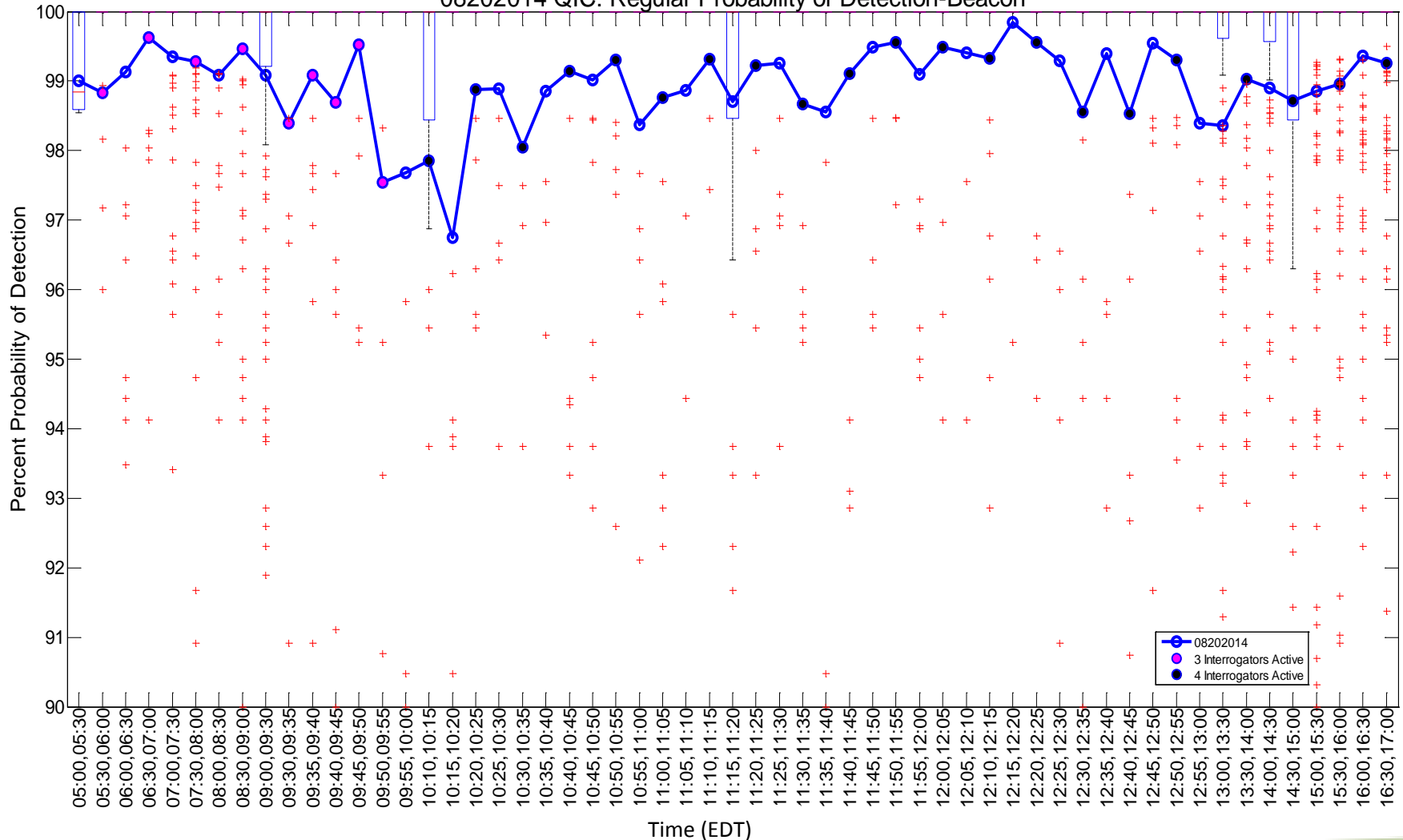


Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08202014 QIC: Regular Probability of Detection-Beacon

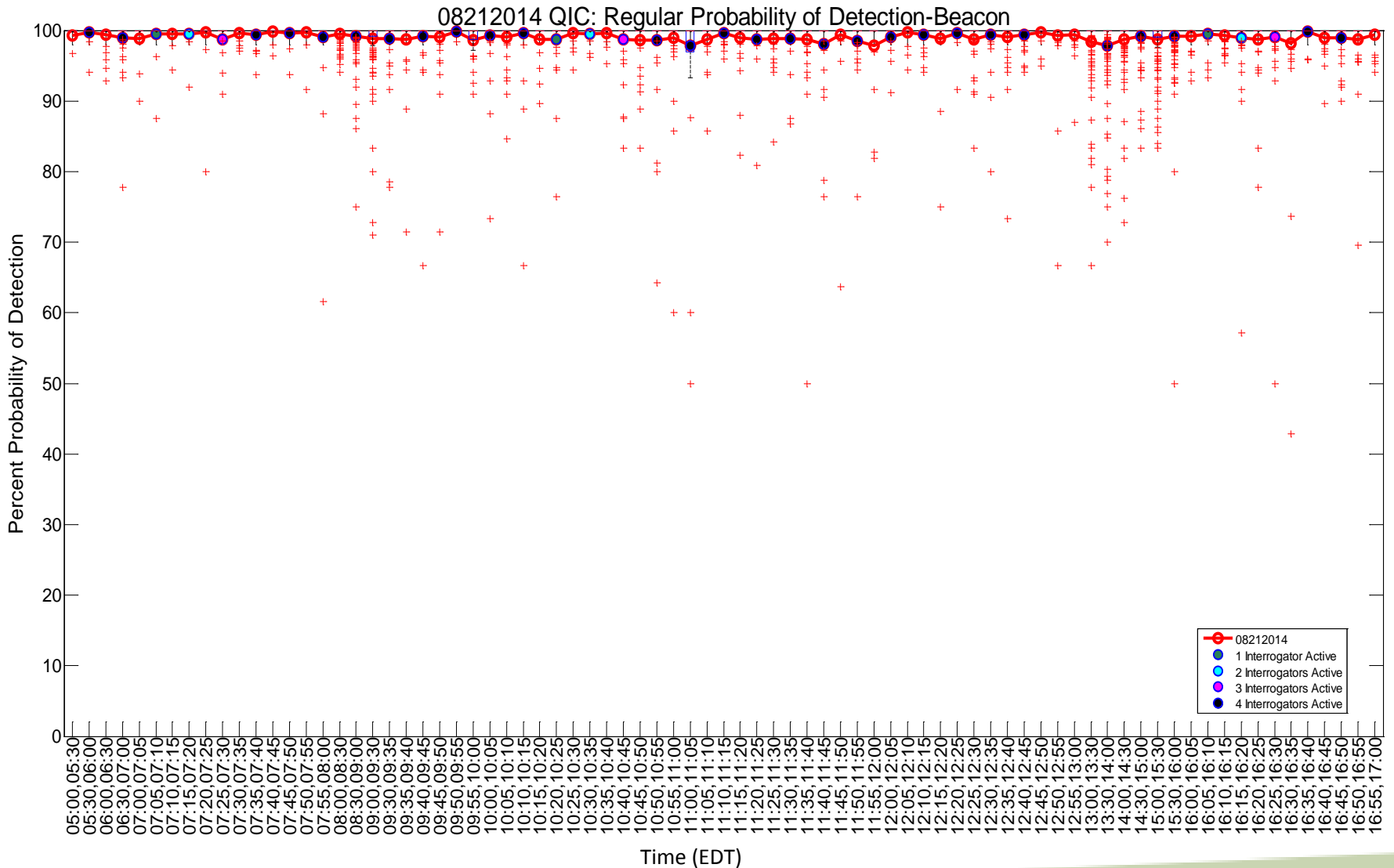


Geographic Filter: None

Target Filter: Exclude Targets < 50 NM

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution



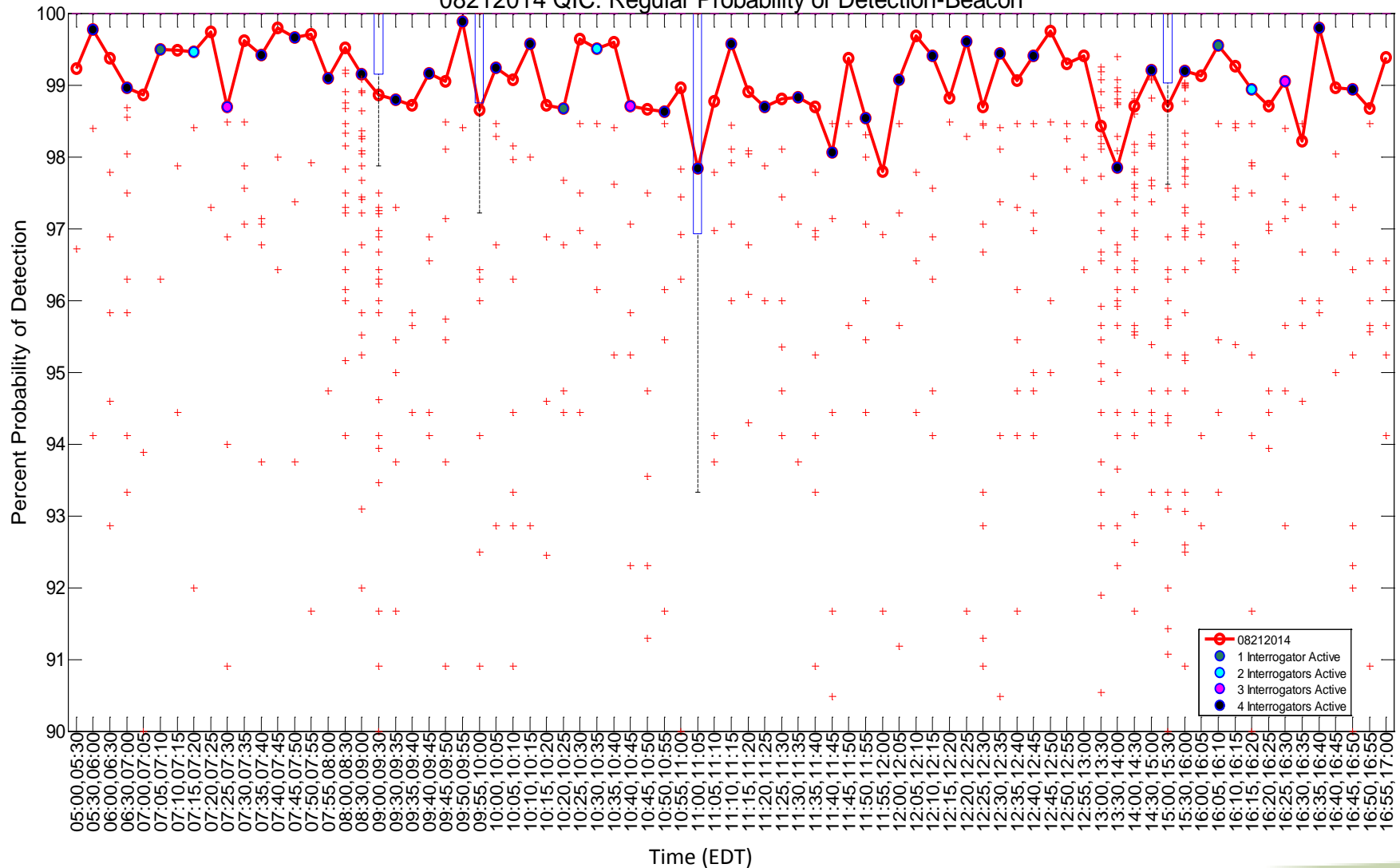
Geographic Filter: None

Target Filter: Exclude Targets < 50 NM

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)

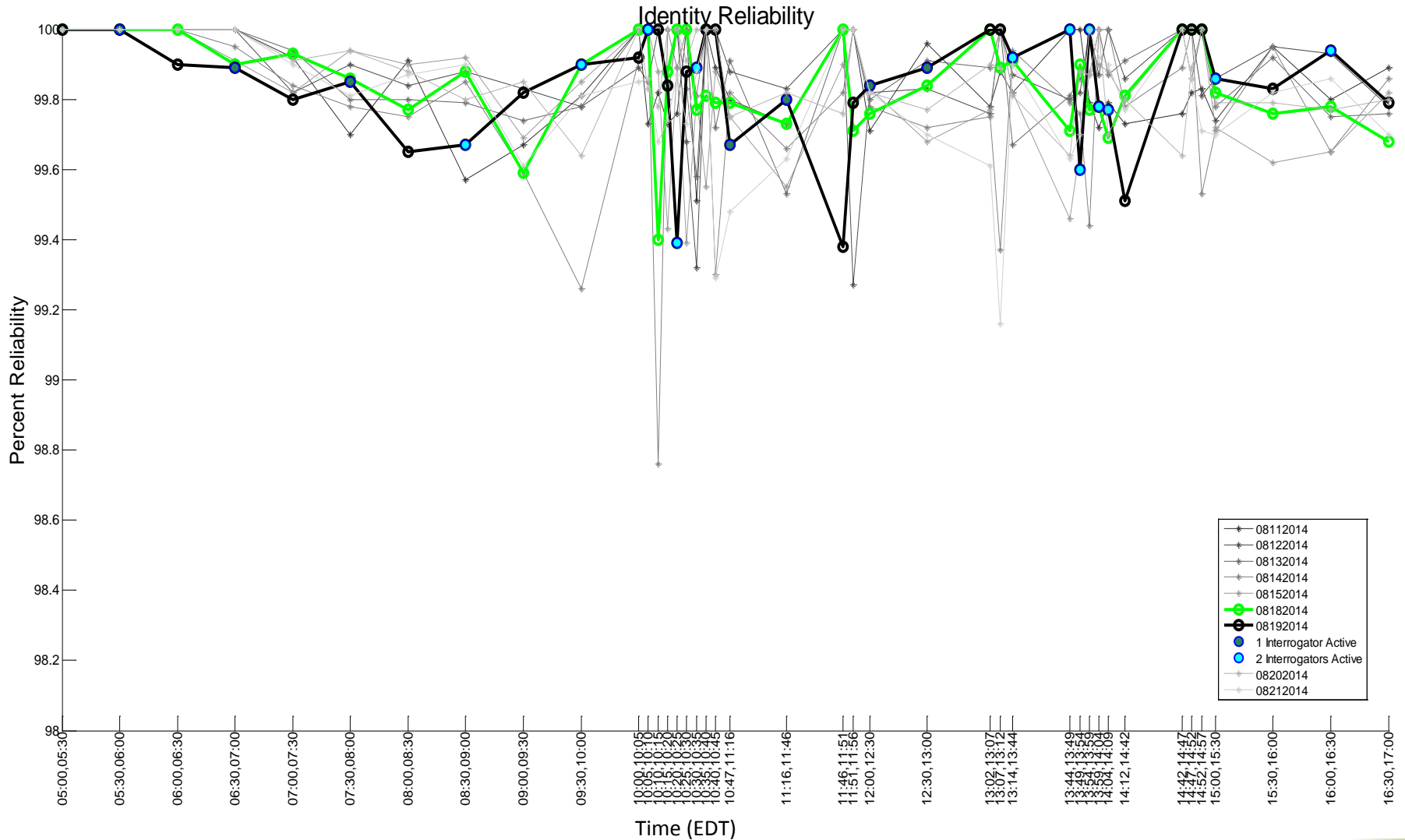
08212014 QIC: Regular Probability of Detection-Beacon



Geographic Filter: None

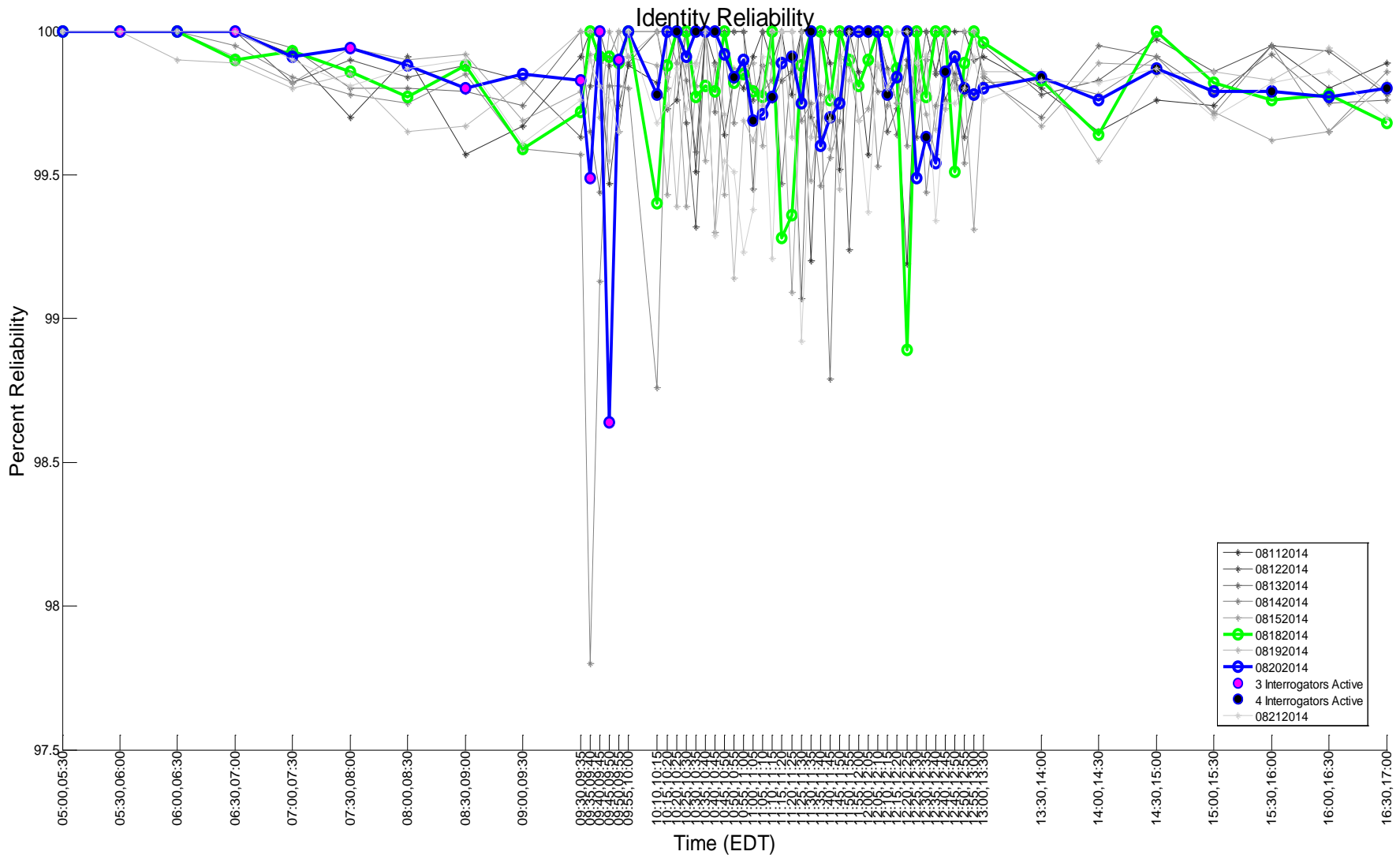
Target Filter: Exclude Targets < 50 NM

# Identity (3/A) Reliability – August 19<sup>th</sup>



Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM

# Identity (3/A) Reliability – August 20<sup>th</sup>

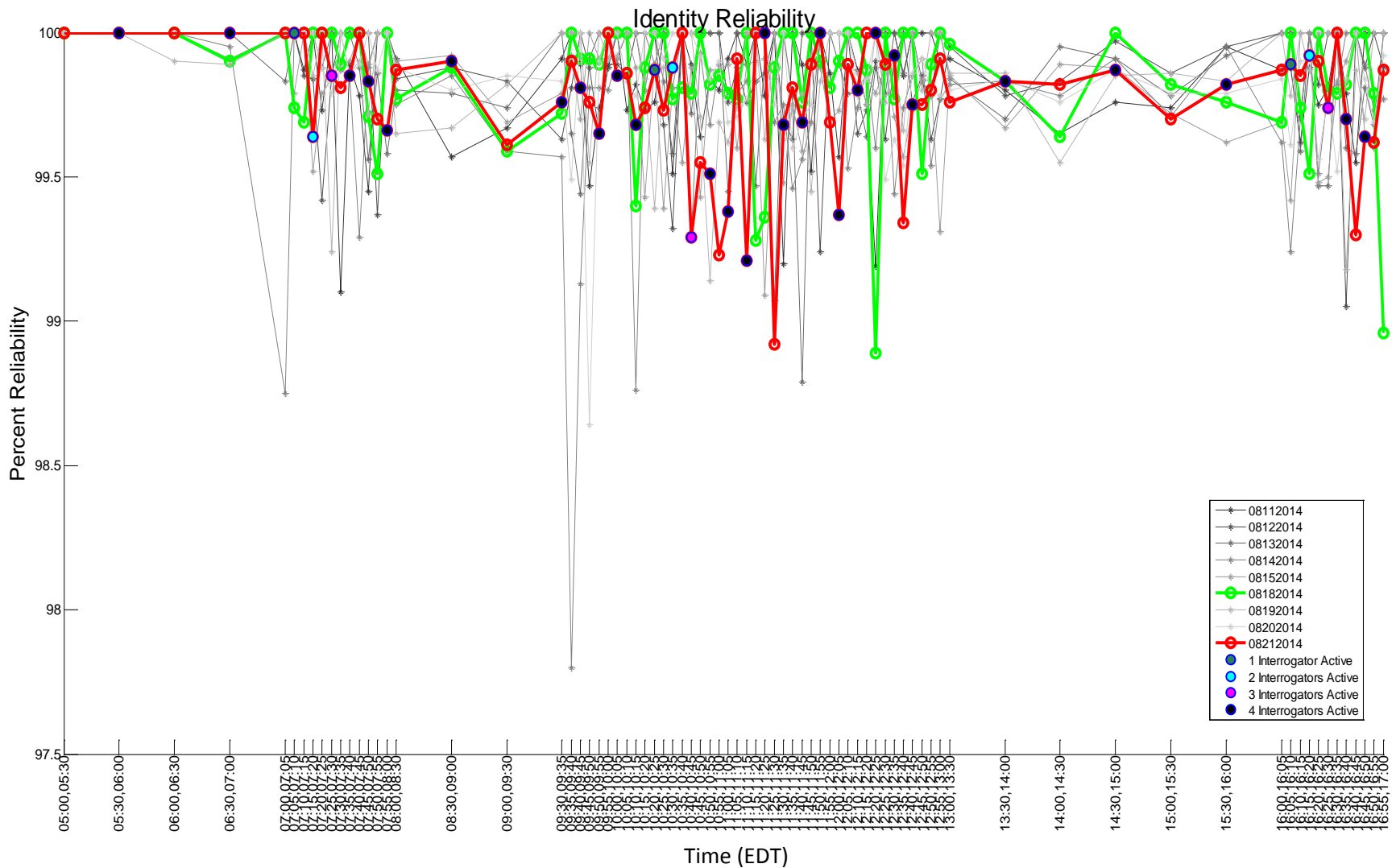


Geographic Filter: None

Target Filter: Exclude Targets < 50 NM



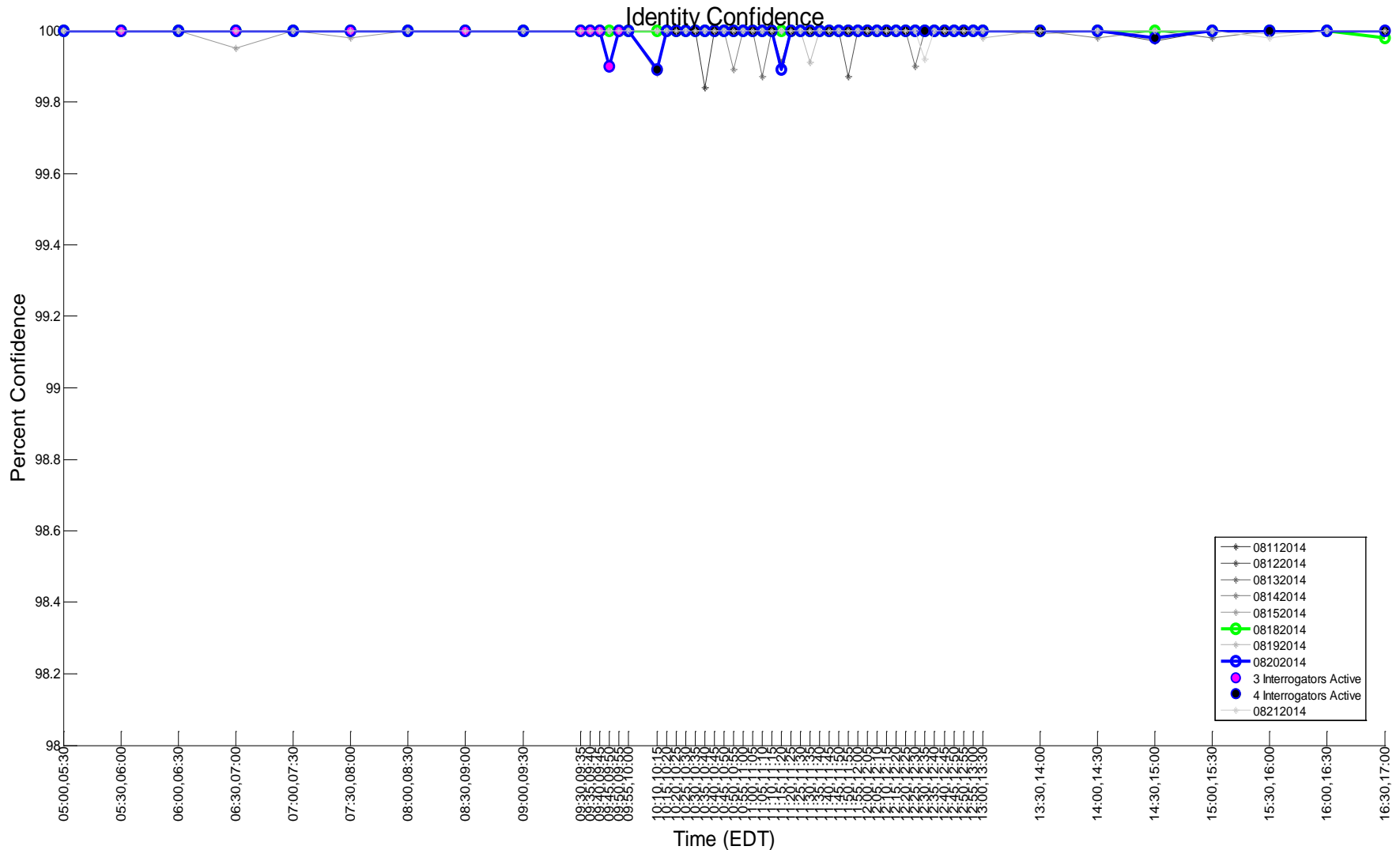
# Identity (3/A) Reliability – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM

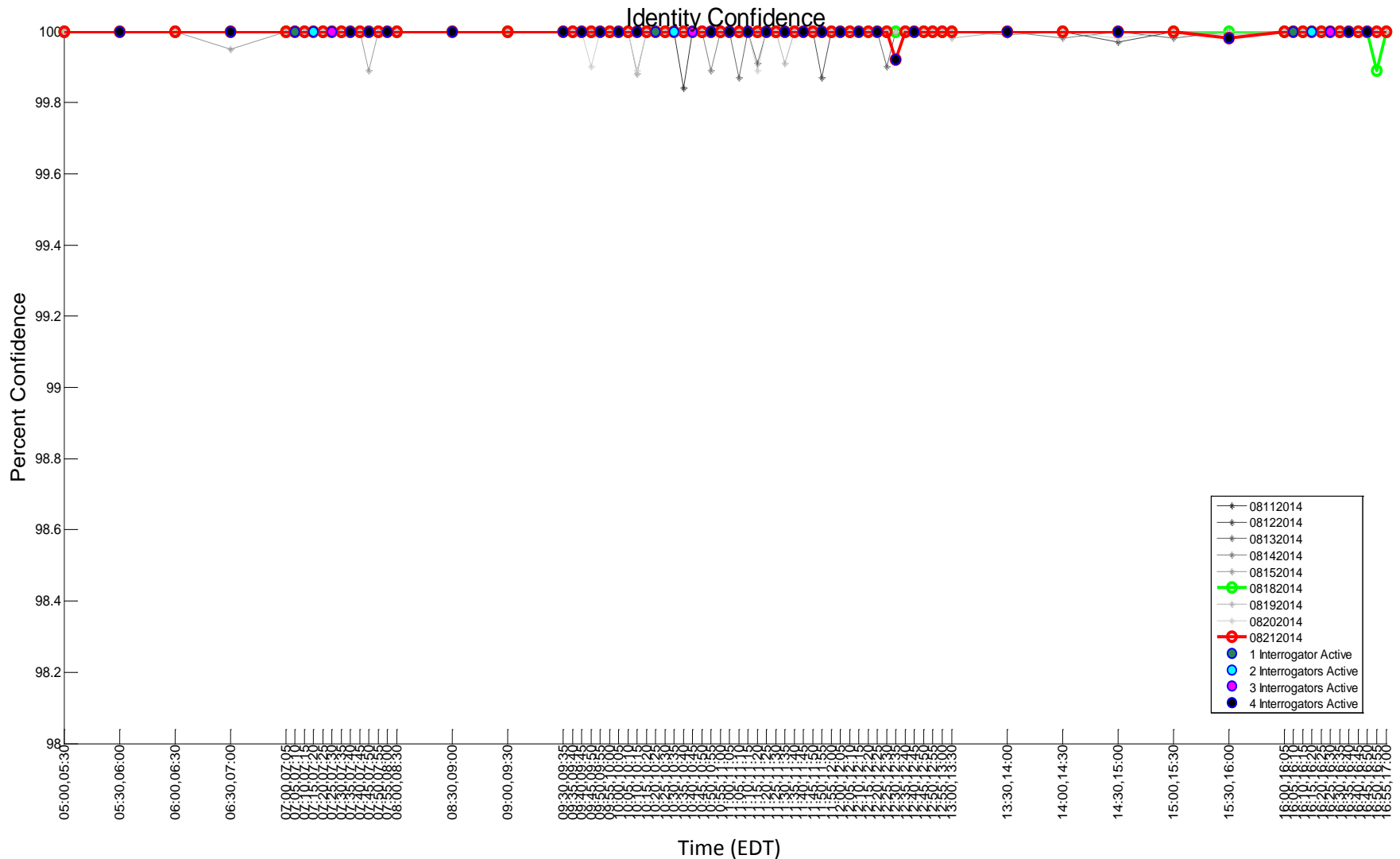


# Identity (3/A) Confidence – August 20<sup>th</sup>



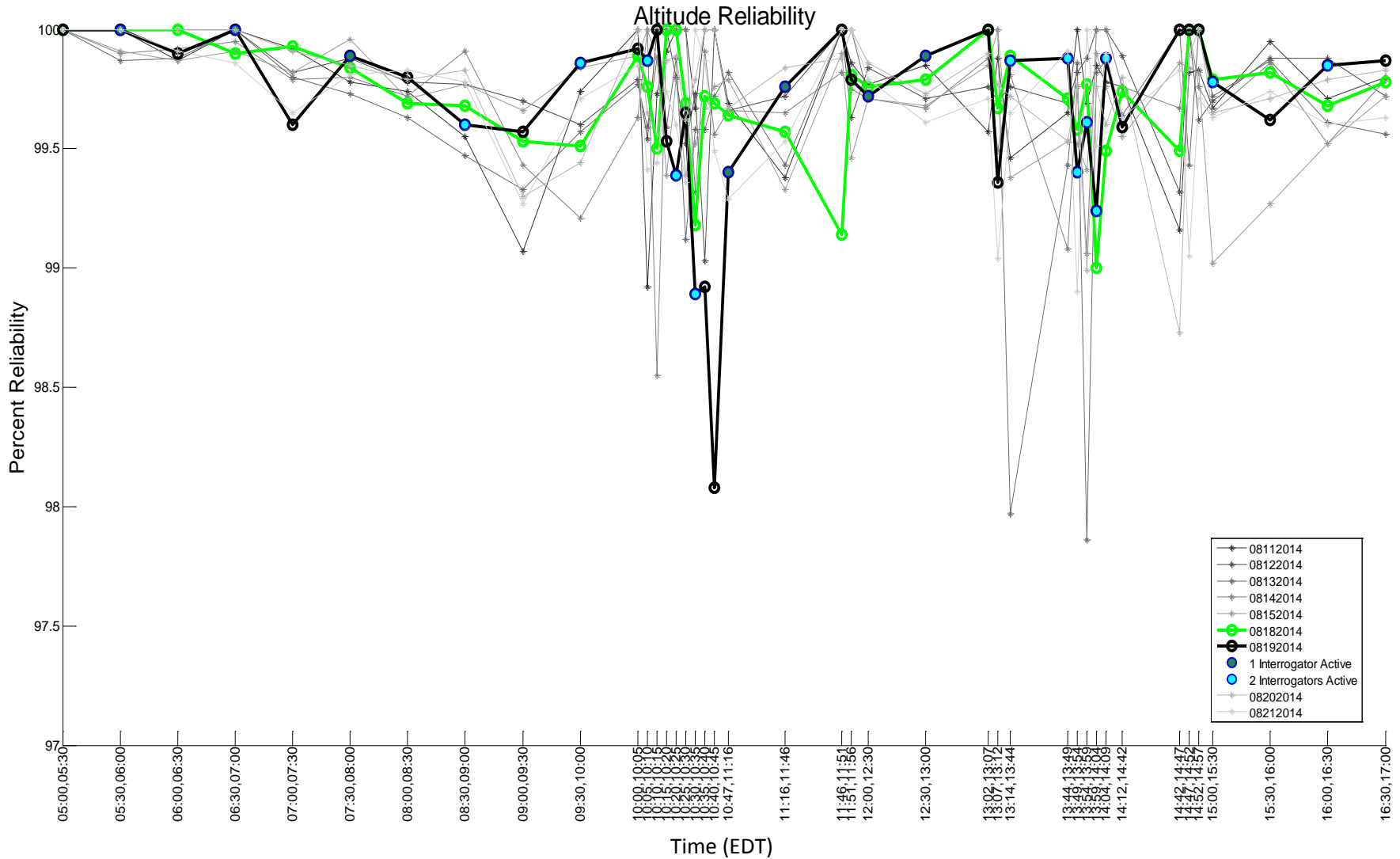
Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM

# Identity (3/A) Confidence – August 21<sup>st</sup>

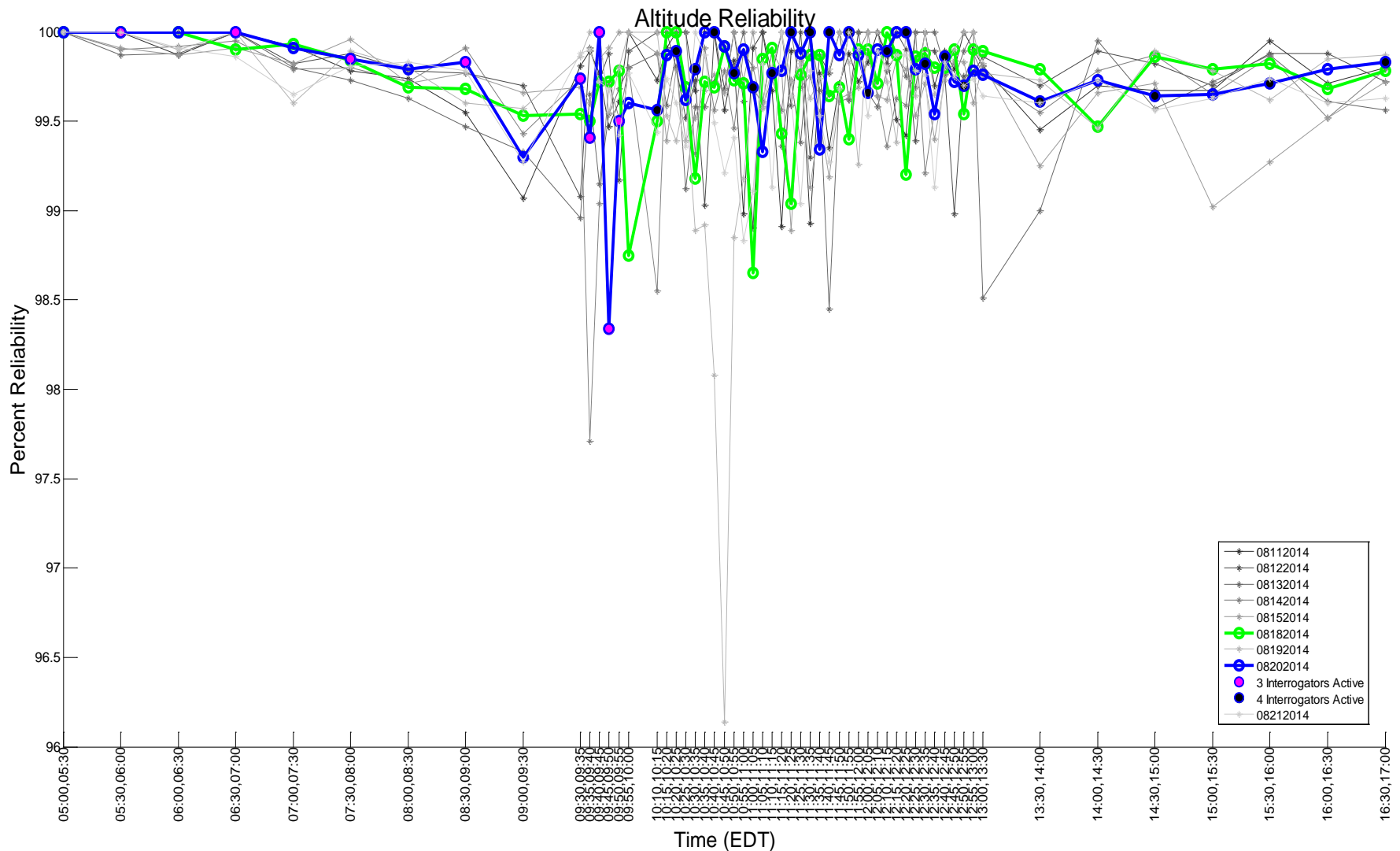


Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM

# Altitude (C) Reliability – August 19<sup>th</sup>

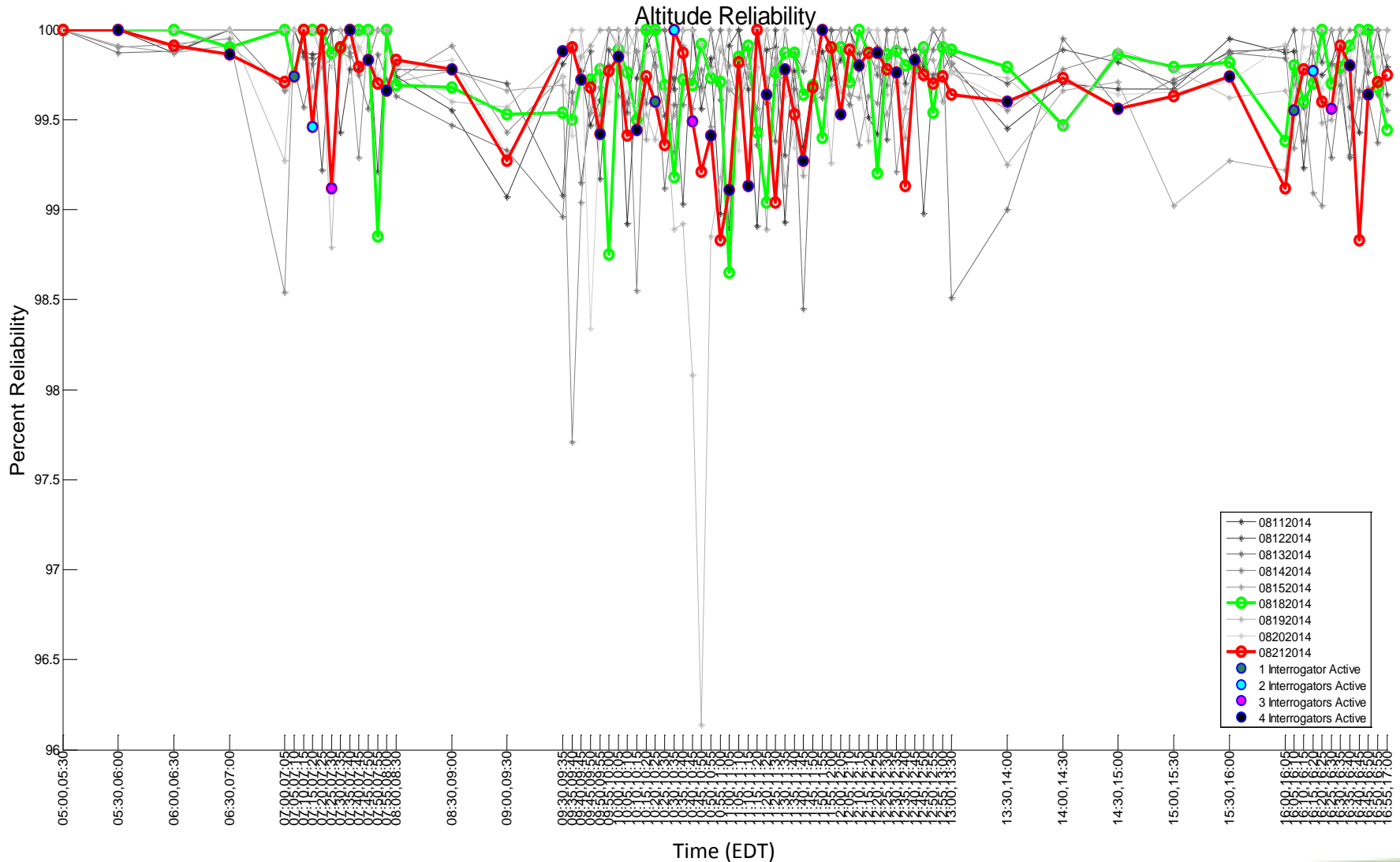


# Altitude (C) Reliability – August 20<sup>th</sup>

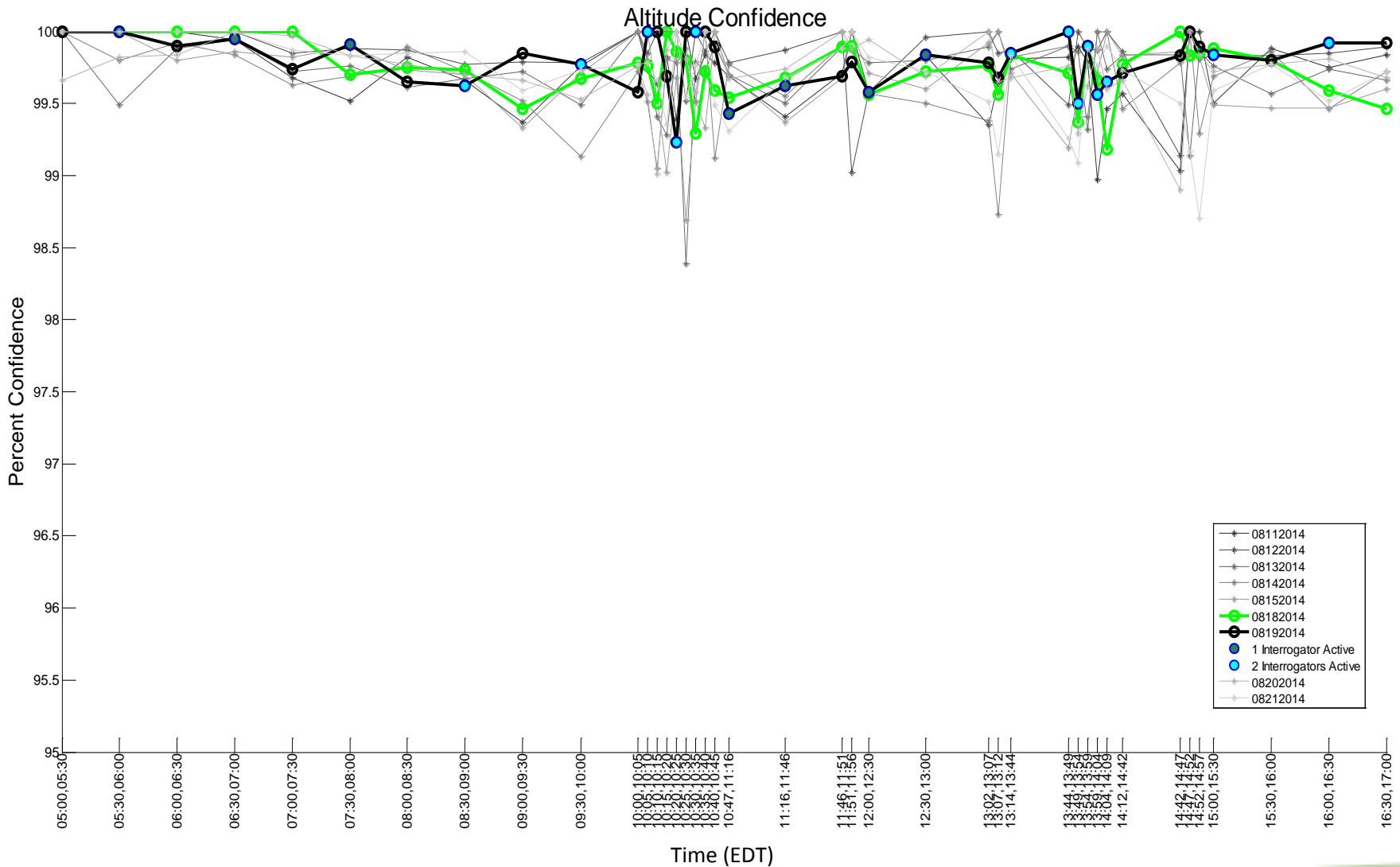


Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM

# Altitude (C) Reliability – August 21<sup>st</sup>

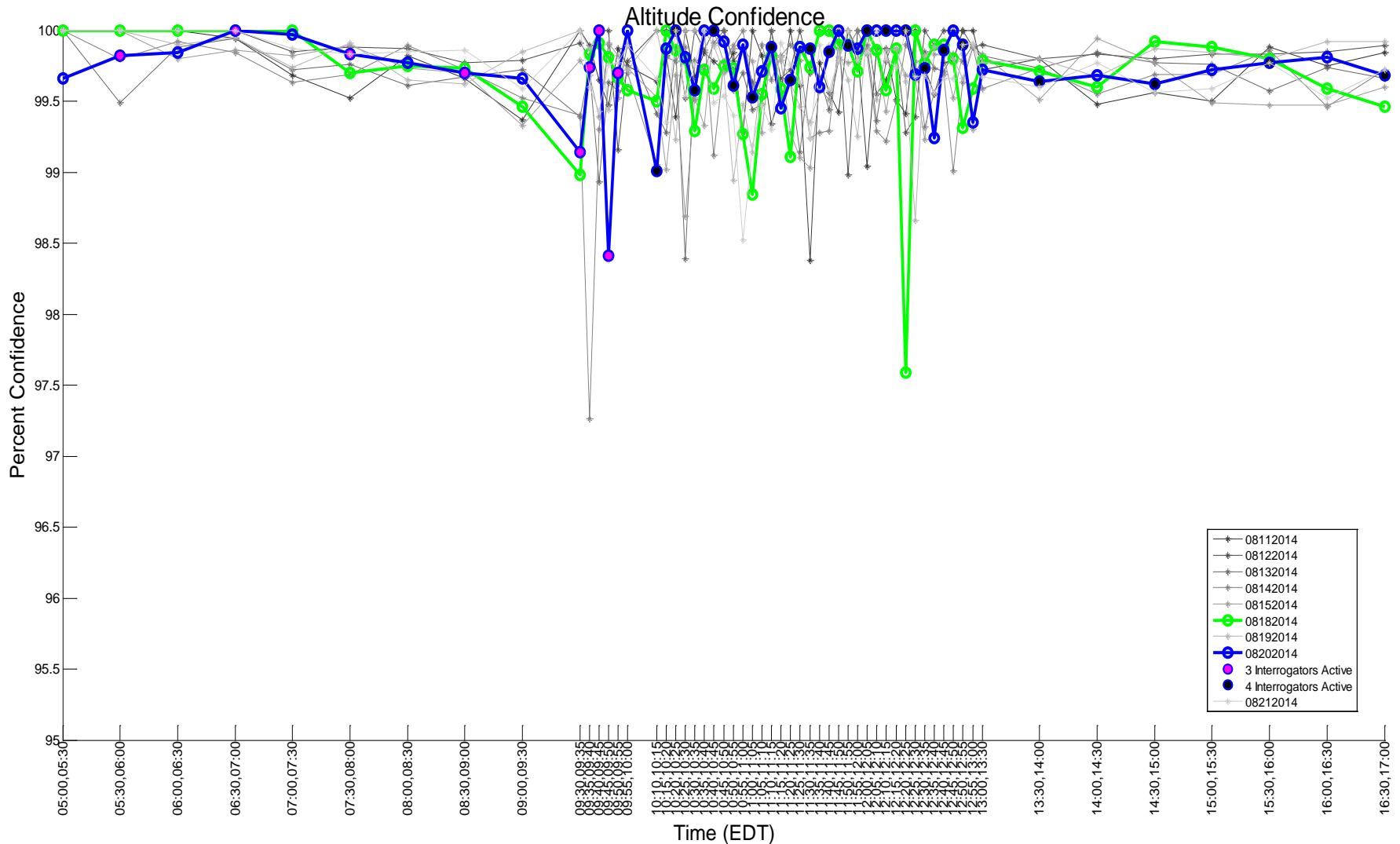


# Altitude (C) Confidence – August 19<sup>th</sup>



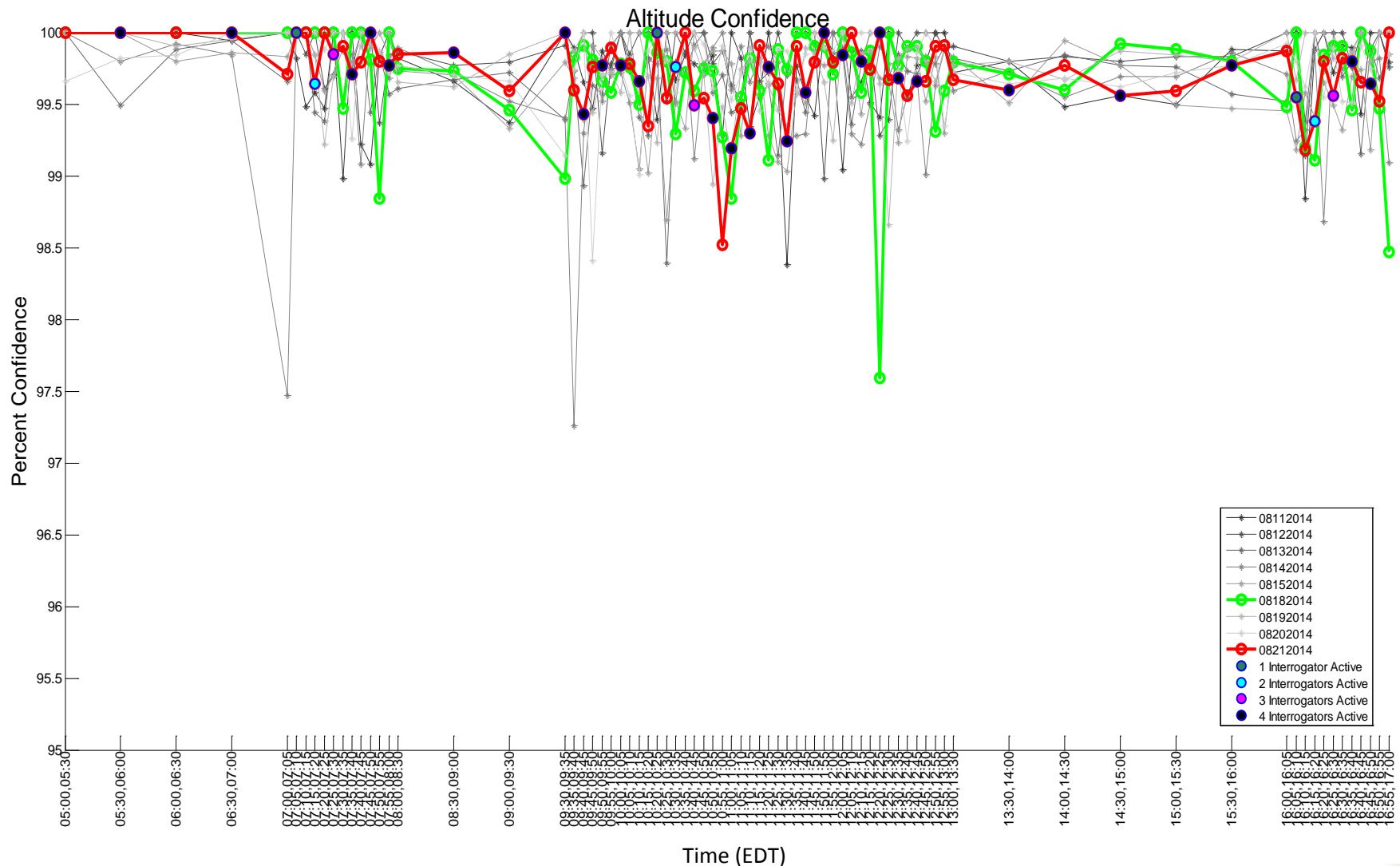


# Altitude (C) Confidence – August 20<sup>th</sup>

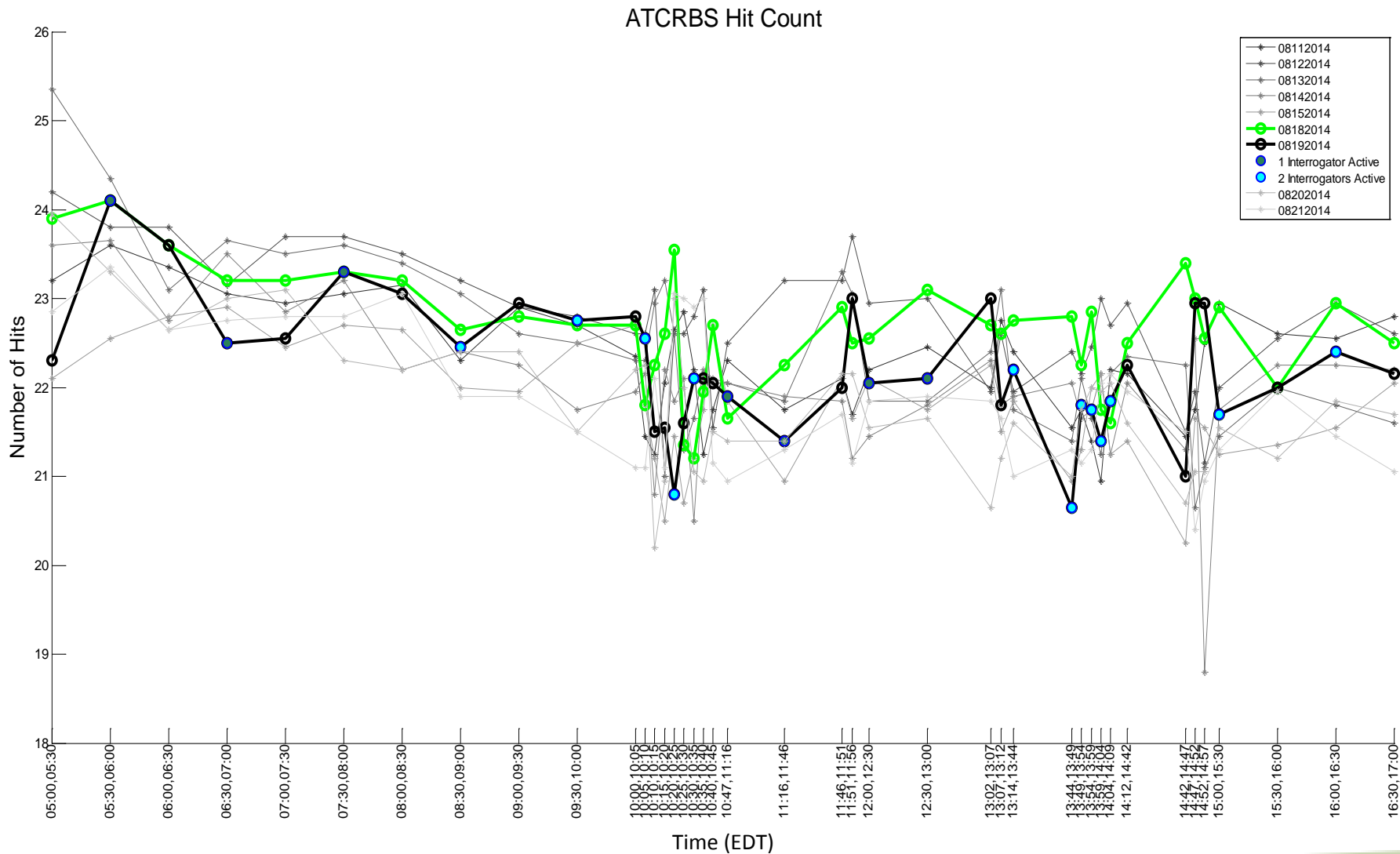


Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM

# Altitude (C) Confidence – August 21<sup>st</sup>



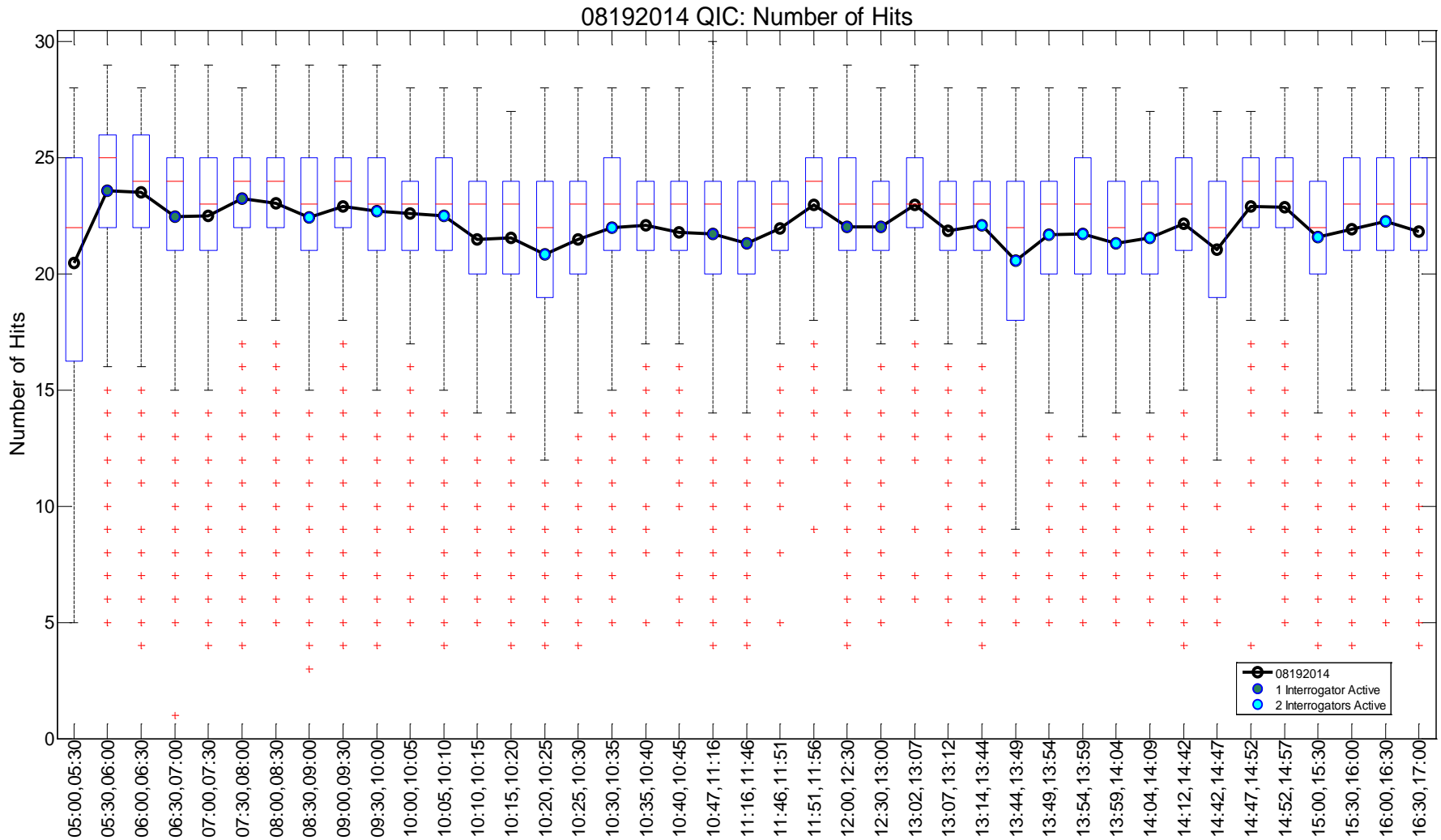
# Hit Count – August 19th



Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM

# Hit Count – August 19<sup>th</sup>

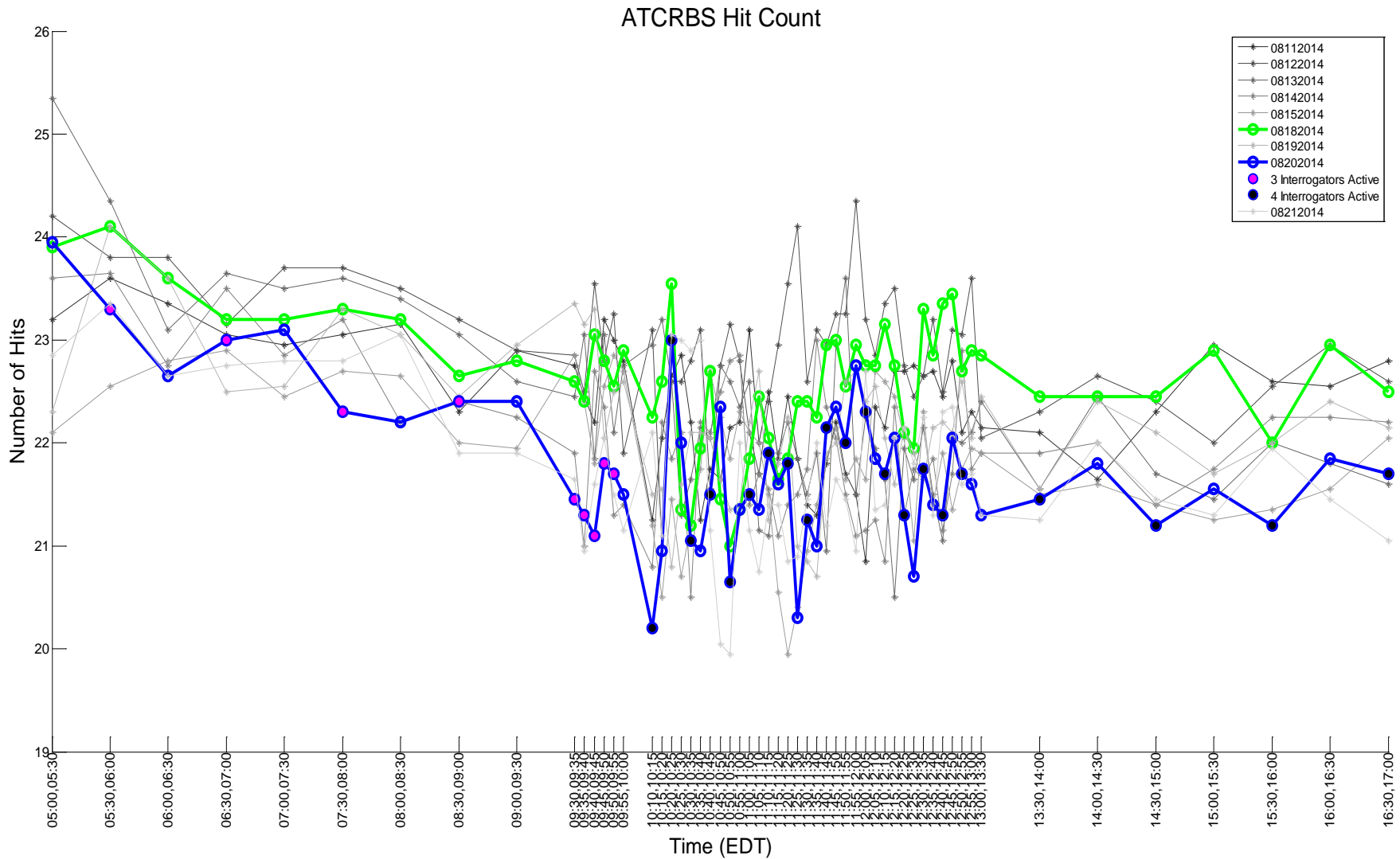
## Individual Aircraft Distribution



Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM

# Hit Count – August 20<sup>th</sup>

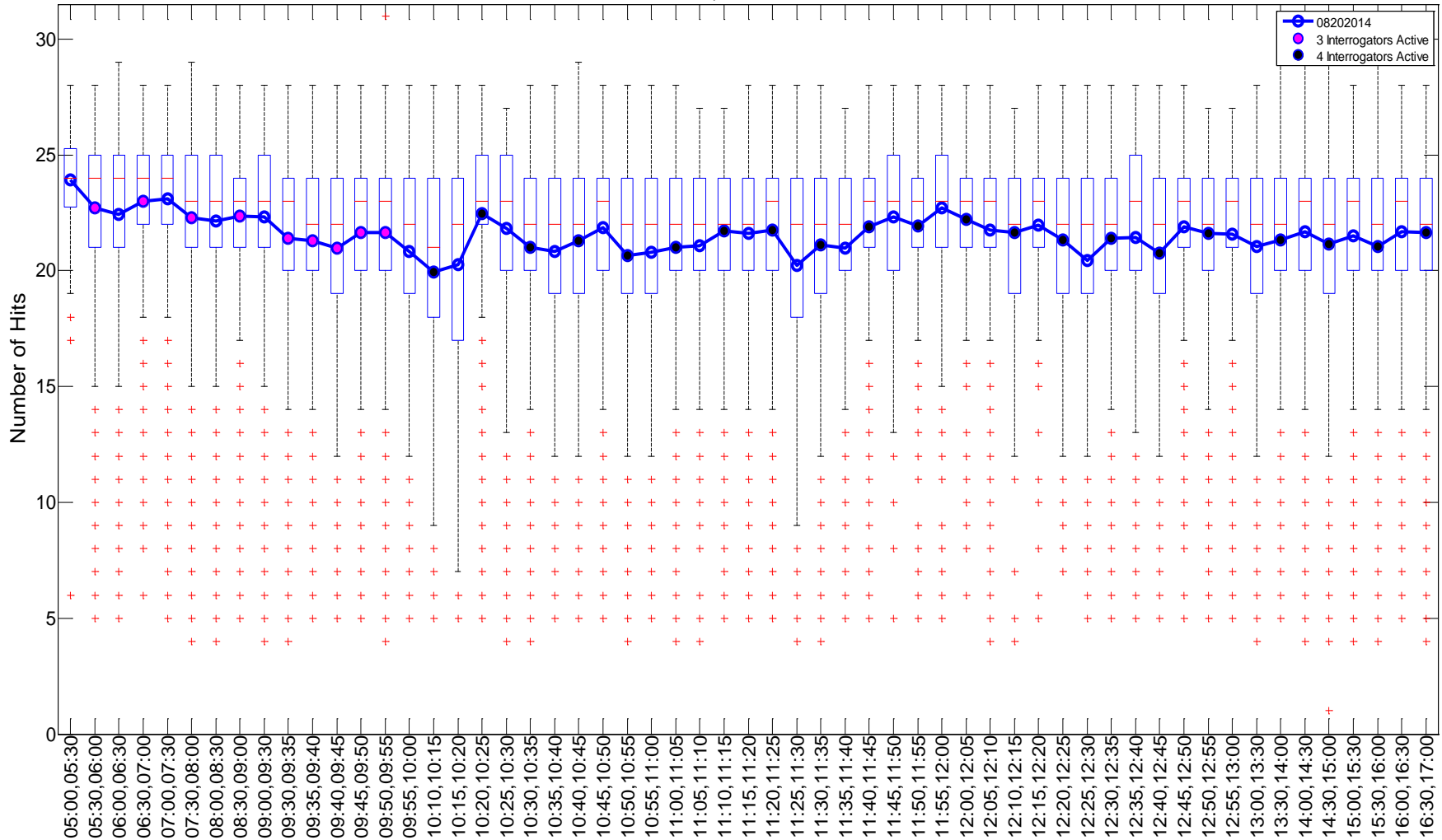


Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM

# Hit Count – August 20<sup>th</sup>

## Individual Aircraft Distribution

08202014 QIC: Number of Hits

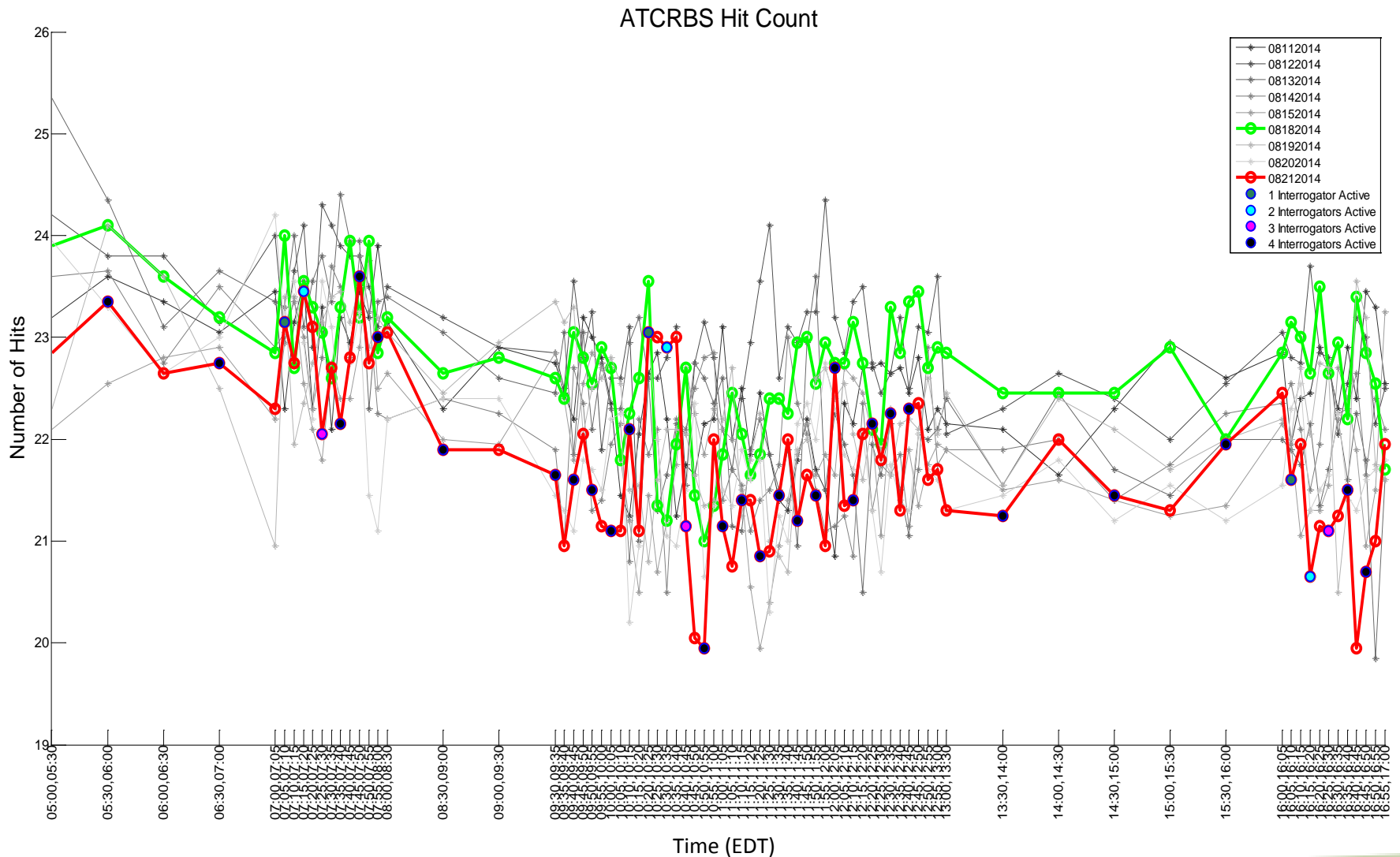


Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

Geographic Filter: None

Target Filter: Exclude Targets < 50 NM

# Hit Count – August 21<sup>st</sup>

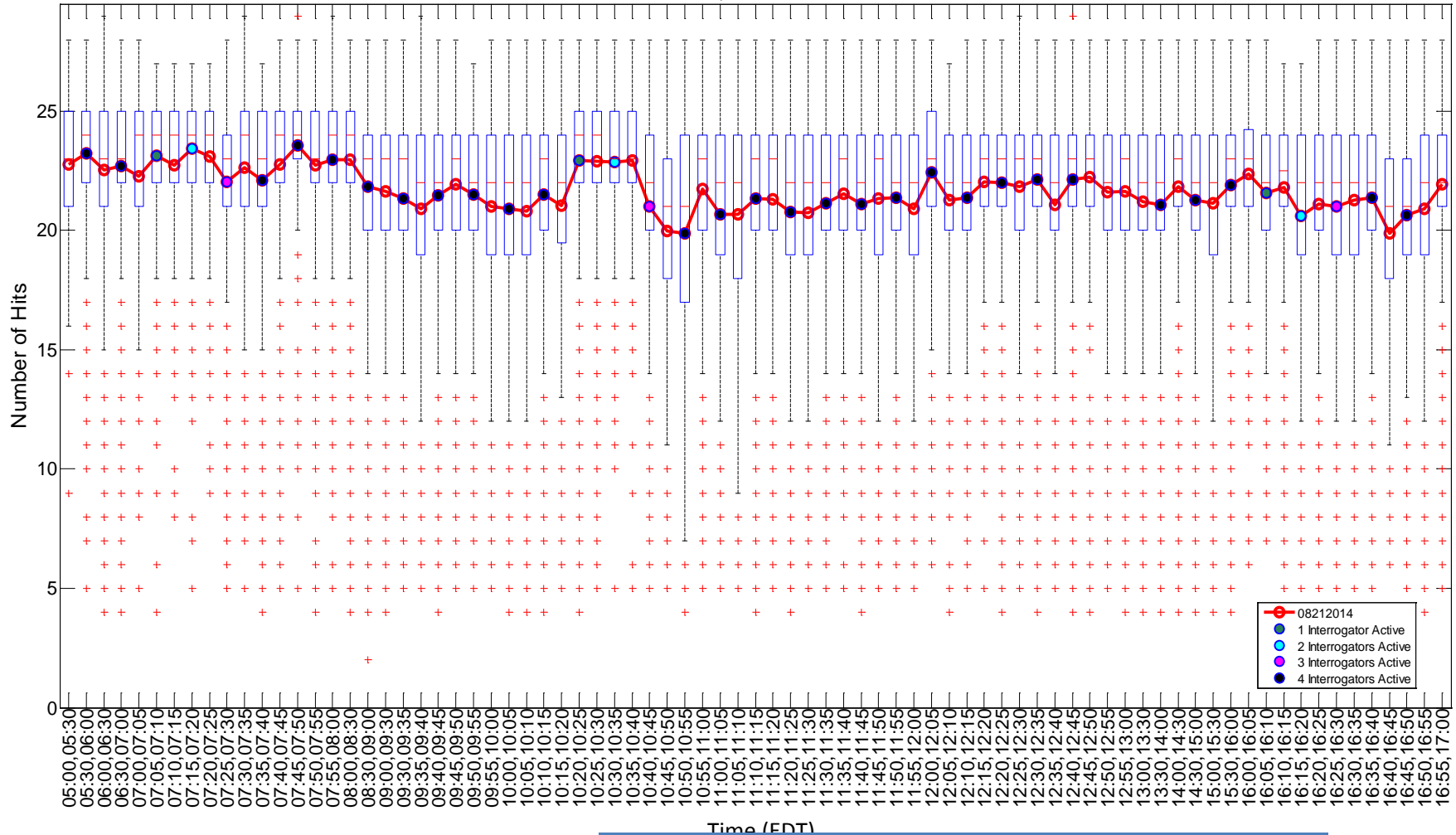


Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM

# Hit Count – August 21<sup>st</sup>

## Individual Aircraft Distribution

08212014 QIC: Number of Hits



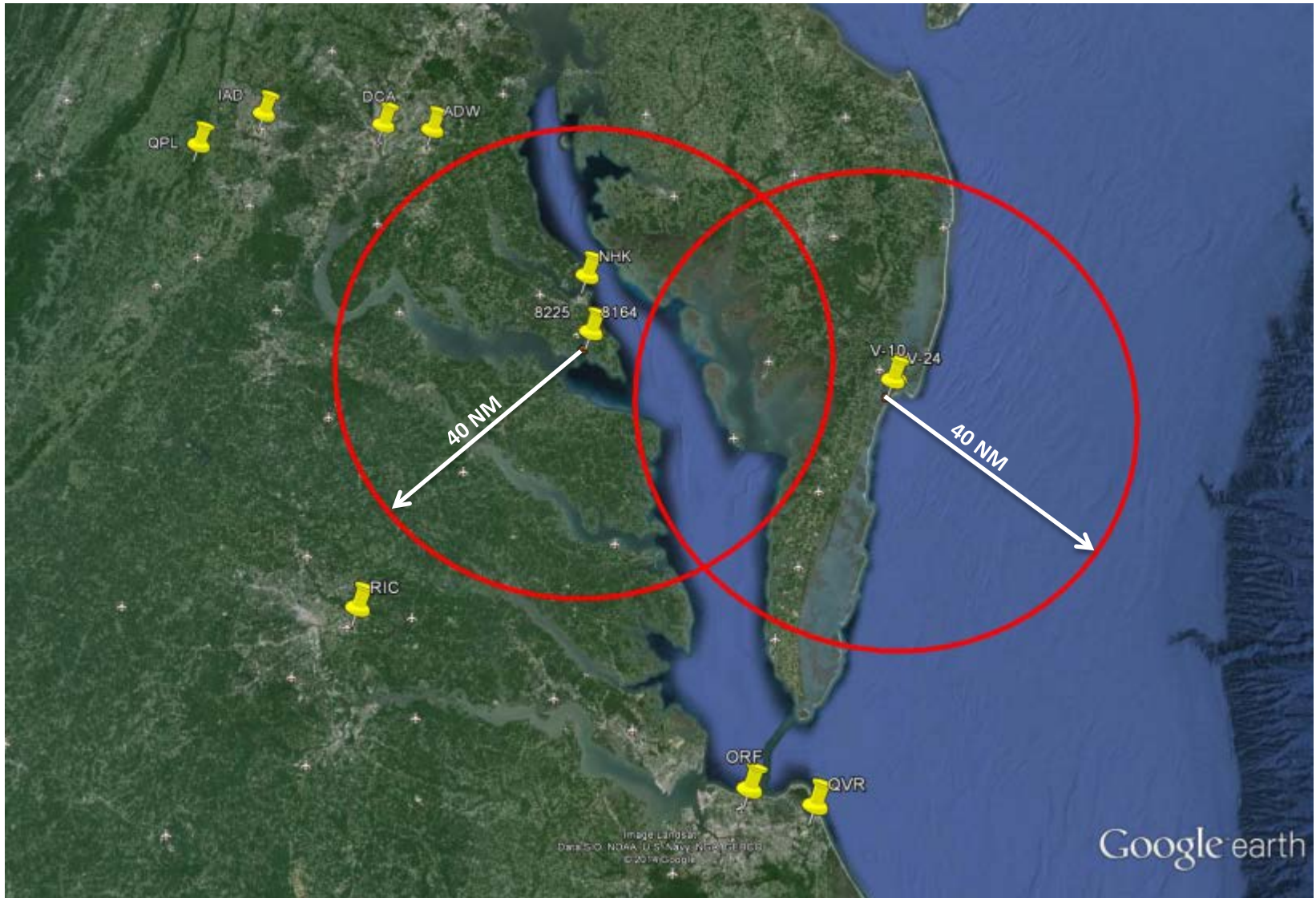
Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

Geographic Filter: None  
Target Filter: Exclude Targets < 50 NM



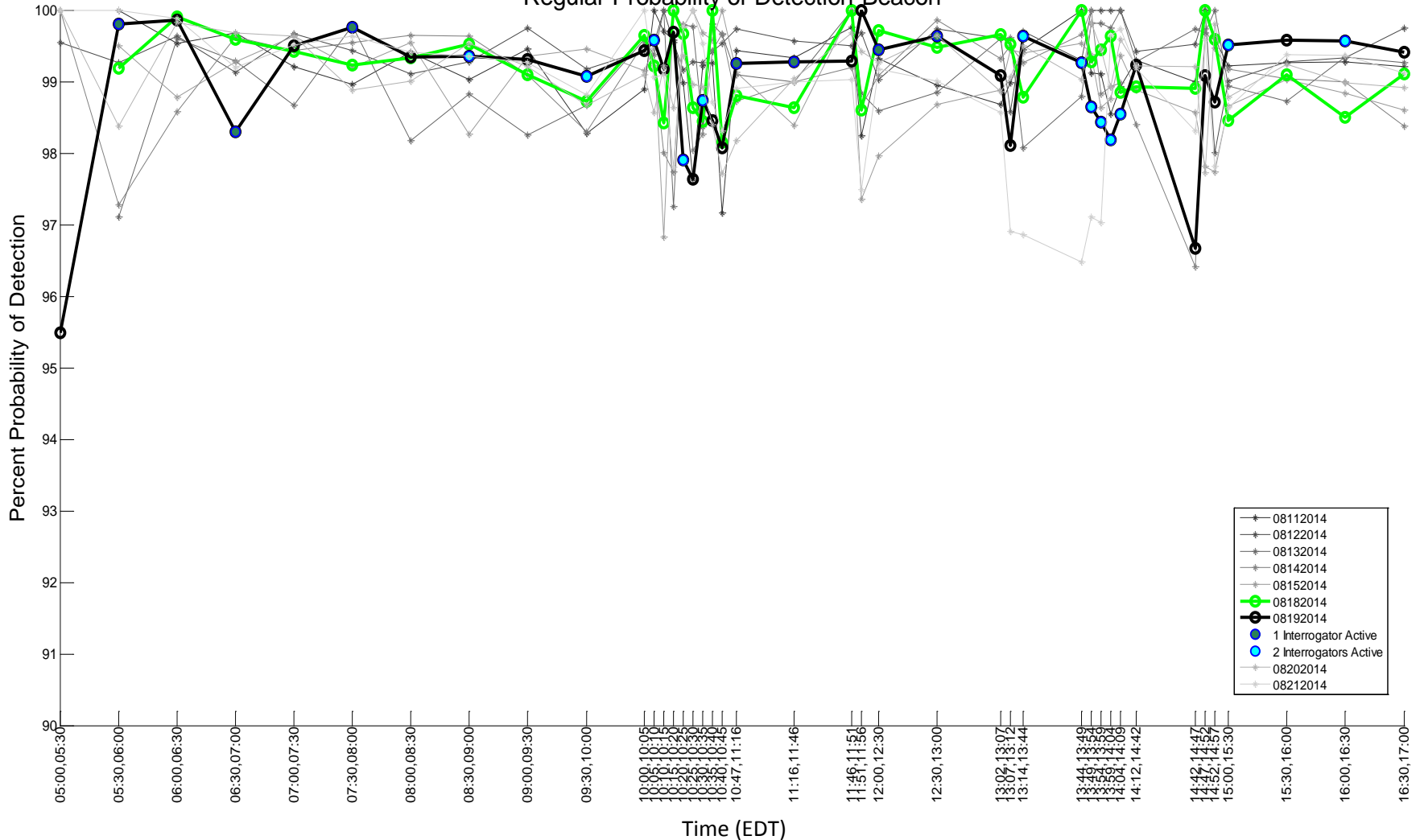
# Target Metrics within the Hotspot Region

# Hotspot Geography



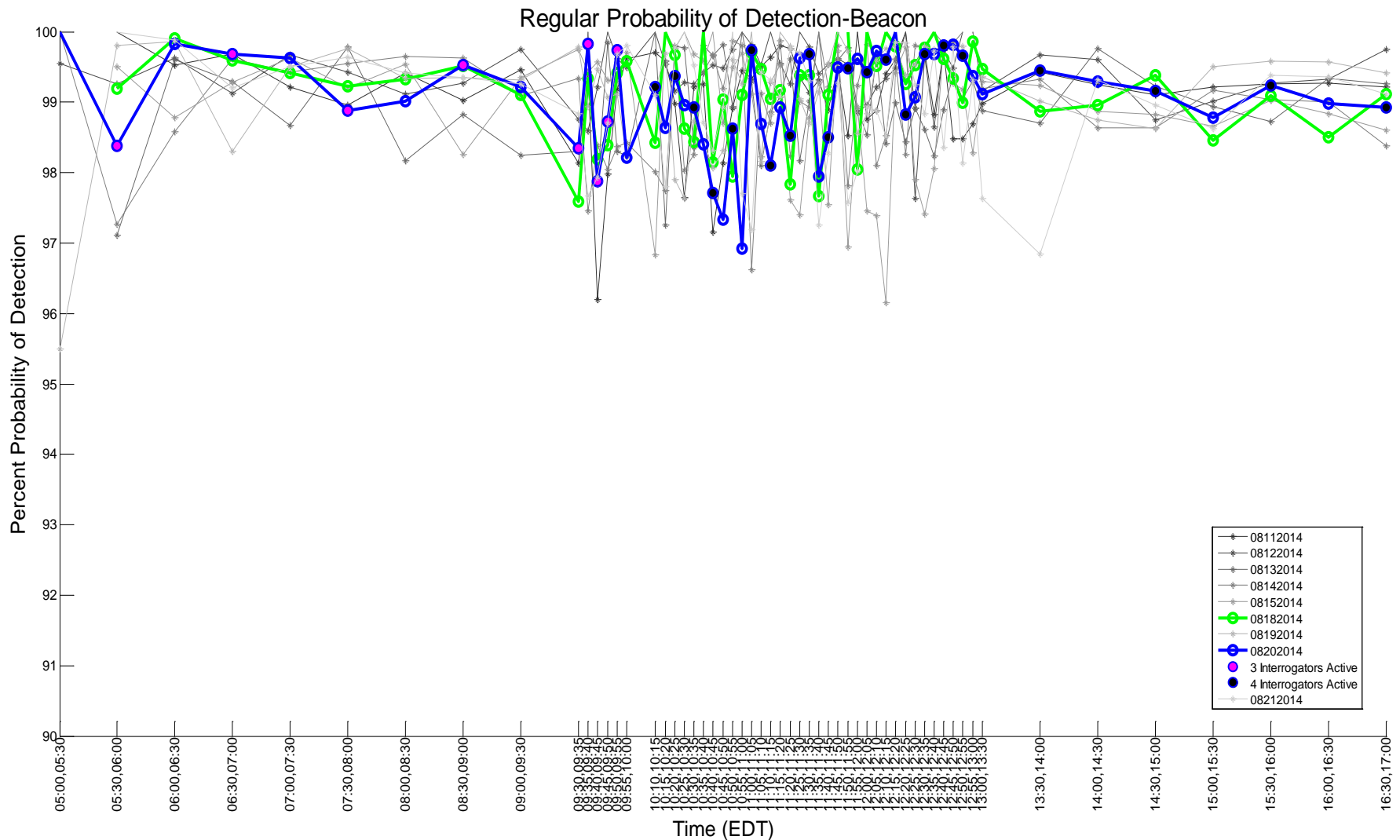
# Probability of Detection – August 19<sup>th</sup>

Regular Probability of Detection-Beacon



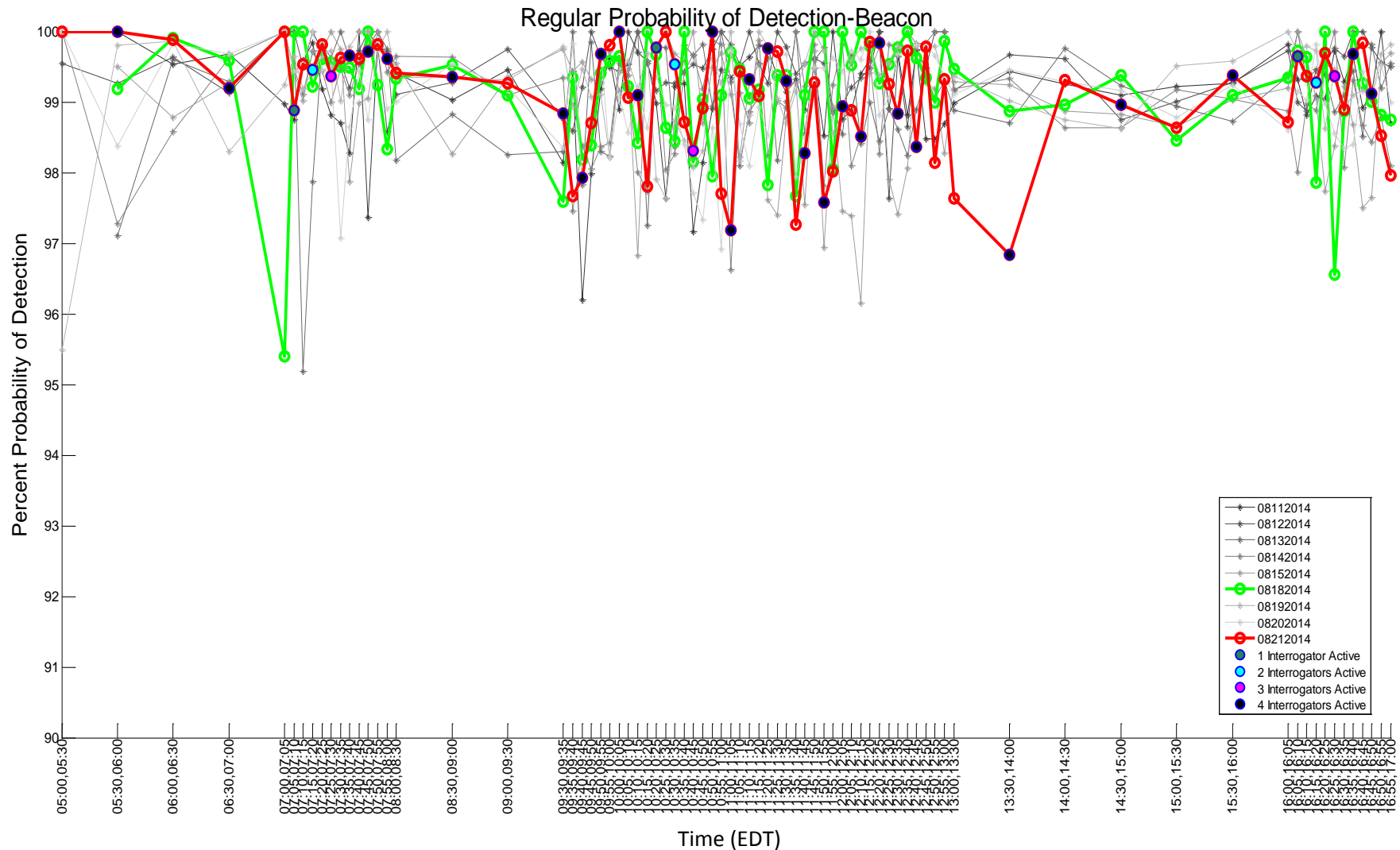
Geographic Filter: Hotspot Region  
 Target Filter: None

# Probability of Detection – August 20<sup>th</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

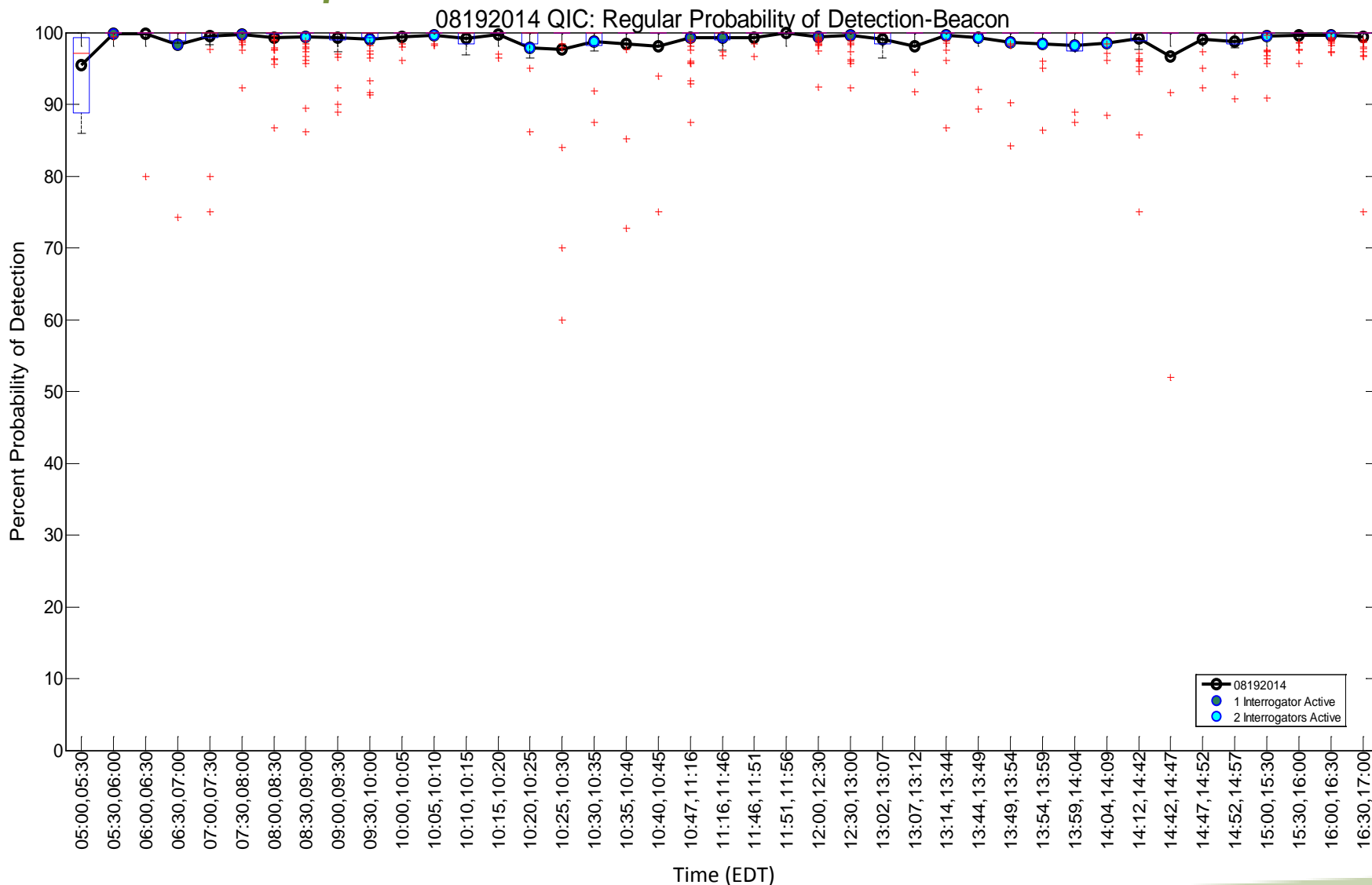
# Probability of Detection – August 21<sup>st</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

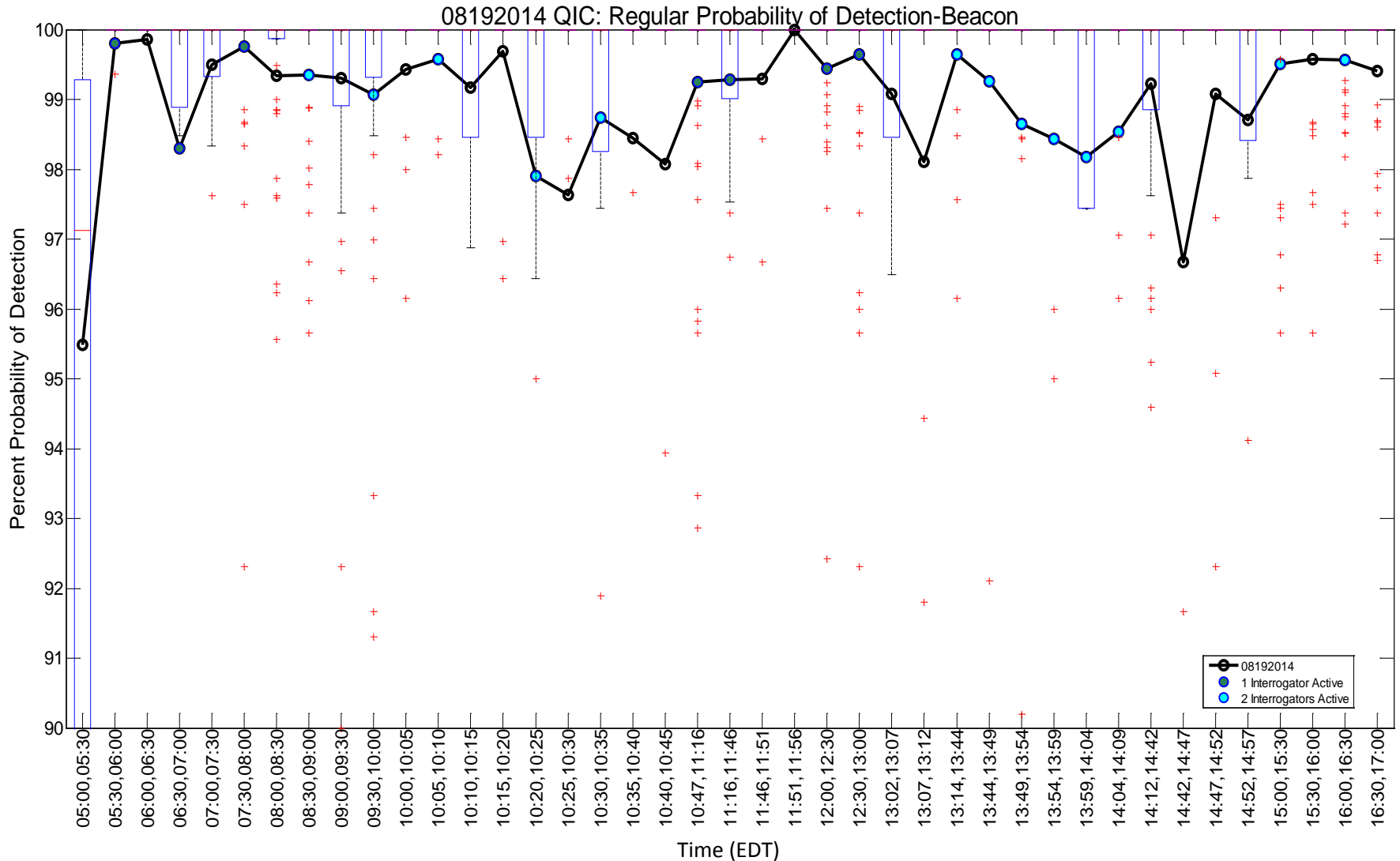
# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution



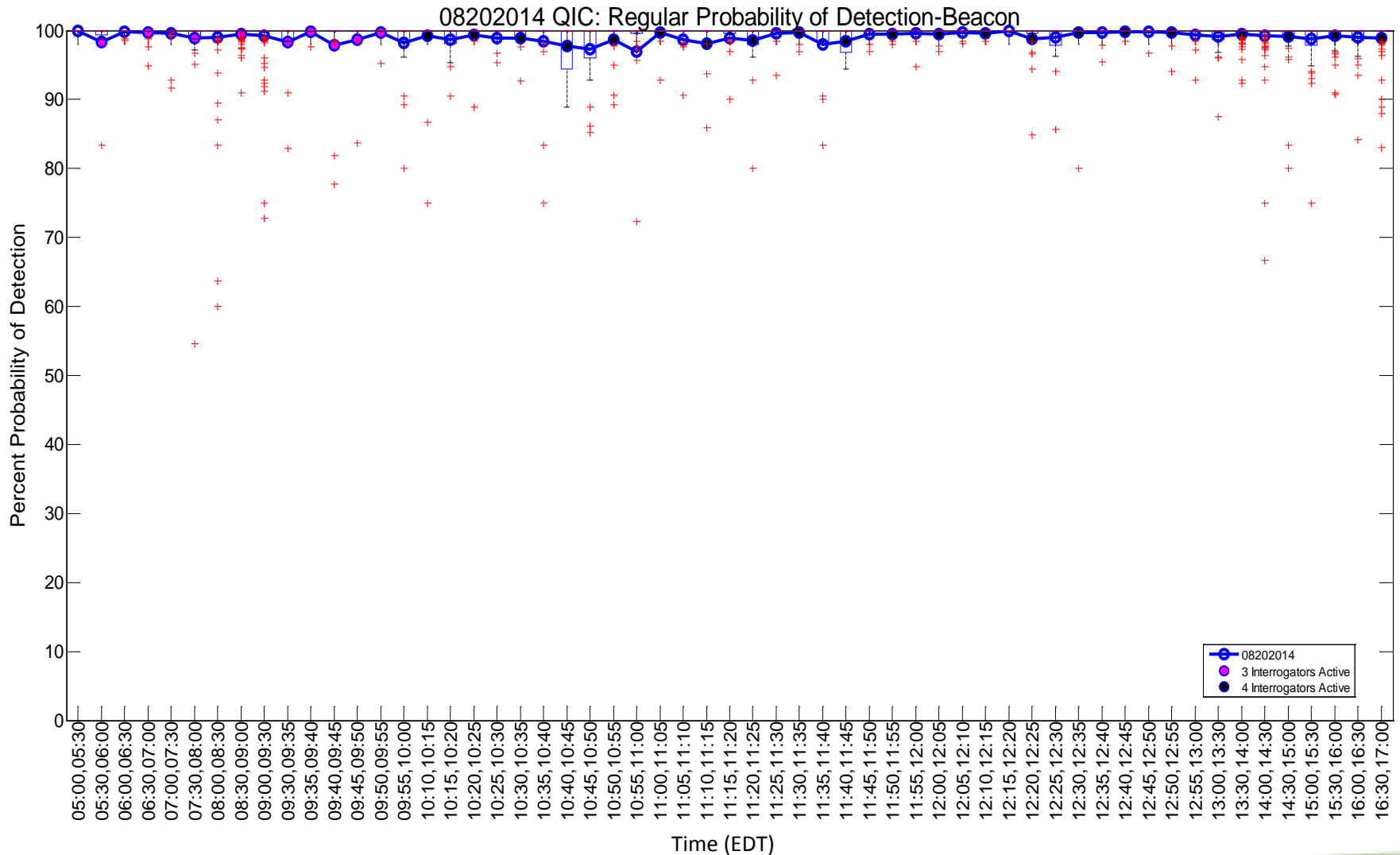
# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution



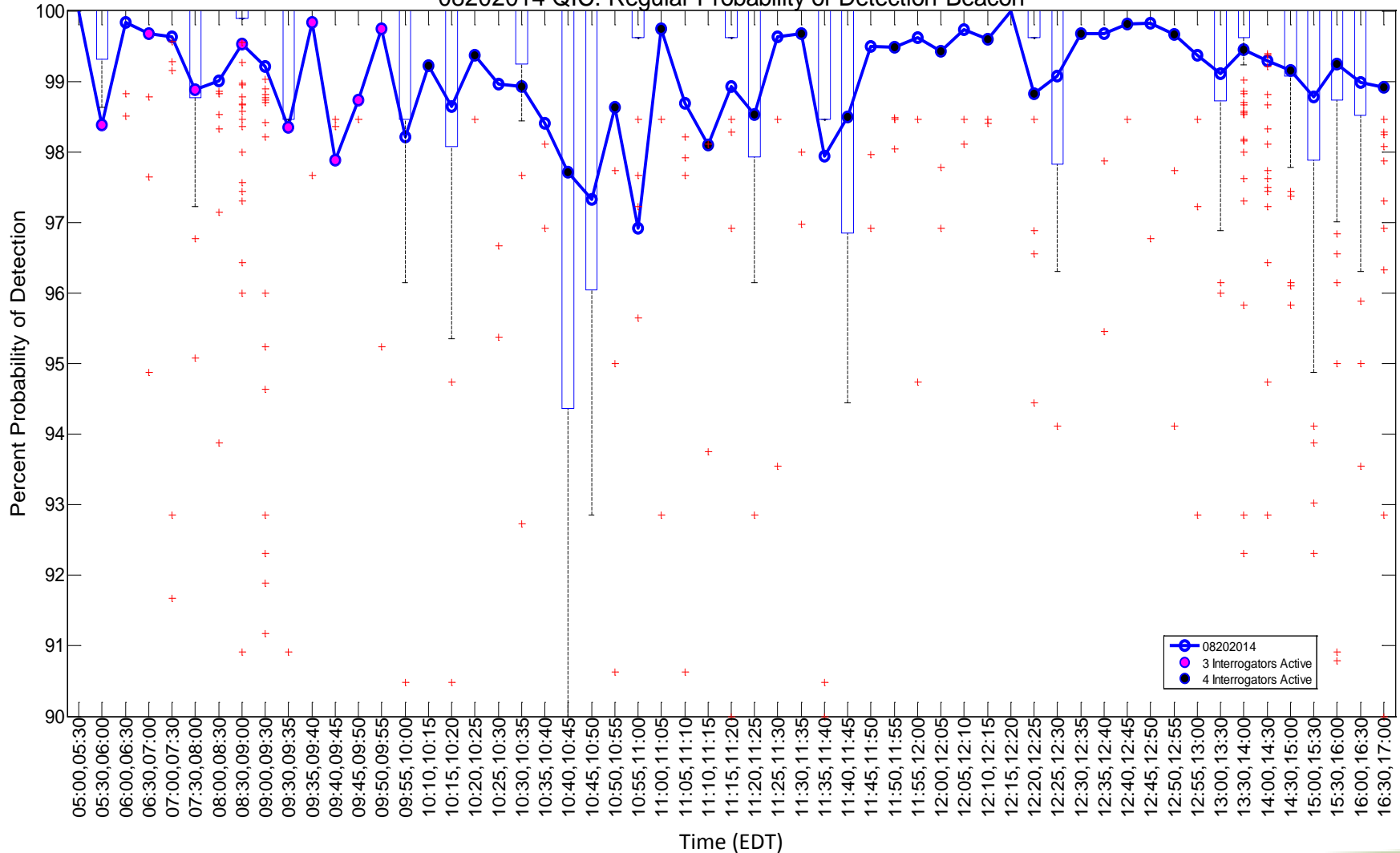
Geographic Filter: Hotspot Region  
 Target Filter: None



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

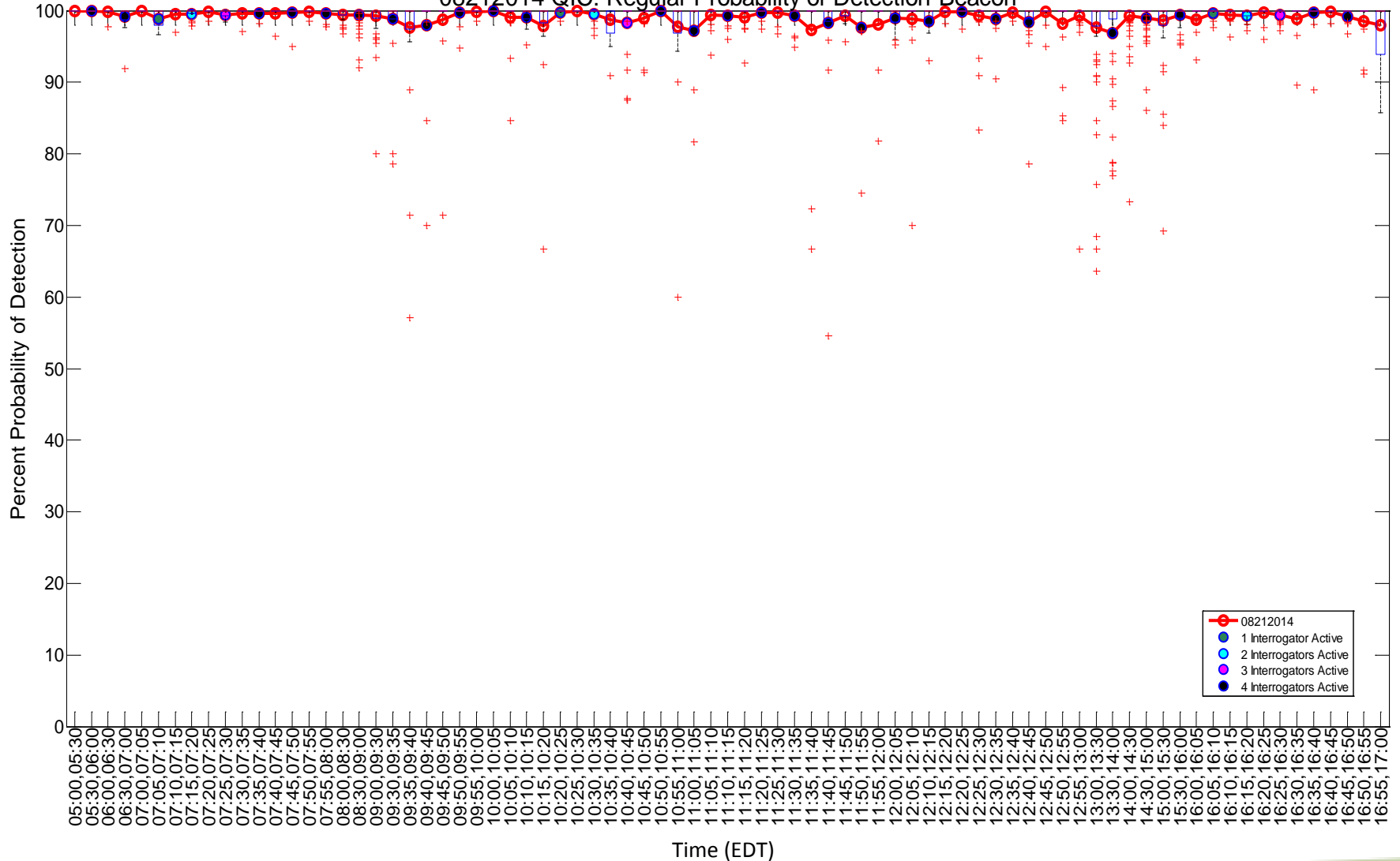
08202014 QIC: Regular Probability of Detection-Beacon



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

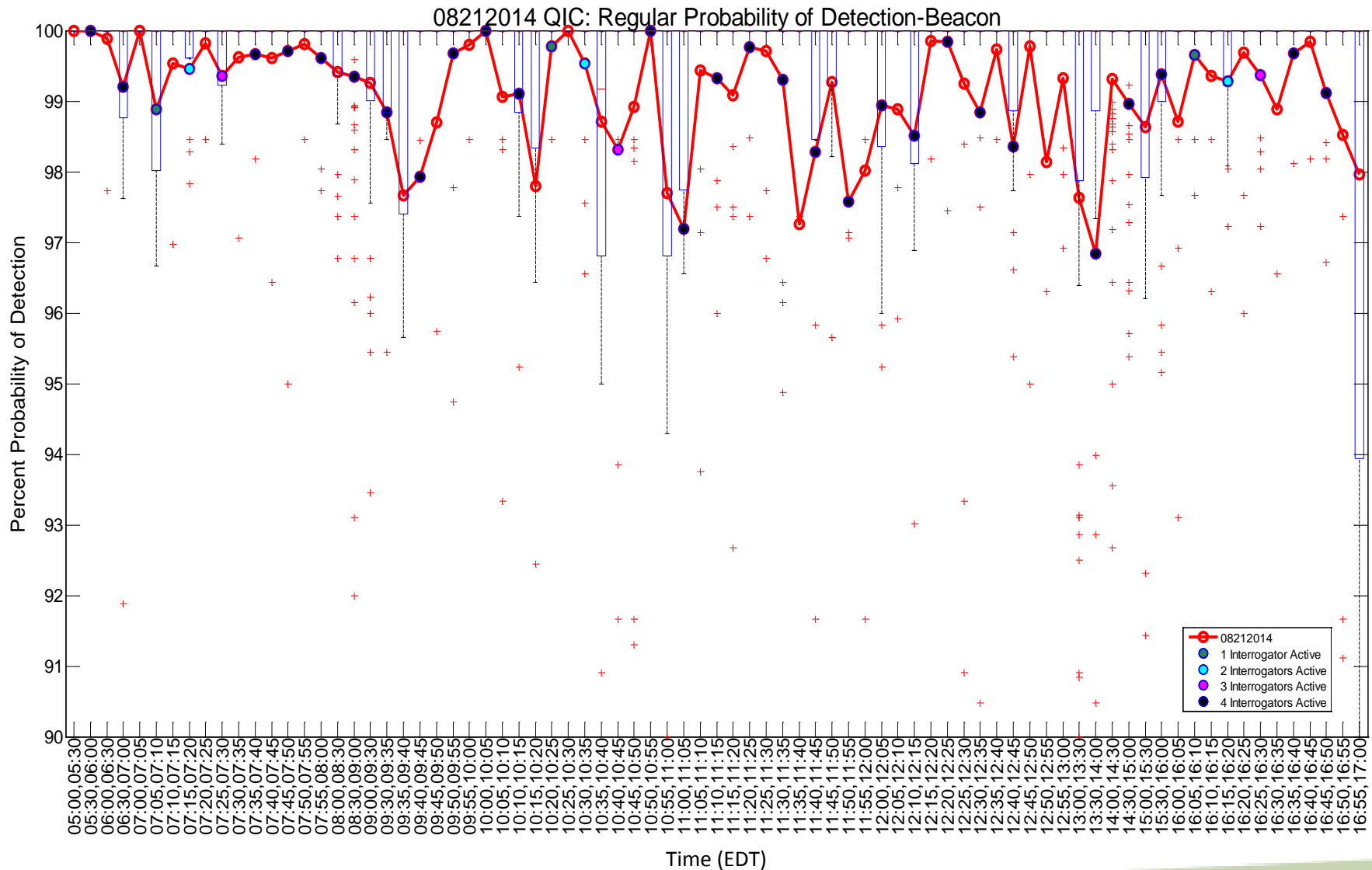
08212014 QIC: Regular Probability of Detection-Beacon



Geographic Filter: Hotspot Region  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)



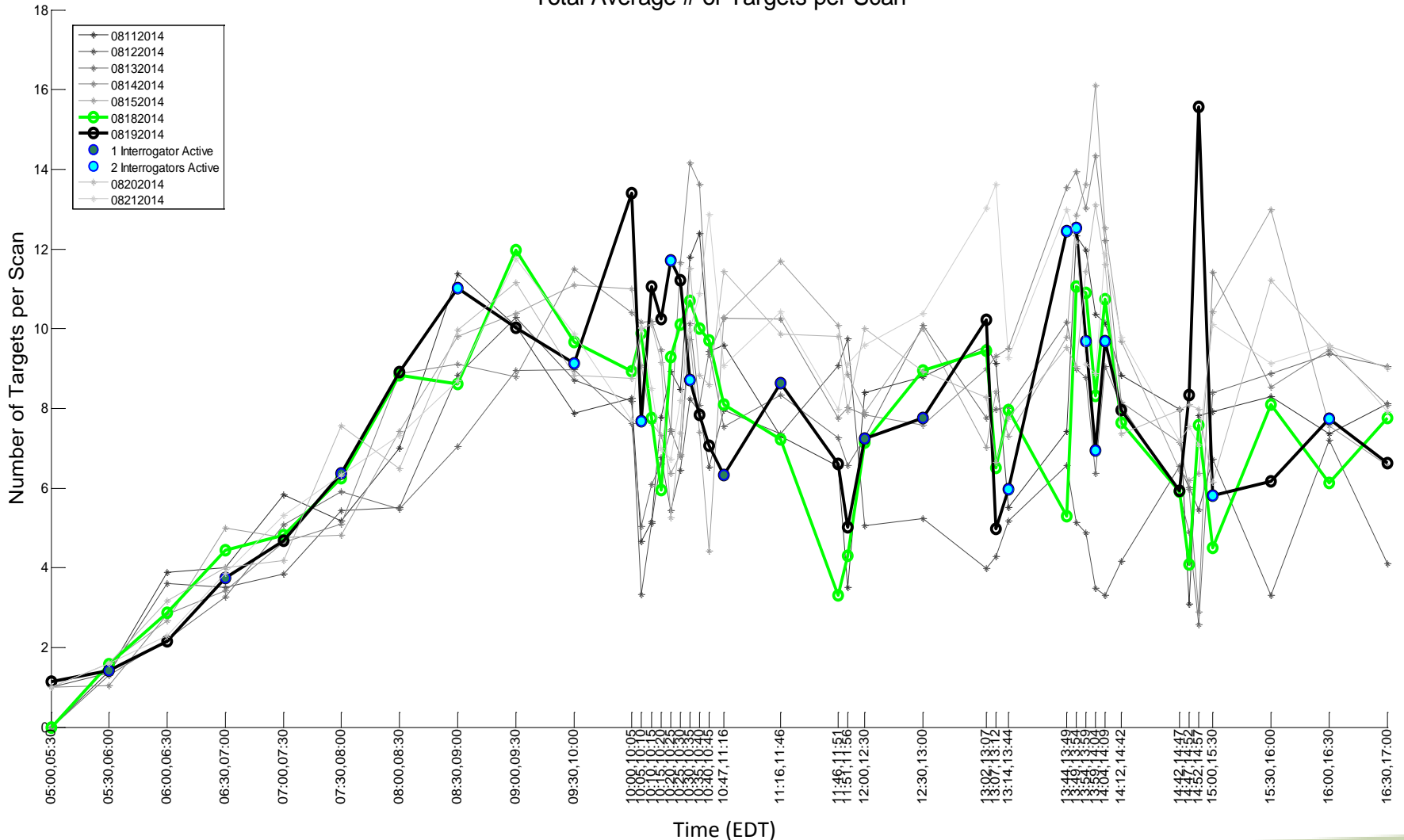
Geographic Filter: Hotspot Region

Target Filter: None



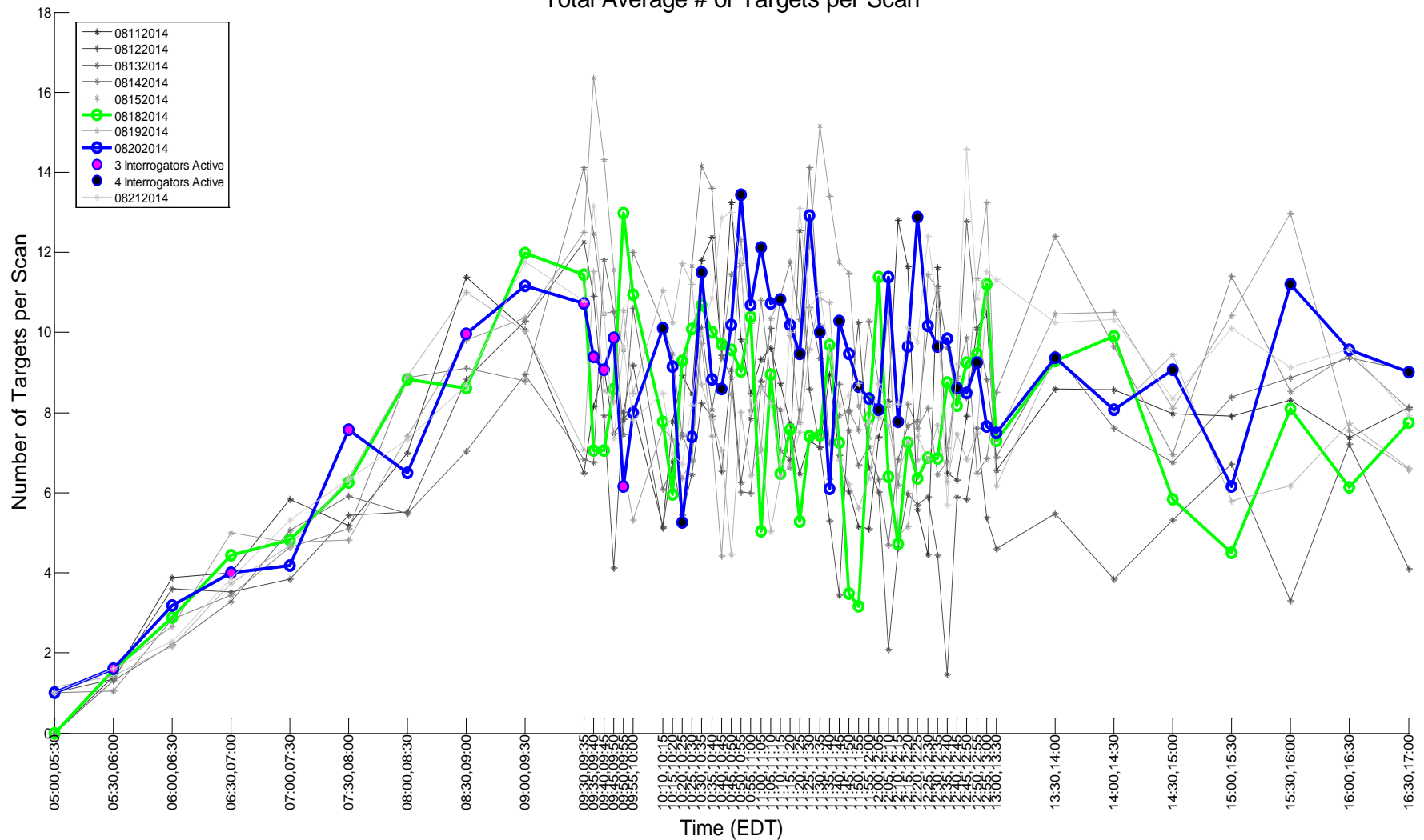
# Targets per Scan – August 19<sup>th</sup>

Total Average # of Targets per Scan



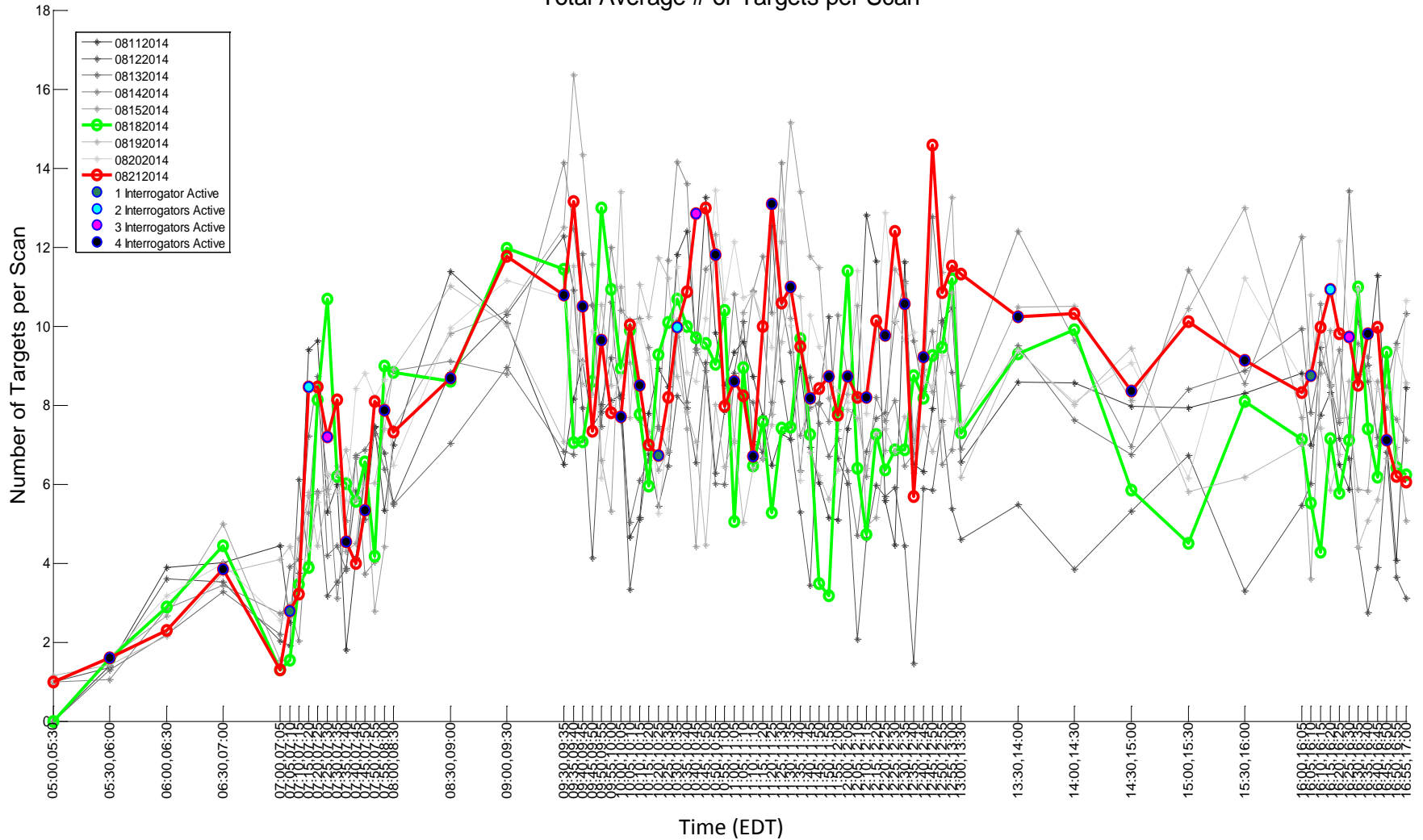
# Targets per Scan – August 20<sup>th</sup>

Total Average # of Targets per Scan



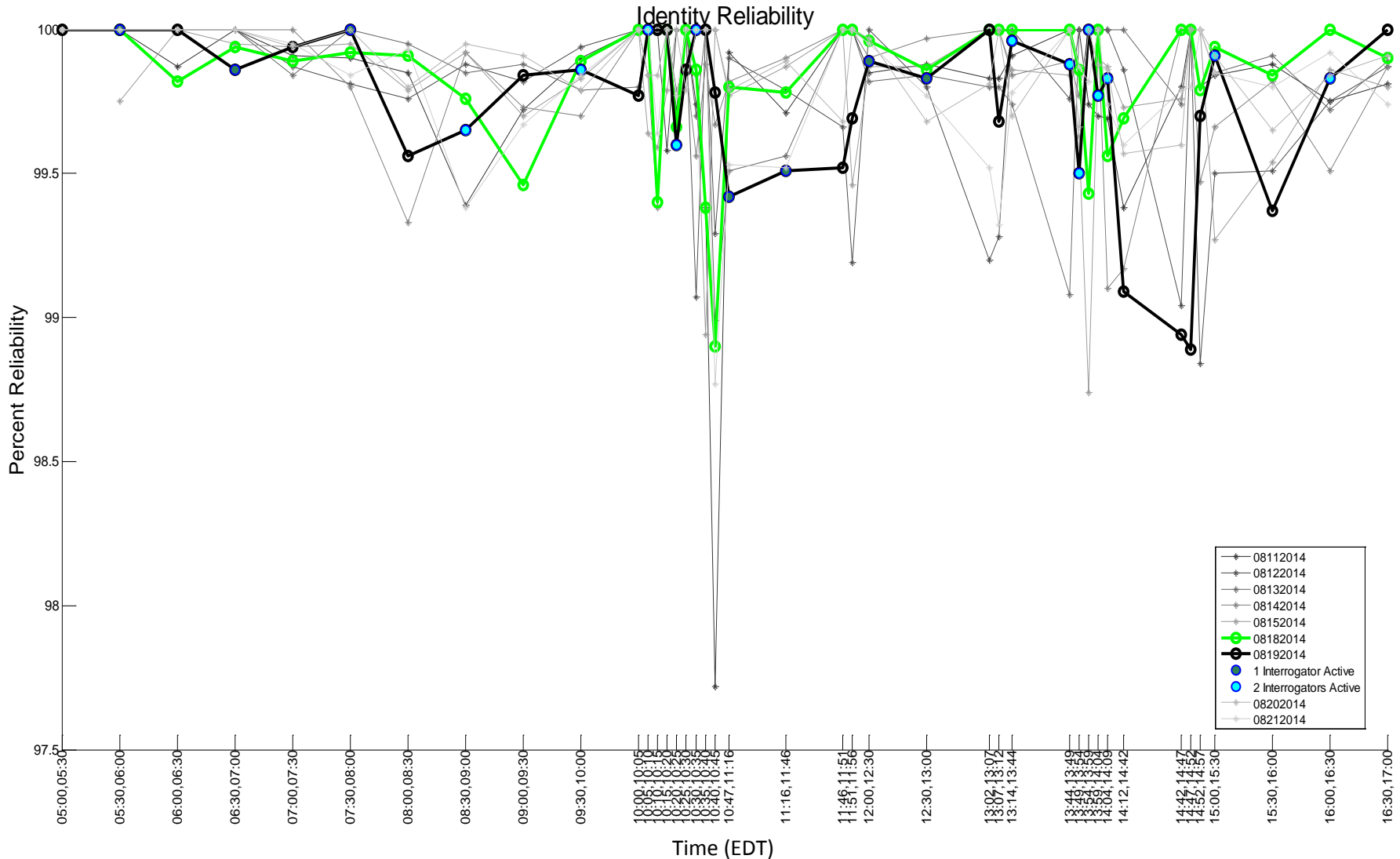
# Targets per Scan – August 21<sup>st</sup>

Total Average # of Targets per Scan



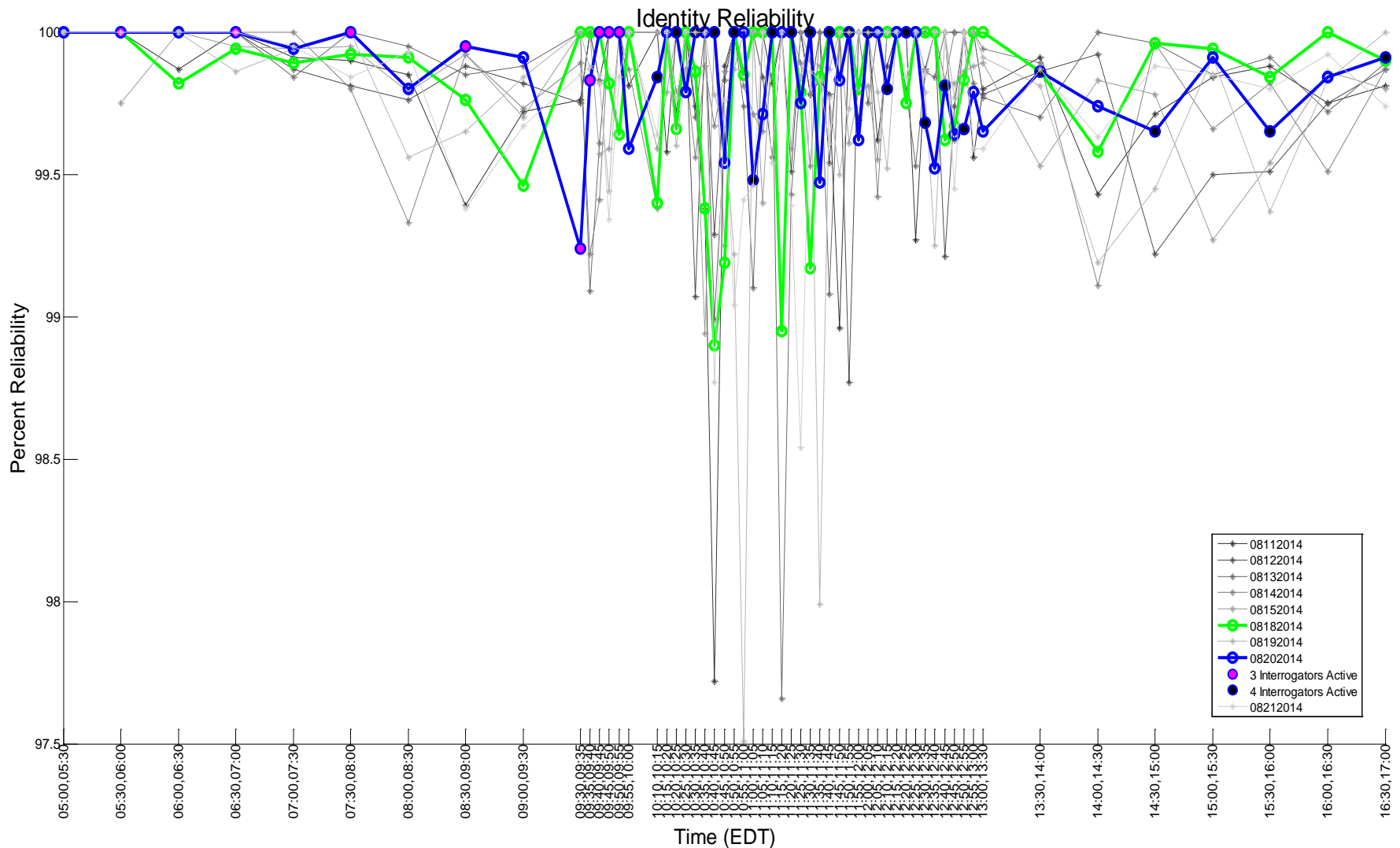
Geographic Filter: Hotspot Region  
Target Filter: None

# Identity (3/A) Reliability – August 19<sup>th</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

# Identity (3/A) Reliability – August 20<sup>th</sup>

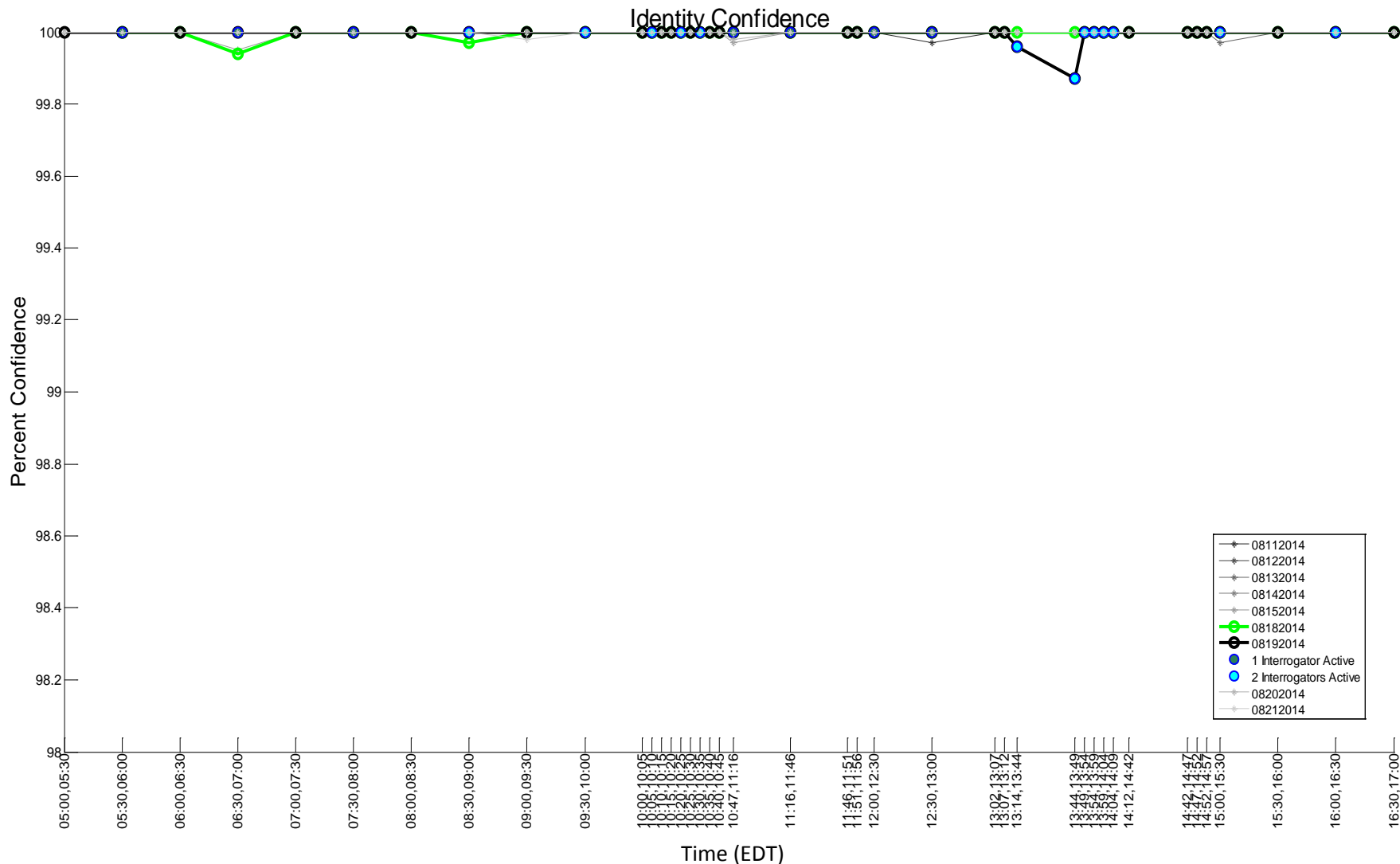


Geographic Filter: Hotspot Region  
Target Filter: None

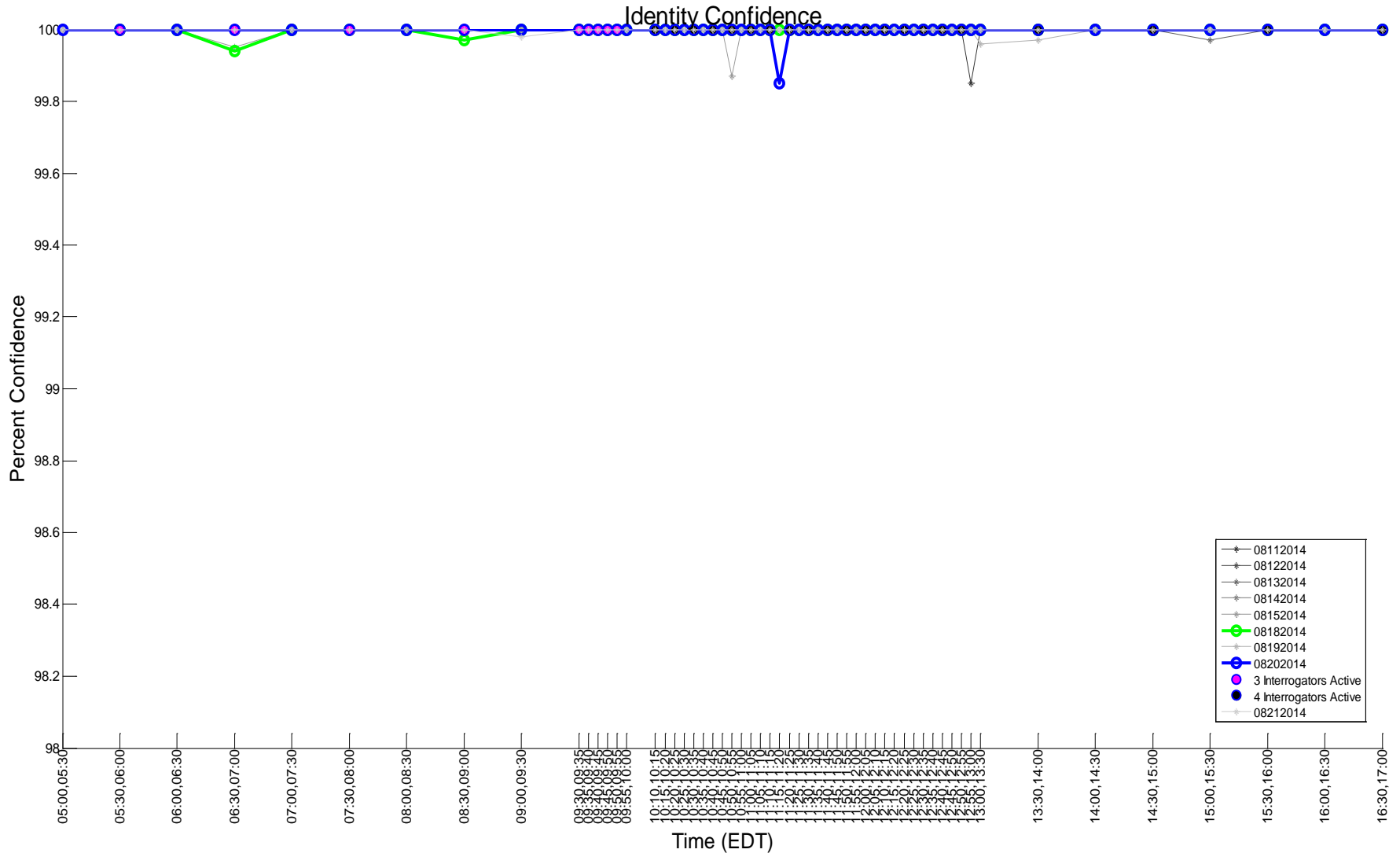




# Identity (3/A) Confidence – August 19<sup>th</sup>

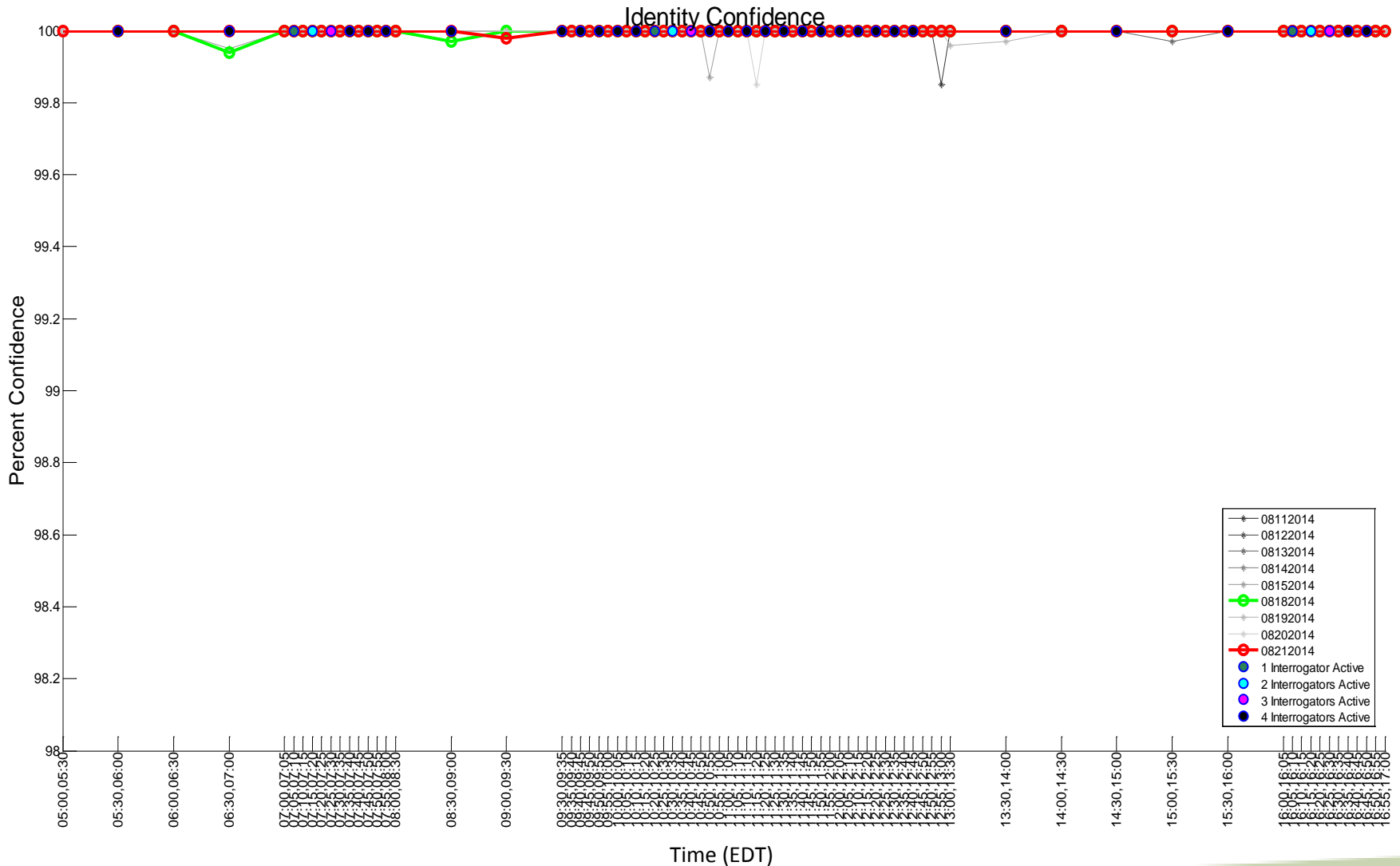


# Identity (3/A) Confidence – August 20<sup>th</sup>



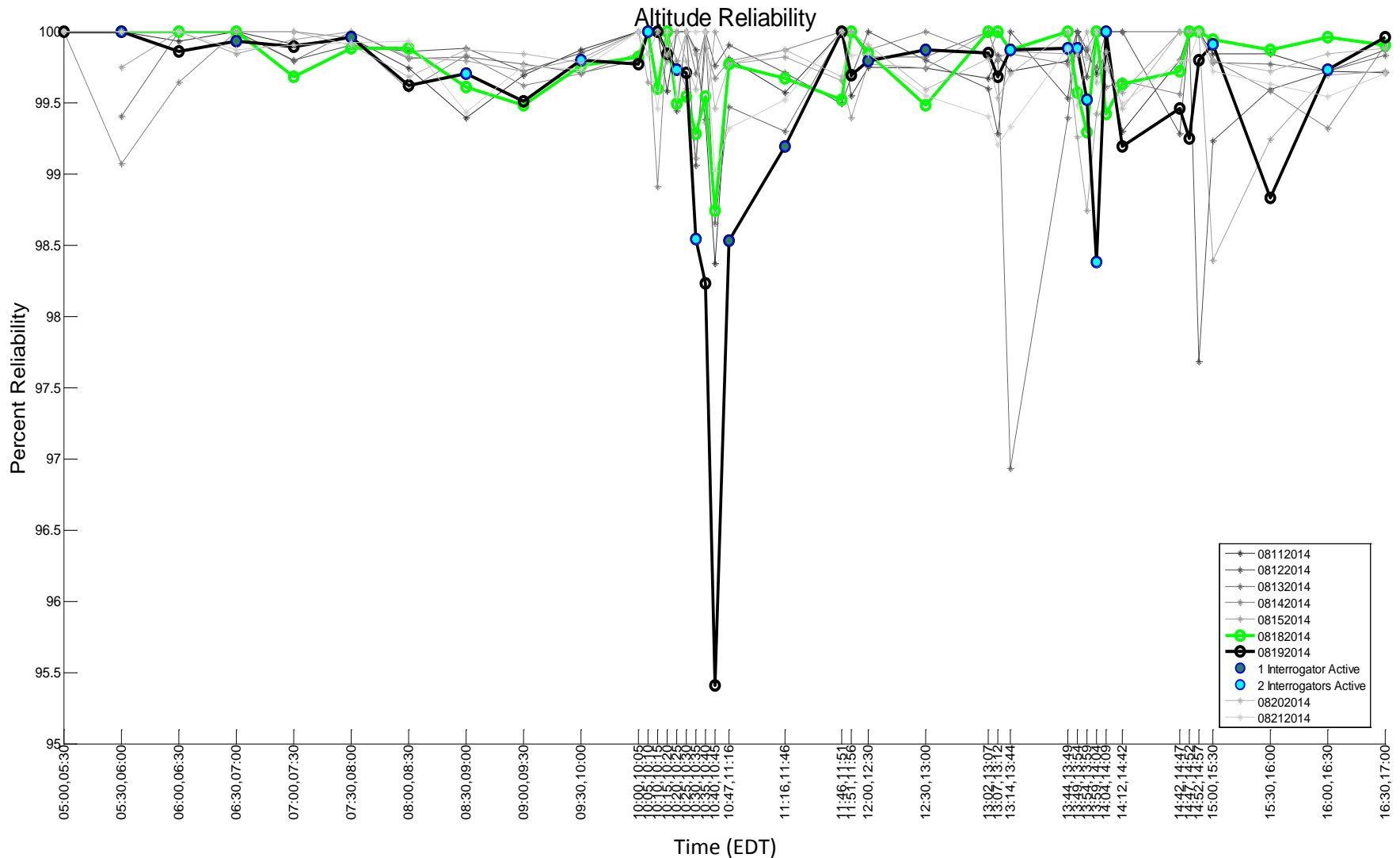
Geographic Filter: Hotspot Region  
 Target Filter: None

# Identity (3/A) Confidence – August 21<sup>st</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

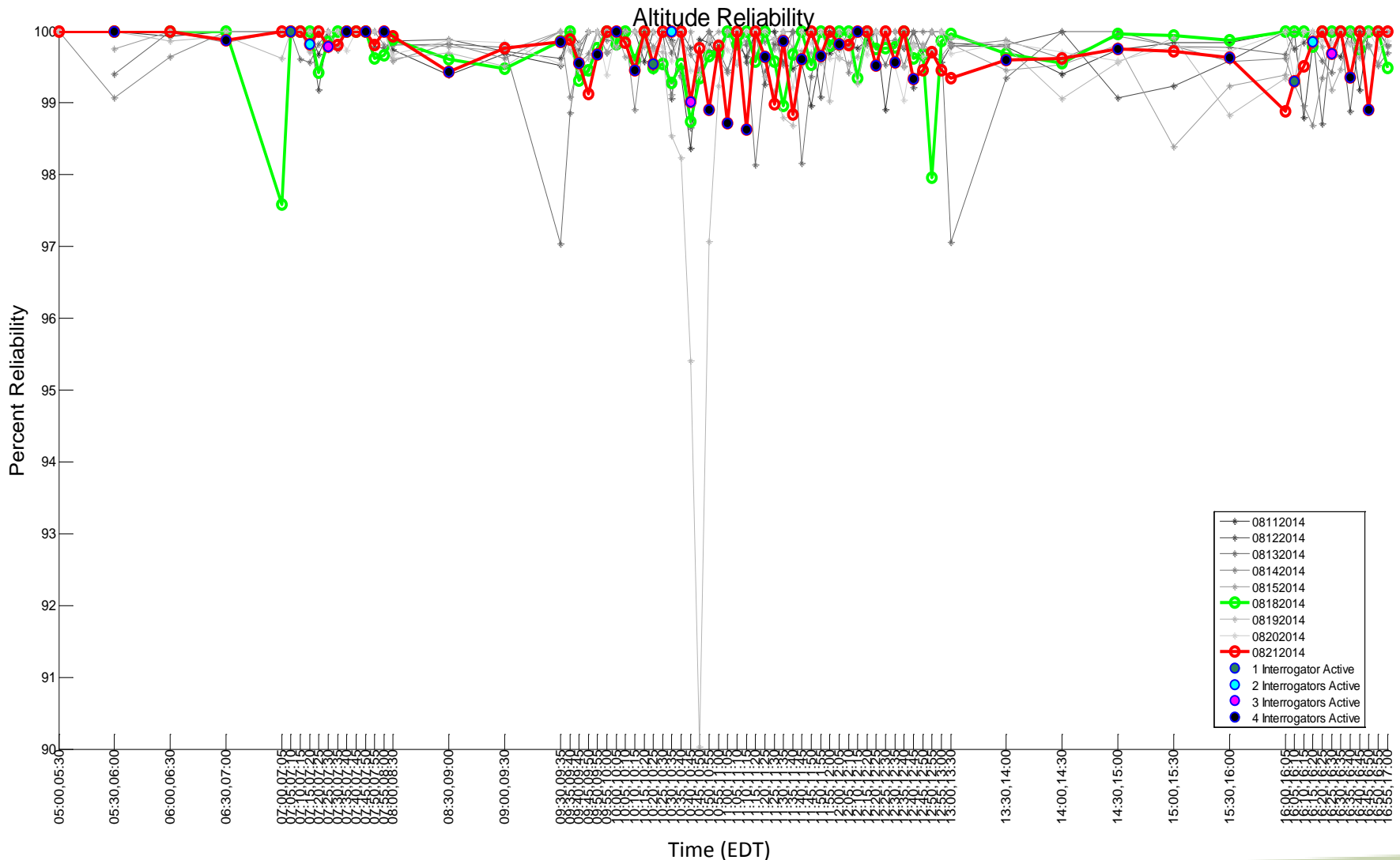
# Altitude (C) Reliability – August 19<sup>th</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

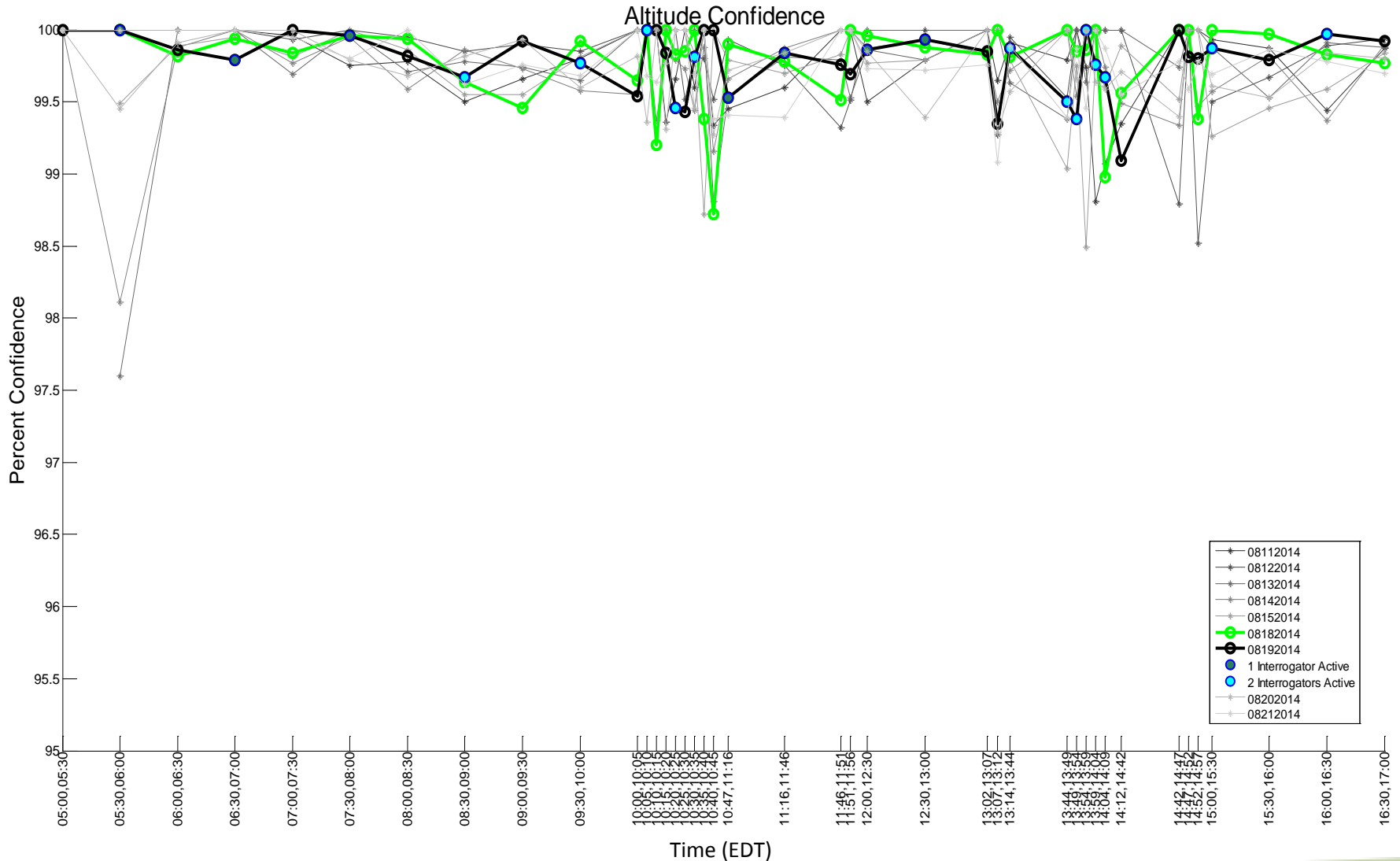


# Altitude (C) Reliability – August 21<sup>st</sup>



Geographic Filter: Hotspot Region  
 Target Filter: None

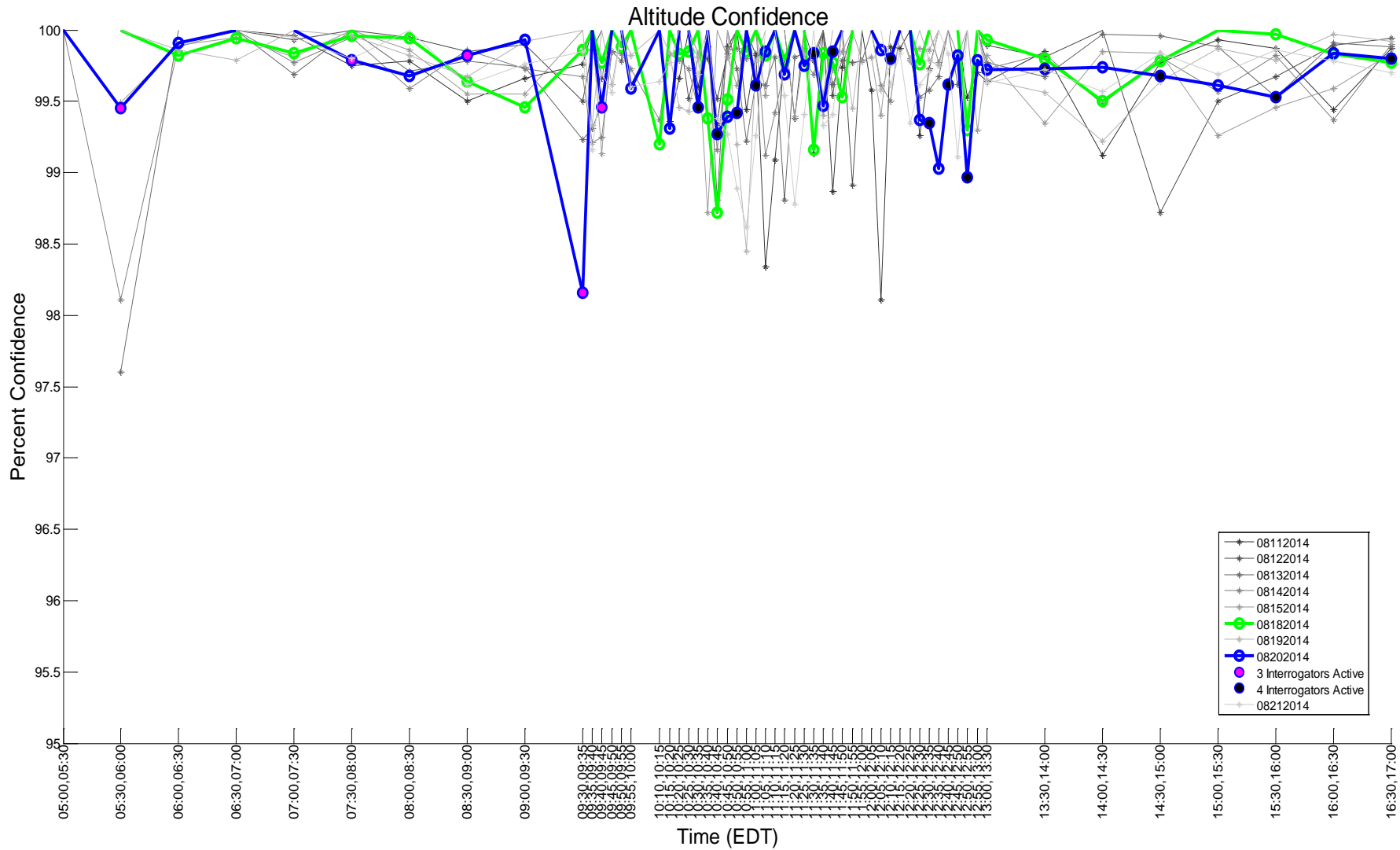
# Altitude (C) Confidence – August 19<sup>th</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

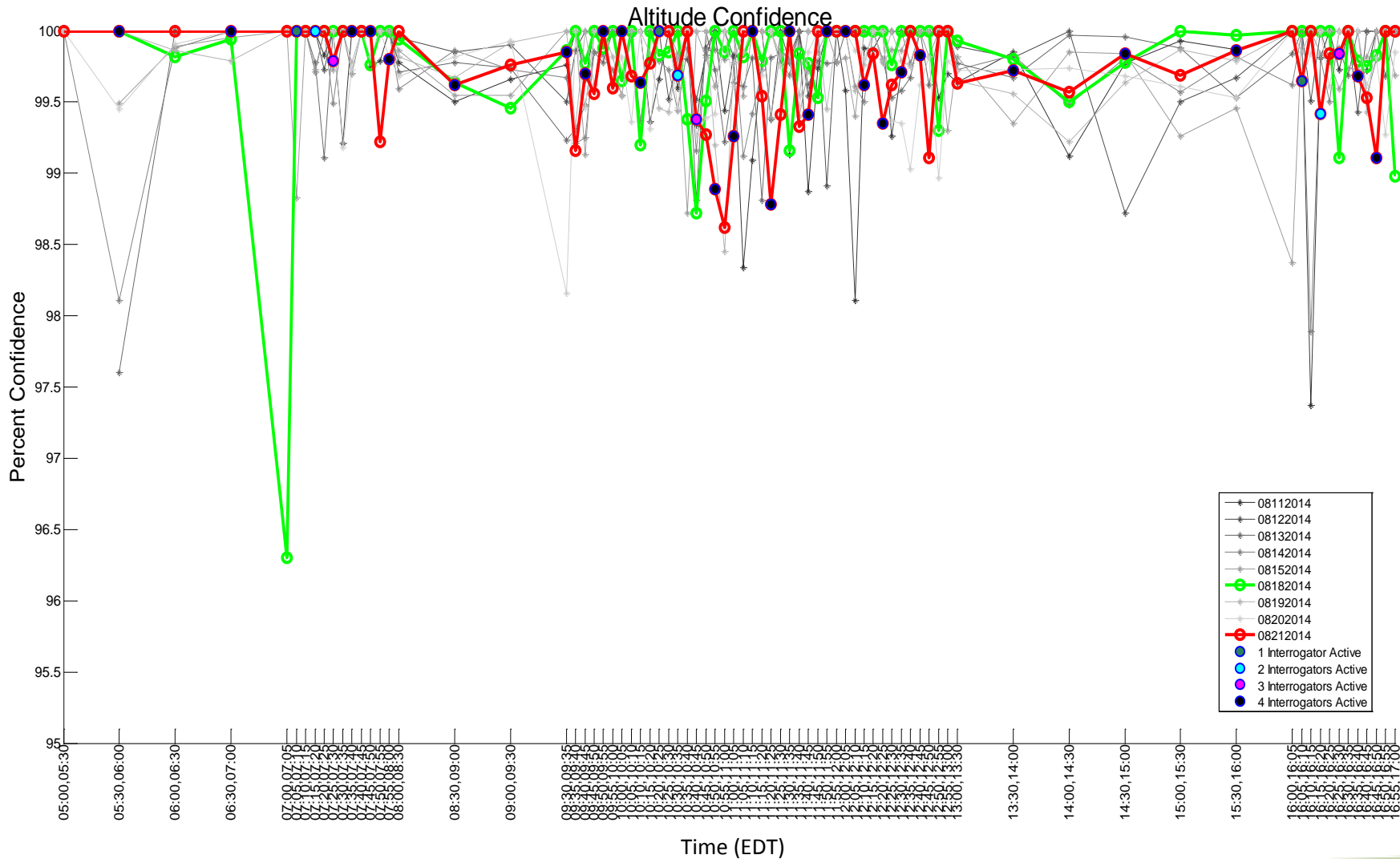


# Altitude (C) Confidence – August 20<sup>th</sup>



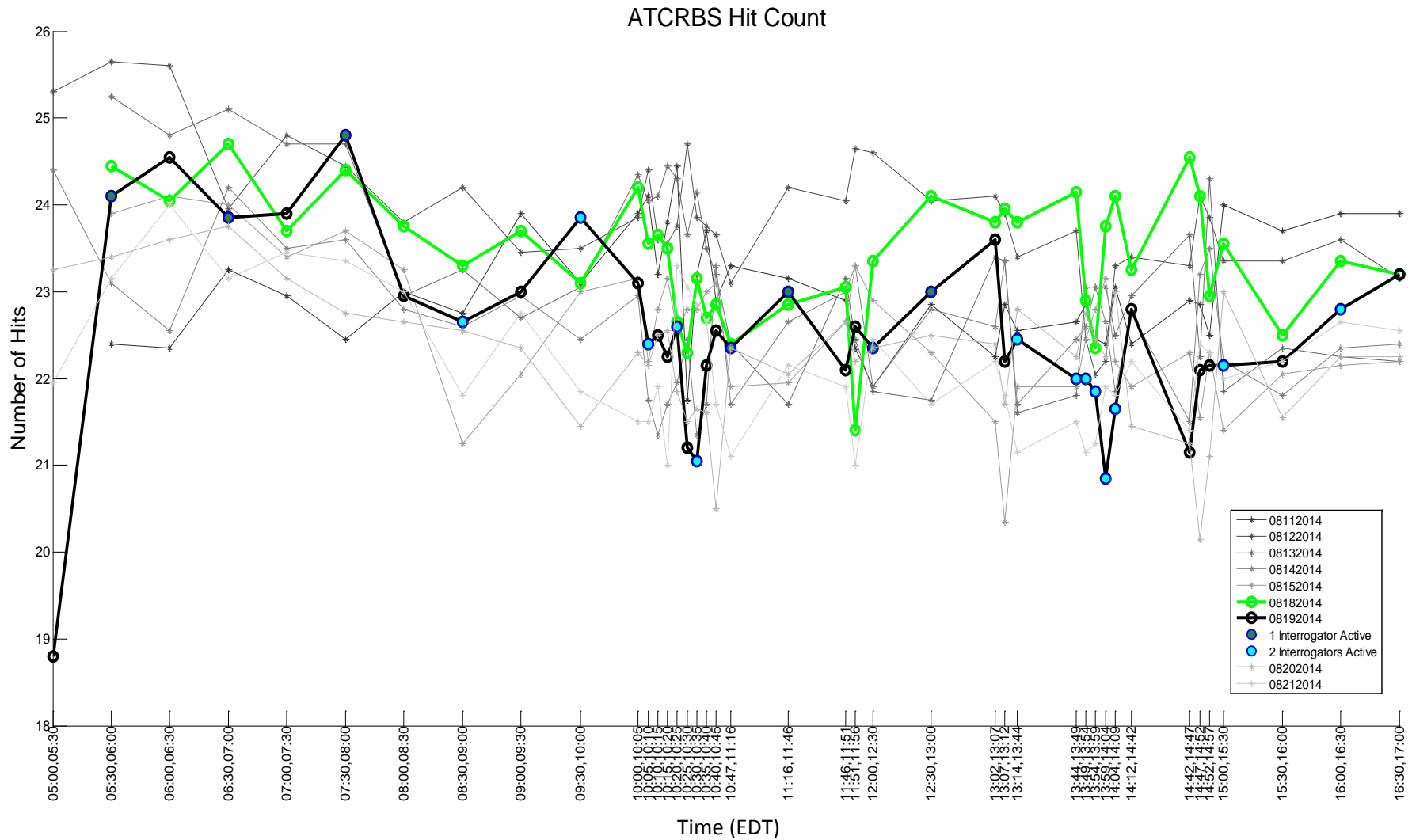
Geographic Filter: Hotspot Region  
 Target Filter: None

# Altitude (C) Confidence – August 21<sup>st</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

# Hit Count – August 19th

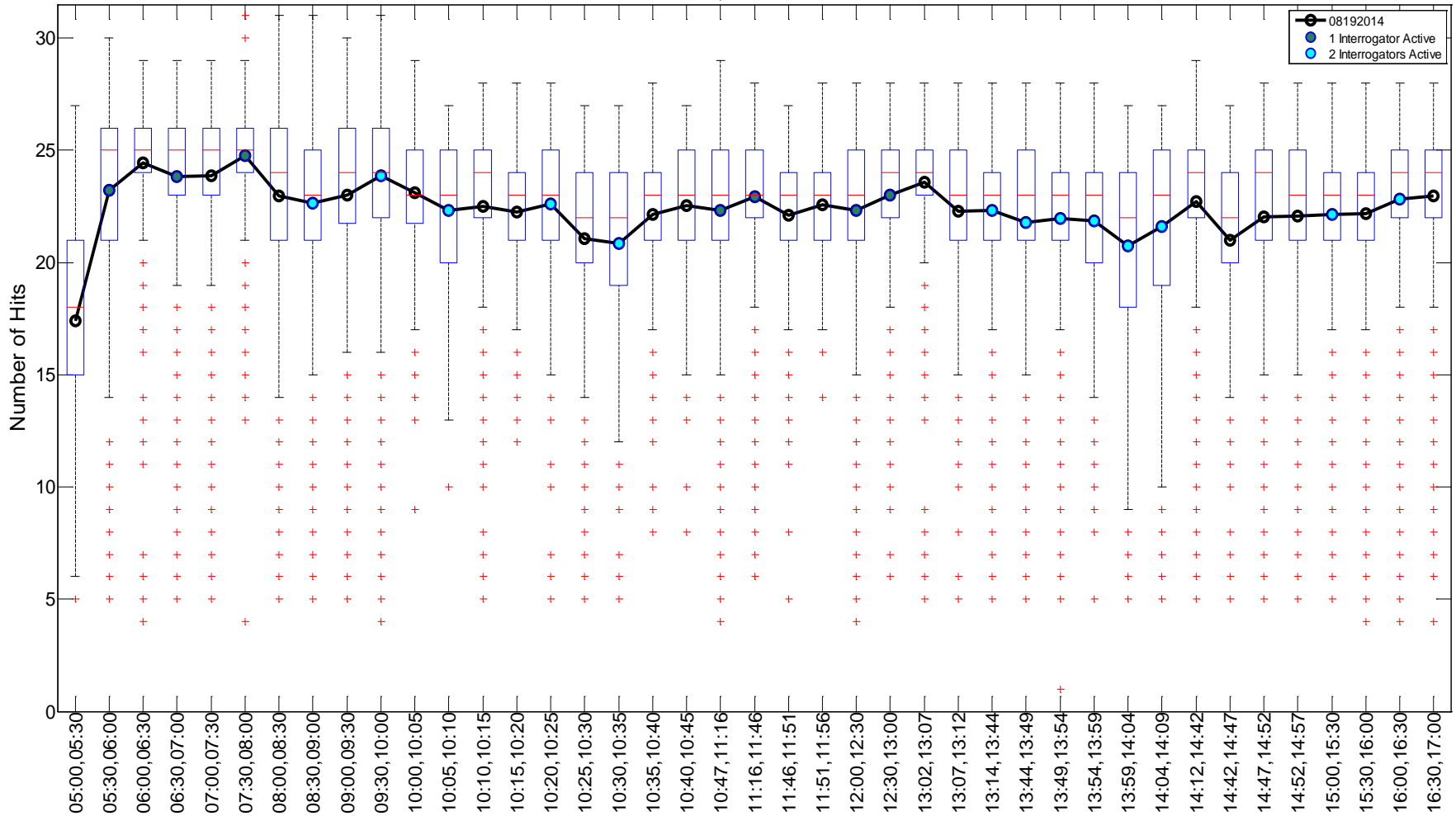


Geographic Filter: Hotspot Region  
 Target Filter: None

# Hit Count – August 19<sup>th</sup>

## Individual Aircraft Distribution

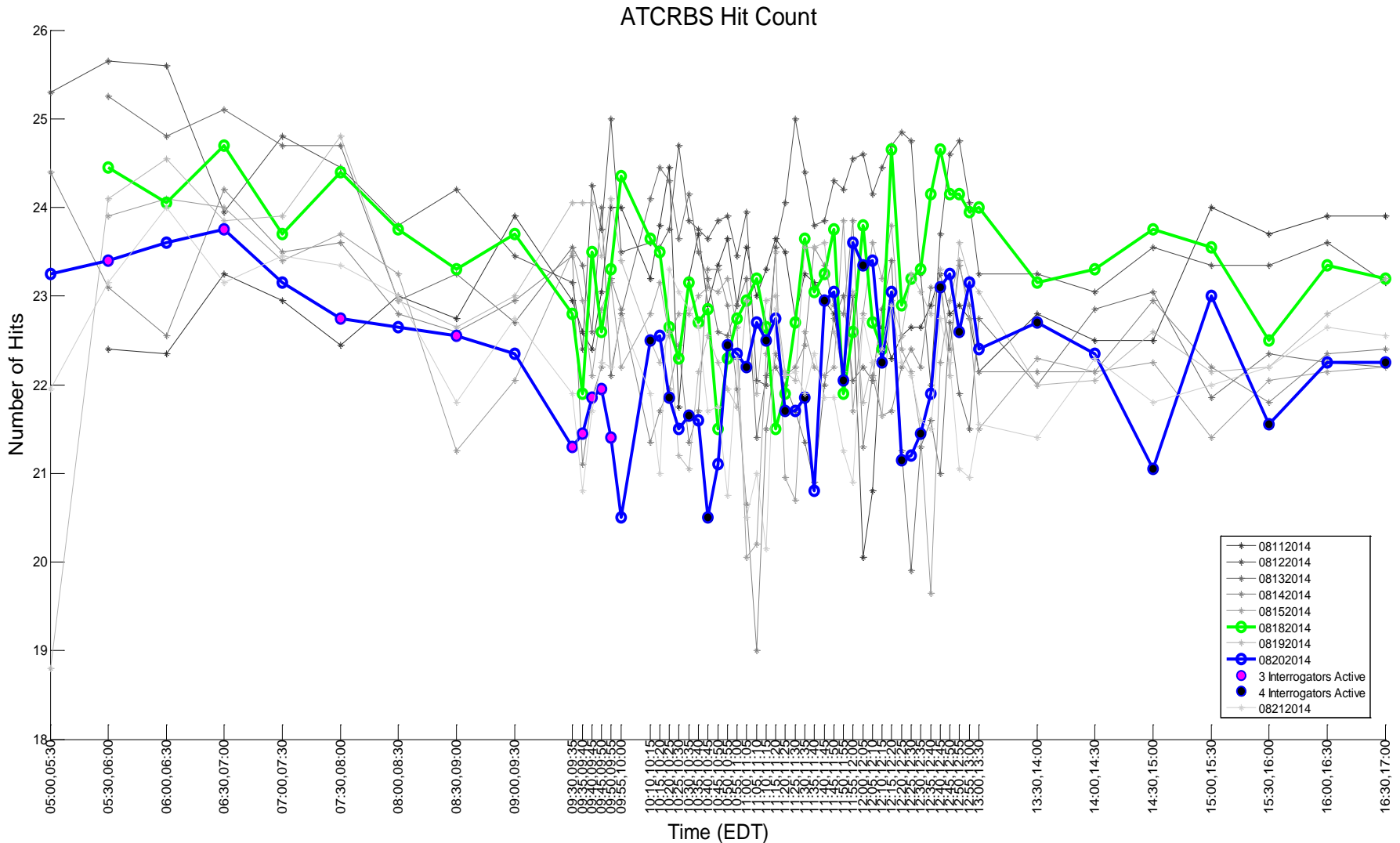
08192014 QIC: Number of Hits



Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

Geographic Filter: Hotspot Region  
Target Filter: None

# Hit Count – August 20<sup>th</sup>

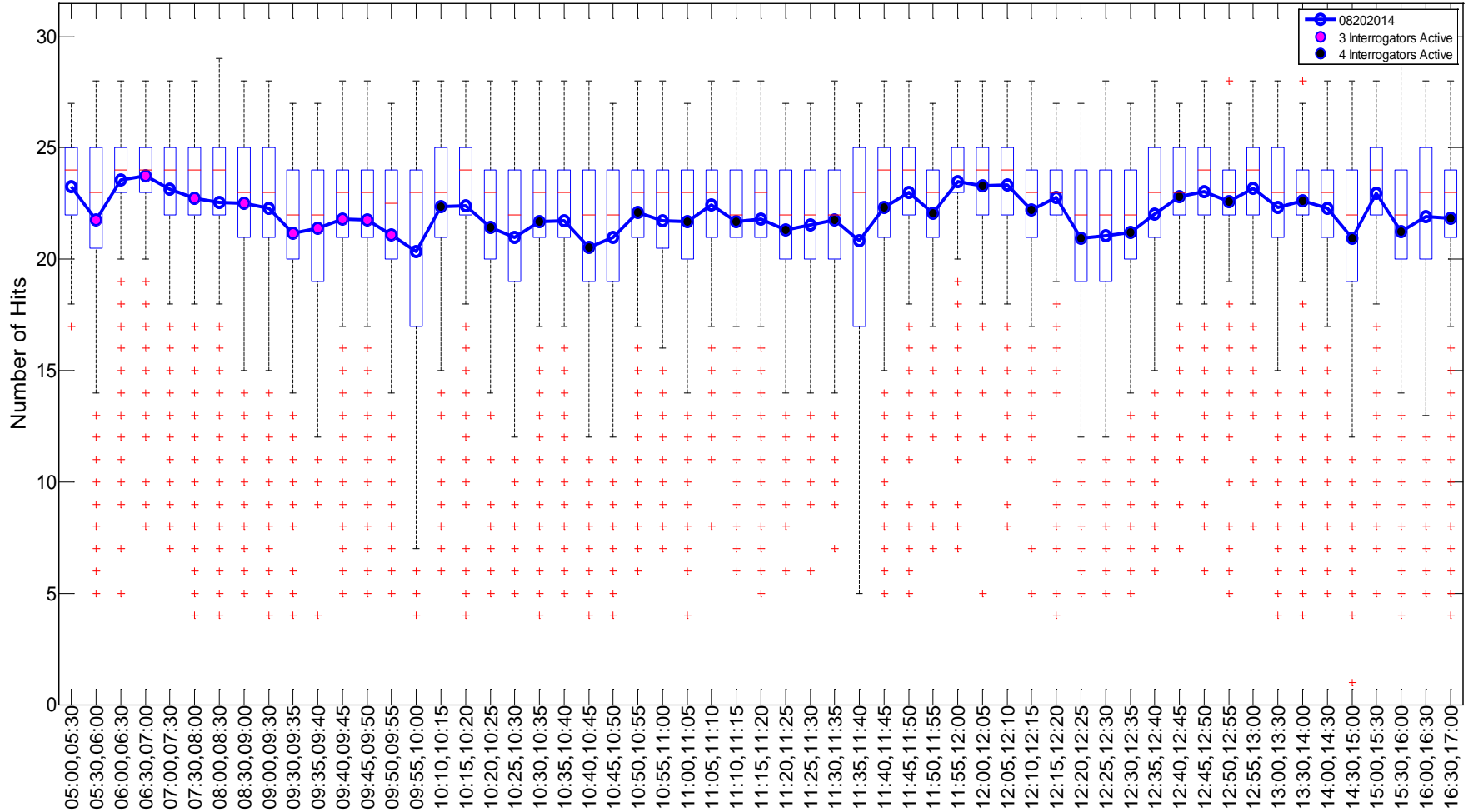


Geographic Filter: Hotspot Region  
Target Filter: None

# Hit Count – August 20<sup>th</sup>

## Individual Aircraft Distribution

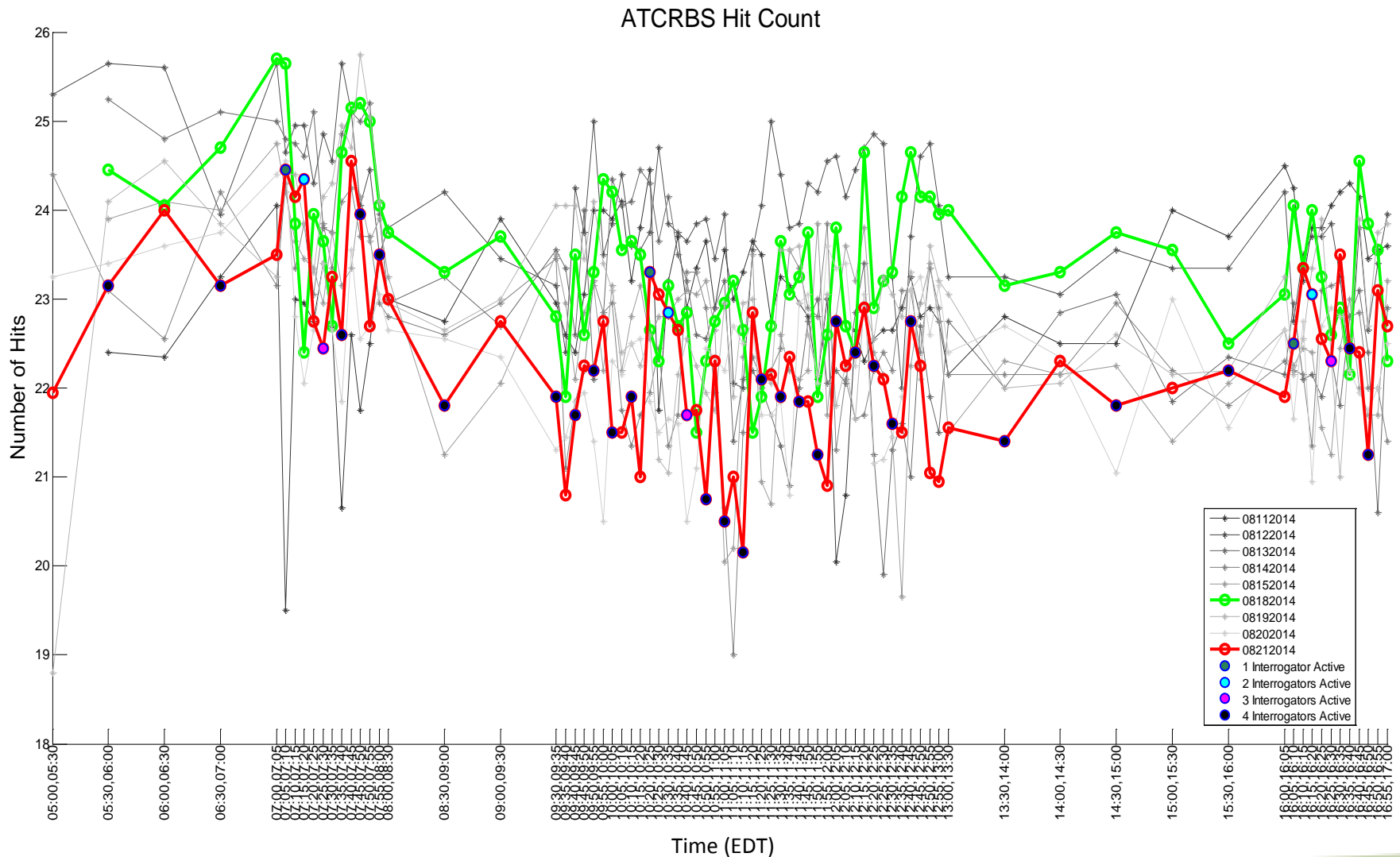
08202014 QIC: Number of Hits



Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

Geographic Filter: Hotspot Region  
Target Filter: None

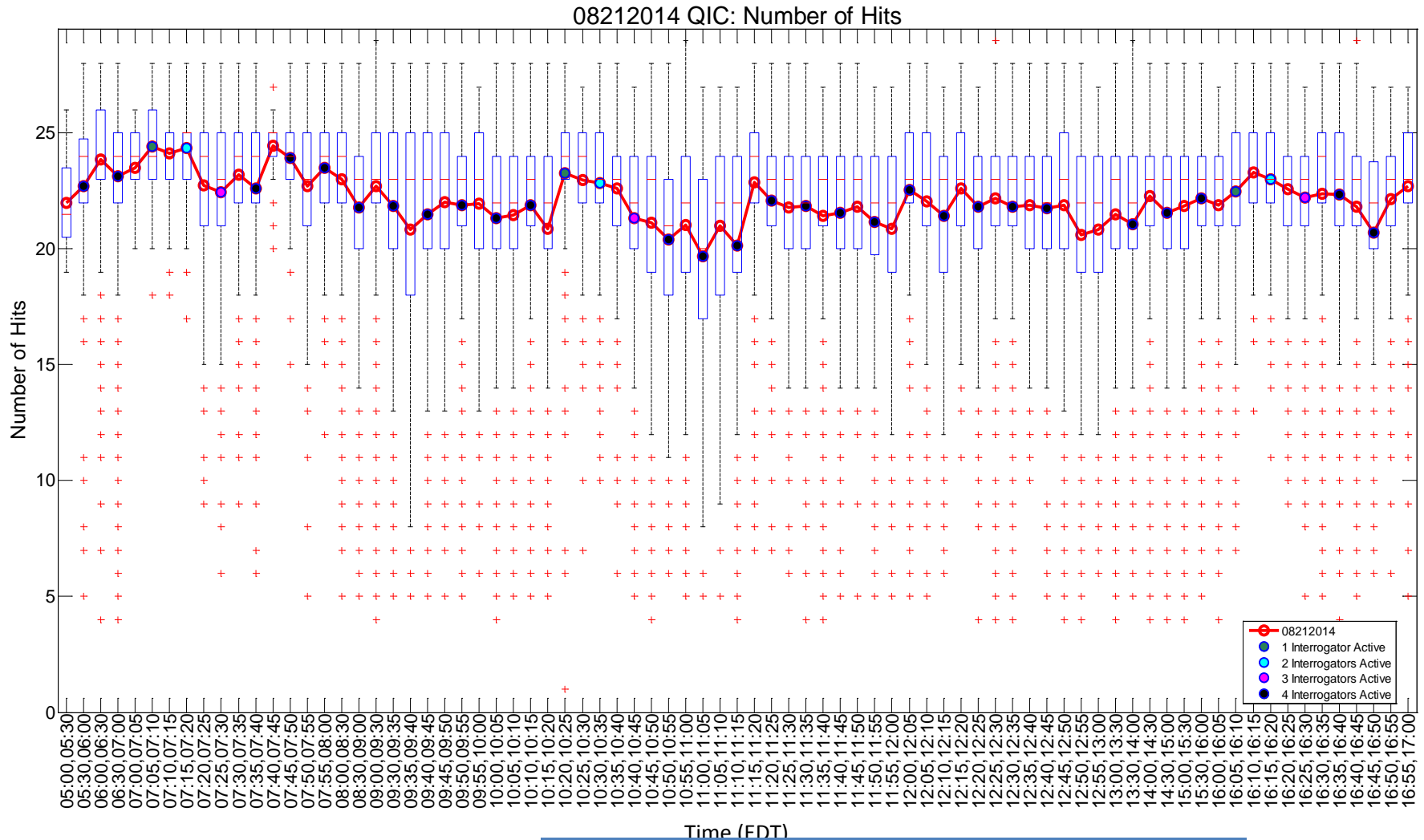
# Hit Count – August 21<sup>st</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

# Hit Count – August 21<sup>st</sup>

## Individual Aircraft Distribution



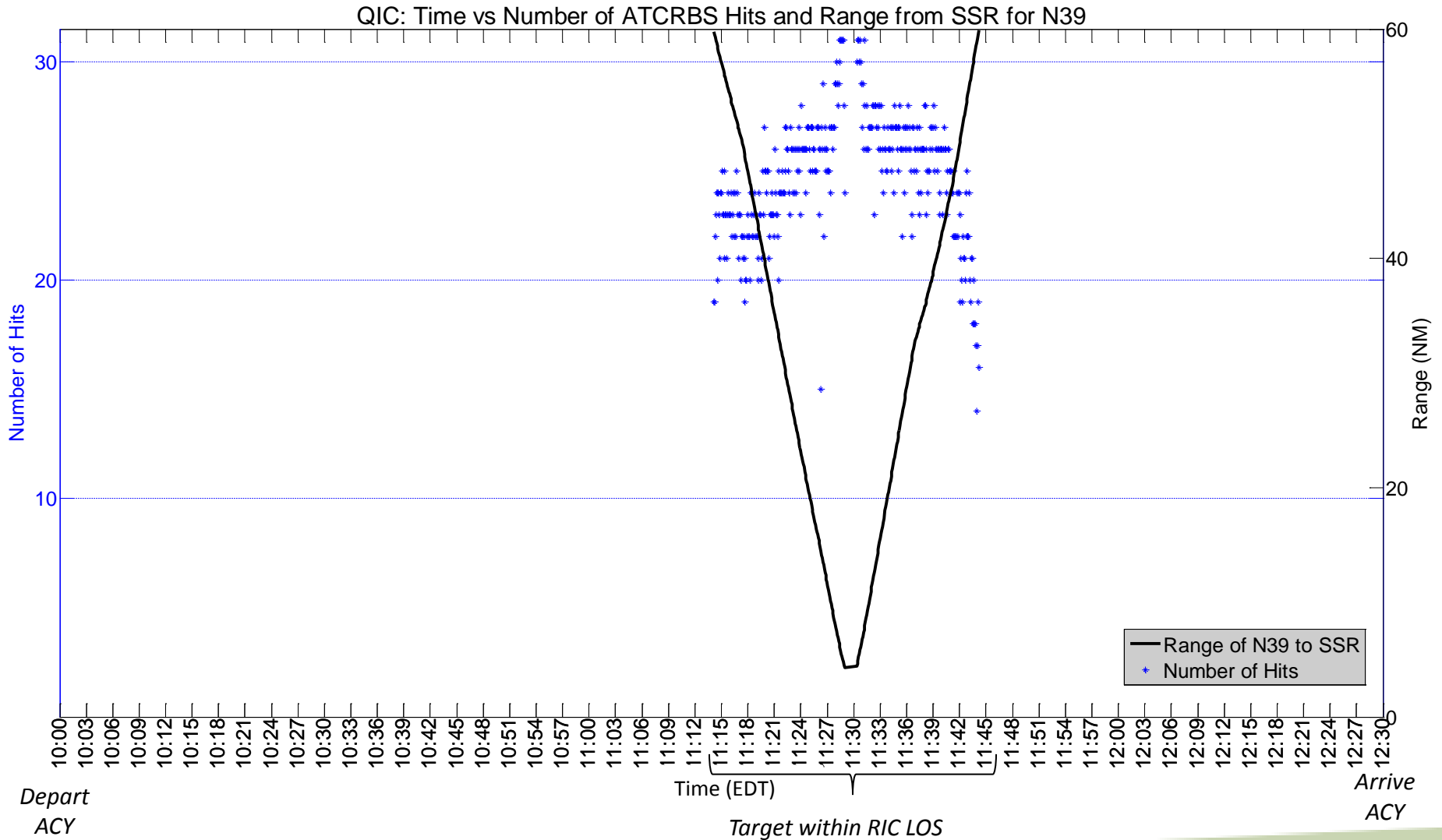
Note that the discrete nature of hit counts makes observation of the relative number of outliers impossible. These outliers will always occur as aircraft reach the edges of radar LOS. It is more important to observe changes in box and whisker lengths to ascertain the effect on the total aircraft population.

Geographic Filter: Hotspot Region  
Target Filter: None



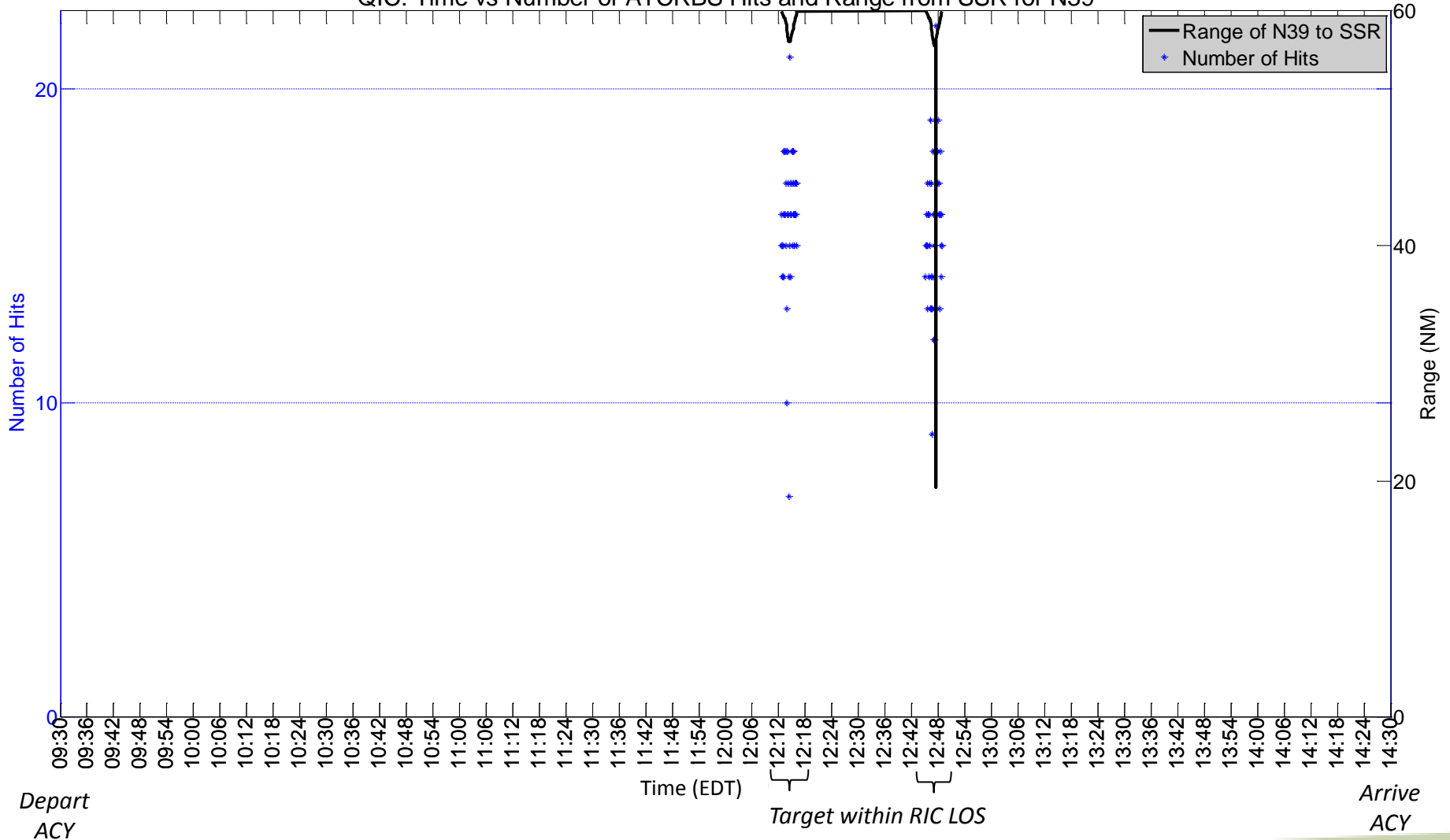
# N39 Statistics

# Time vs Range and Number of ATCRBS Hits on N39 – August 18<sup>th</sup>

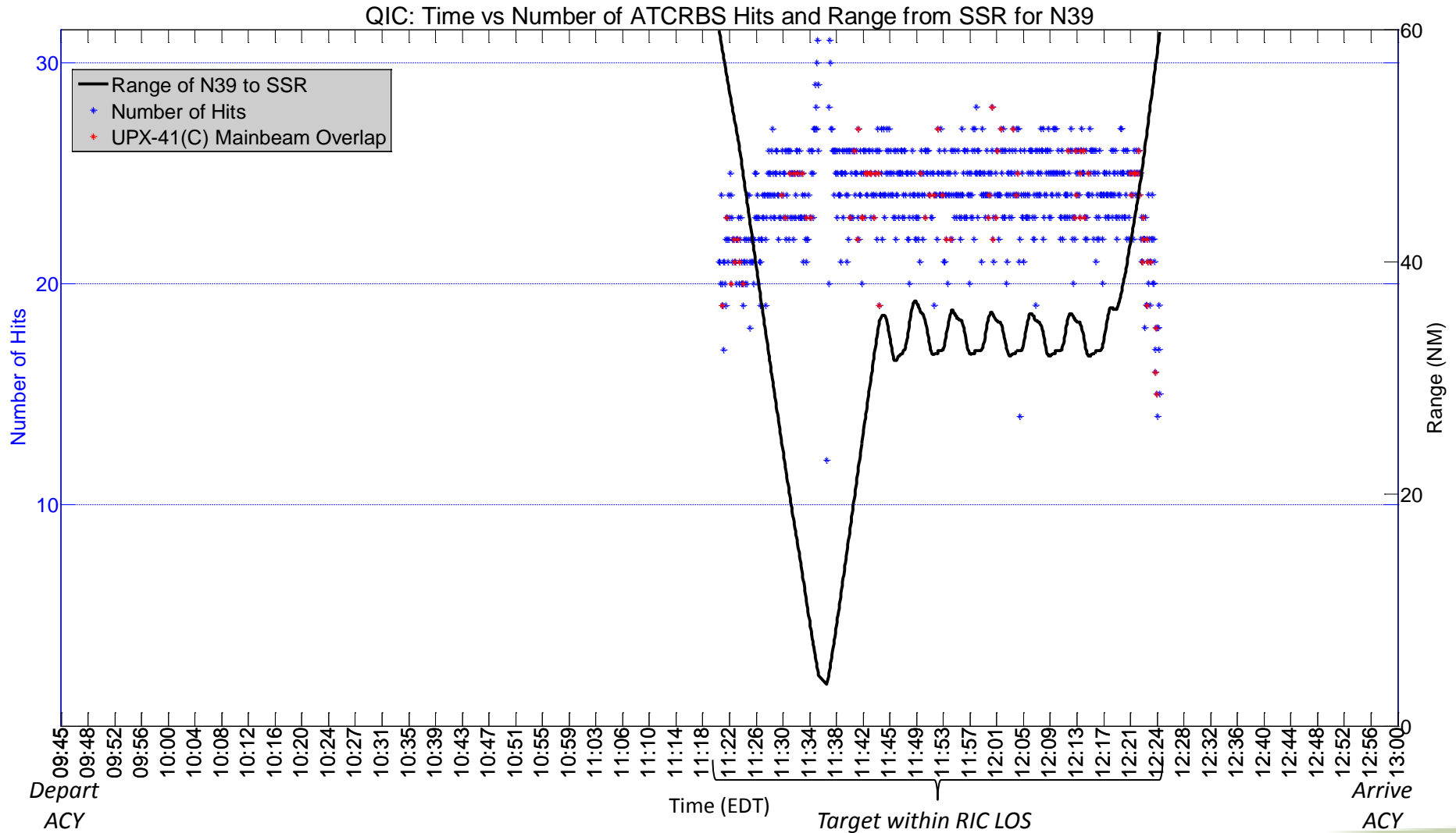


# Time vs Range and Number of ATCRBS Hits on N39 – August 19<sup>th</sup>

QIC: Time vs Number of ATCRBS Hits and Range from SSR for N39

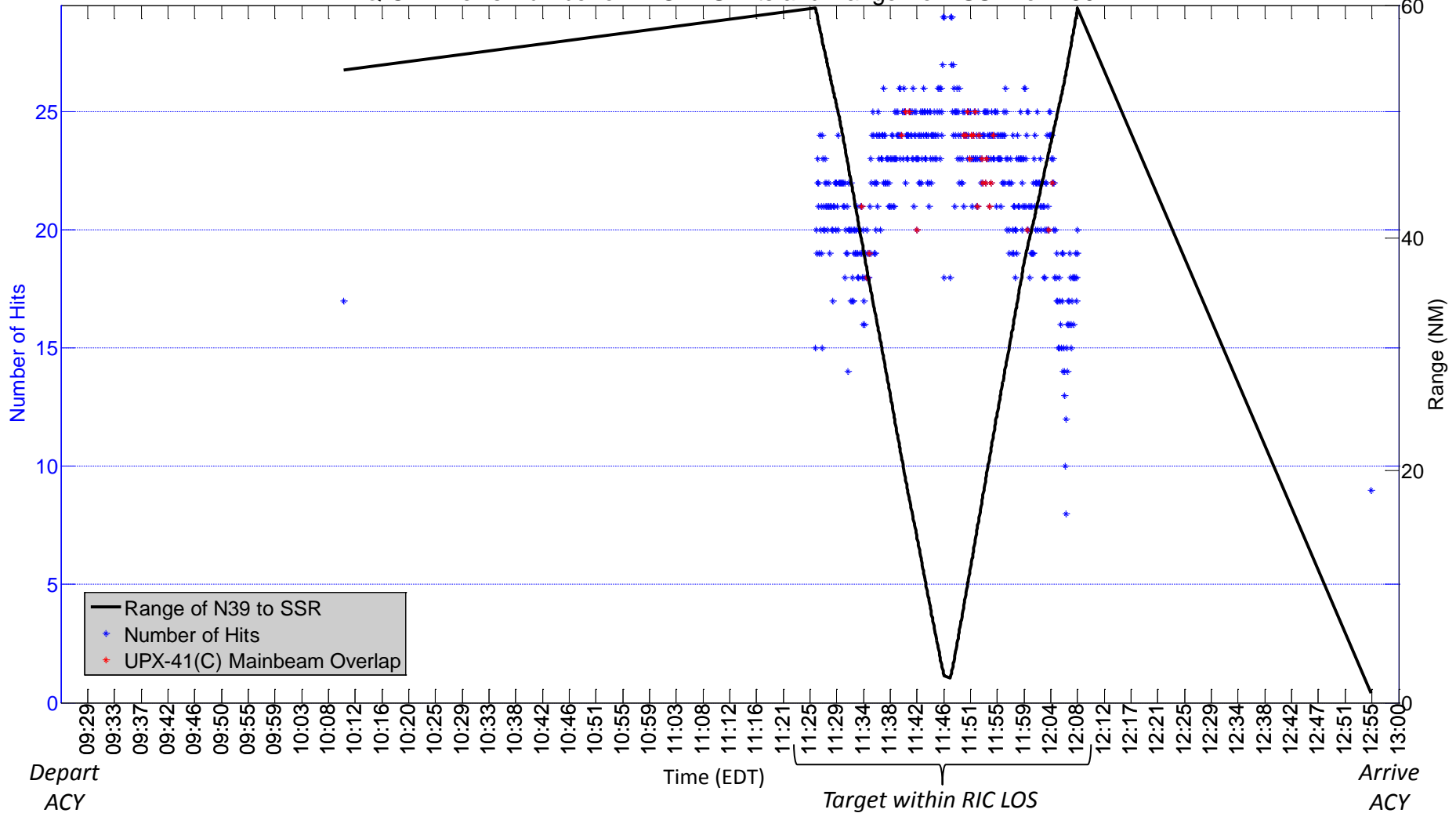


# Time vs Range and Number of ATCRBS Hits on N39 – August 20<sup>th</sup>



# Time vs Range and Number of ATCRBS Hits on N39 – August 21<sup>st</sup>

QIC: Time vs Number of ATCRBS Hits and Range from SSR for N39





# Executive Summary

- ❑ The Probability of Detection, Identity Reliability and Confidence, Altitude Reliability and Confidence, False Targets, 0000 Codes, and Targets per Scan exhibit no observable adverse trend with respect to periods of radiation by the AN/UPX-41(C) interrogator.
- ❑ During AN/UPX-41(C) interrogator radiation, the variations or volatility of the aforementioned metrics are within the bounds of the variations of the same metrics on non-test days (baseline).

# Background

- ❑ The AN/UPX-41(C)\* Stage-4 operational transmit certification for AEGIS-Class ships was signed by NTIA on June 22, 2012 with geographic and platform number restrictions when operating in proximity to the NAS.<sup>†</sup>
- ❑ Additionally, the Stage-4 certification contained a requirement for a joint FAA-Navy test to validate the operational restrictions.
- ❑ The Volpe Center, in conjunction with the Navy, FAA Spectrum, and FAA aeronautical surveillance and collision avoidance systems (ASCAS) SMEs created a test plan to validate the operational restrictions.
- ❑ From August 18-21, 2014 the FAA and Navy conducted the above-mentioned joint test, under the management of the Volpe Center.
- ❑ Since the test, the Volpe Center has analyzed recorded data to look for instances of harmful interference that would affect ASCAS system performance.

\*AN/UPX-41(C) Digital Interrogator System when operated in conjunction with the OE-120 antenna, the AN/UPX-29(V) Identification Friend or Foe (IFF) system, and the AN/UPX-24 software interface Version 2.1.2, controlled by the Cooperative Engagement Capability (CEC), in Naval surface vessels

<sup>†</sup>See SPS-18778\_1 Navy AN-UPX-41 V5.5 St4



# Test Plan Refresher

- ❑ Baseline week: August 11<sup>th</sup> – 15<sup>th</sup>
  - Baseline recording of data from 5 AM – 5 PM
    - No AN/UPX-41(C) systems Active
- ❑ Test week: August 18<sup>th</sup> – 21<sup>st</sup>
  - August 18<sup>th</sup> – Baseline recording of data from 5 AM – 5 PM
    - No AN/UPX-41(C) systems Active
  - August 19<sup>th</sup> – Record data from 5 AM – 5 PM
    - Cycle 1 and 2 AN/UPX-41(C) systems Active and OFF
  - August 20<sup>th</sup> – Record data from 5 AM – 5 PM
    - Cycle 3 and 4 AN/UPX-41(C) systems Active and OFF
  - August 21<sup>st</sup> – Record data from 5 AM – 5 PM
    - Cycle 1, 2, 3, and 4 AN/UPX-41(C) systems Active and OFF

QPL

75NM

8225

8164

Pax River  
AN/UPX-41(C)  
test sites

122 NM

V-24

V-10

Wallops Island  
AN/UPX-41(C)  
test sites

- ❑ Cycling of AN/UPX-41(C) systems Active/OFF occurred every 30 minutes; however, if N39 (Tech Center signal recording aircraft) was in the air, cycling occurred every 5 minutes
- ❑ During the test week, non-essential DoD interrogator platforms were scheduled to be inactive in order to get an accurate baseline of civil ASCAS activity
  - This did not occur. Non-test platform radiation was discovered through flight test data.

# Data Recording

- ❑ During the August test, Enroute Common Gateway (ECG) data was recorded at the Tech Center from the QPL site.
- ❑ The Radar Beacon Analysis Tool (RBAT) was used to analyze ECG data to produce statistics for the following list of parameters:
  - Targets per Scan
  - Probability of Detection
  - Identity Reliability
  - Identity Confidence
  - Altitude Reliability
  - Altitude Confidence
  - False Target Percentage
  - 0000 Code Percentage

# Data Analysis Methodology

- ❑ Applied time bins that corresponded to the AN/UPX-41(C) Active/OFF periods from test days (August 19<sup>th</sup>-21<sup>st</sup>) to baseline days to produce baseline statistics
- ❑ Data was first analyzed without any geographic or target filters
  - In analyzing possible cases of interference, it was determined that targets at low elevation angles exhibited relatively low probabilities of detection regardless of Active/OFF period
  - This behavior was not conducive to pinpointing interference events
- ❑ Analysis of targets at elevation angles greater than 0.5° was prepared
  - Interference events would be easier to see if targets that were already behaving poorly were excluded from the analysis
- ❑ Targets that were beyond 190 NM from the SSR site were analyzed
  - Replies from targets at the edge of the coverage area are more likely to be lost to overpowering FRUIT
- ❑ Data was analyzed using a geographic filter that represented the area of AN/UPX-41(C) systems' sidelobes (subsequently referred to as the Hotspot area) – the area where transponder occupancy due to AN/UPX-41(C) would be the greatest
  - Assumption: AN/UPX-41(C) sidelobes extend 40 NM
  - Recent developments from flight test data show that P2 pulse can be seen up to 40 NM; however, only caused N39 ownship transponder suppressions up to 20 NM

# Analysis Limitations

- ❑ The theoretical or textbook definition of probability of detection is a function of interrogation/reply round reliability.
- ❑ However, probability of detection in RBAT is the percentage of target updates versus total number of beam dwells over all targets.
- ❑ Therefore, the ability for probability of detection calculated by RBAT to properly represent theoretical probability of detection is minimized as the sample size decreases (either through geographical or time constraints) since it no longer reliably reflects the target population mean.
- ❑ Example: A target population of two where both targets miss one update out of ten scans (approximately 50 seconds) results in a probability of detection of 90%. While this is unacceptable by QARS blip/scan minimums, we have no knowledge of the updates that occurred outside of the given time constraint . If both targets received ten out of ten updates for the previous as well as the next 10 scans, the probability of detection is now 96.7%.

# Analysis Objective

- ❑ We are attempting to observe distinct patterns of change in the metrics of interest between times when the AN/UPX-41(C) systems are OFF and when they are Active.
- ❑ While geographic and time filters reduces target update sample sizes such that a small sample size itself influences the metric of interest, it is more important to focus on the change from Off to Active since both the Off and Active periods have the same constraints applied.

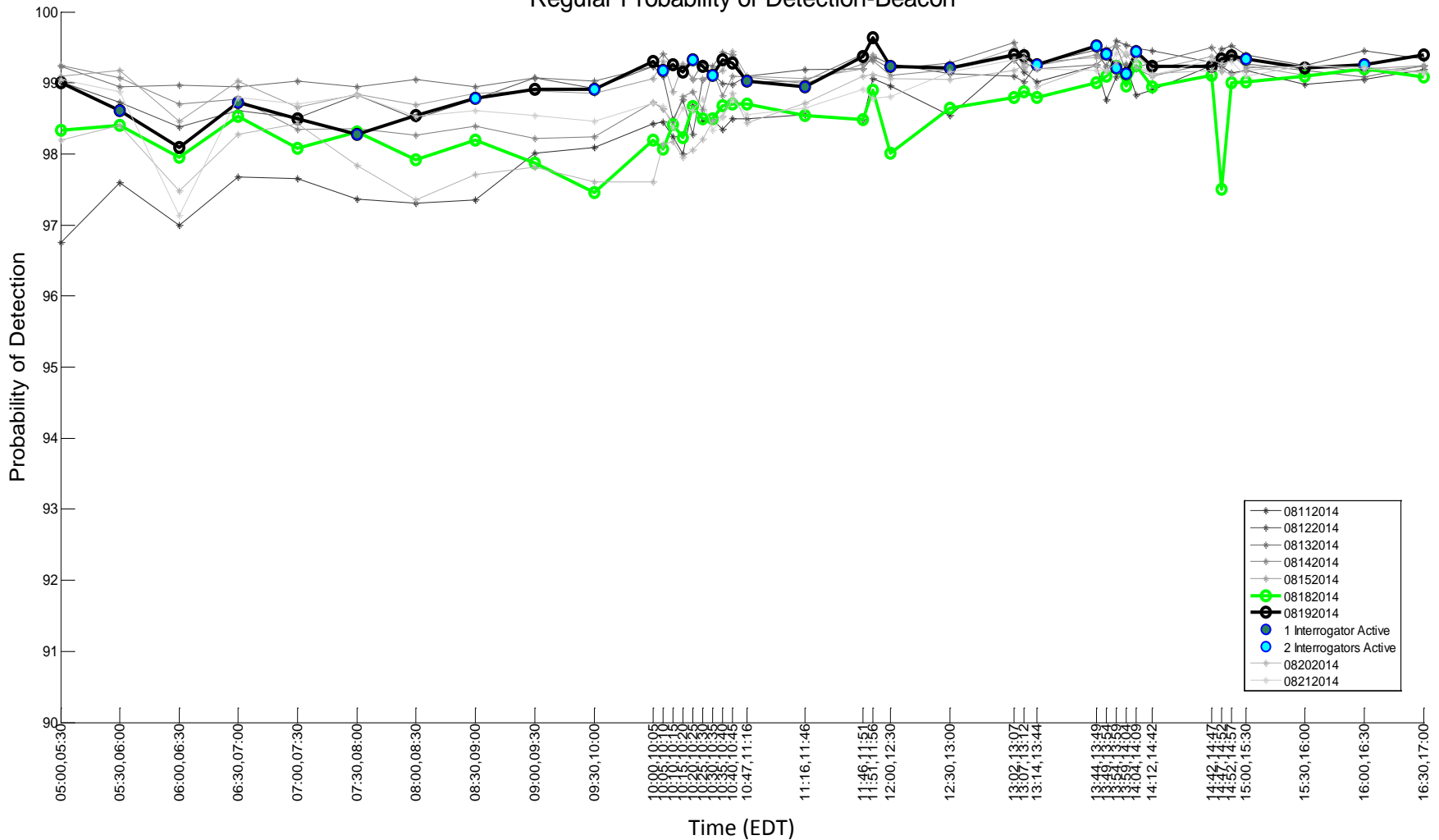
# Plot Guide

- ❑ There are four sets of plots that correspond to the data analysis methodology discussed previously
  1. No filters
  2. Filter on targets with elevation angle greater than 0.5 degrees
  3. Filter on targets with range greater than 190 NM from SSR
  4. Filter on targets within Hotspot
- ❑ Plots with multiple days of data utilize the time filters from the Active/Off periods for the date given in the slide's title
- ❑ Plots that use boxplots
  - The edges of the box are the 25<sup>th</sup> and 75<sup>th</sup> percentiles. The maximum whisker length represents approximately 2.7 sigma (99.3%). Points in red are shown as outliers.
  - For five minute time bins, there are only 25 QPL scans and, if you miss one target update, Pd will automatically drop to 96% (24 out of 25 possible target reports).
  - Horizontal axis 30-min and 5-min time bins are not scaled according to duration

# Target Metrics with No Filter

# Probability of Detection – August 19<sup>th</sup>

Regular Probability of Detection-Beacon

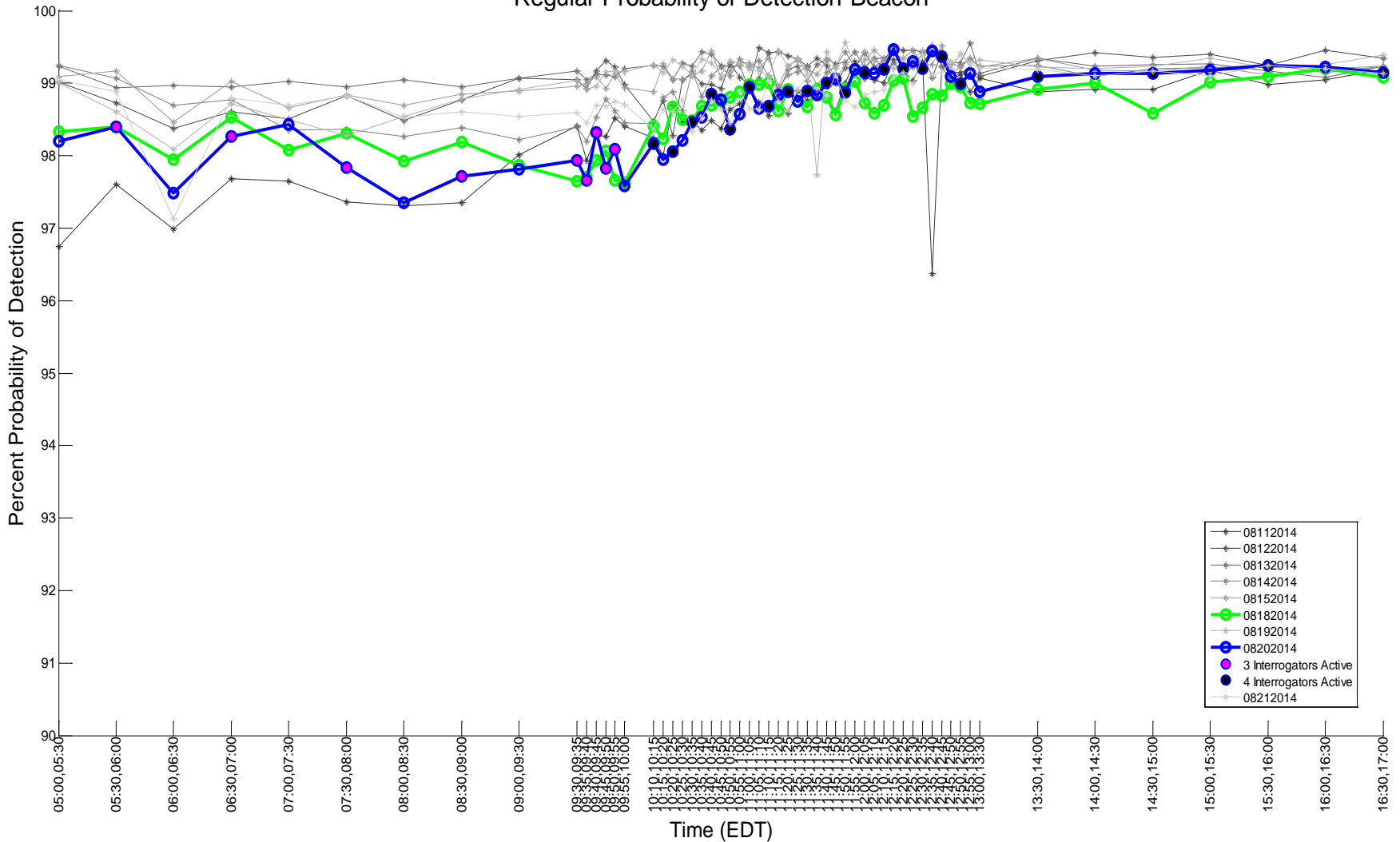


Geographic Filter: None  
Target Filter: None



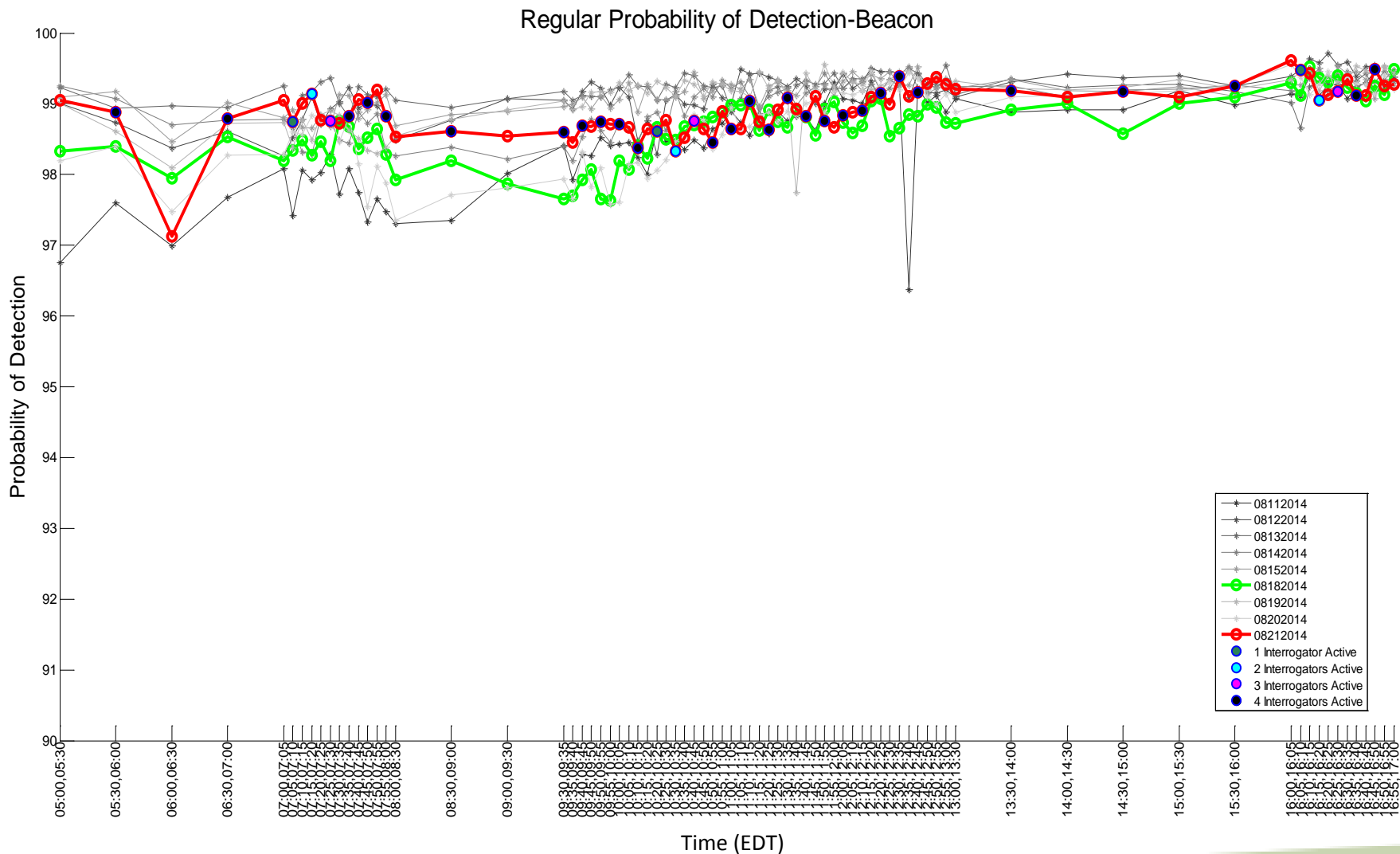
# Probability of Detection – August 20<sup>th</sup>

Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

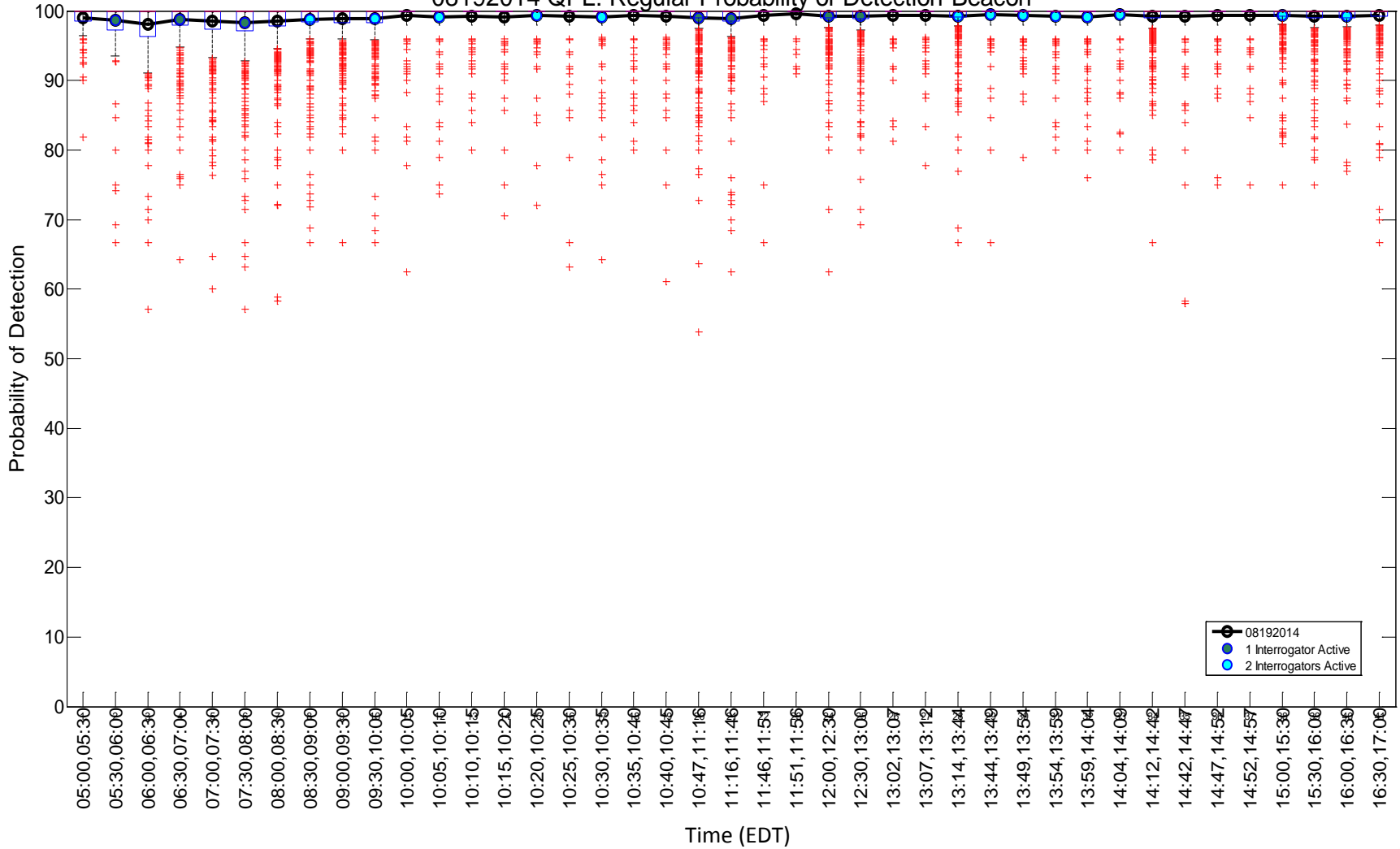


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution

08192014 QPL: Regular Probability of Detection-Beacon

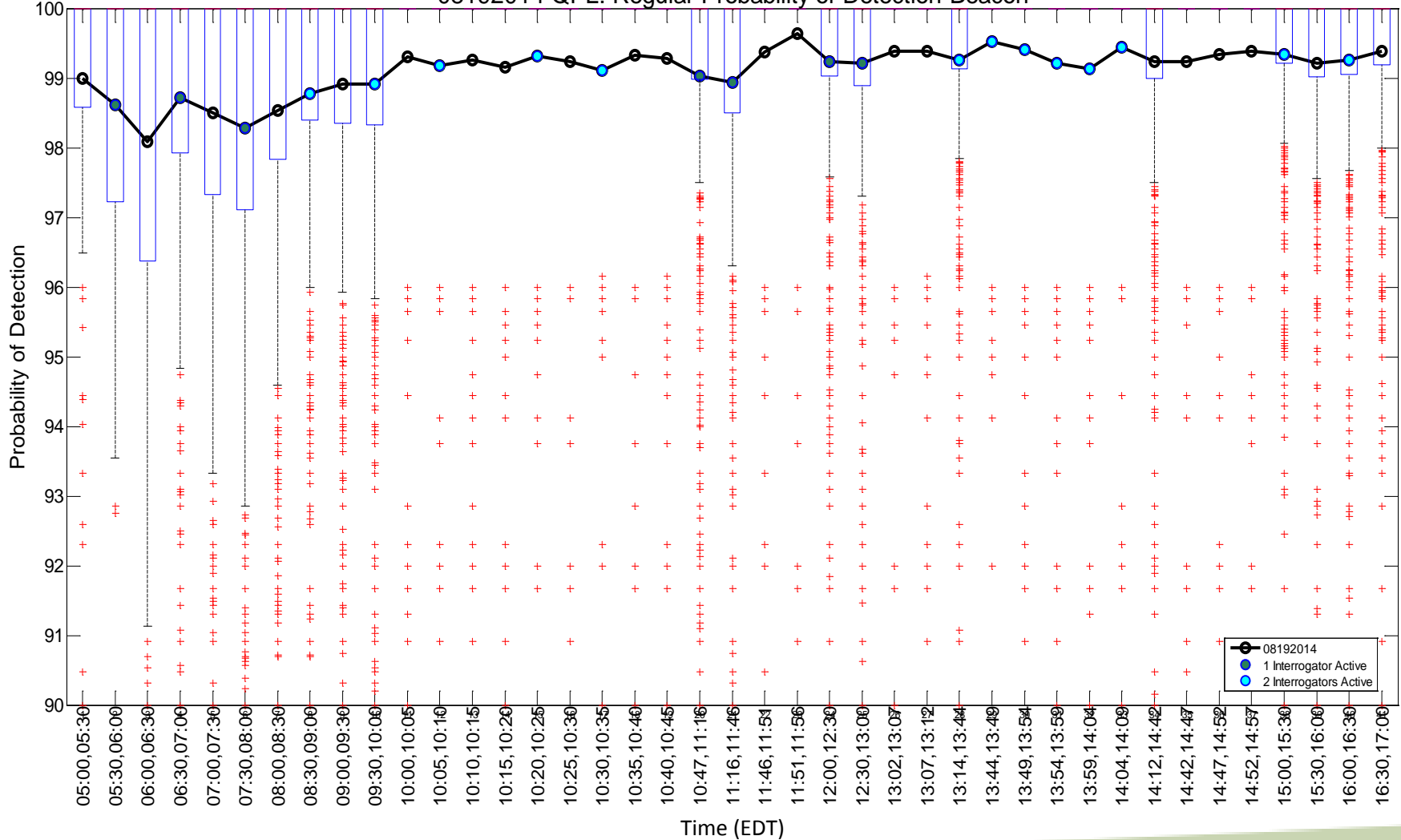


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

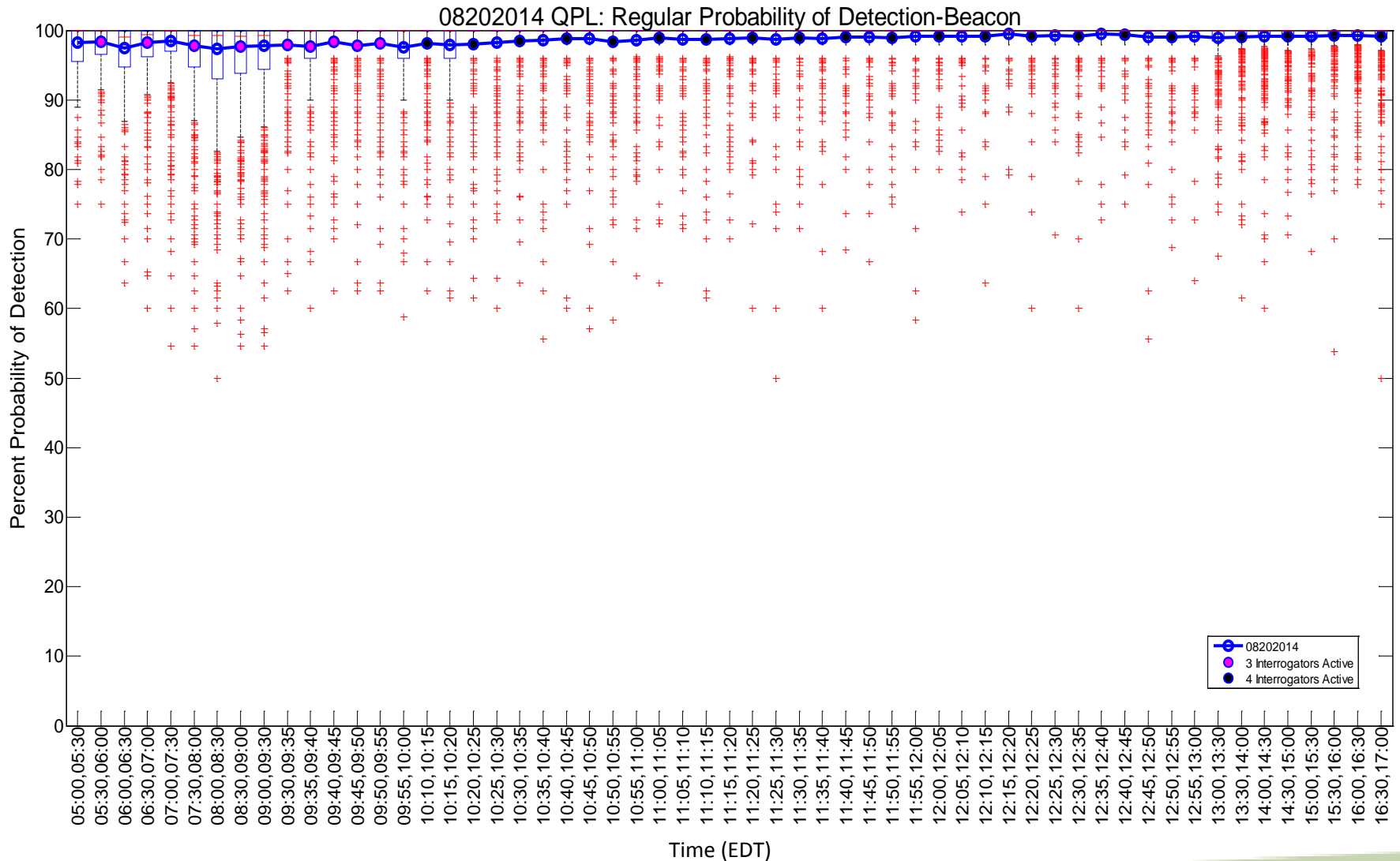
08192014 QPL: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

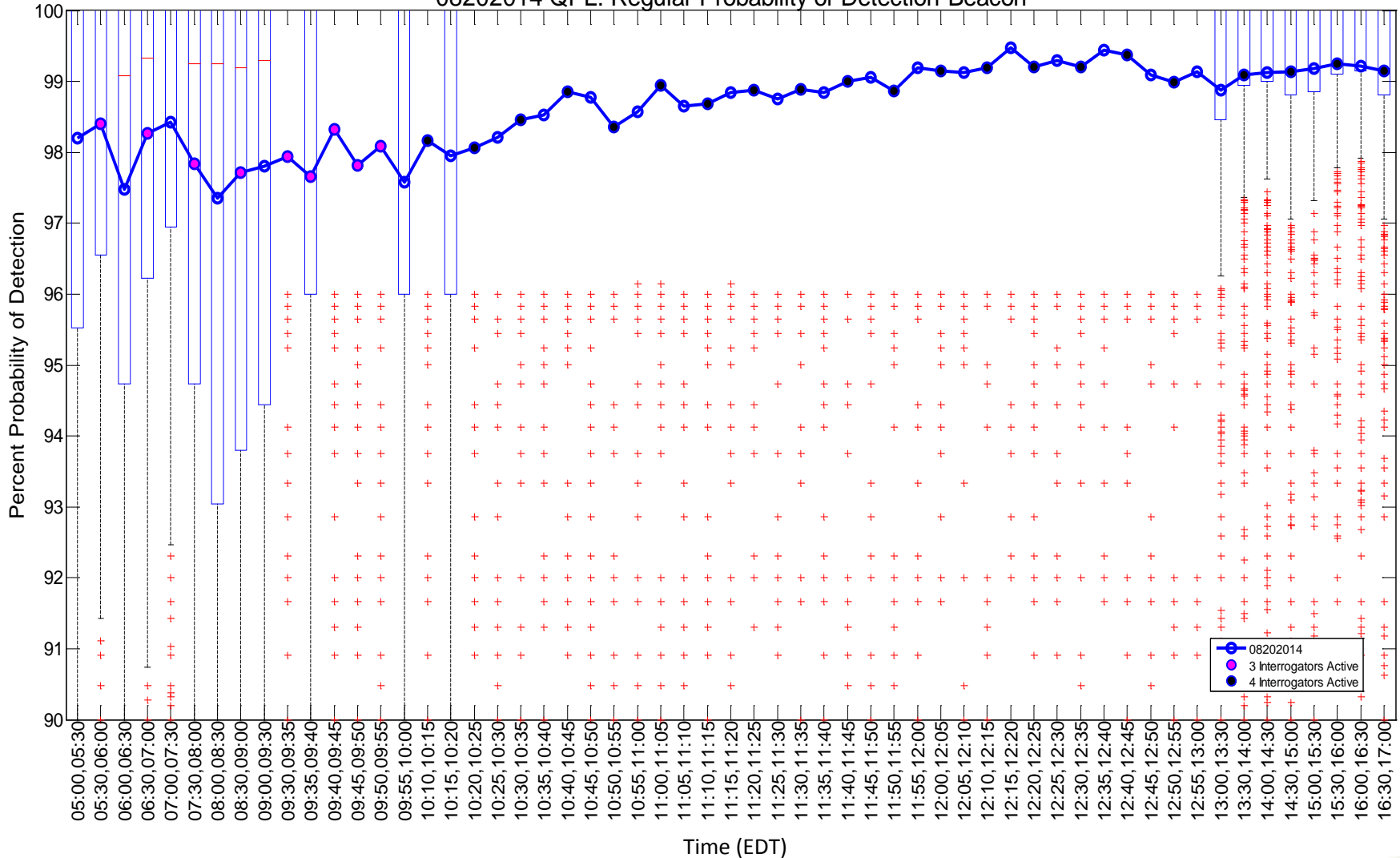


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

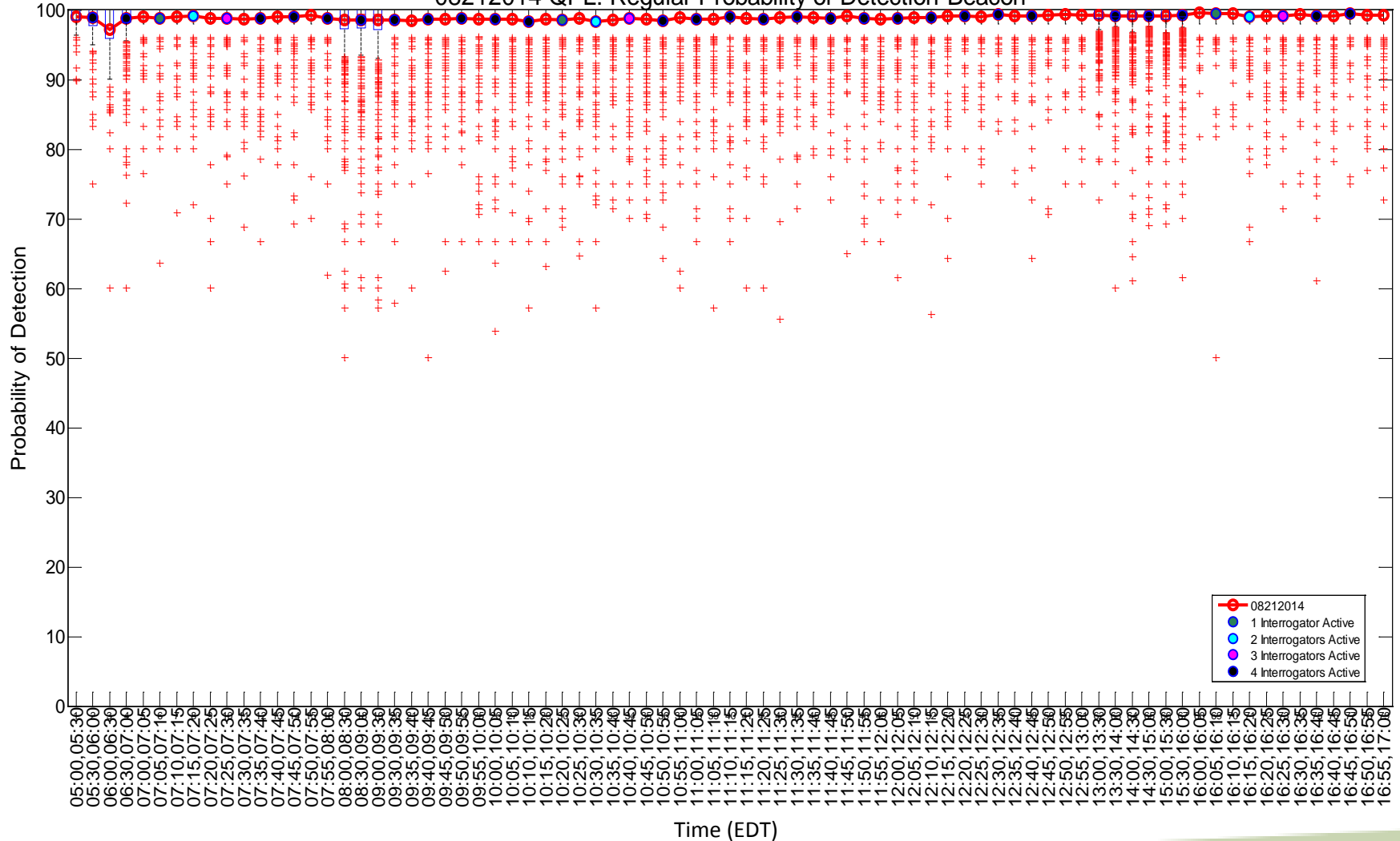
08202014 QPL: Regular Probability of Detection-Beacon



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

08212014 QPL: Regular Probability of Detection-Beacon

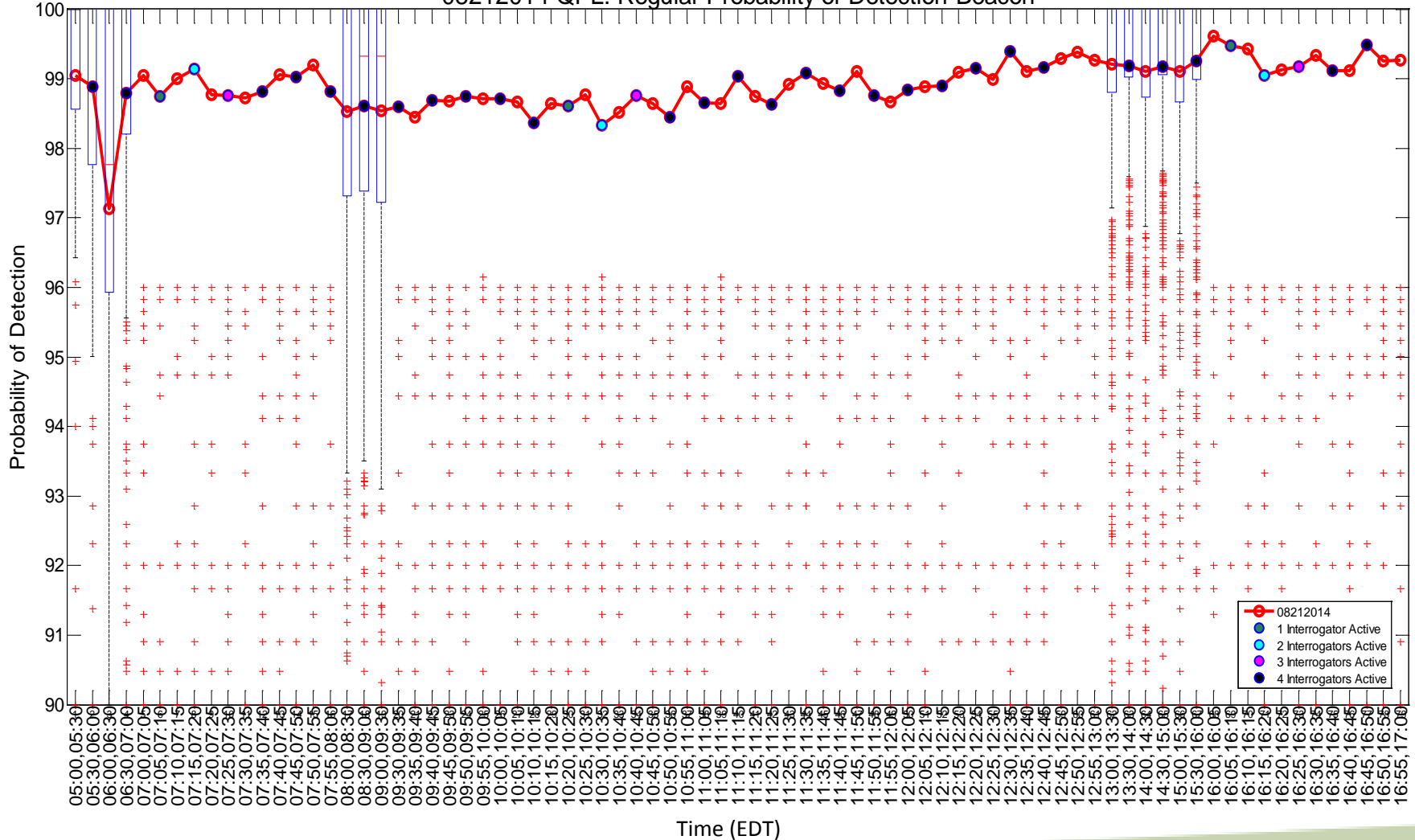


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)

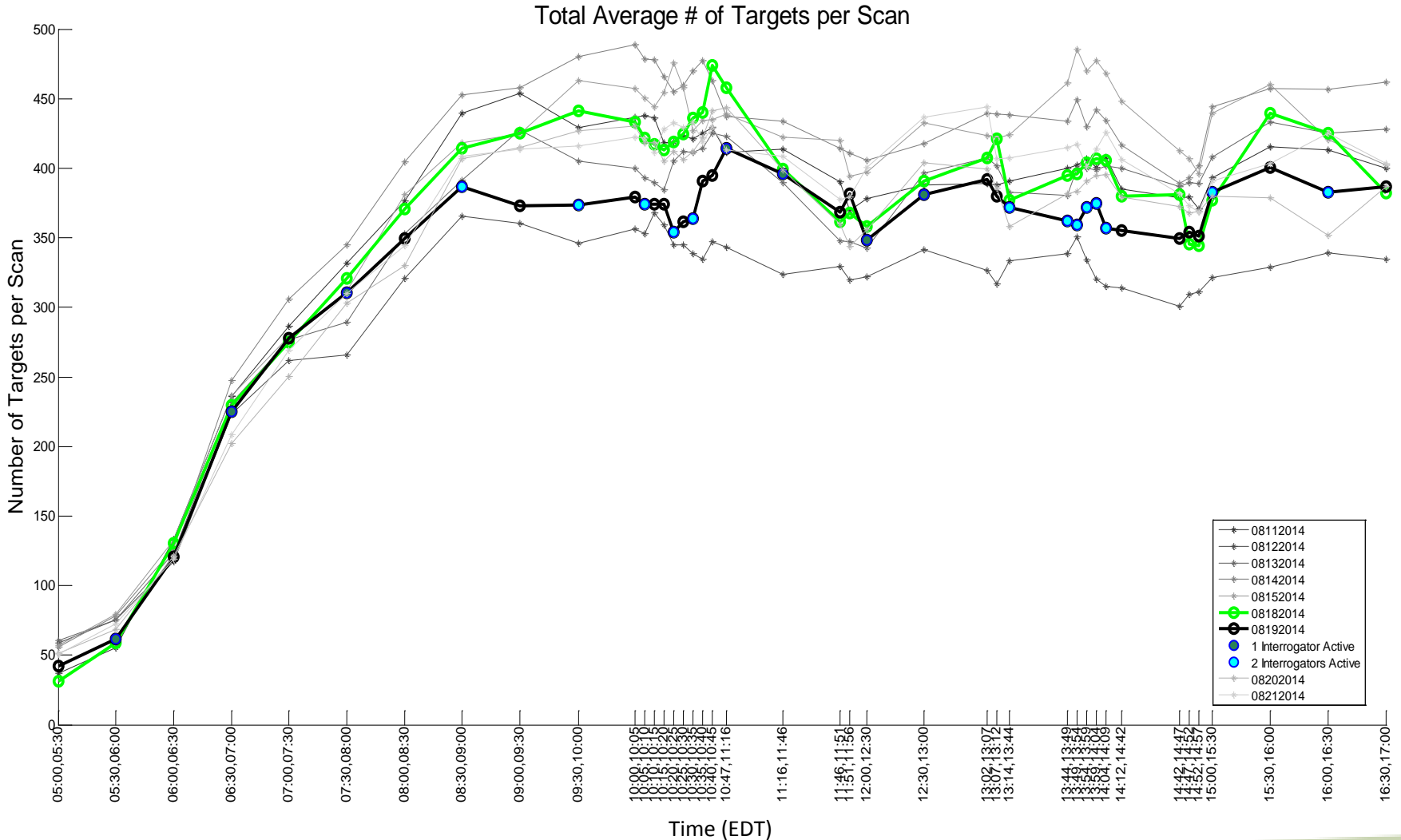
08212014 QPL: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None



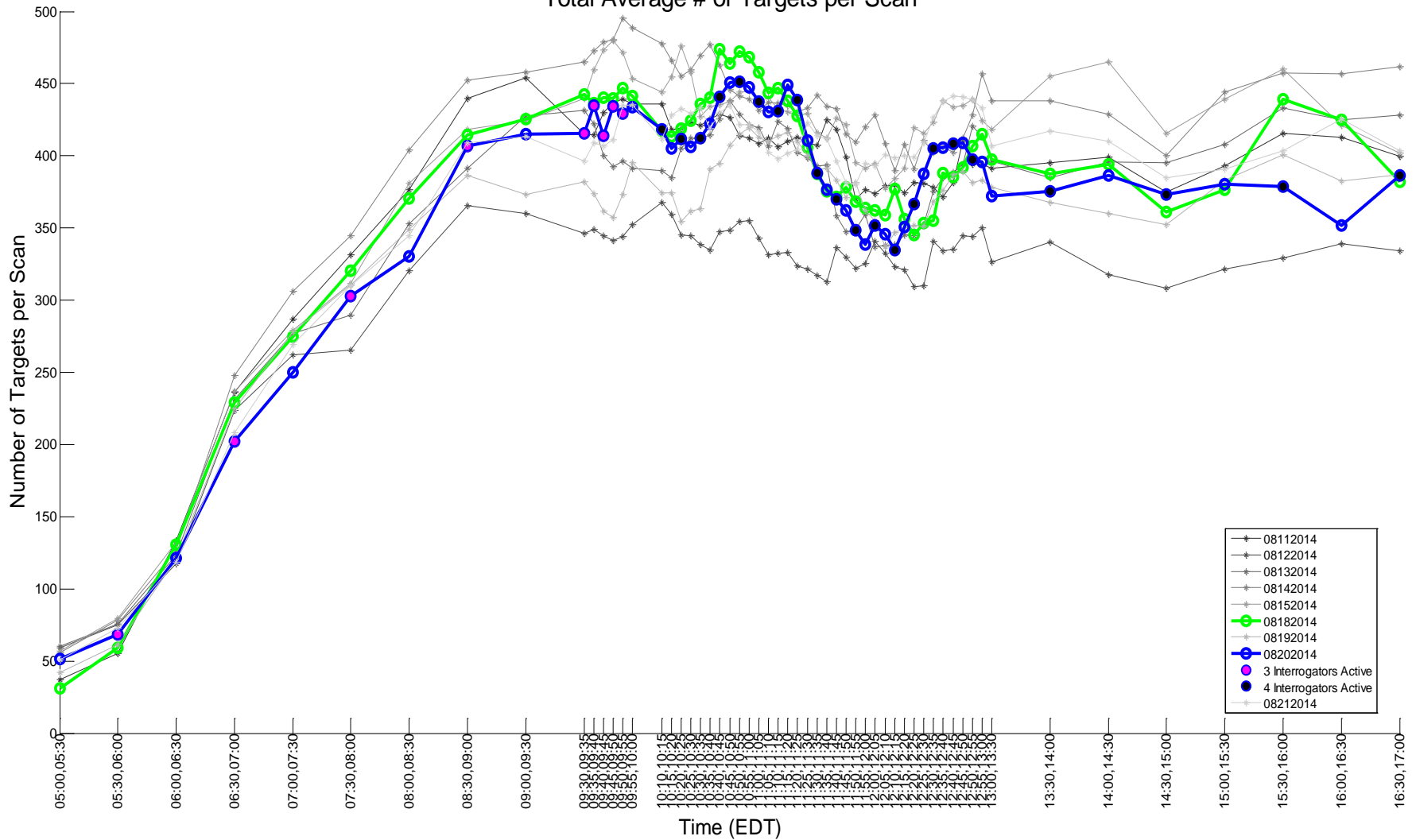
# Targets per Scan – August 19<sup>th</sup>



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 20<sup>th</sup>

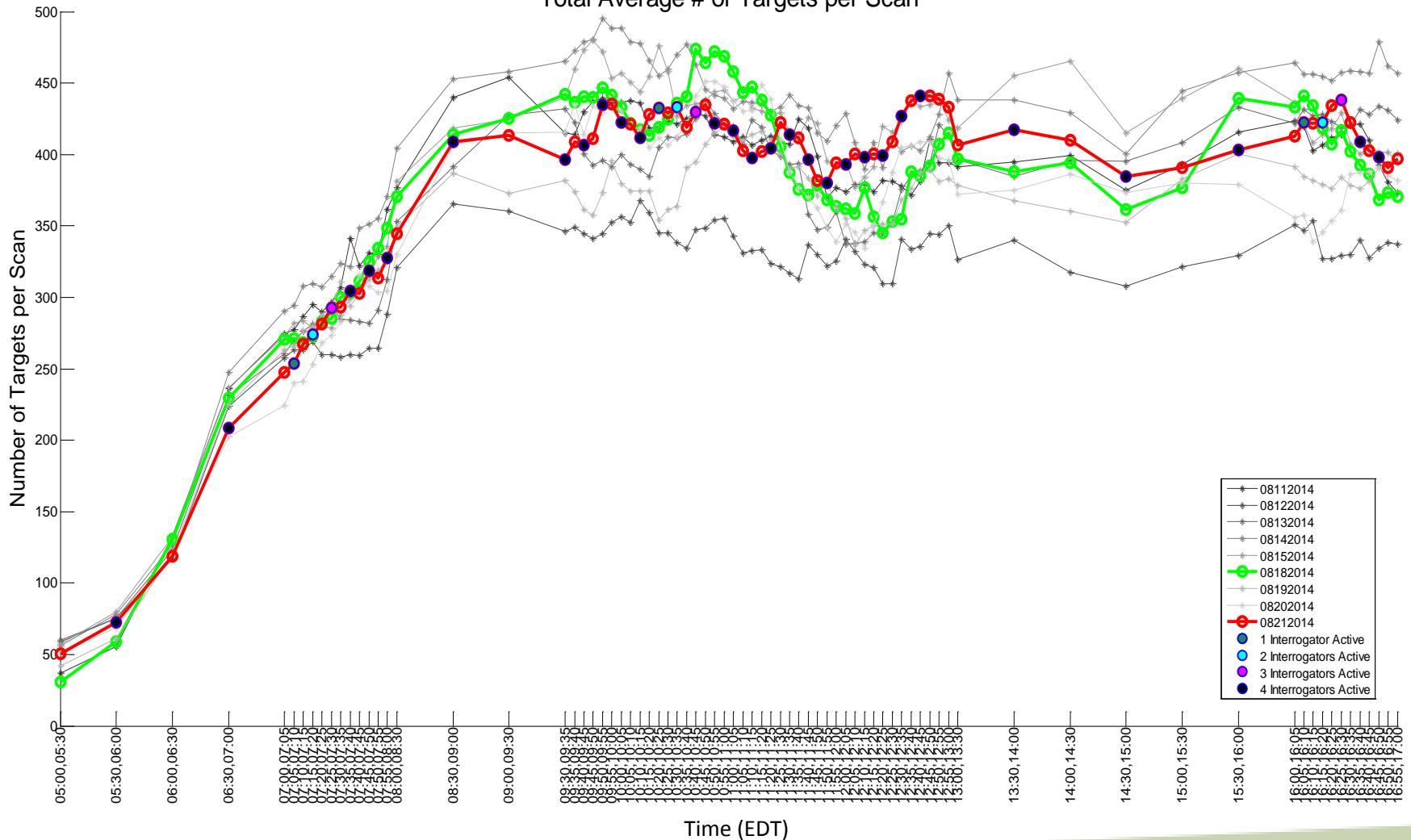
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

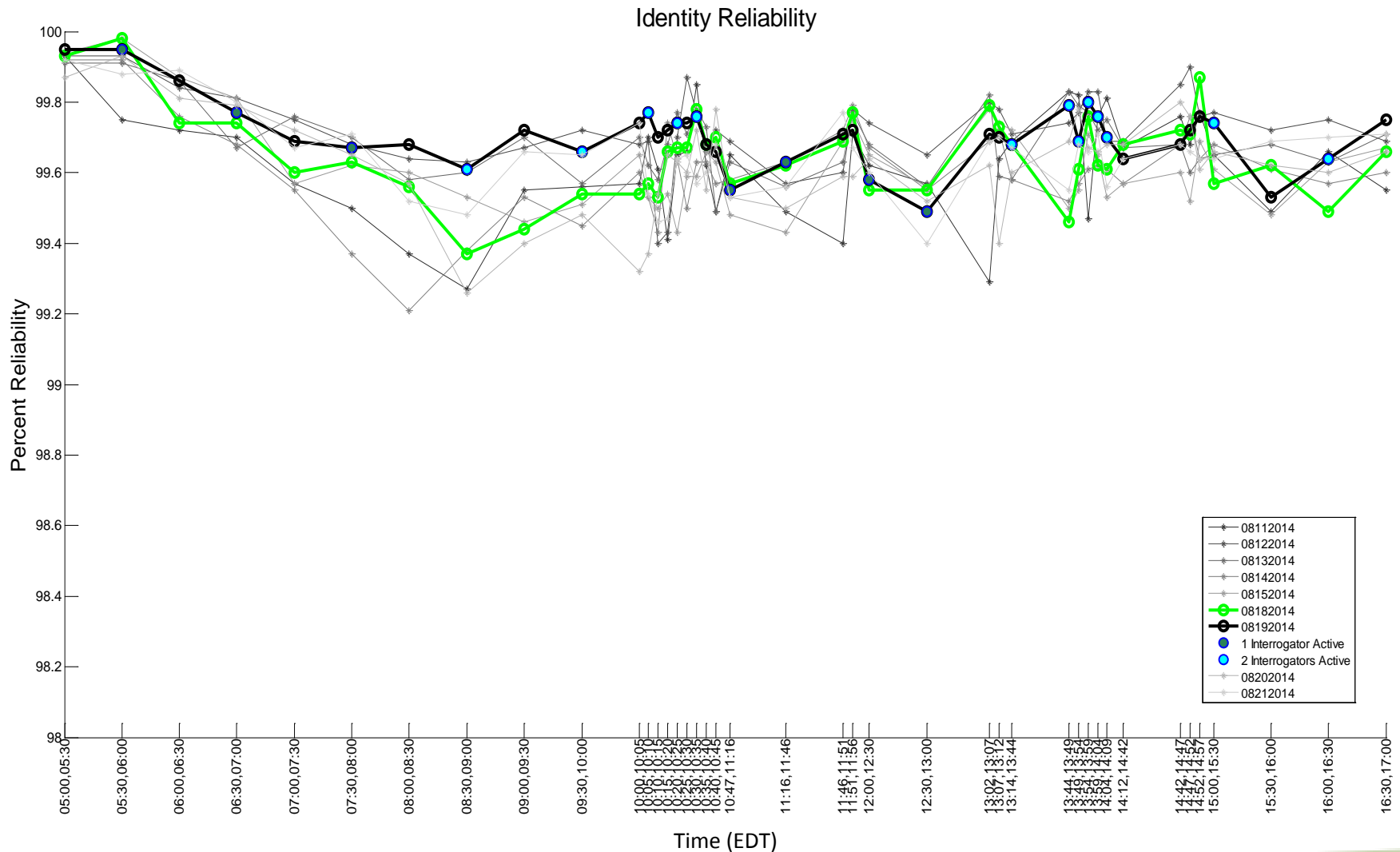
# Targets per Scan – August 21<sup>st</sup>

Total Average # of Targets per Scan



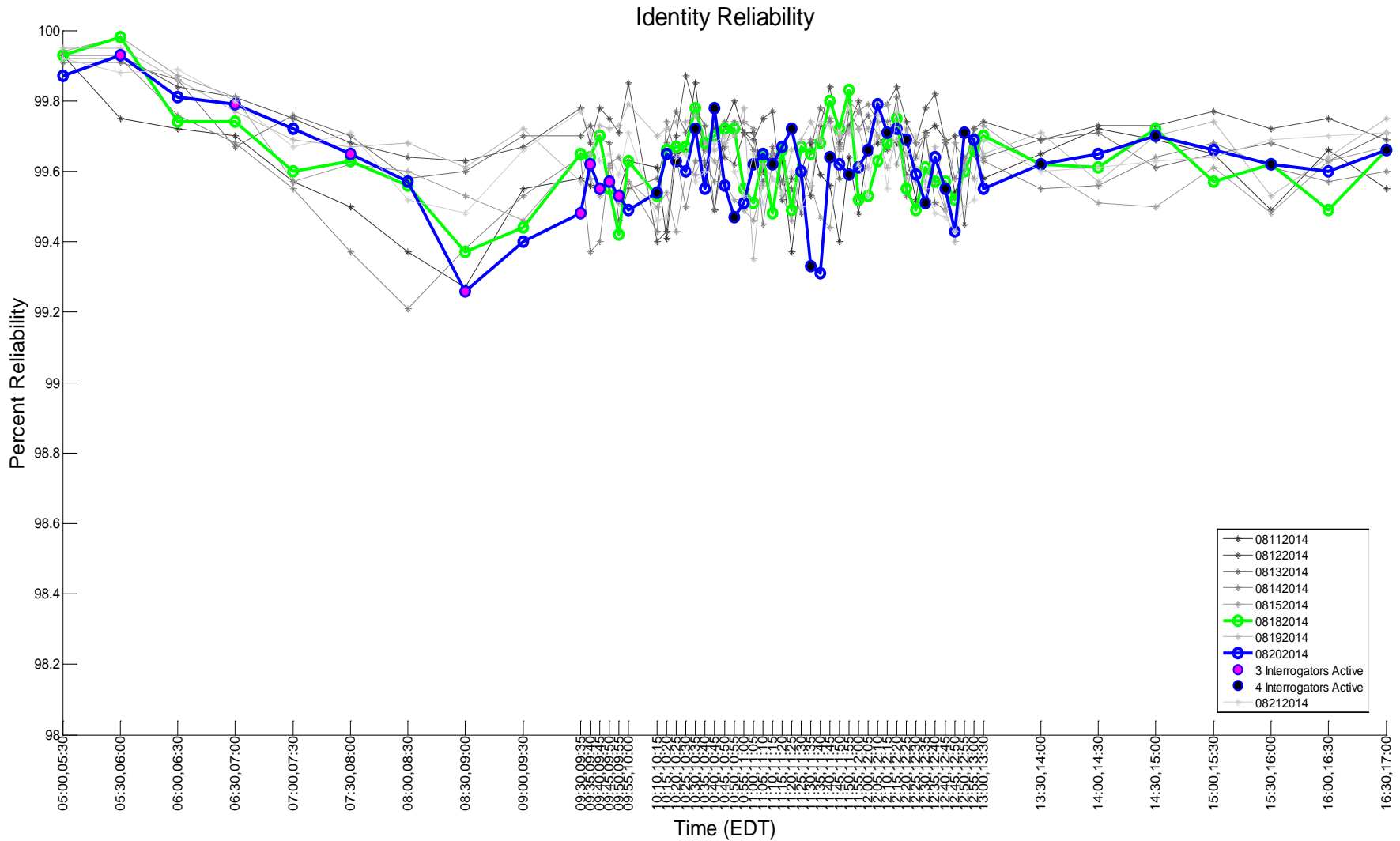
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 19th



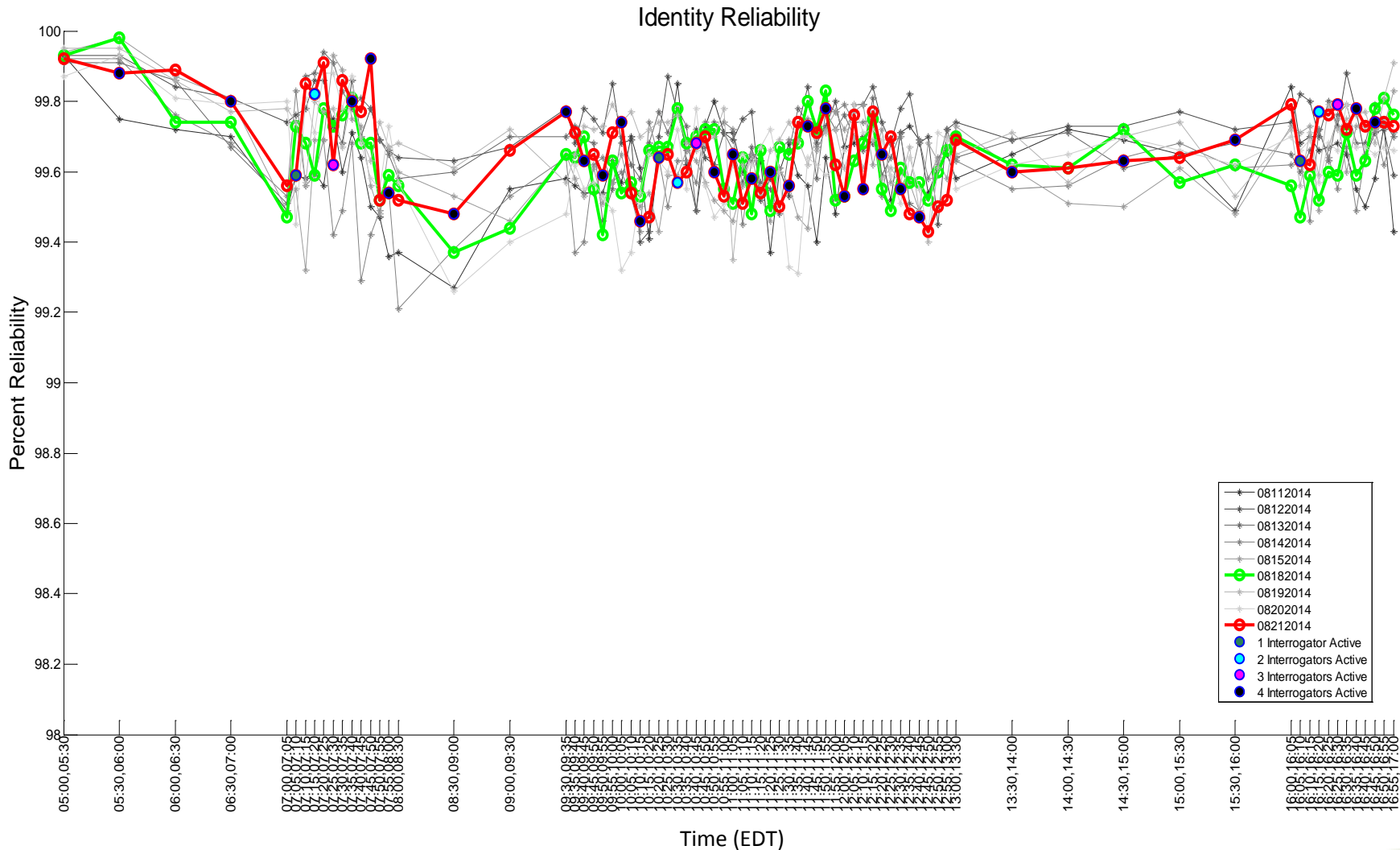
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 20<sup>th</sup>



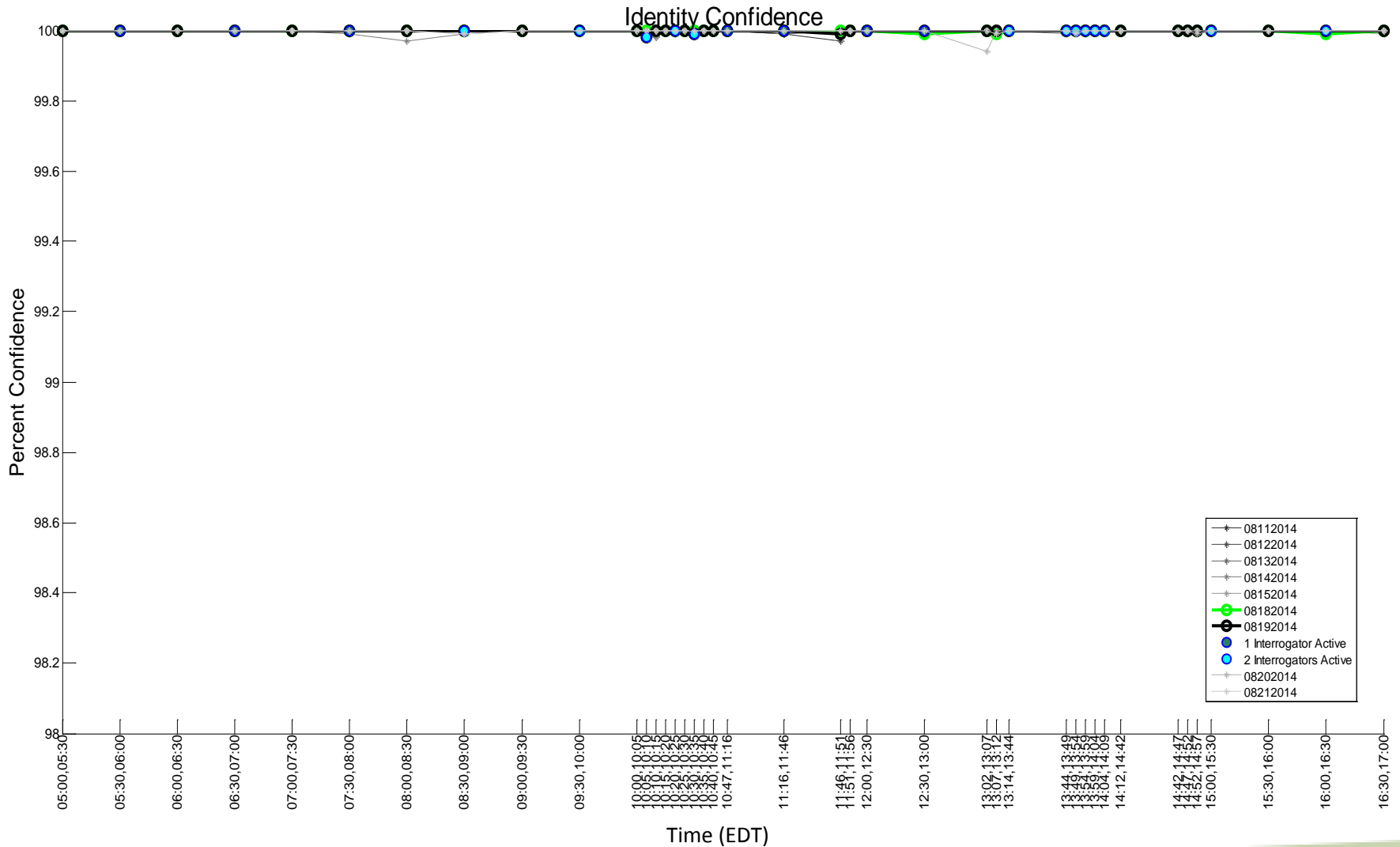
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 21<sup>st</sup>



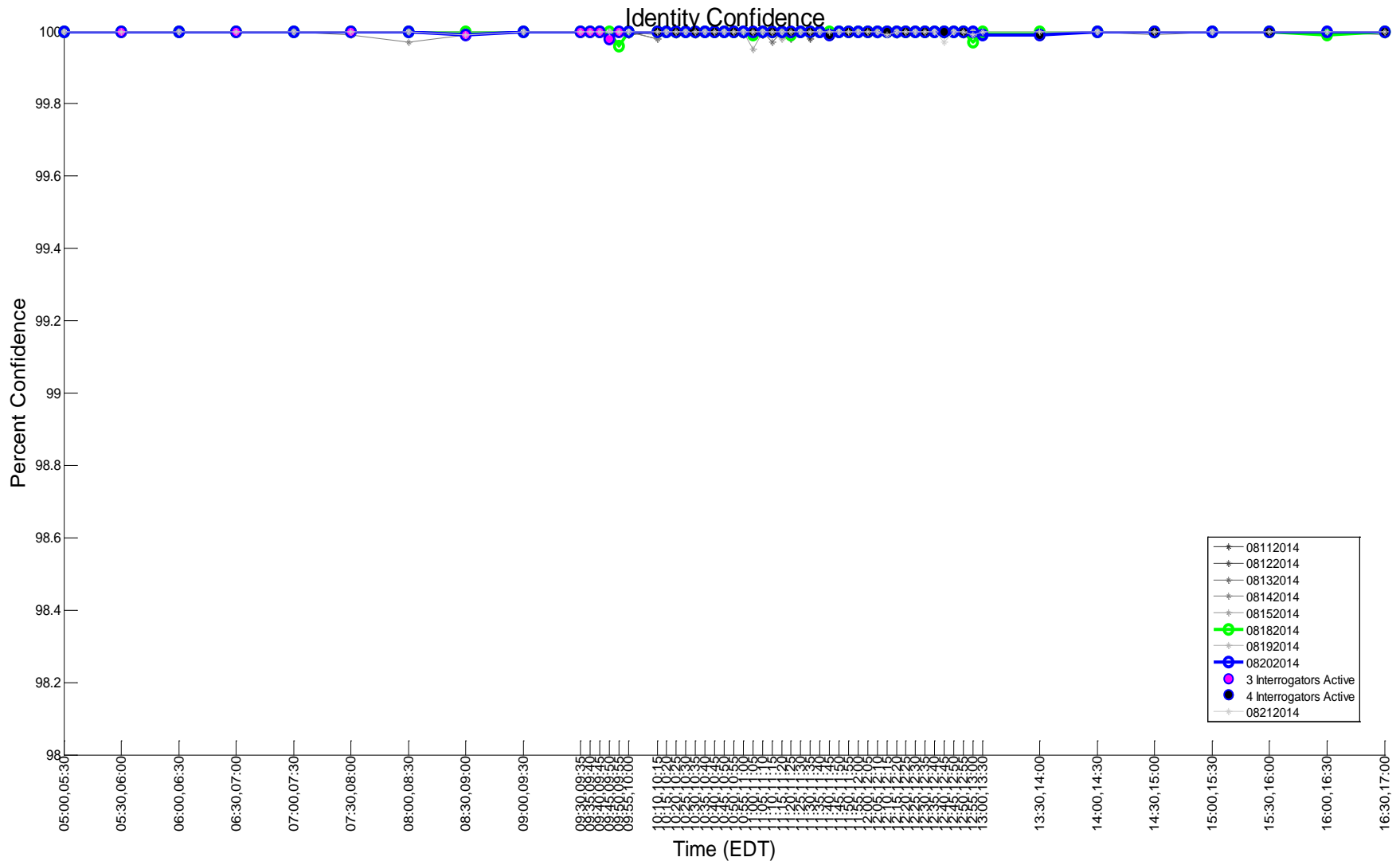
Geographic Filter: None  
Target Filter: None

# Identity (3/A) Confidence – August 19th



Geographic Filter: None  
Target Filter: None

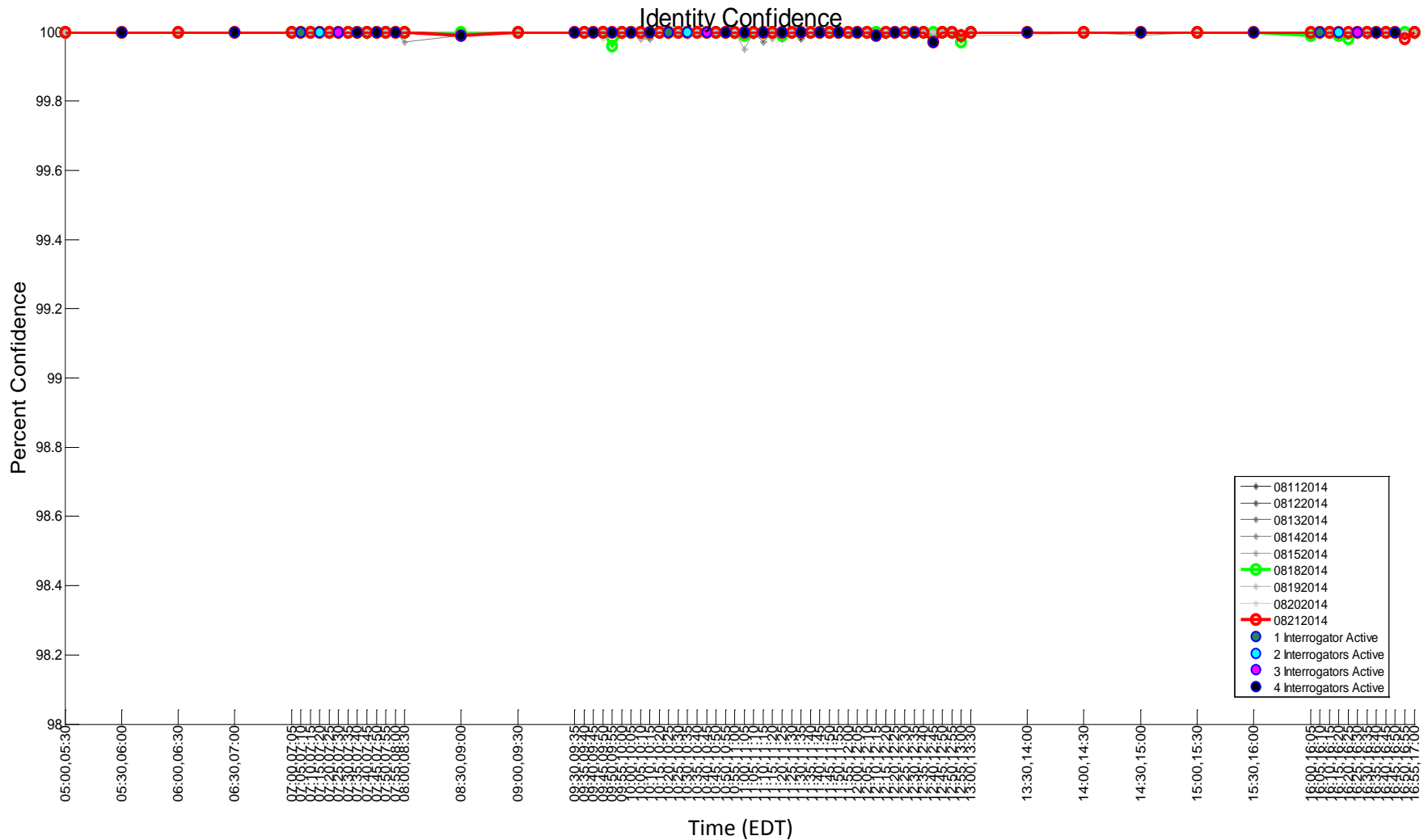
# Identity (3/A) Confidence – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

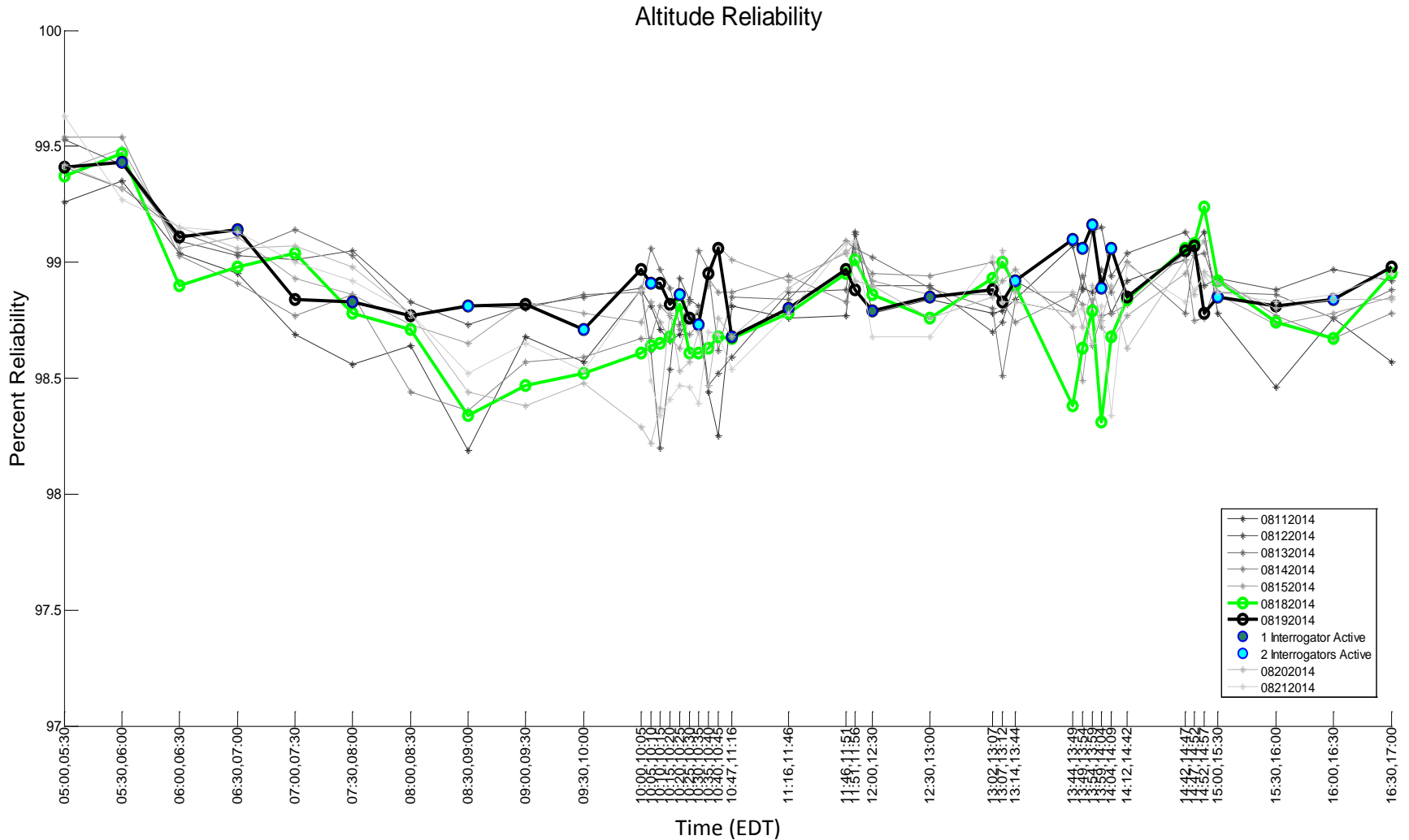


# Identity (3/A) Confidence – August 21<sup>st</sup>

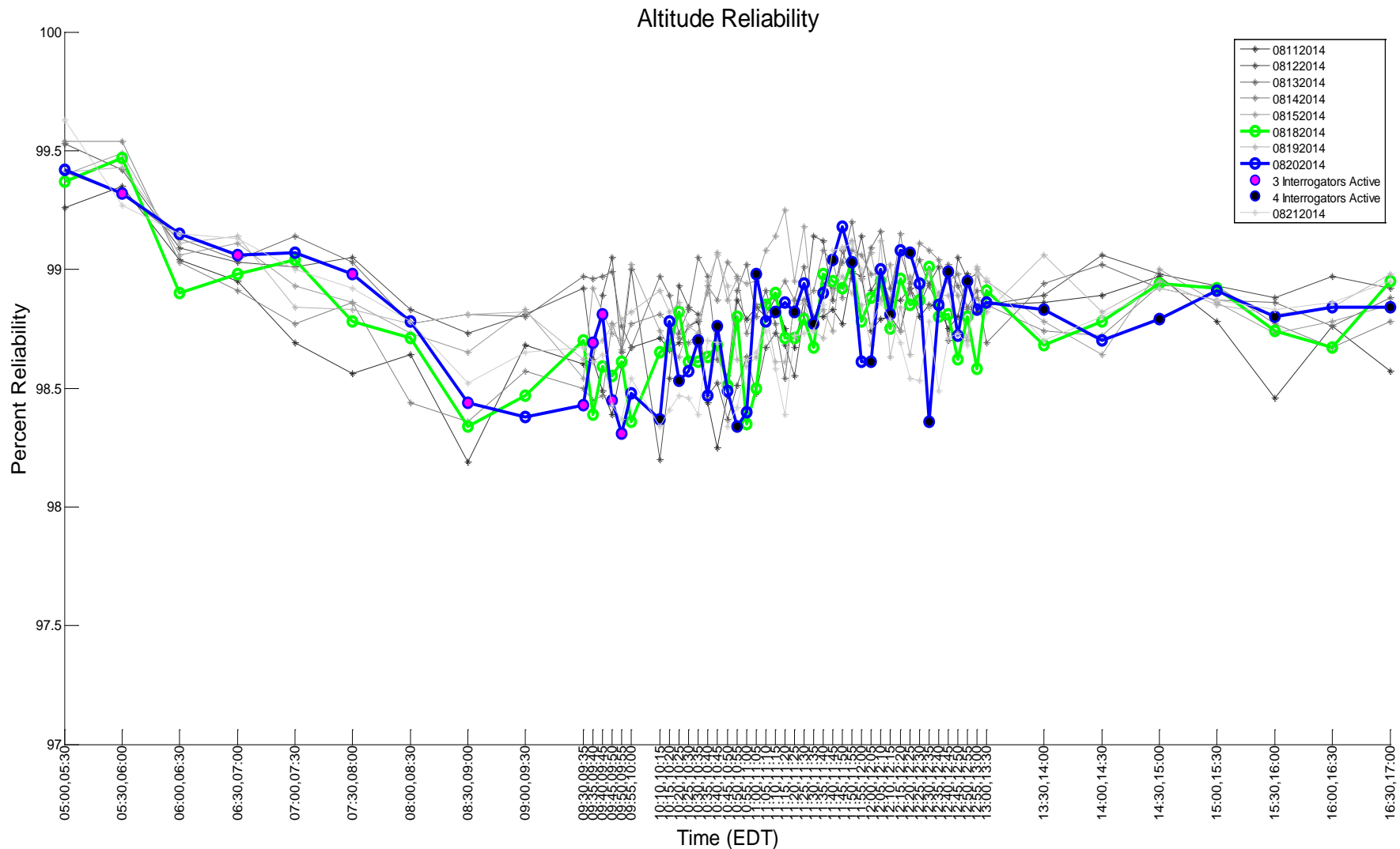


Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 19th

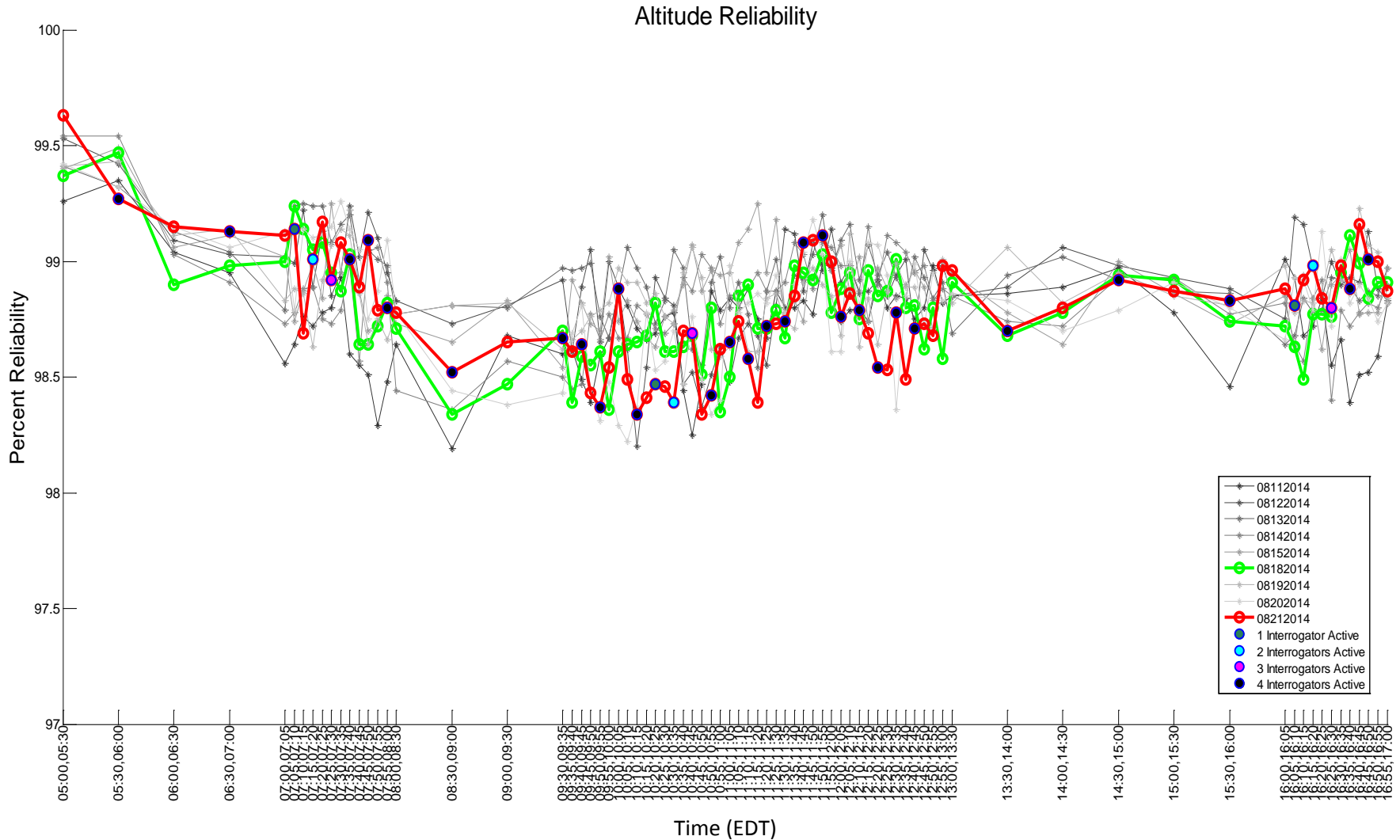


# Altitude (C) Reliability – August 20<sup>th</sup>



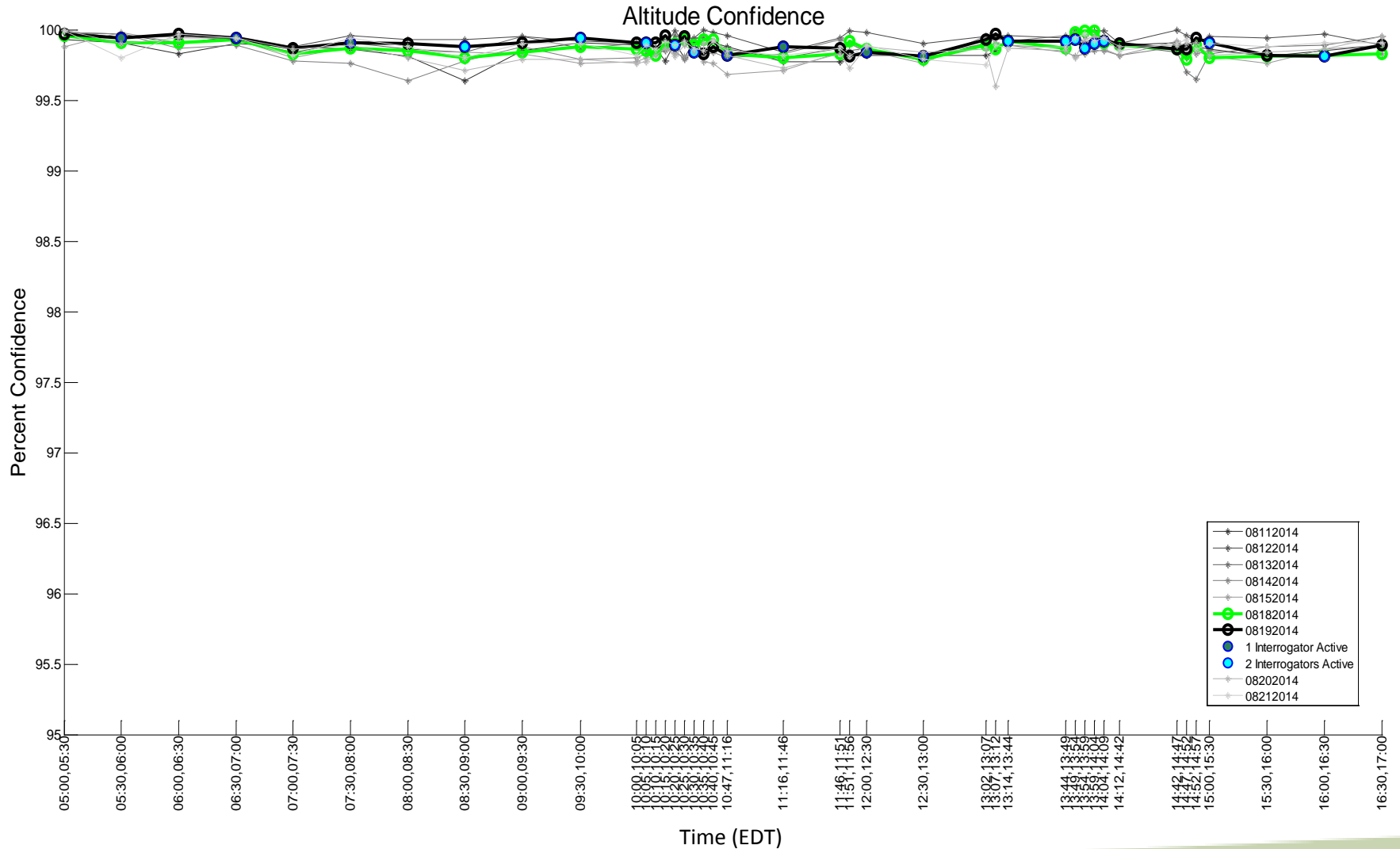
Geographic Filter: None  
Target Filter: None

# Altitude (C) Reliability – August 21<sup>st</sup>



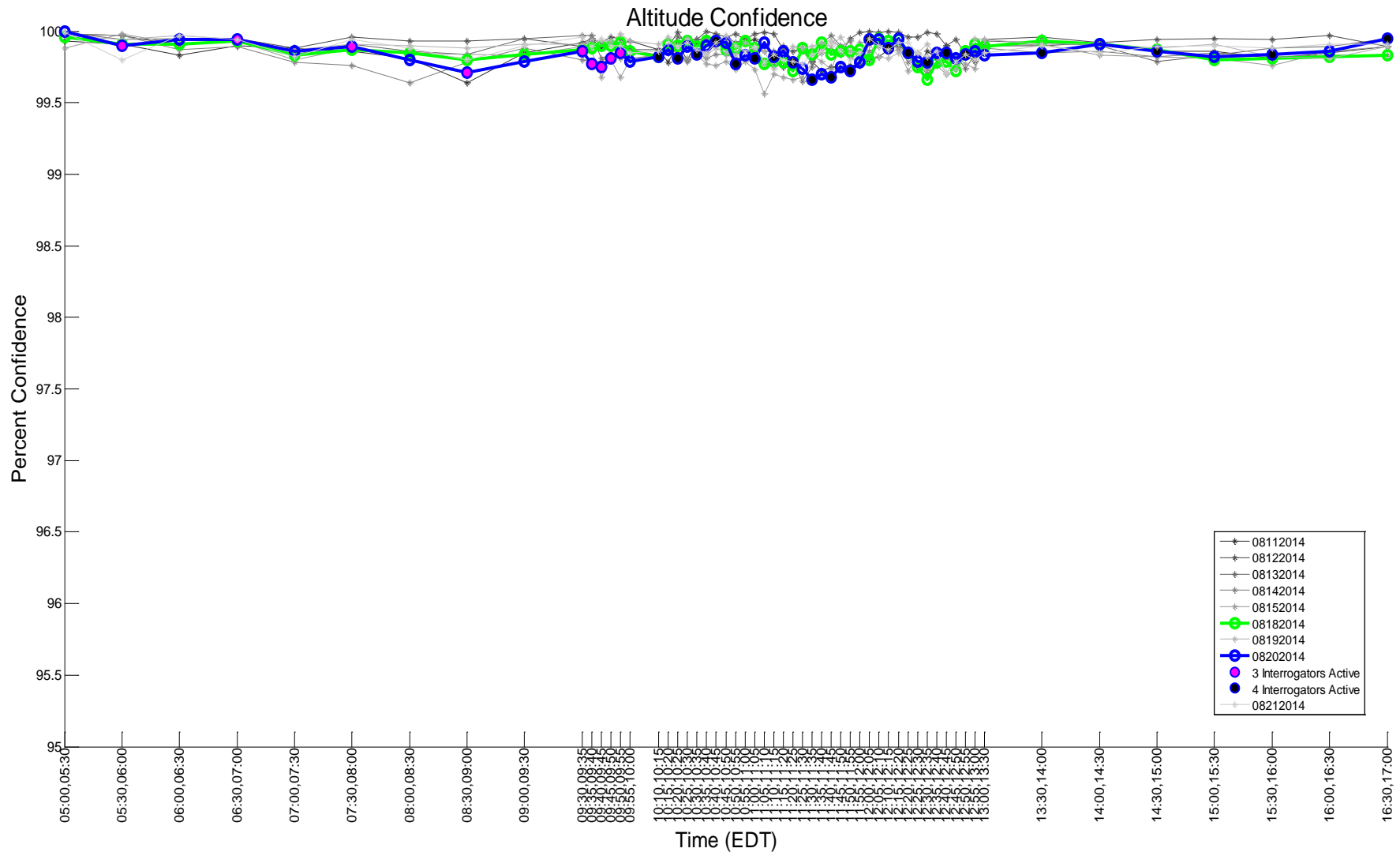
Geographic Filter: None  
Target Filter: None

# Altitude (C) Confidence – August 19th



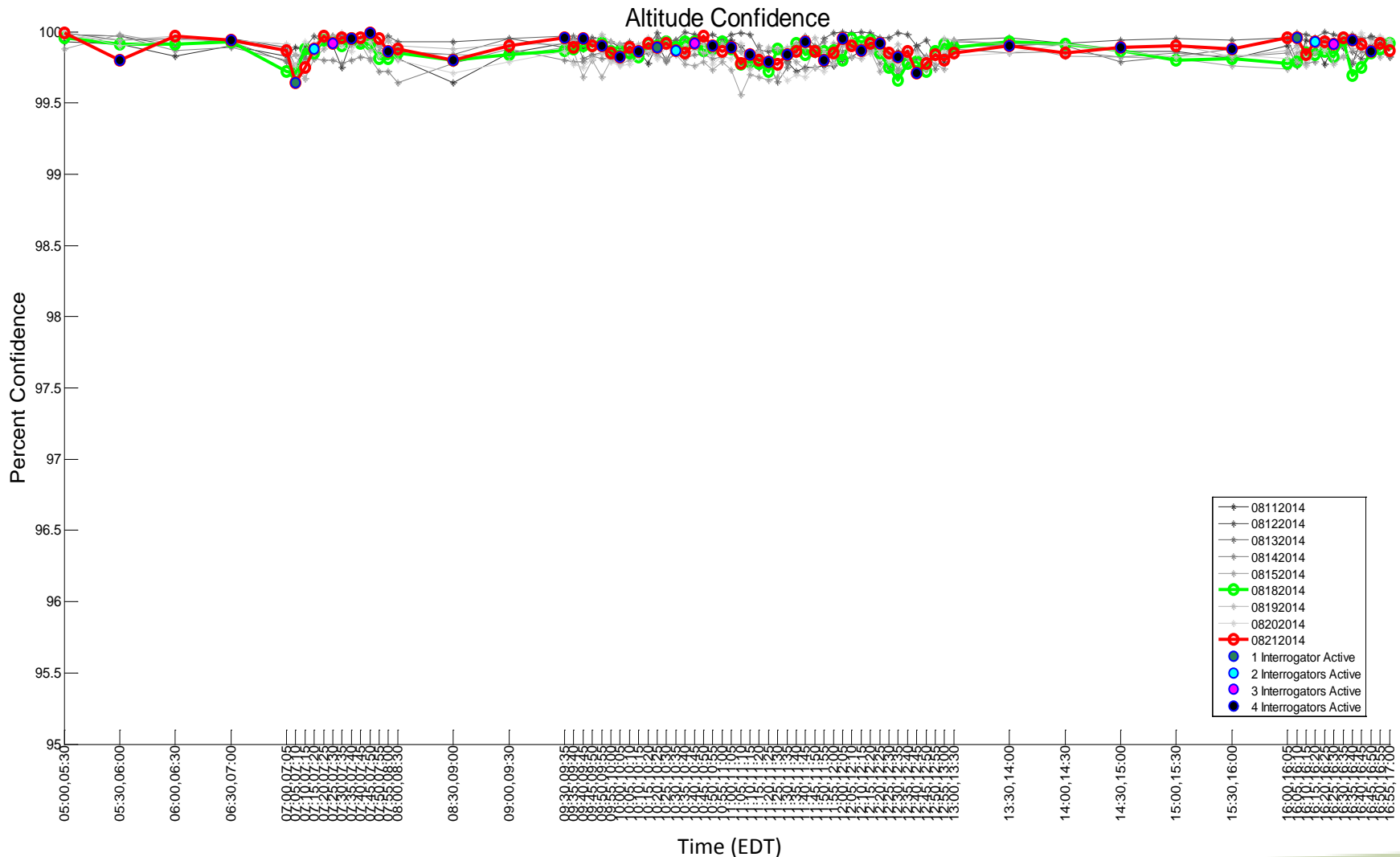
Geographic Filter: None  
Target Filter: None

# Altitude (C) Confidence – August 20<sup>th</sup>



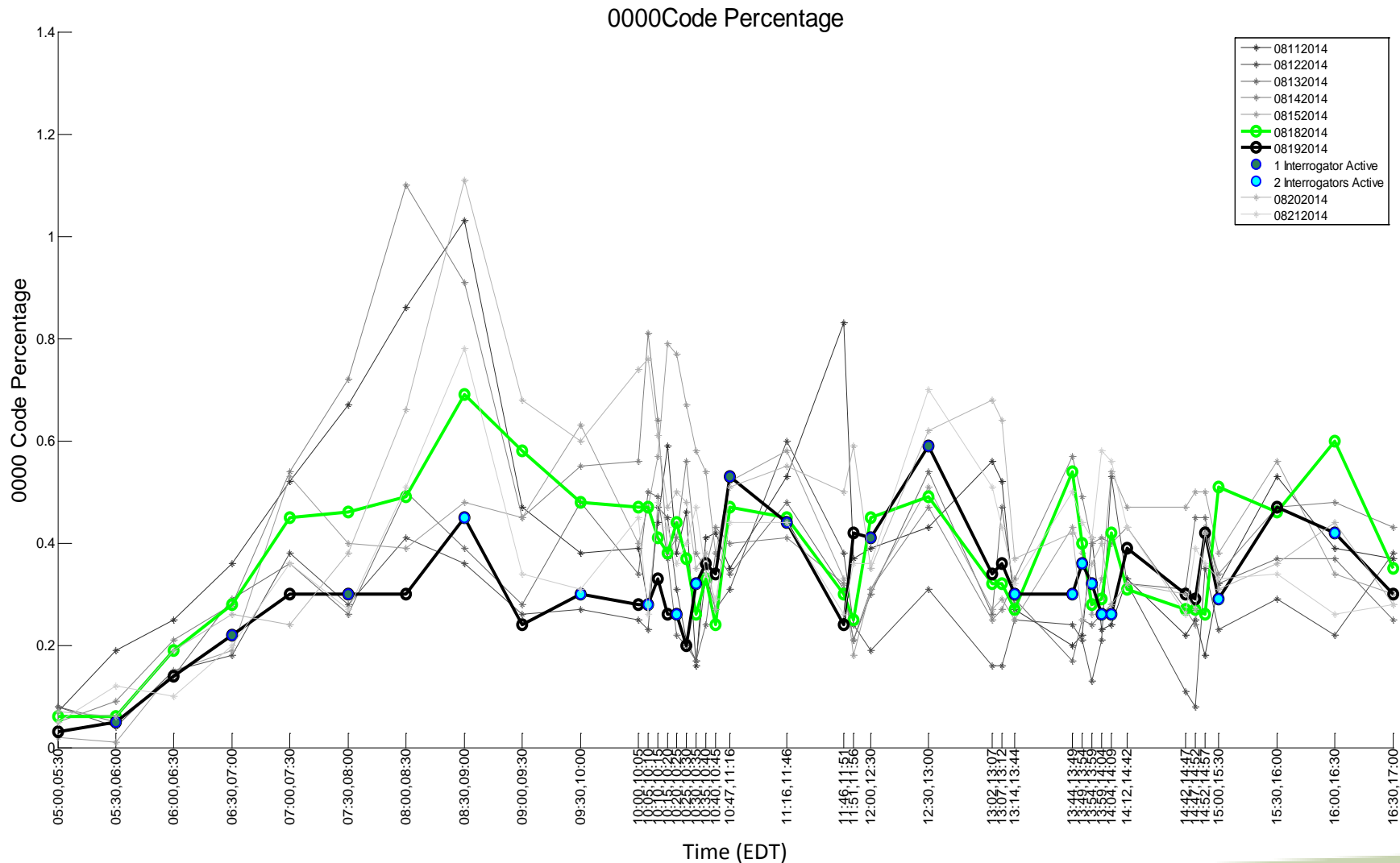
Geographic Filter: None  
Target Filter: None

# Altitude (C) Confidence – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 19th

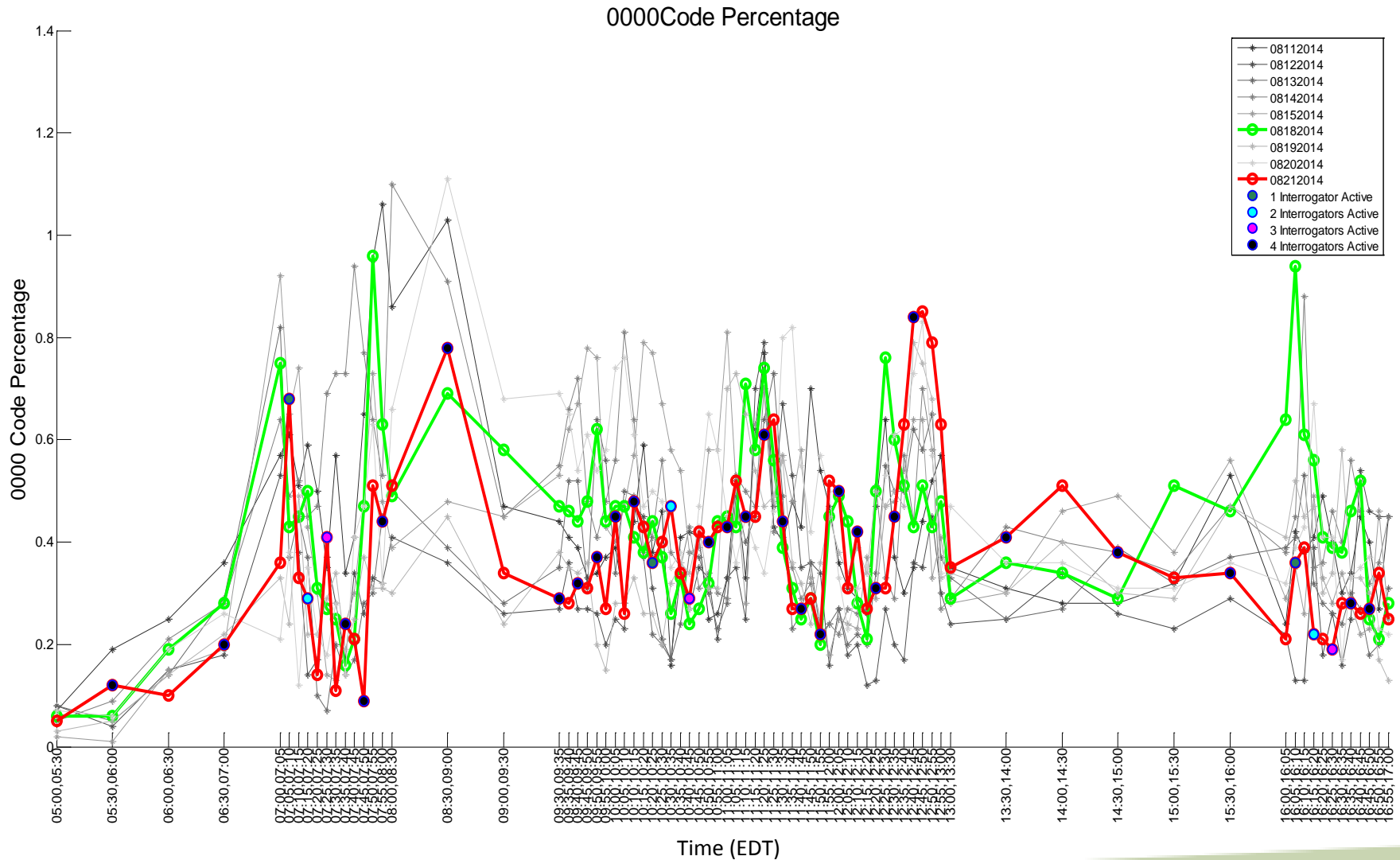


Geographic Filter: None  
Target Filter: None



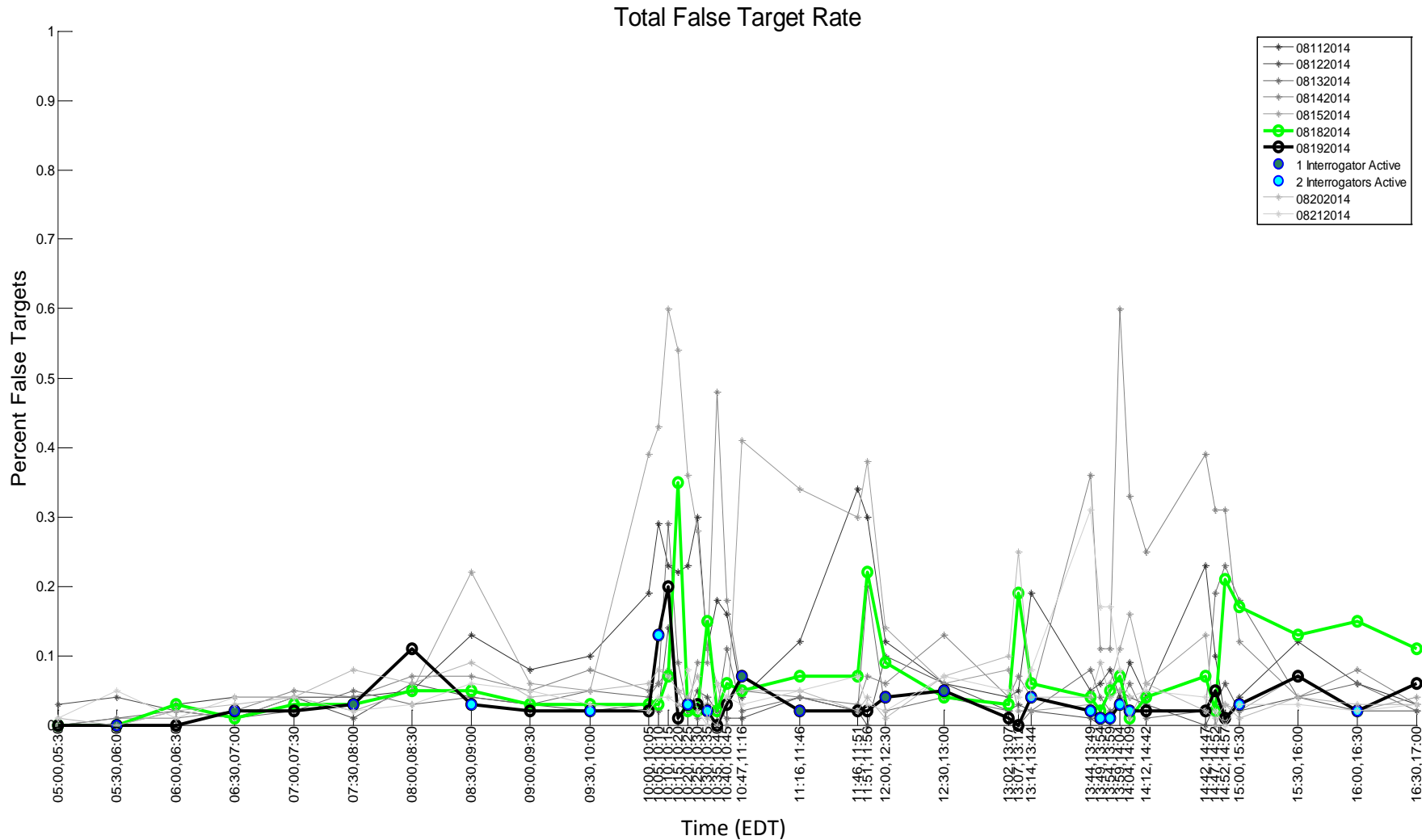


# 0000 Codes – August 21<sup>st</sup>



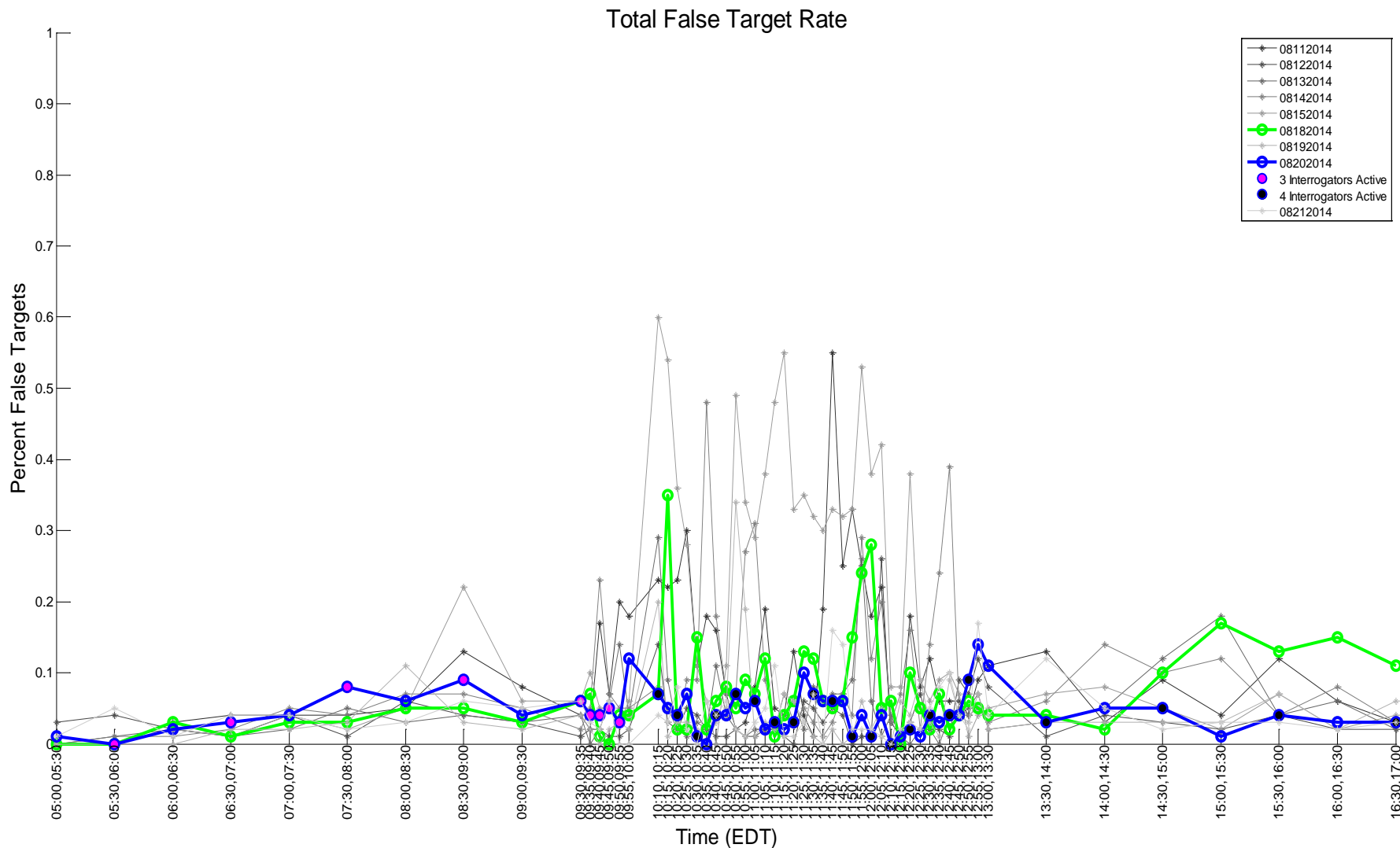
Geographic Filter: None  
Target Filter: None

# False Targets – August 19th



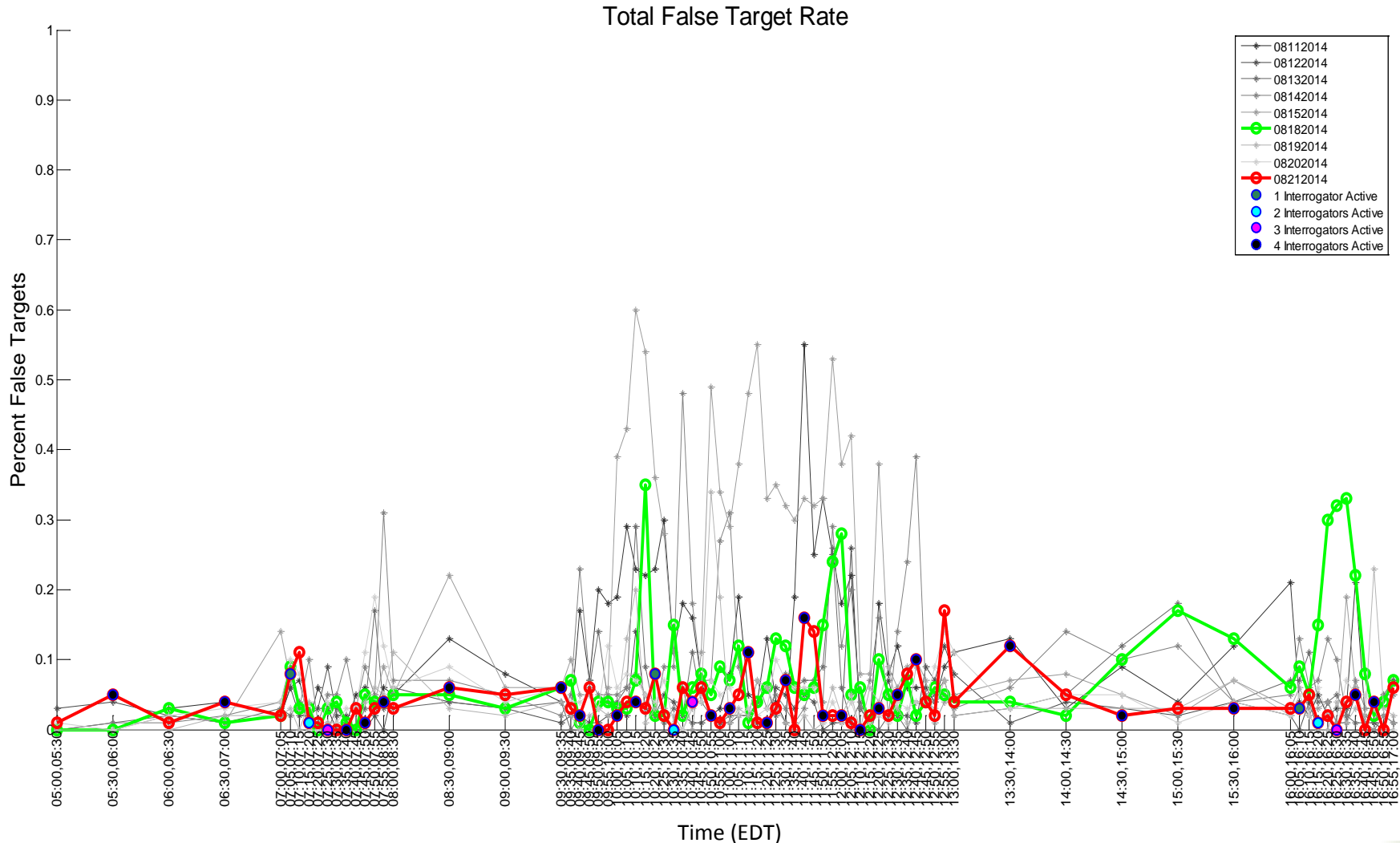
Geographic Filter: None  
Target Filter: None

# False Targets – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

# False Targets – August 21<sup>st</sup>



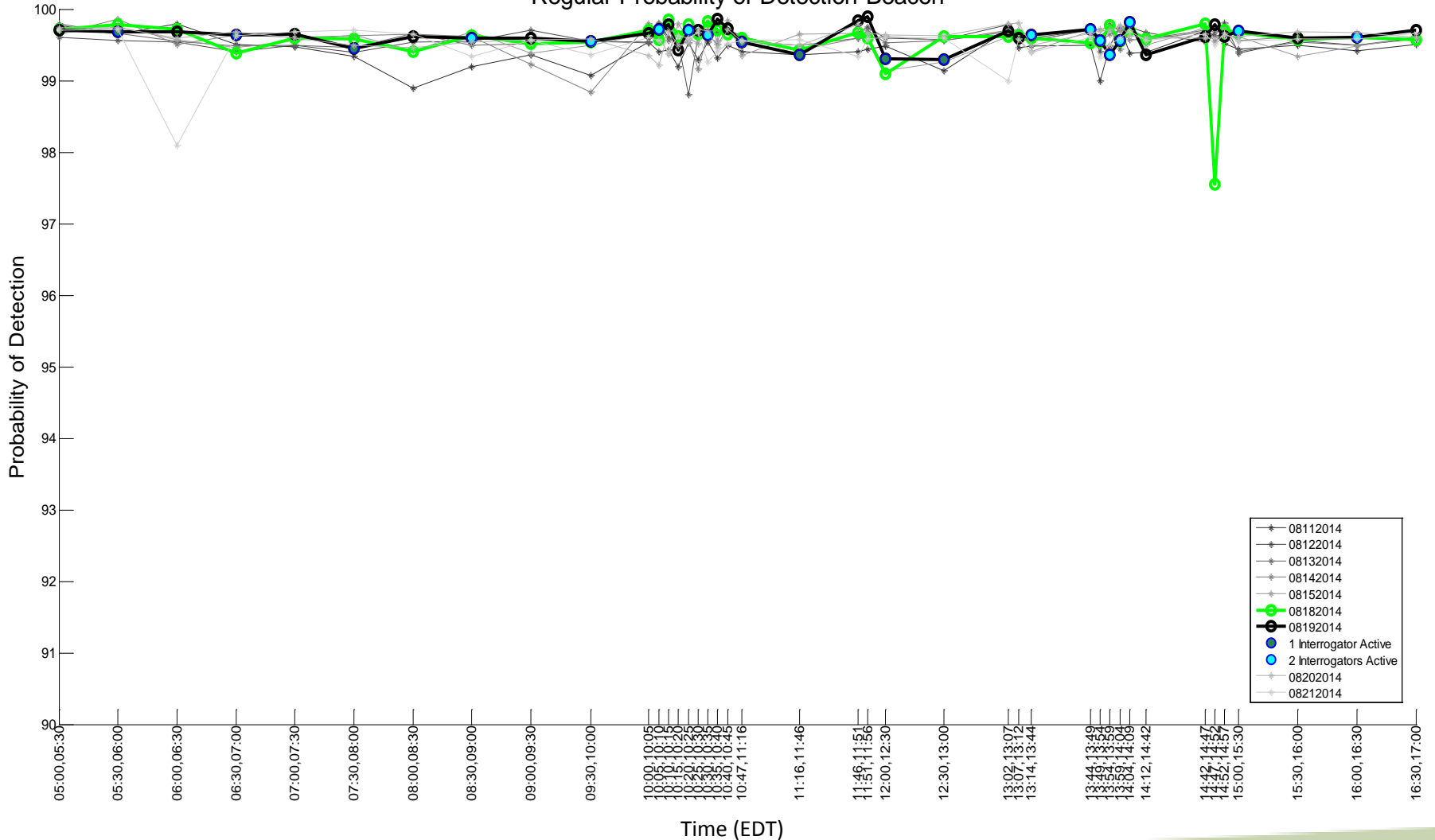
Geographic Filter: None  
Target Filter: None

# Target Metrics with Elevation Angle Greater than 0.5 Degrees

*\* Number of Targets Unavailable*

# Probability of Detection – August 19<sup>th</sup>

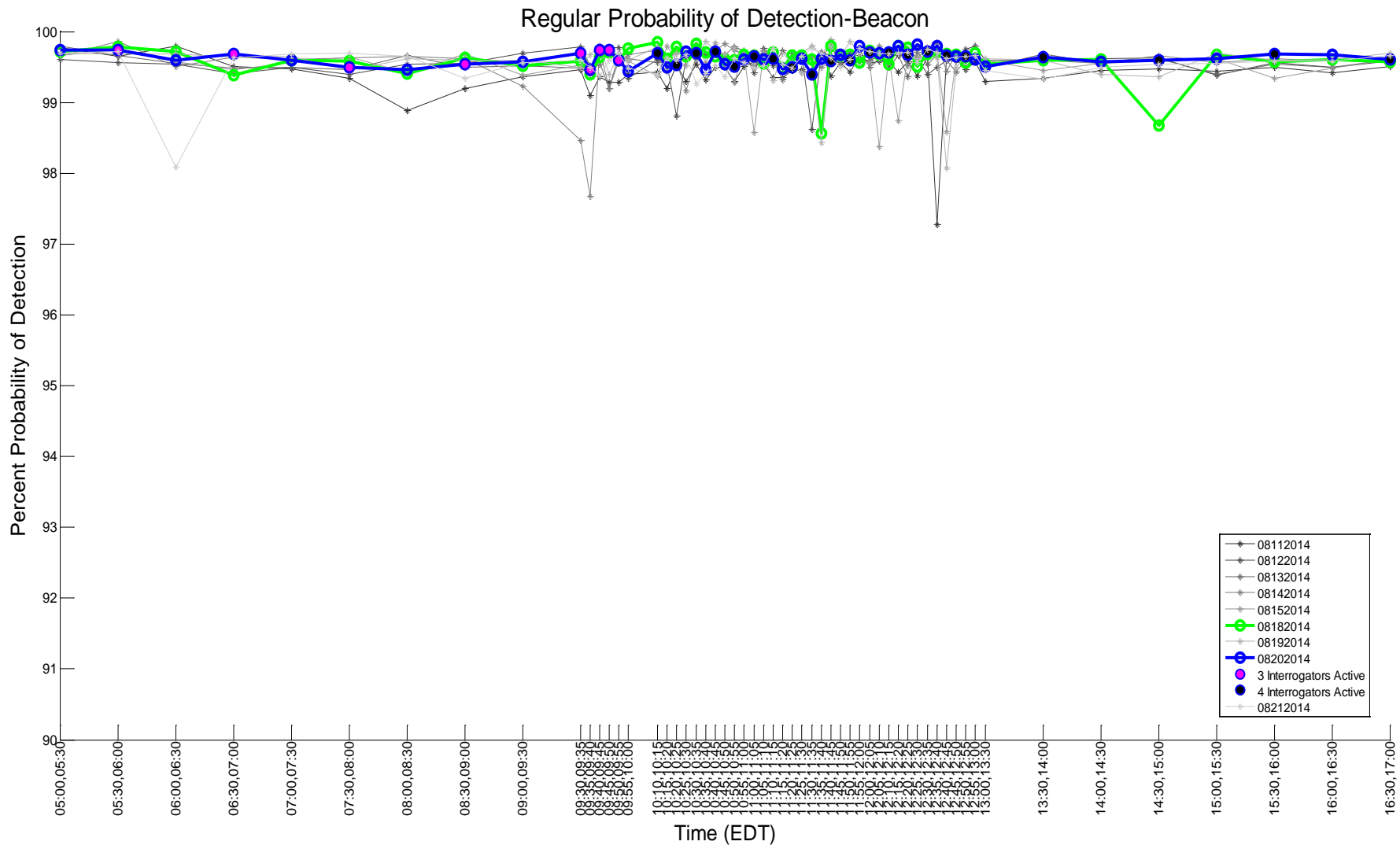
Regular Probability of Detection-Beacon



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 20<sup>th</sup>

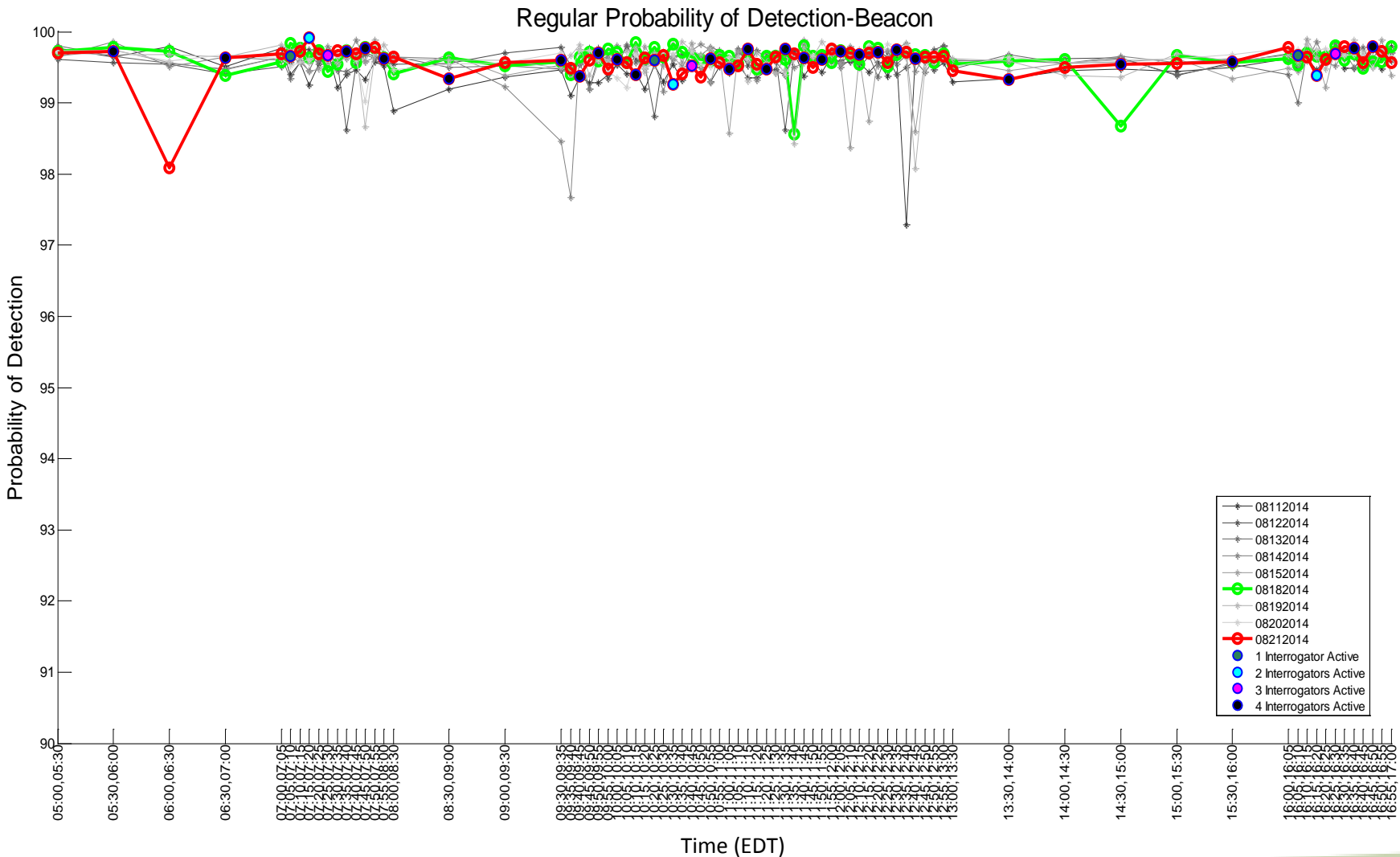


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°



# Probability of Detection – August 21<sup>st</sup>

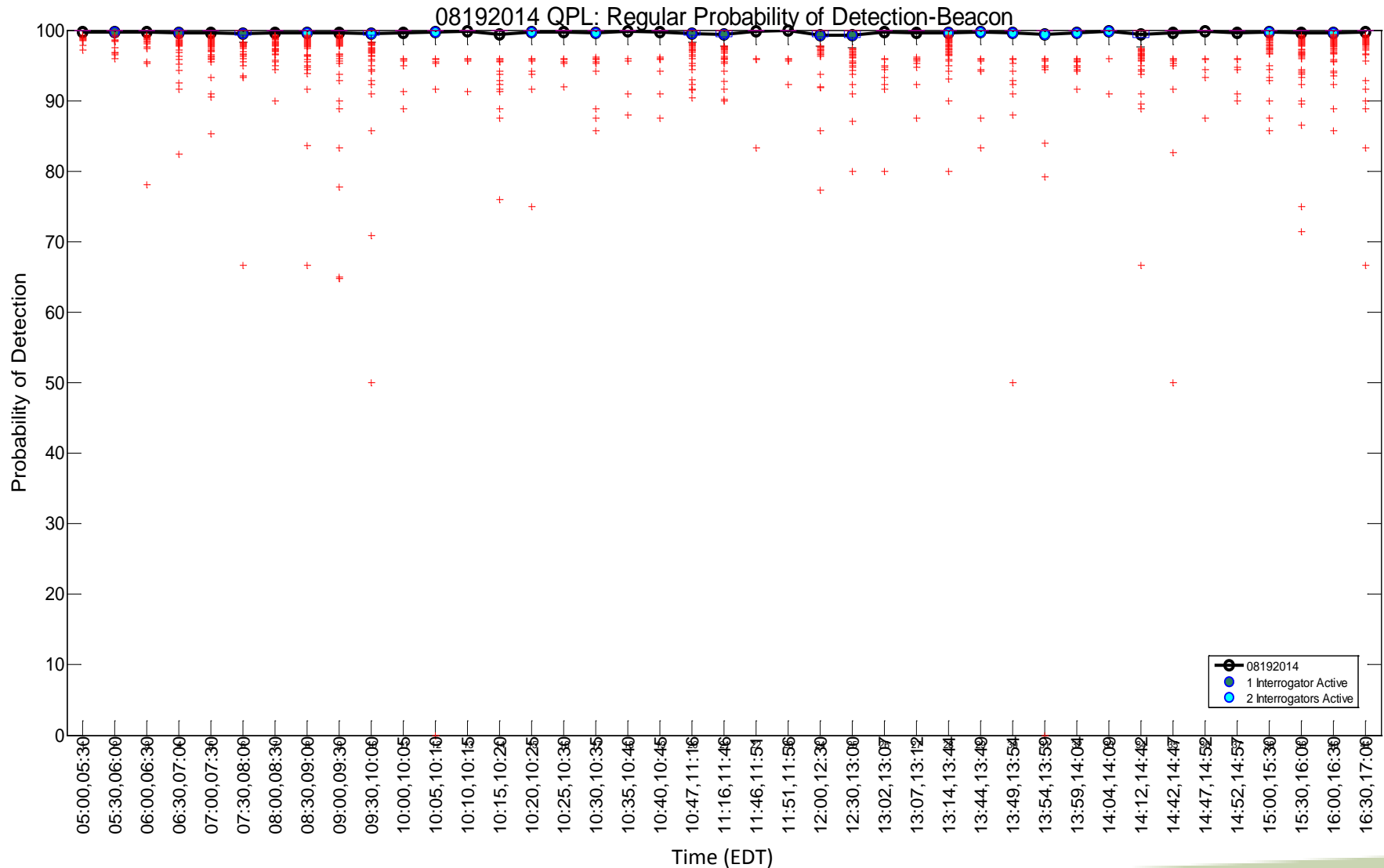


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution



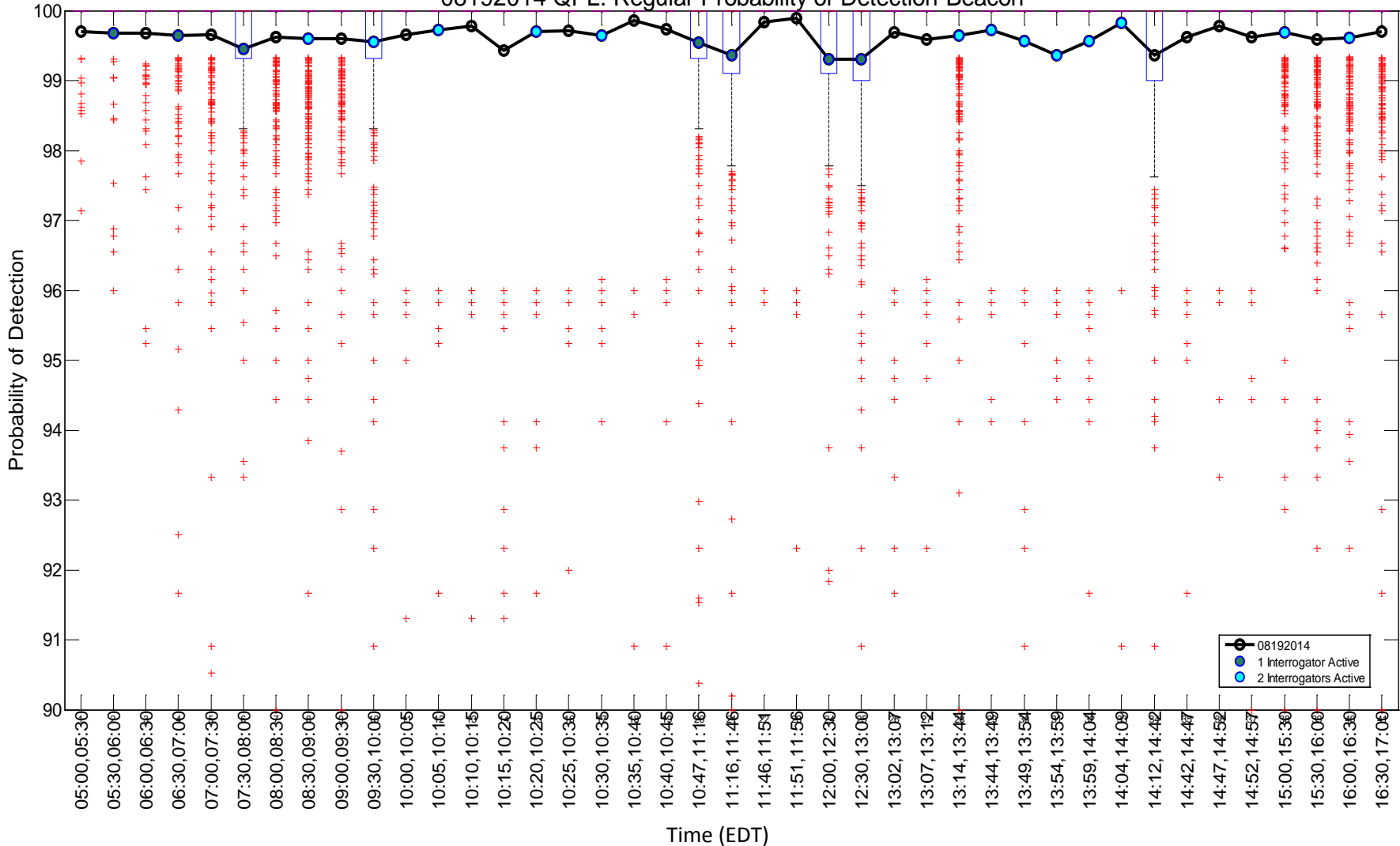
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08192014 QPL: Regular Probability of Detection-Beacon

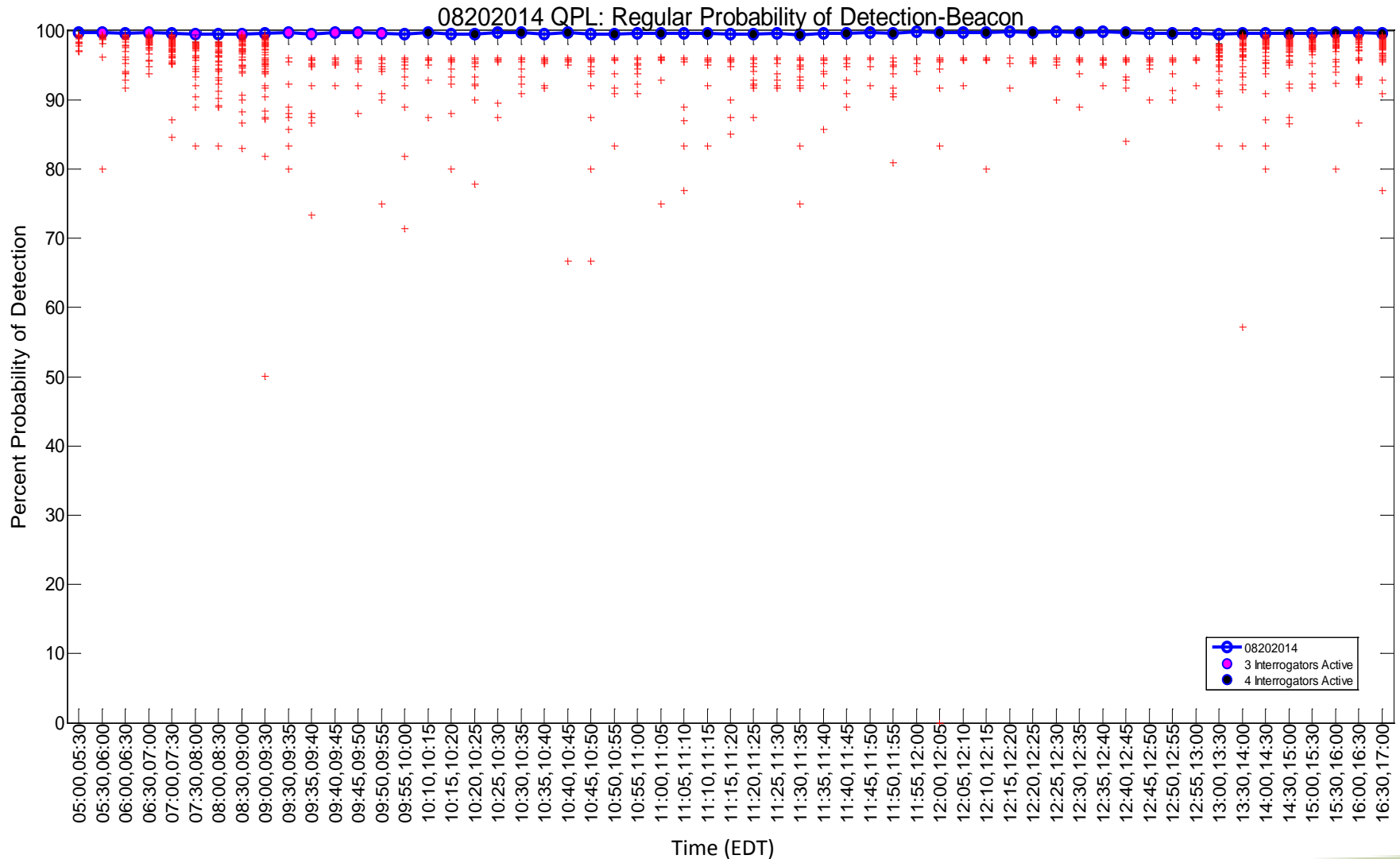


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

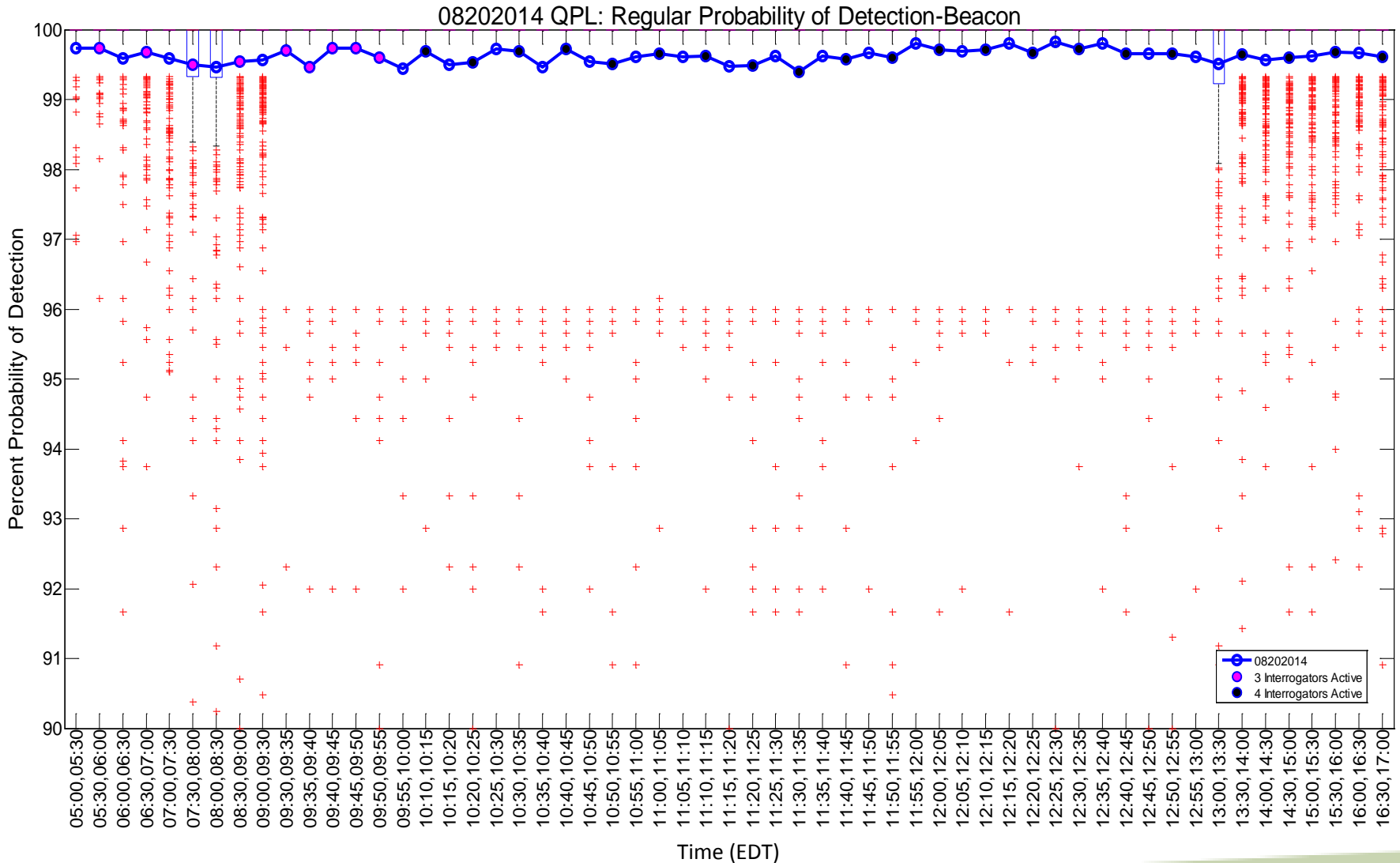


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

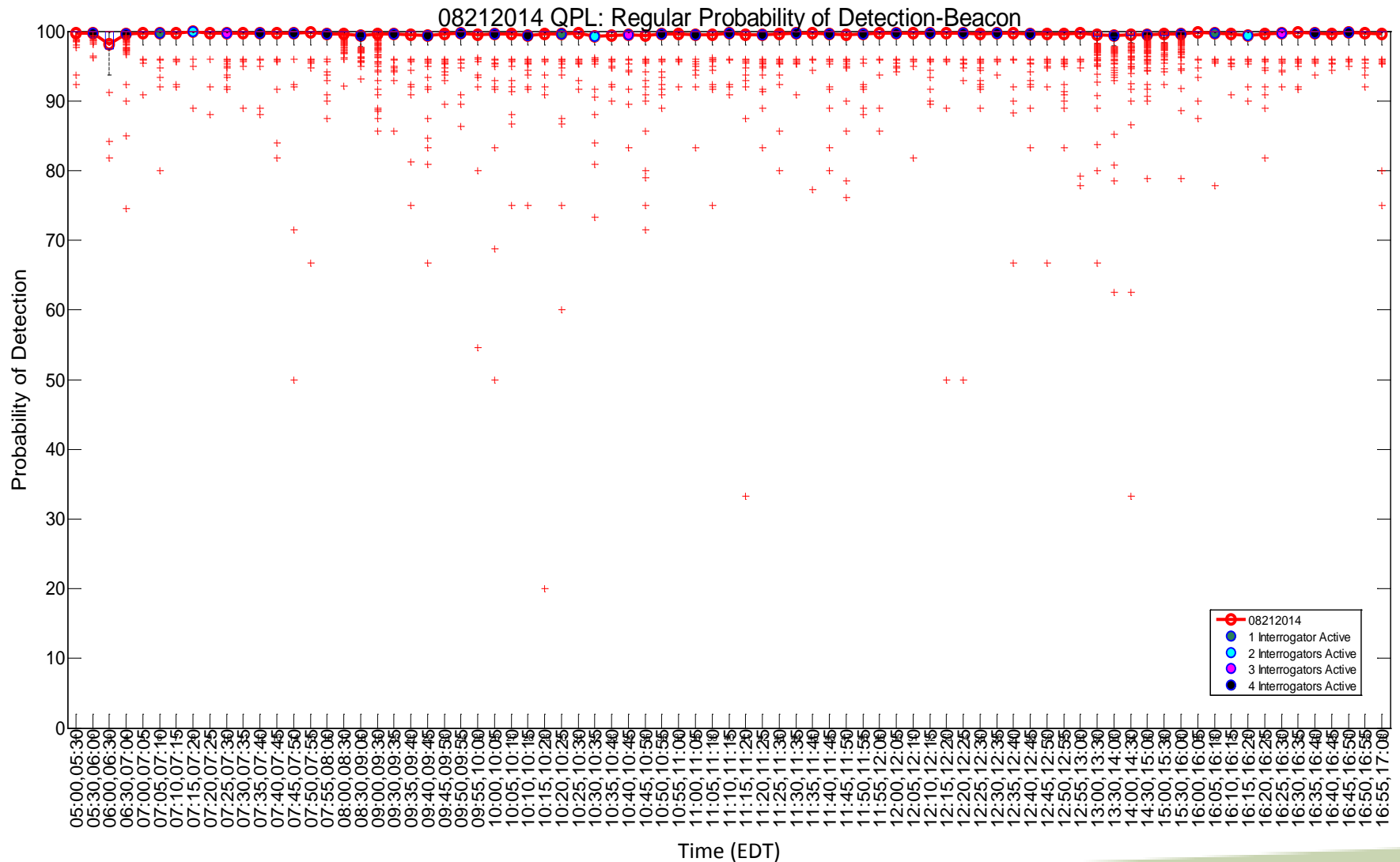


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

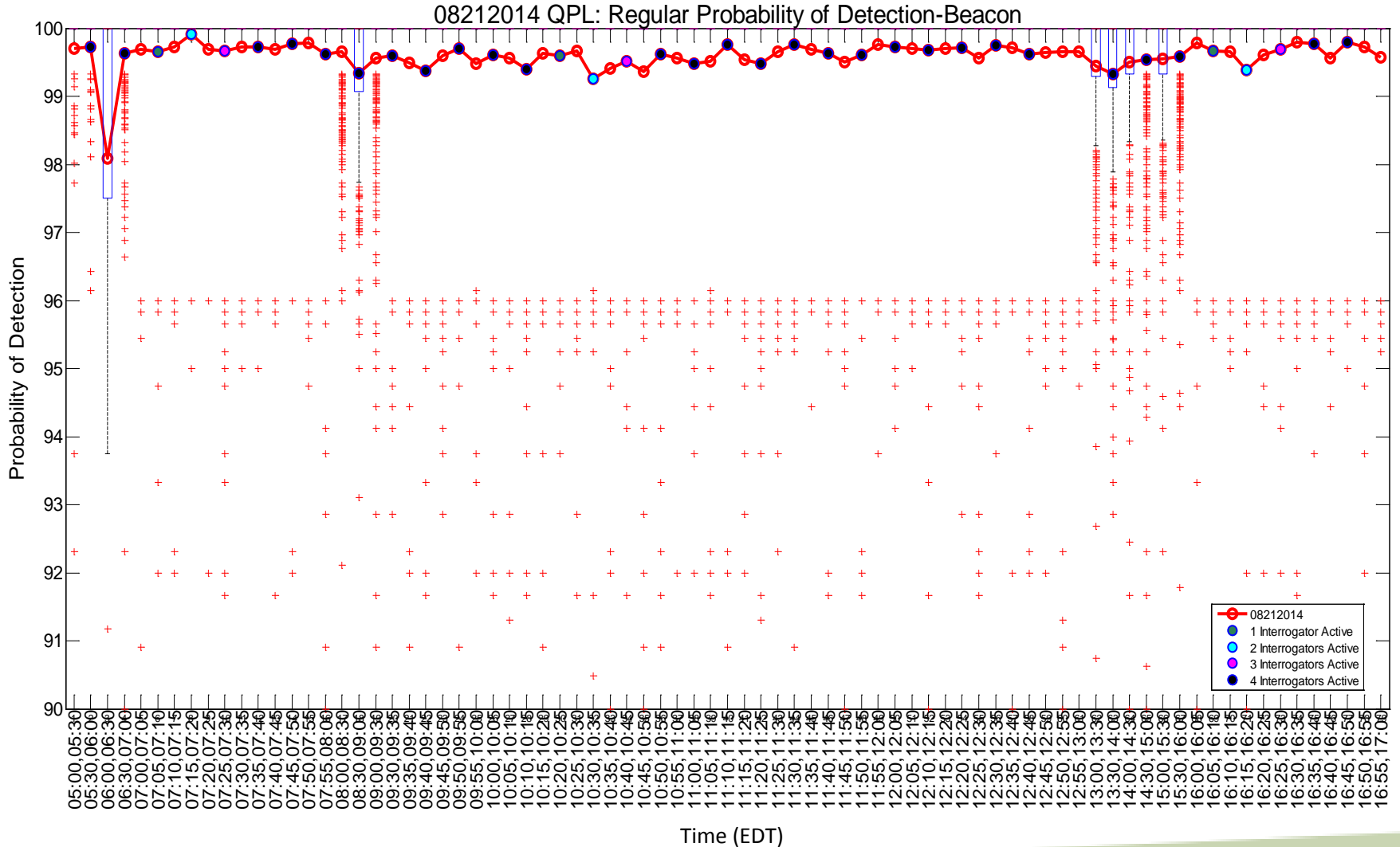


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)



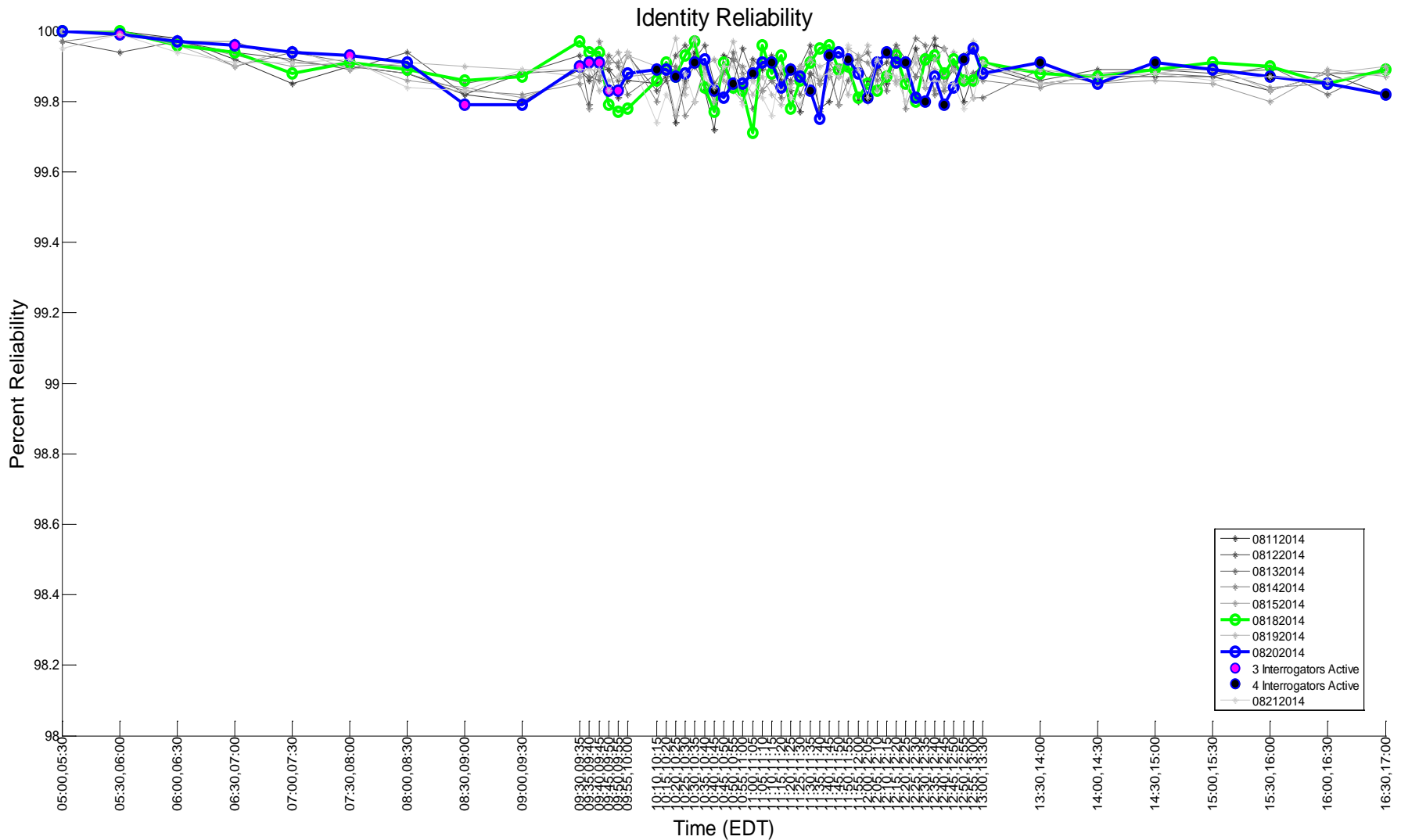
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°





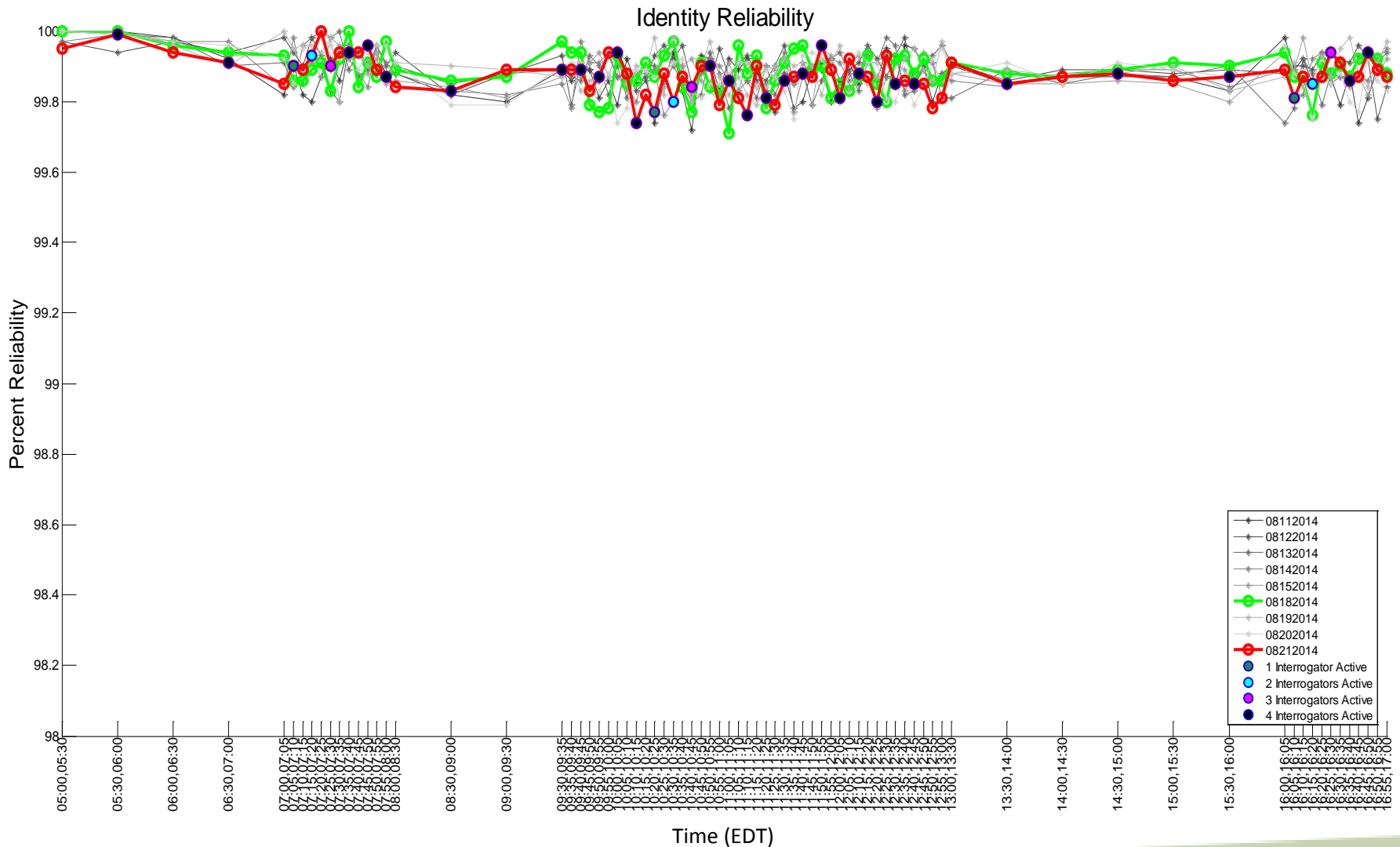
# Identity (3/A) Reliability – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

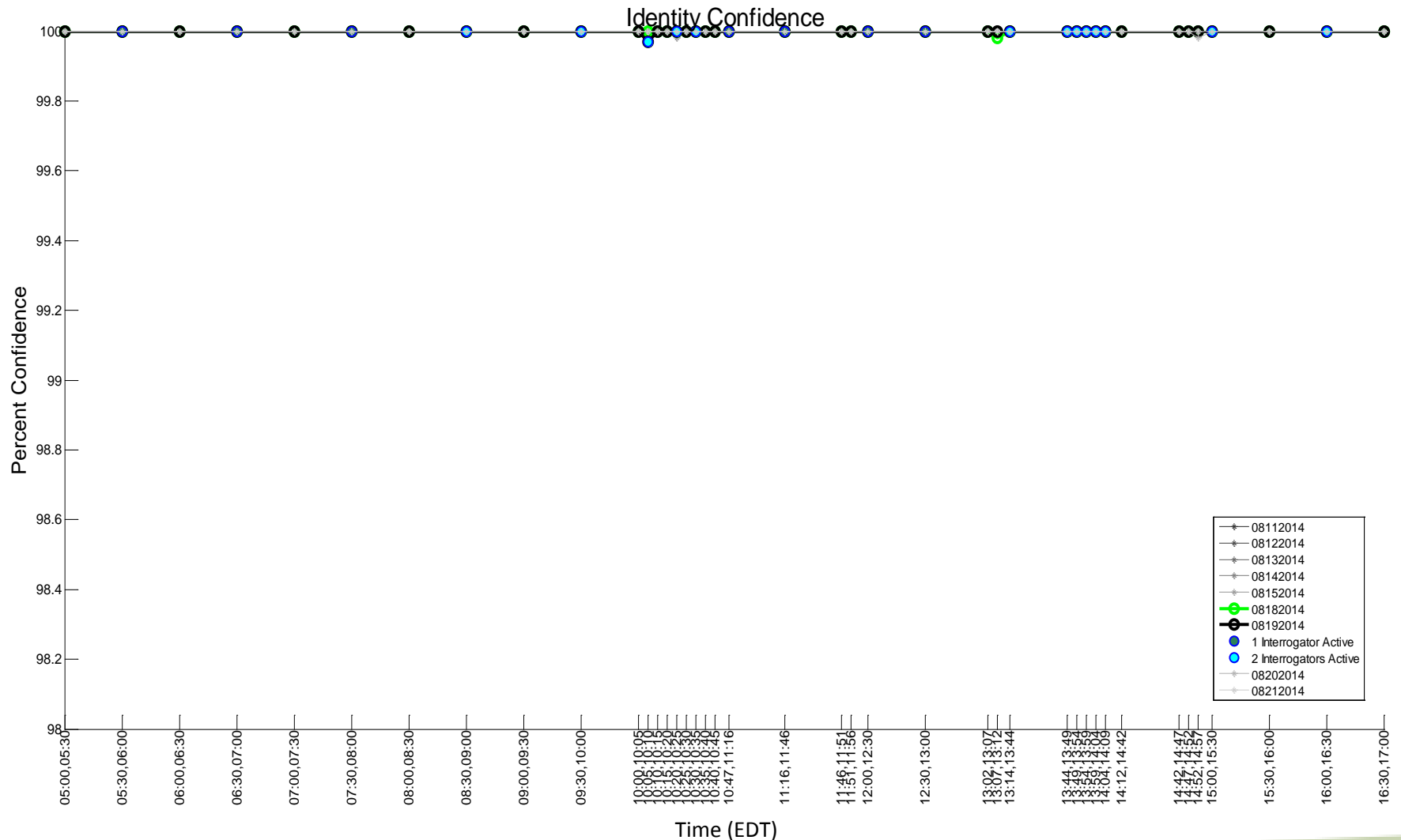
# Identity (3/A) Reliability – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

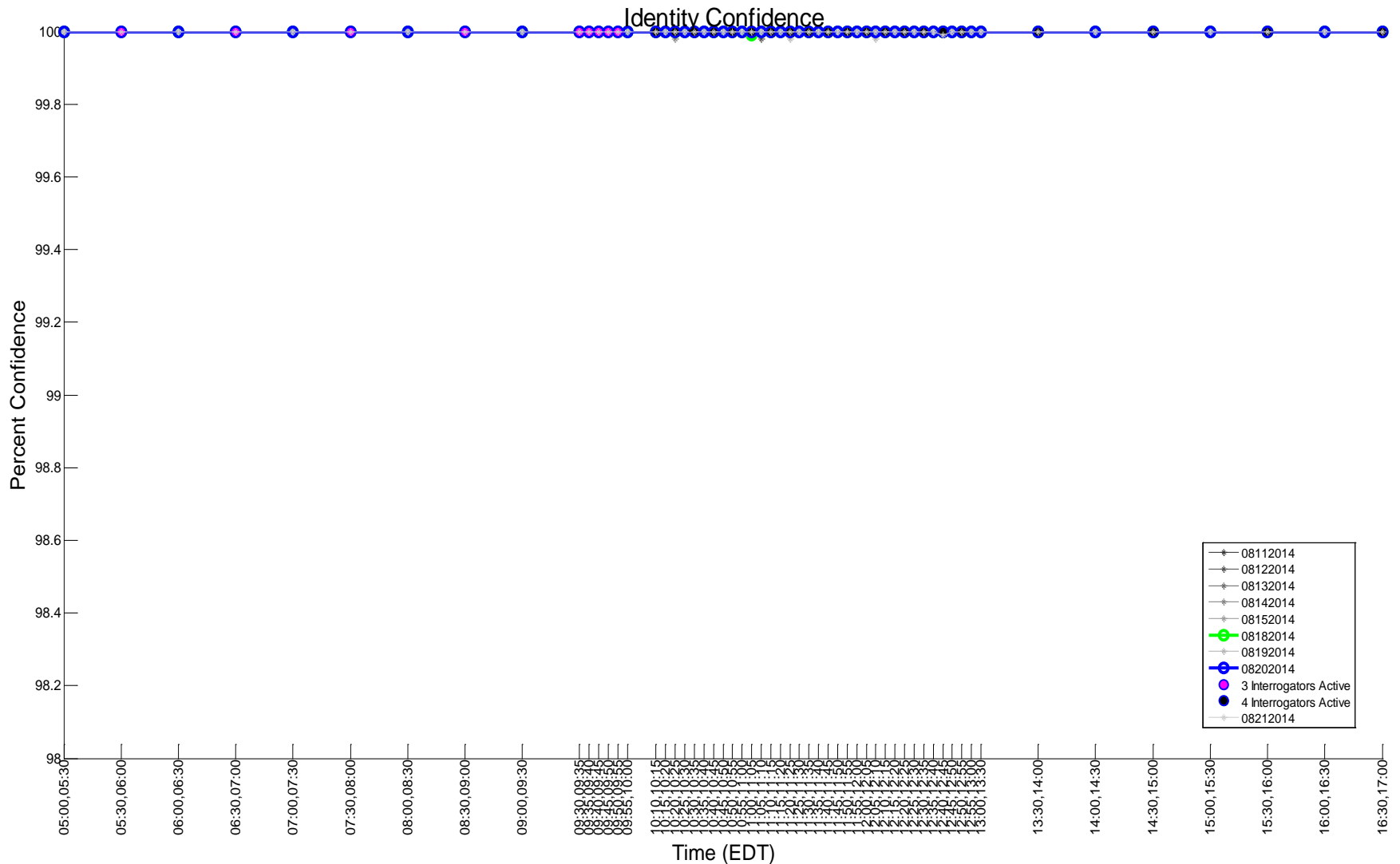
# Identity (3/A) Confidence – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

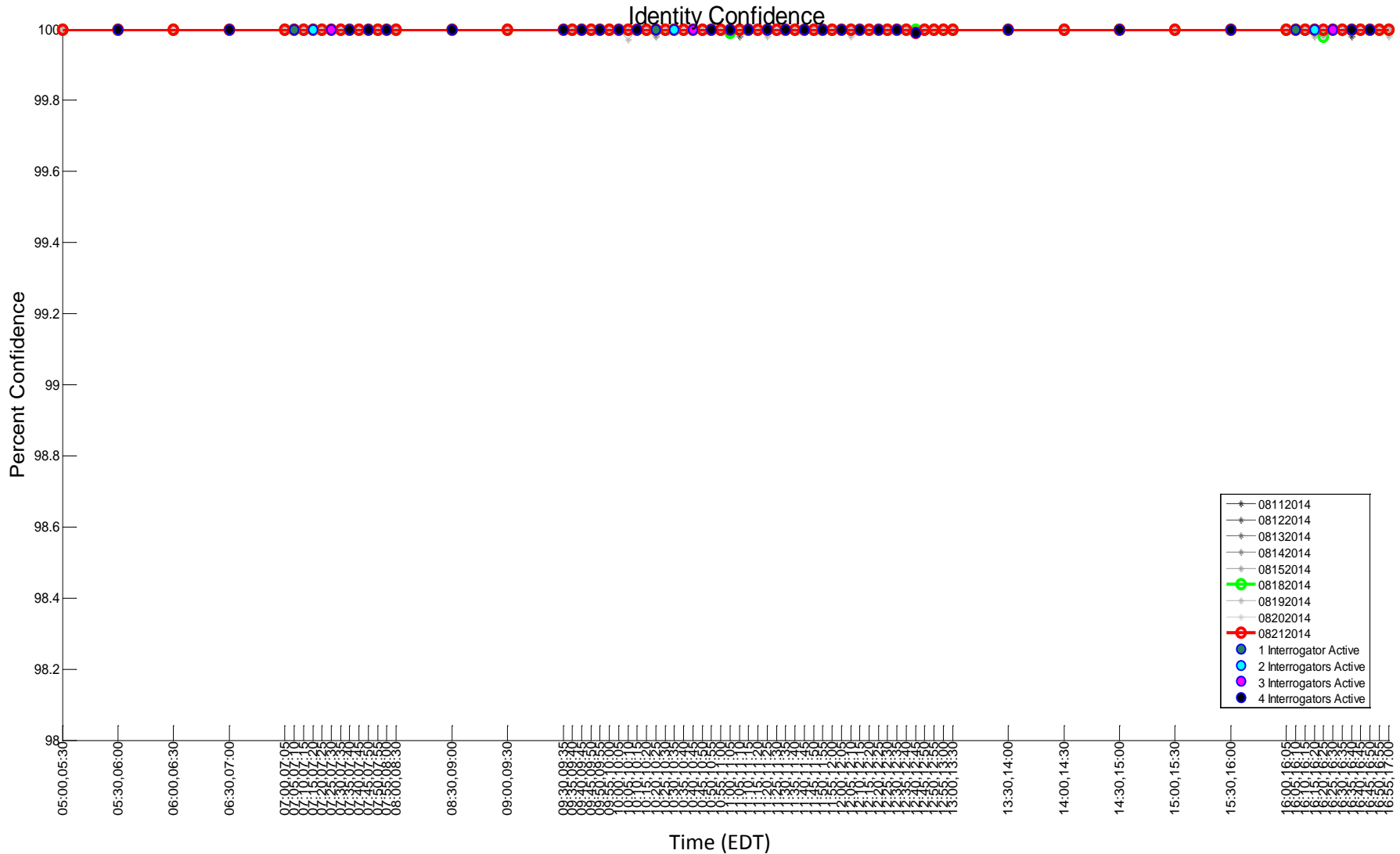
# Identity (3/A) Confidence – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

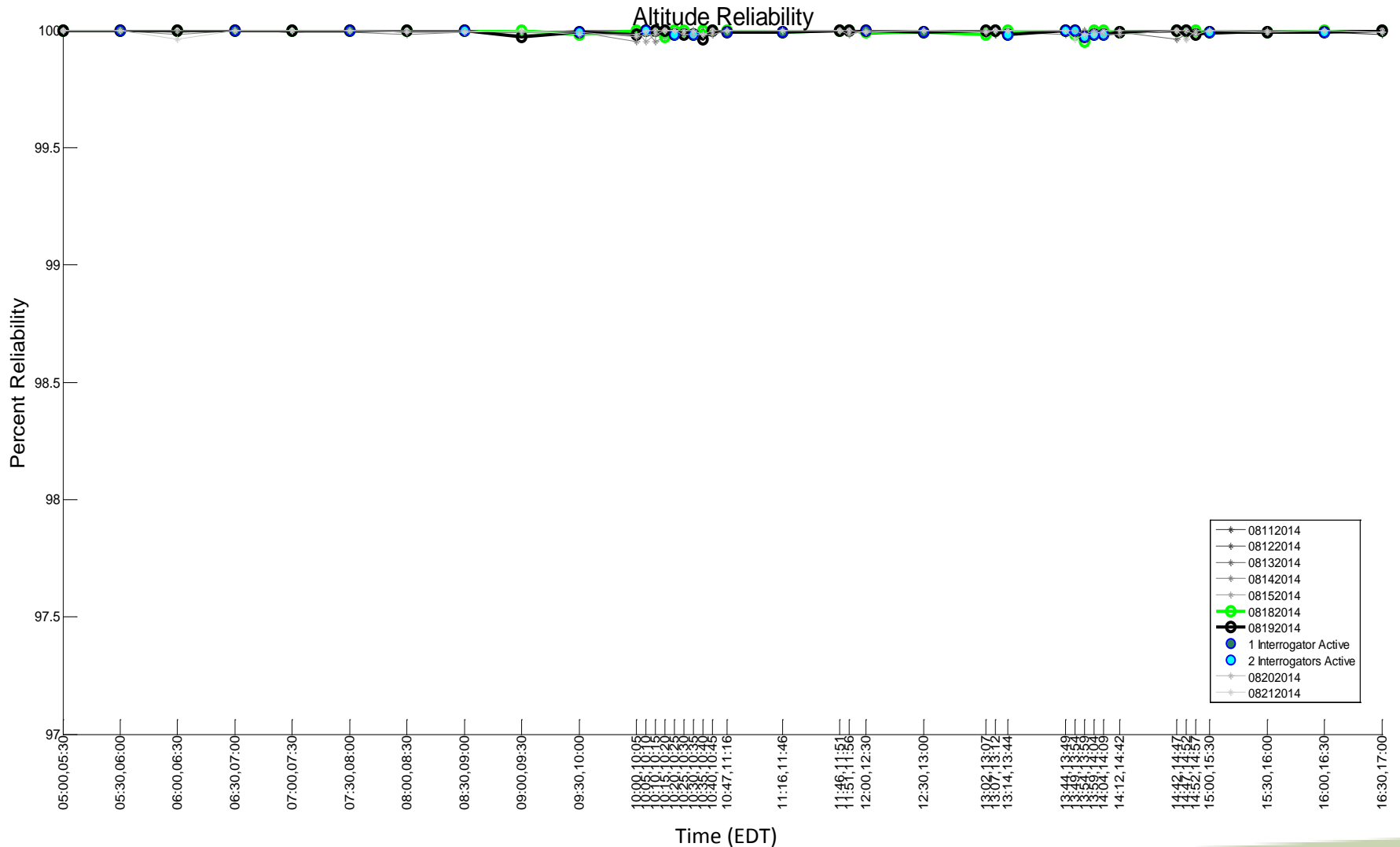
# Identity (3/A) Confidence – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

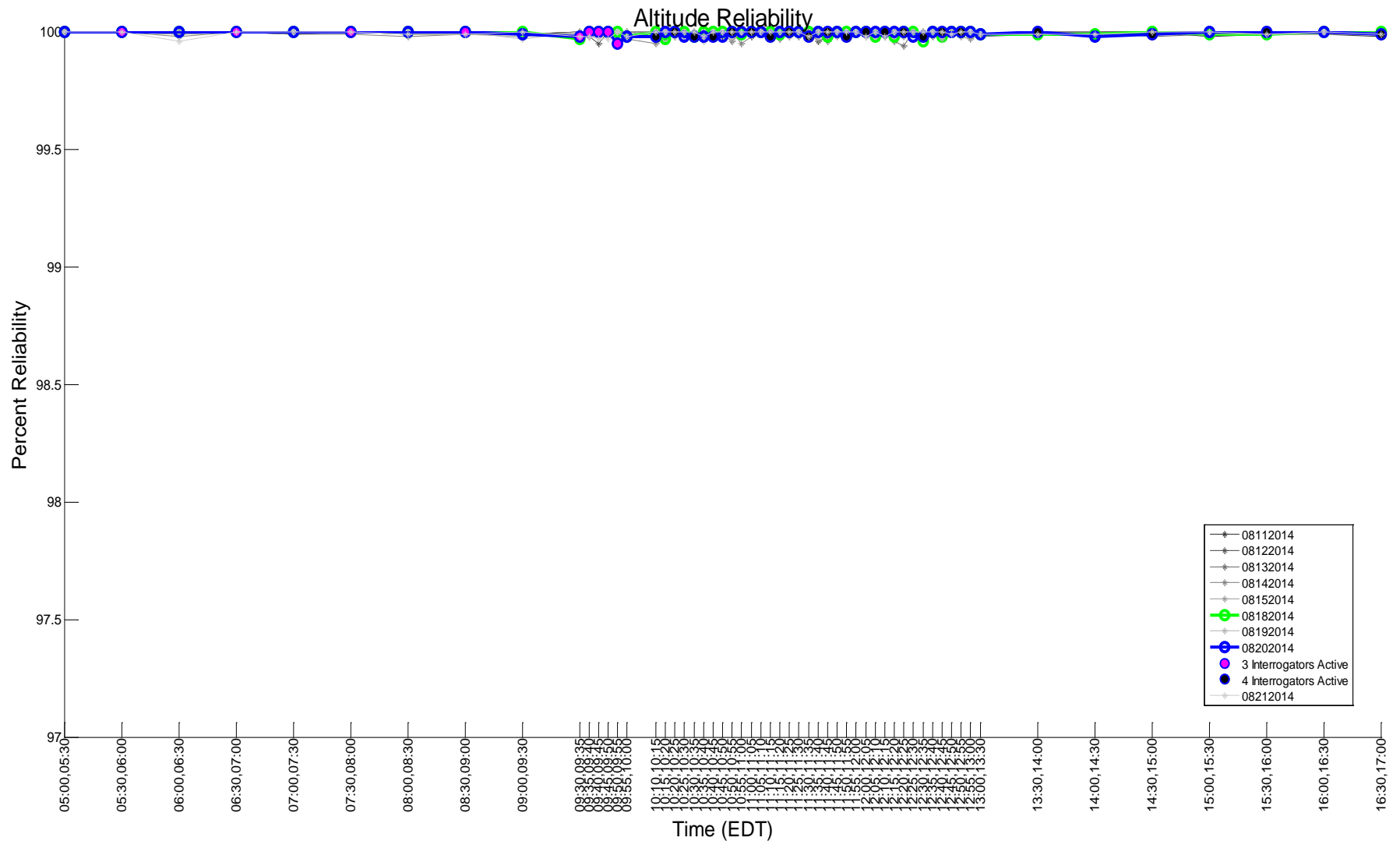
# Altitude (C) Reliability – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

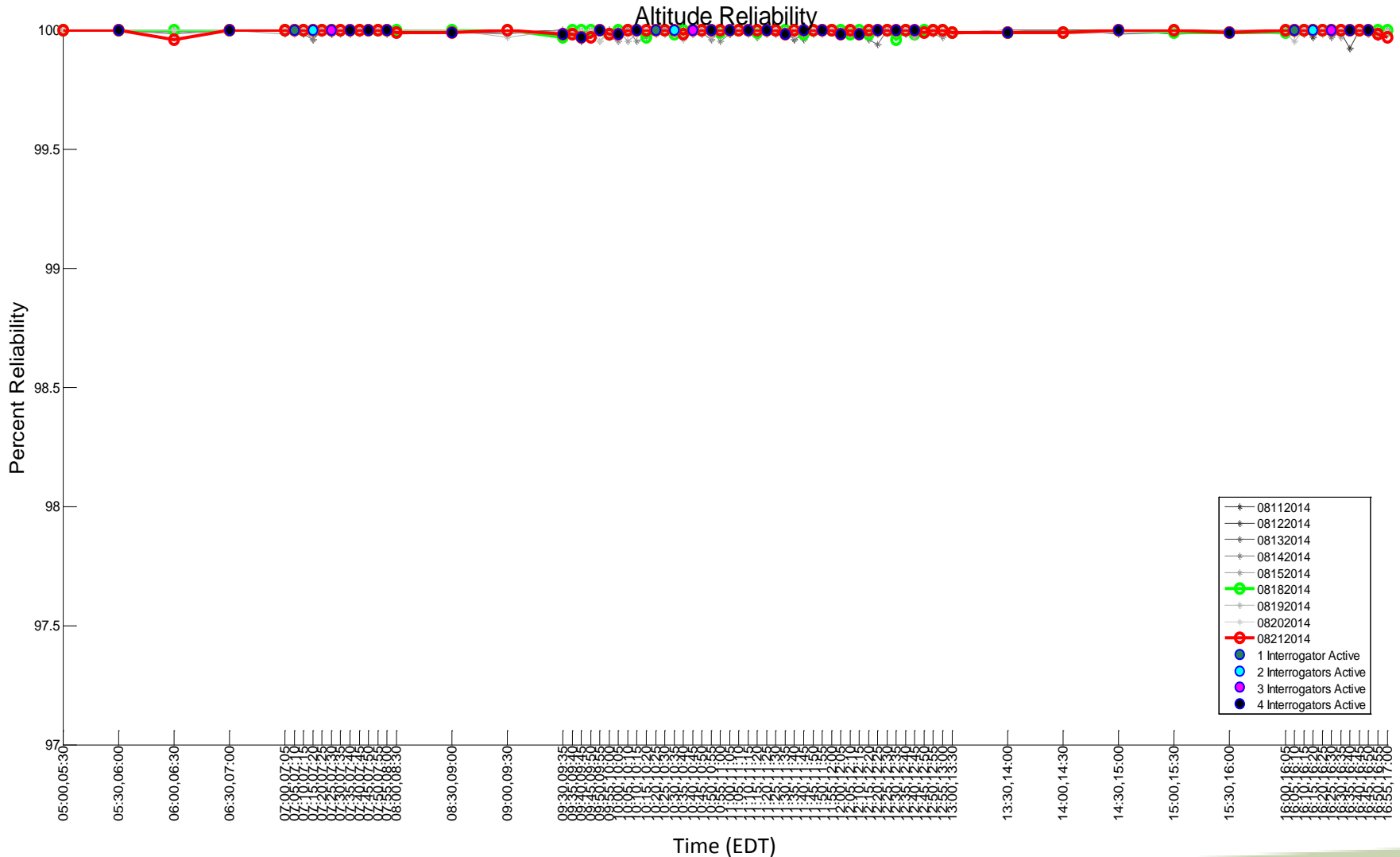
# Altitude (C) Reliability – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Altitude (C) Reliability – August 21<sup>st</sup>

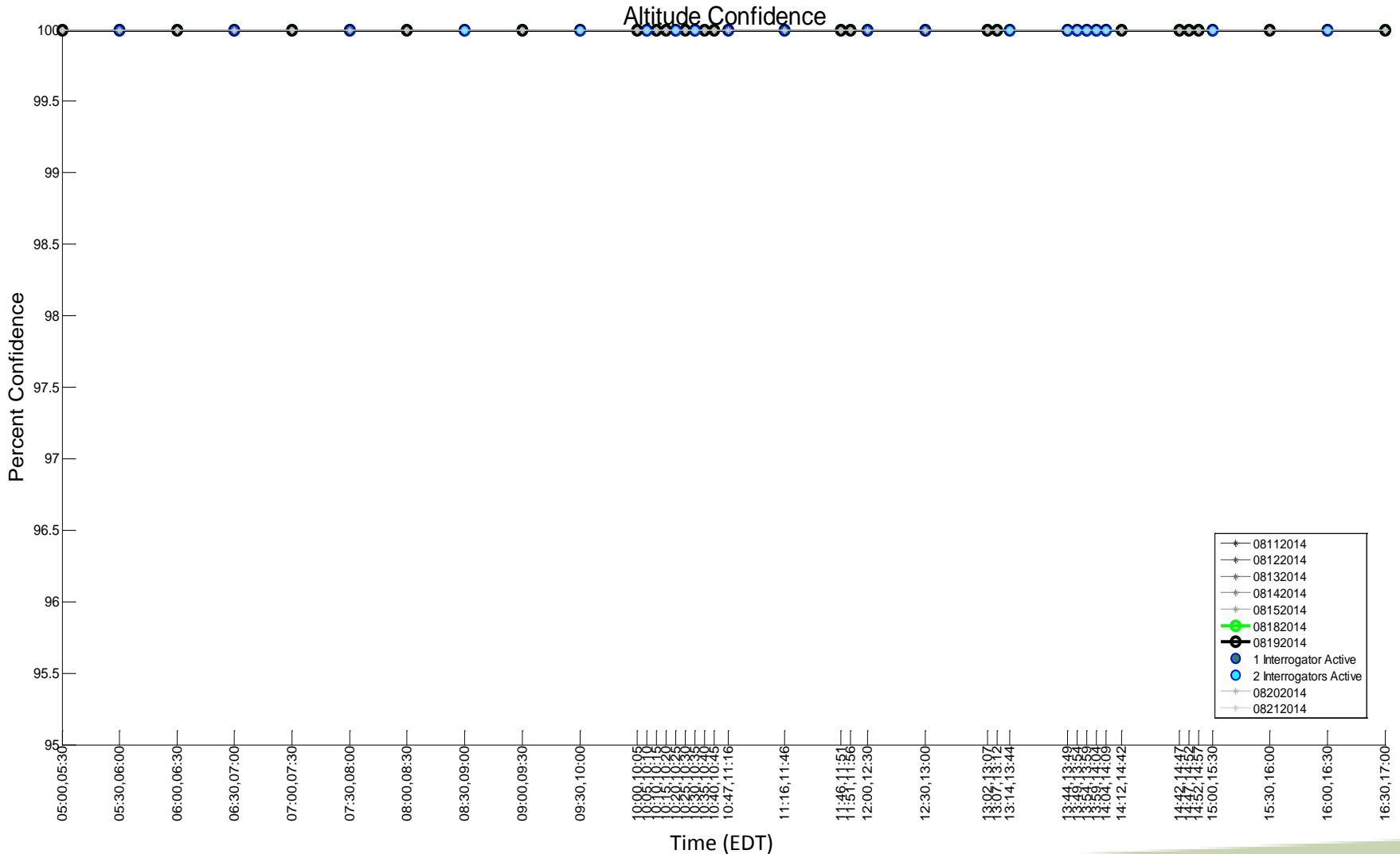


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°



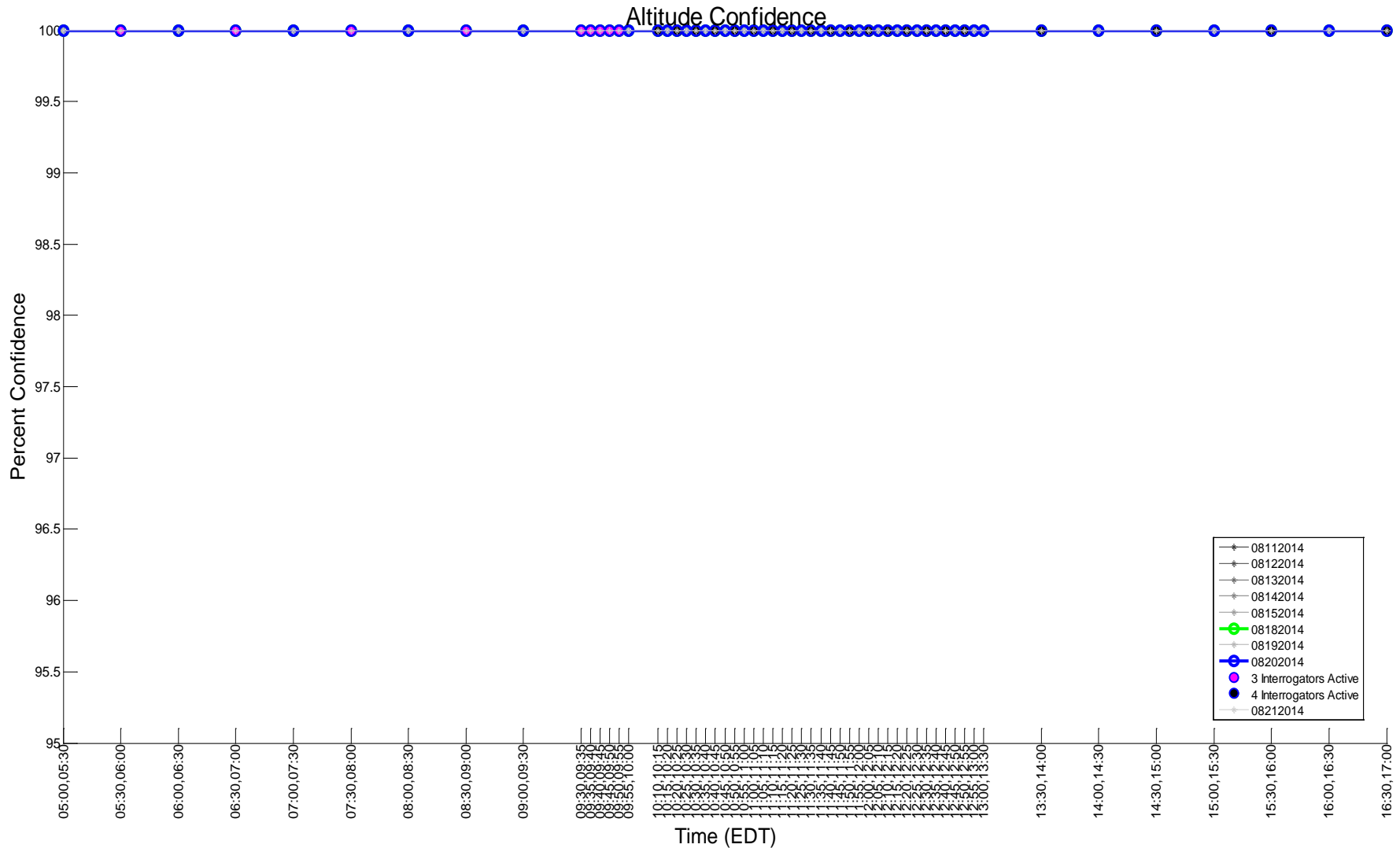
# Altitude (C) Confidence – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

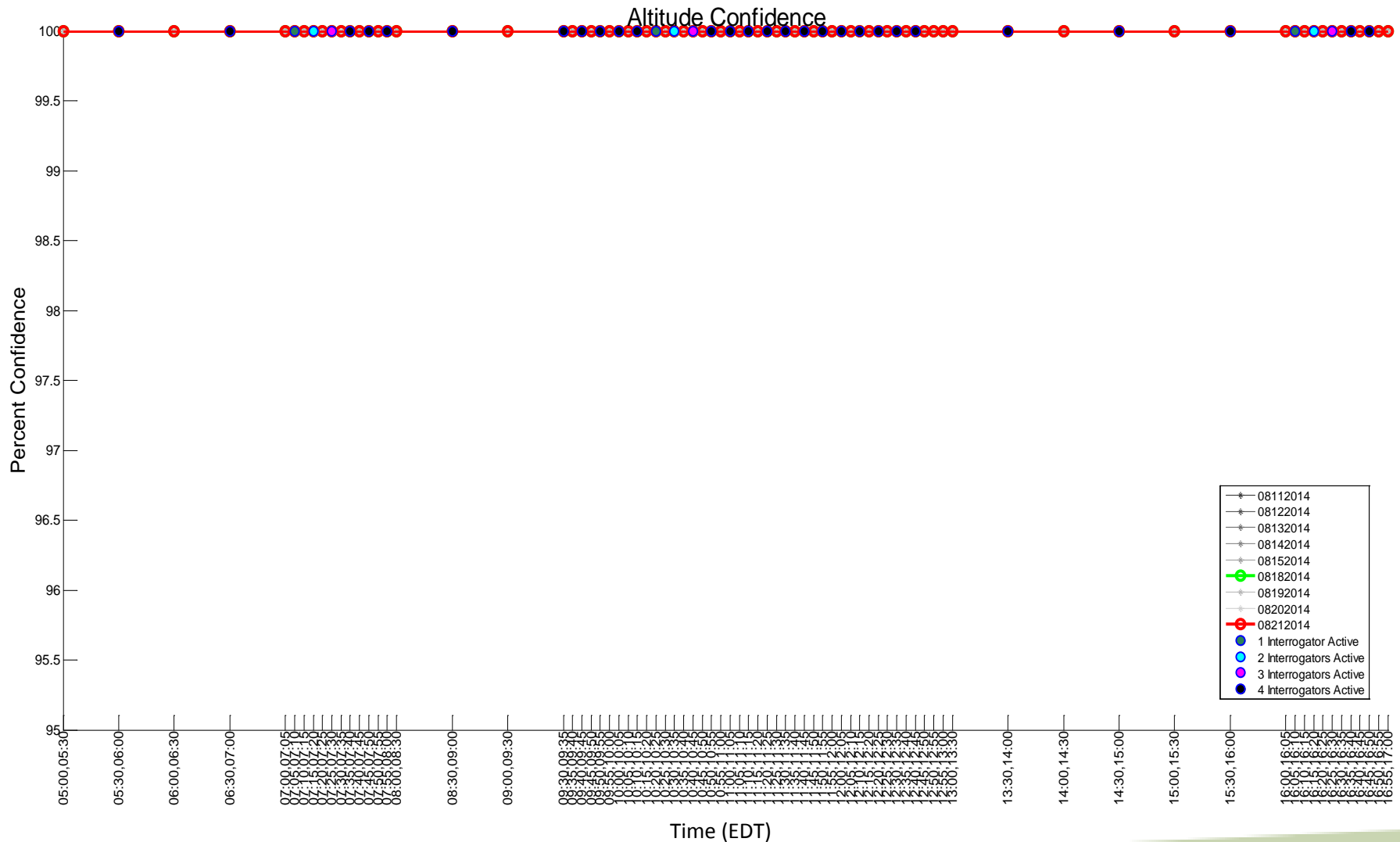
# Altitude (C) Confidence – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Altitude (C) Confidence – August 21<sup>st</sup>



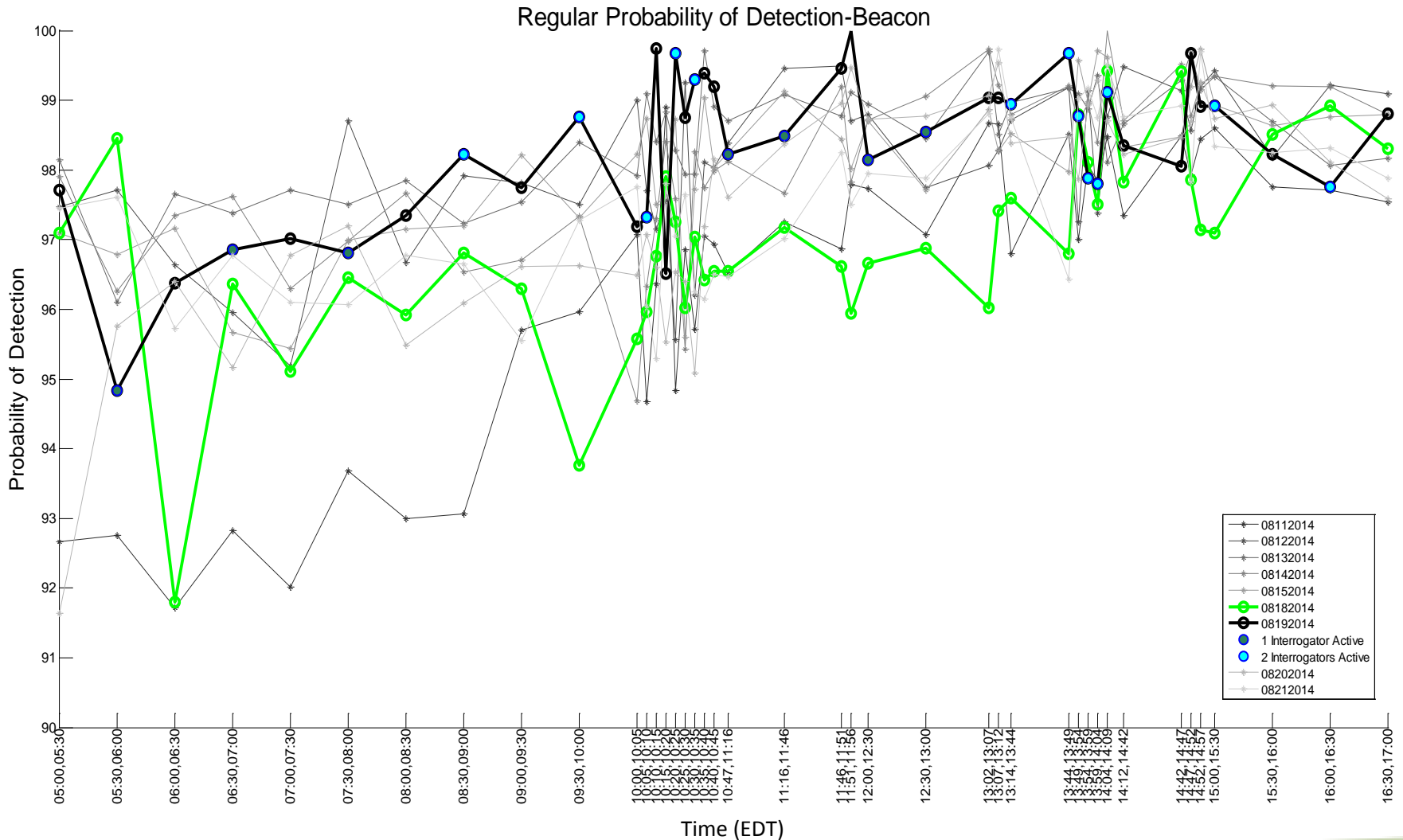
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Target Metrics with Range greater than 190 NM from SSR

*\* Number of Targets Unavailable*

# Probability of Detection – August 19<sup>th</sup>

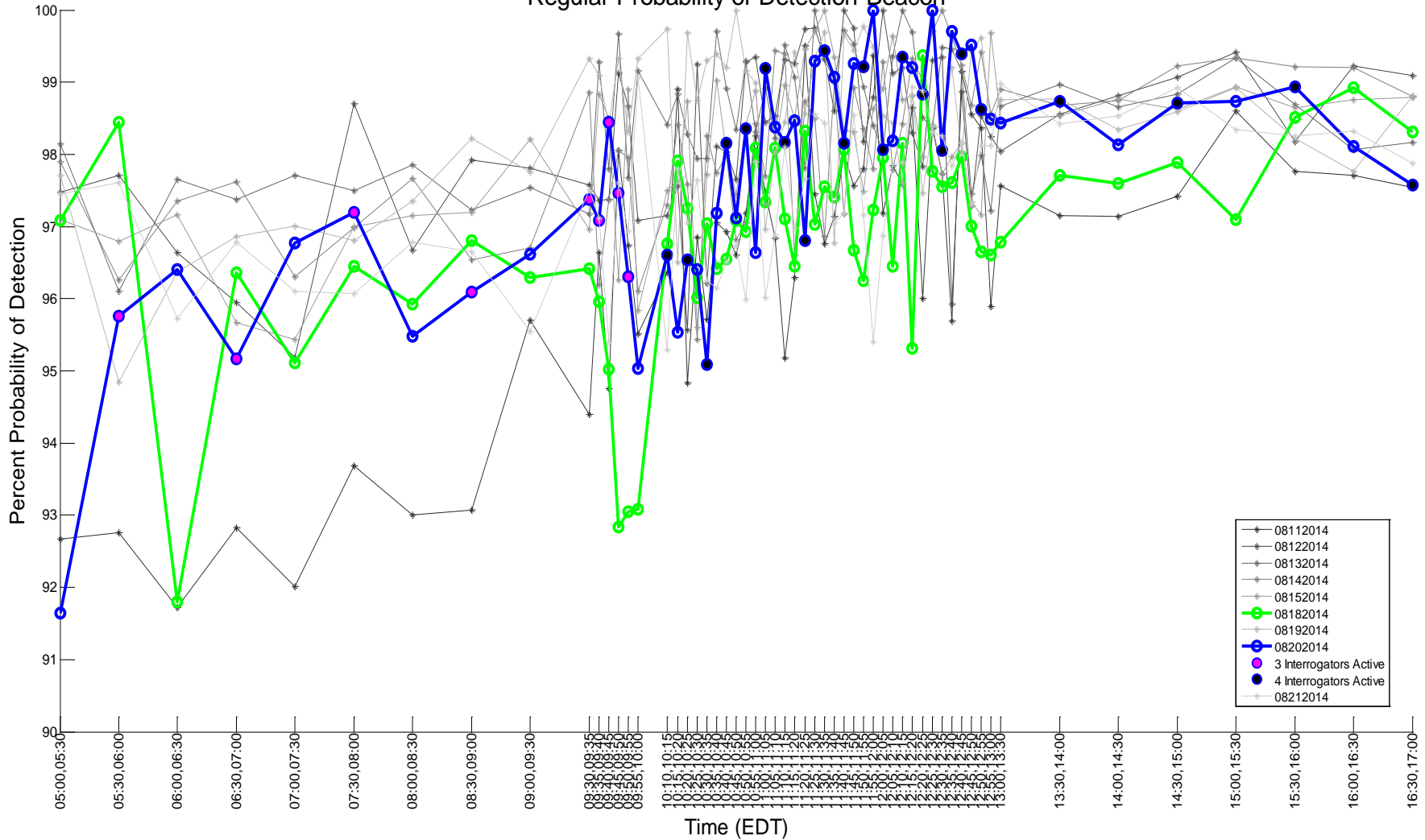


Geographic Filter: None

Target Filter: Exclude Targets < 190 NM

# Probability of Detection – August 20<sup>th</sup>

Regular Probability of Detection-Beacon

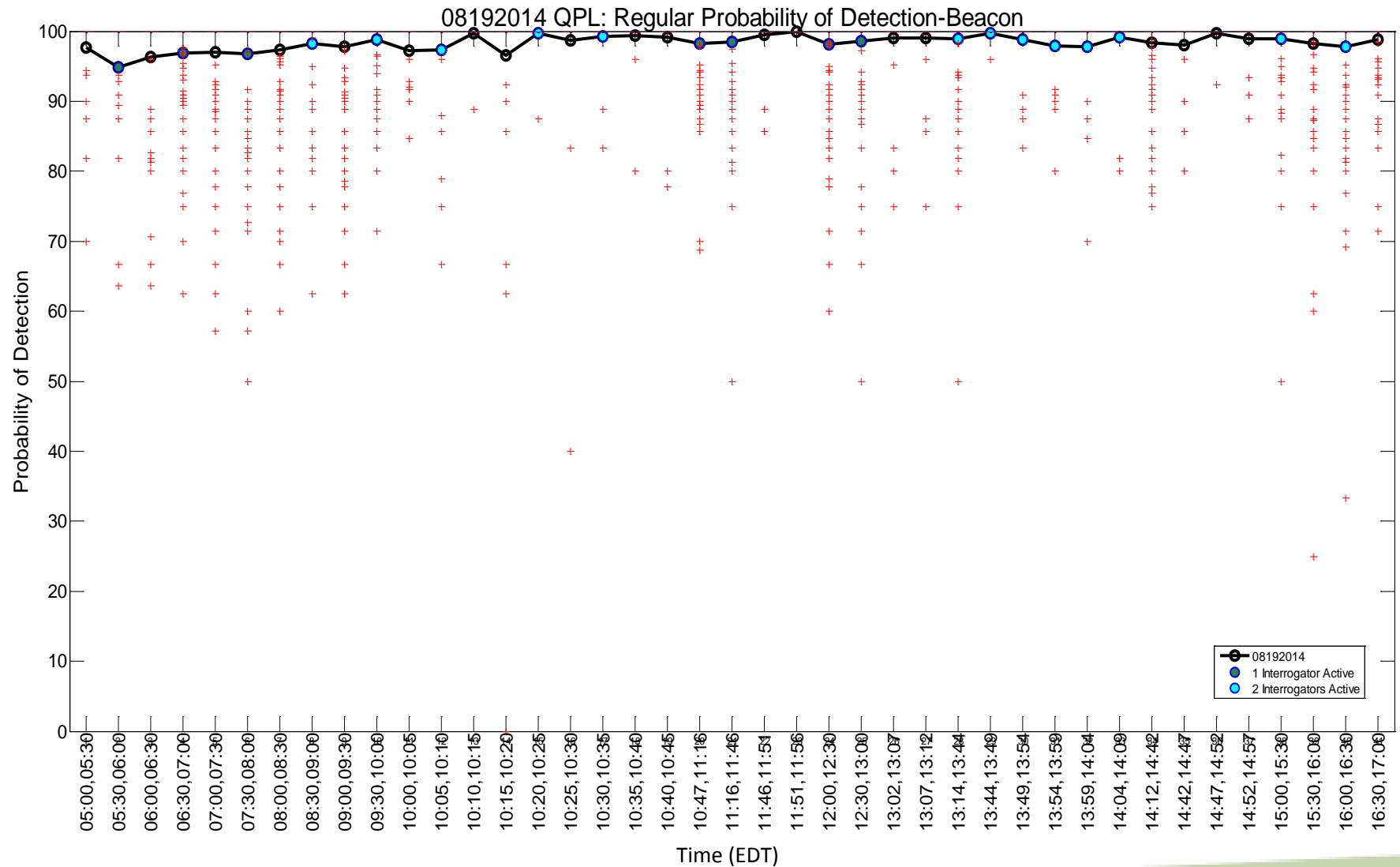


Geographic Filter: None  
Target Filter: Exclude Targets < 190 NM



# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution

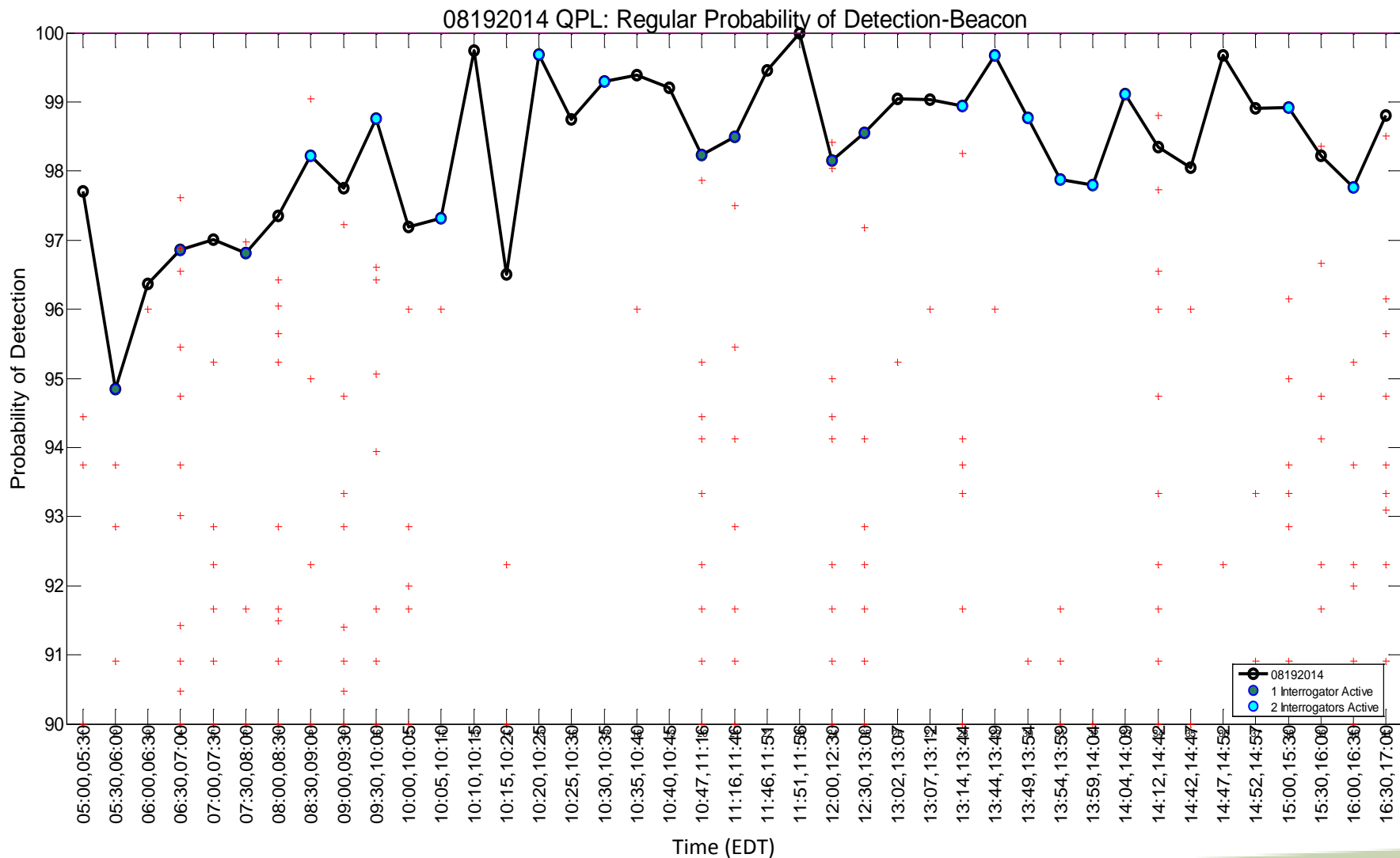


Geographic Filter: None  
 Target Filter: Exclude Targets < 190 NM



# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

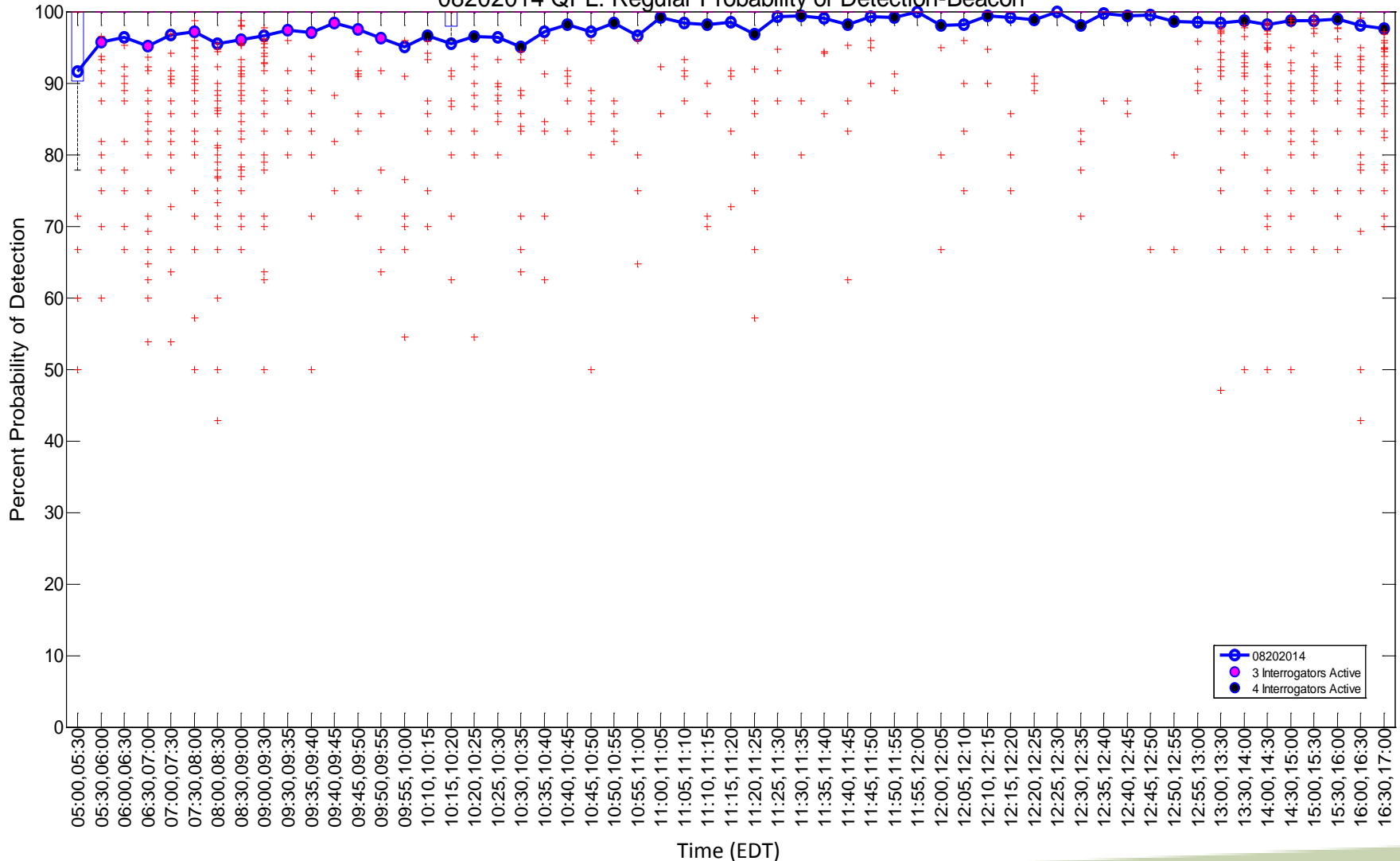


Geographic Filter: None  
 Target Filter: Exclude Targets < 190 NM

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

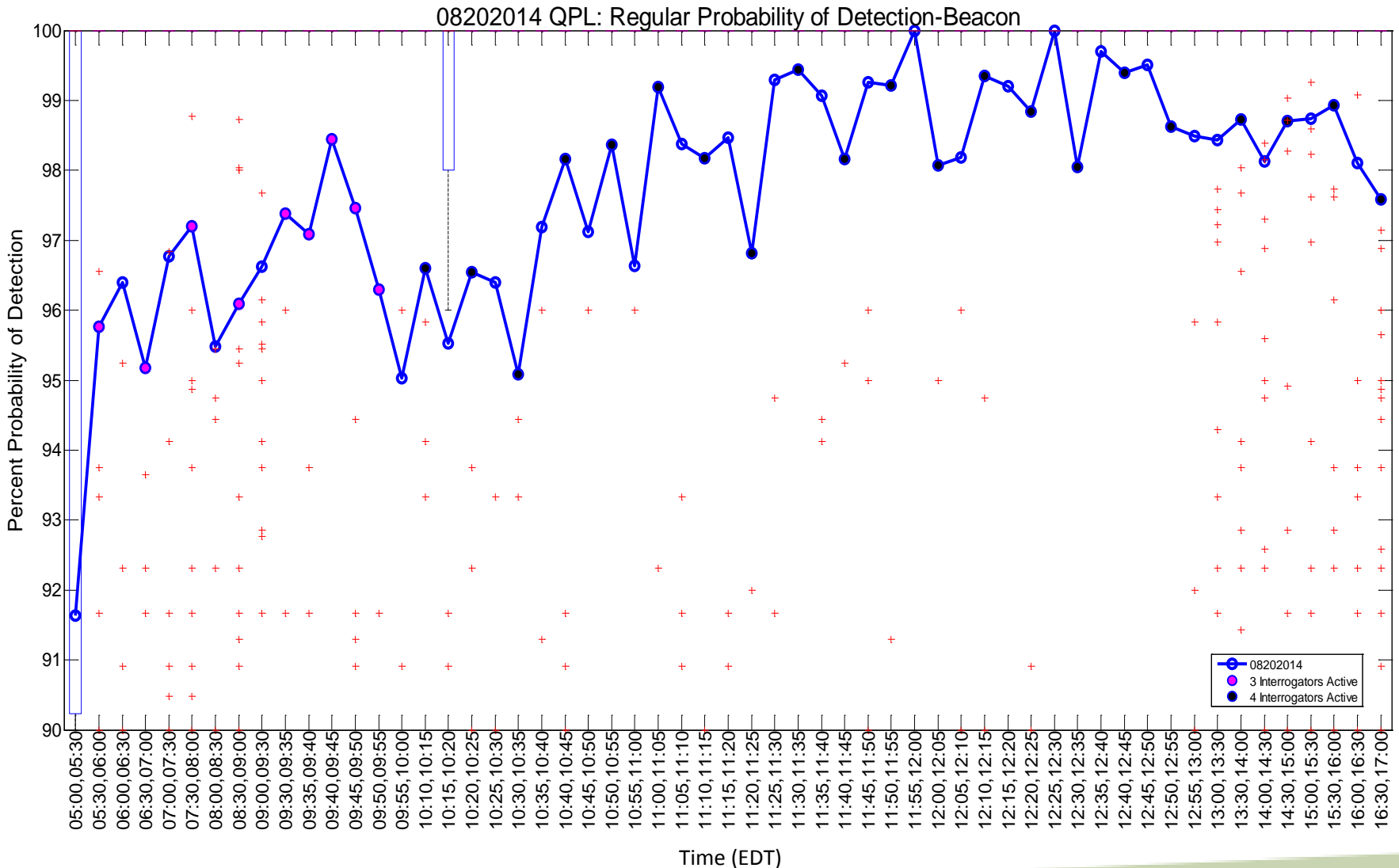
08202014 QPL: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: Exclude Targets < 190 NM

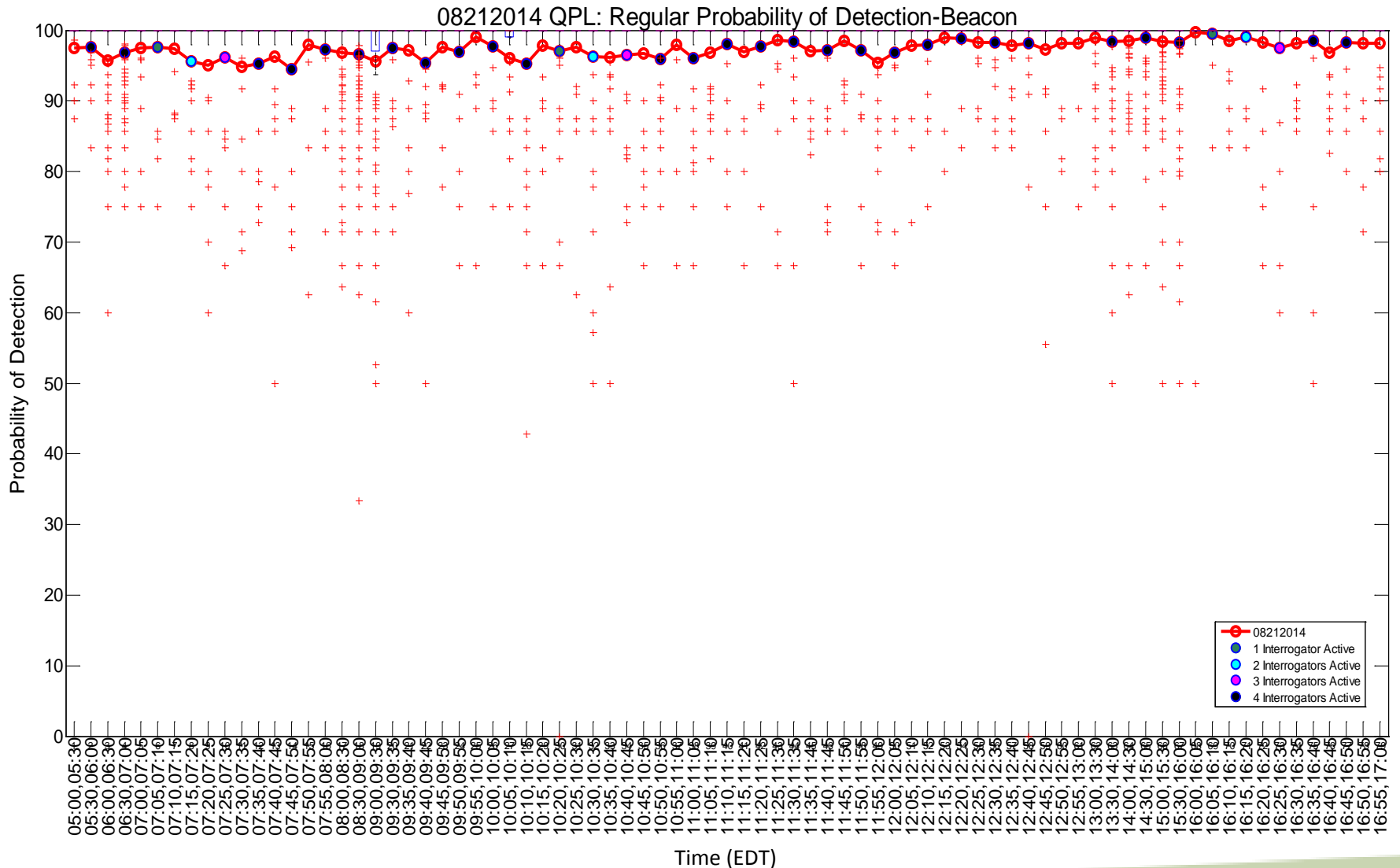
# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

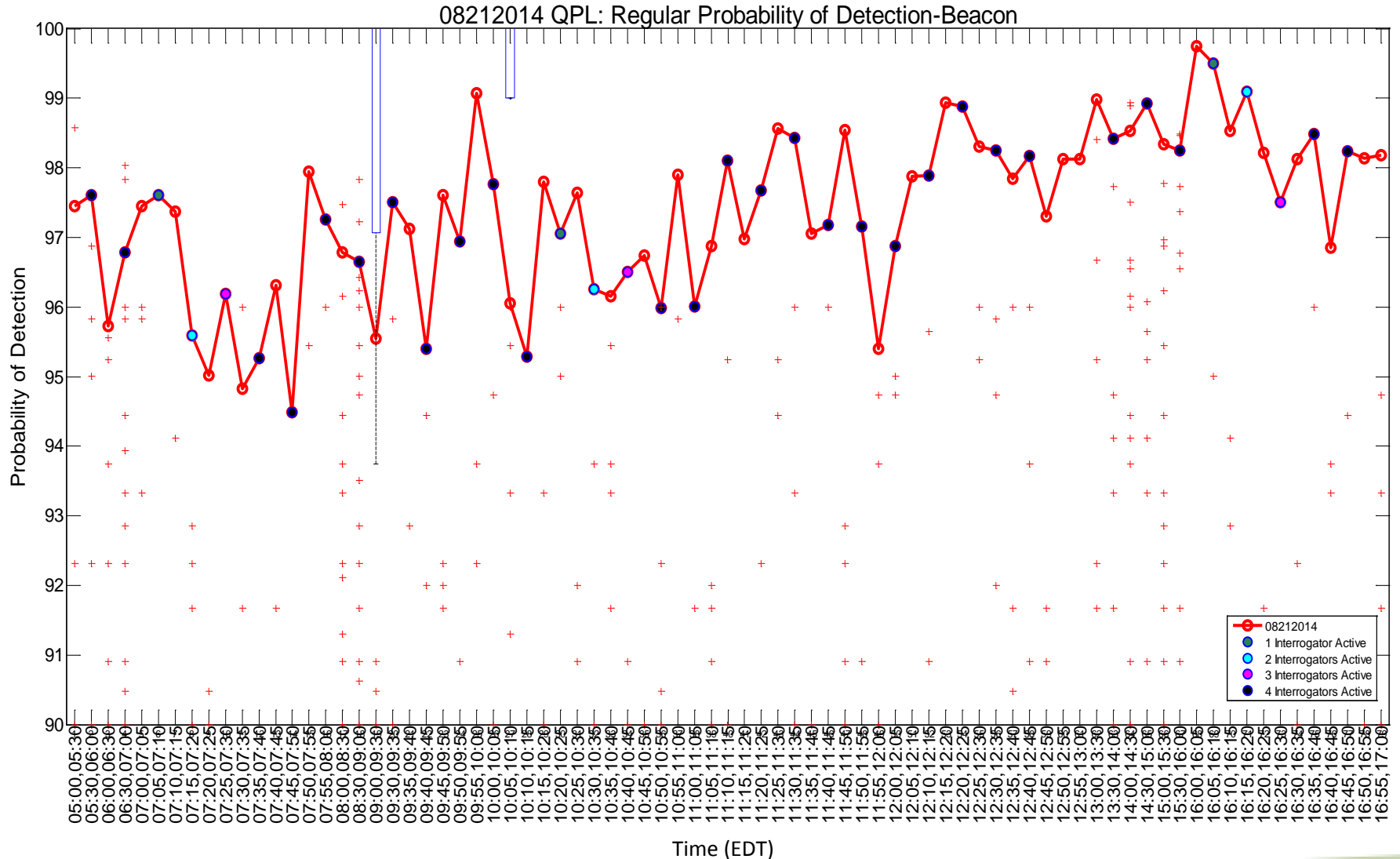


Geographic Filter: None

Target Filter: Exclude Targets < 190 NM

# Probability of Detection – August 21<sup>st</sup>

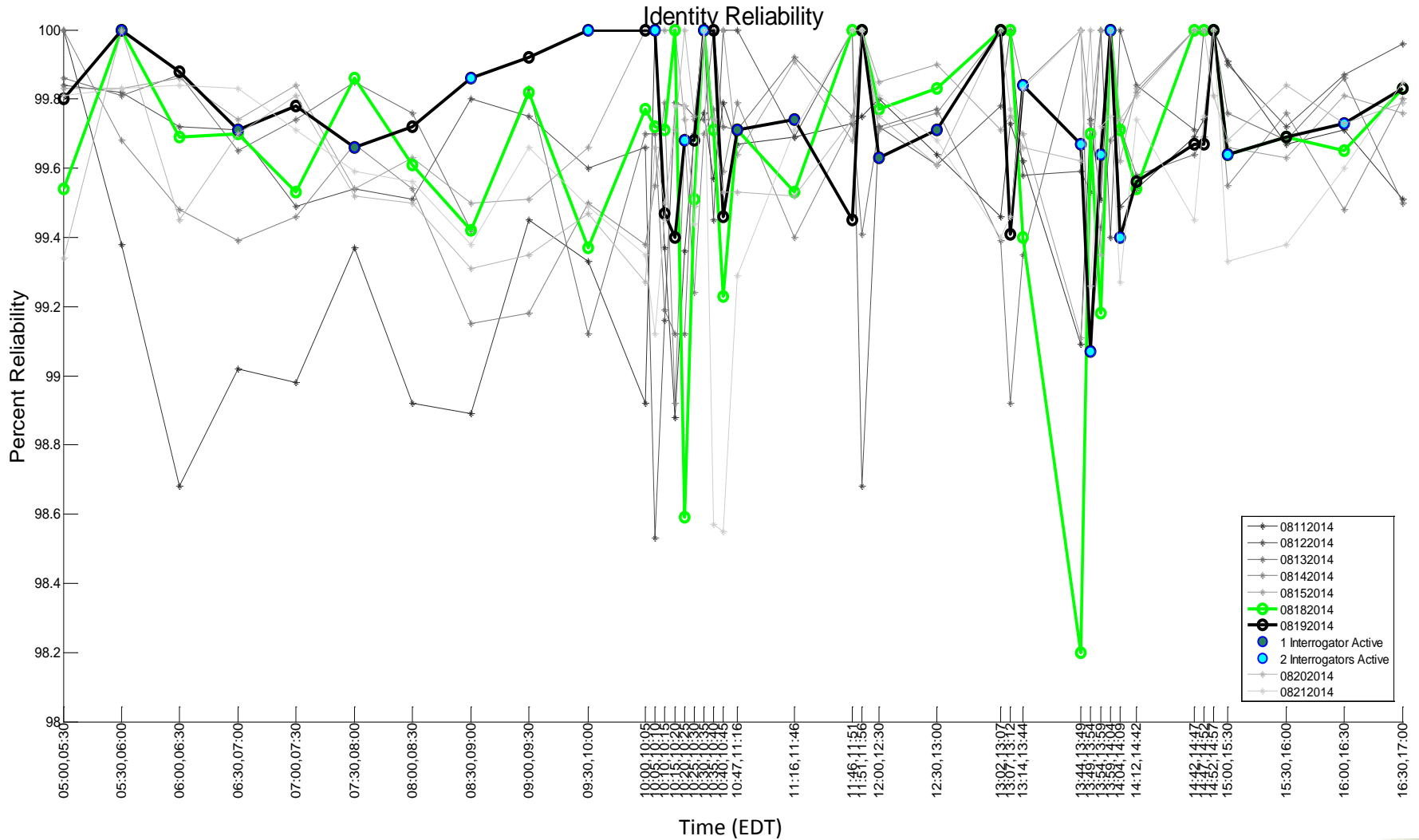
## Individual Aircraft Distribution (zoom-in)



Geographic Filter: None

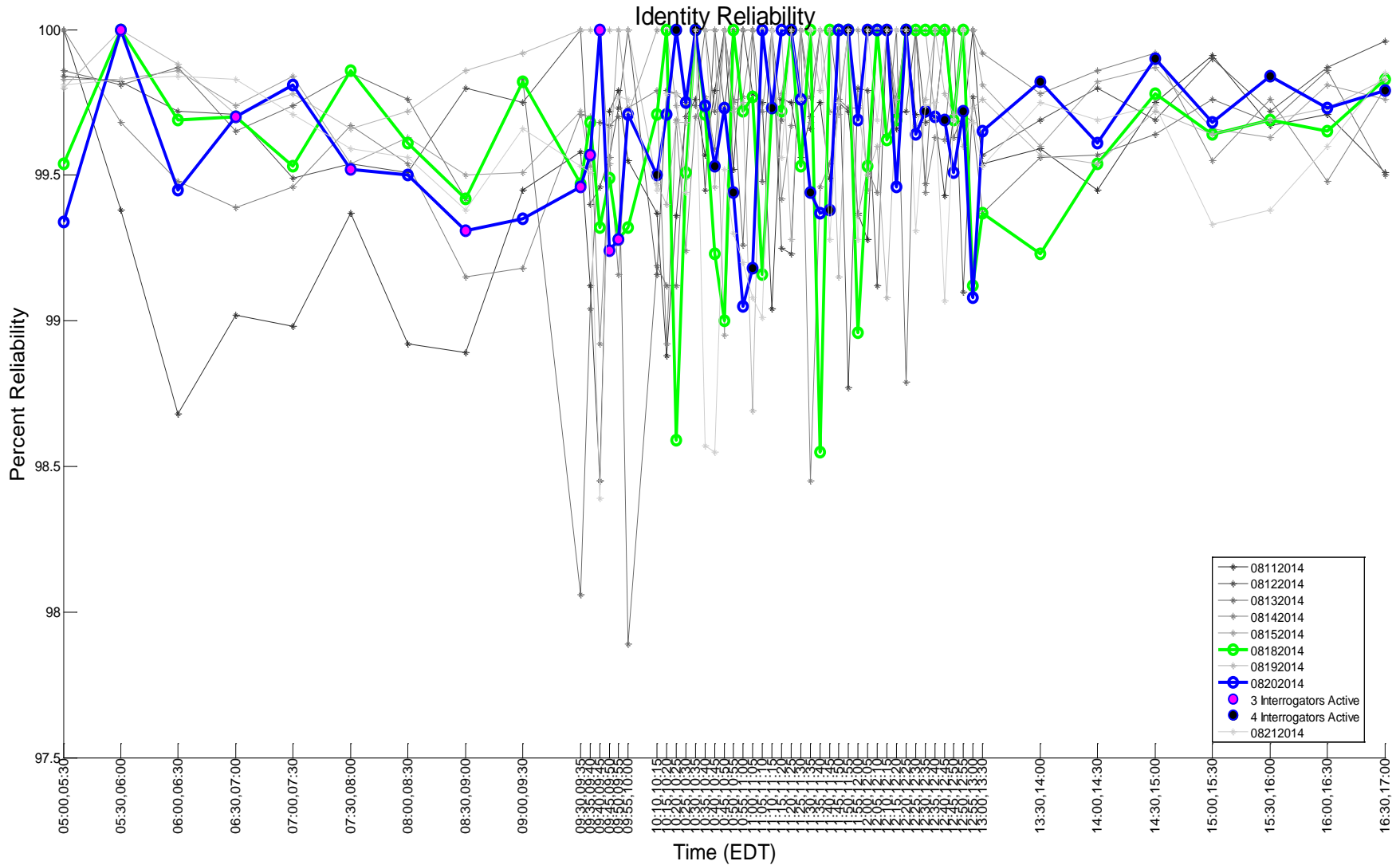
Target Filter: Exclude Targets < 190 NM

# Identity (3/A) Reliability – August 19<sup>th</sup>



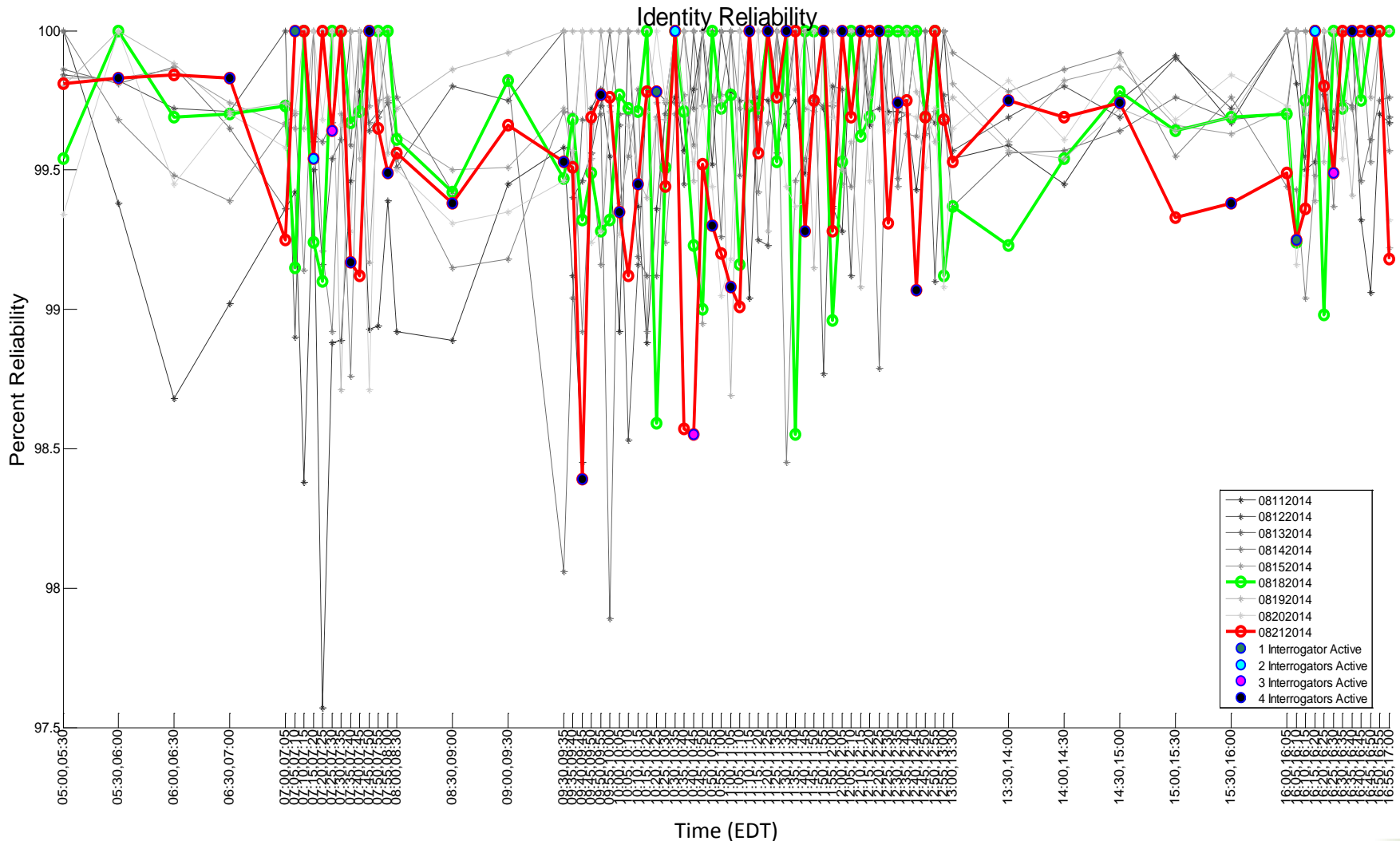
Geographic Filter: None  
Target Filter: Exclude Targets < 190 NM

# Identity (3/A) Reliability – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: Exclude Targets < 190 NM

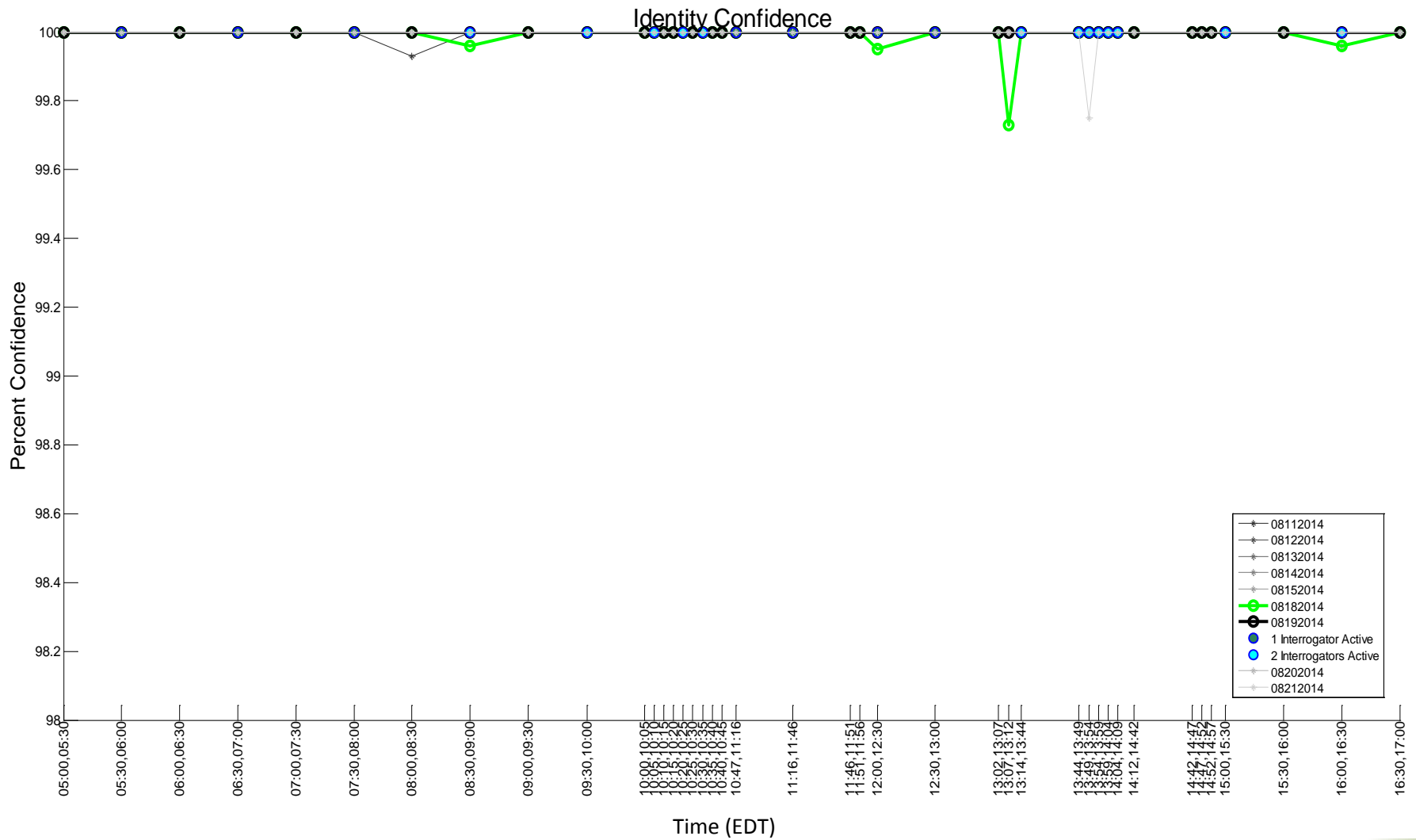
# Identity (3/A) Reliability – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: Exclude Targets < 190 NM

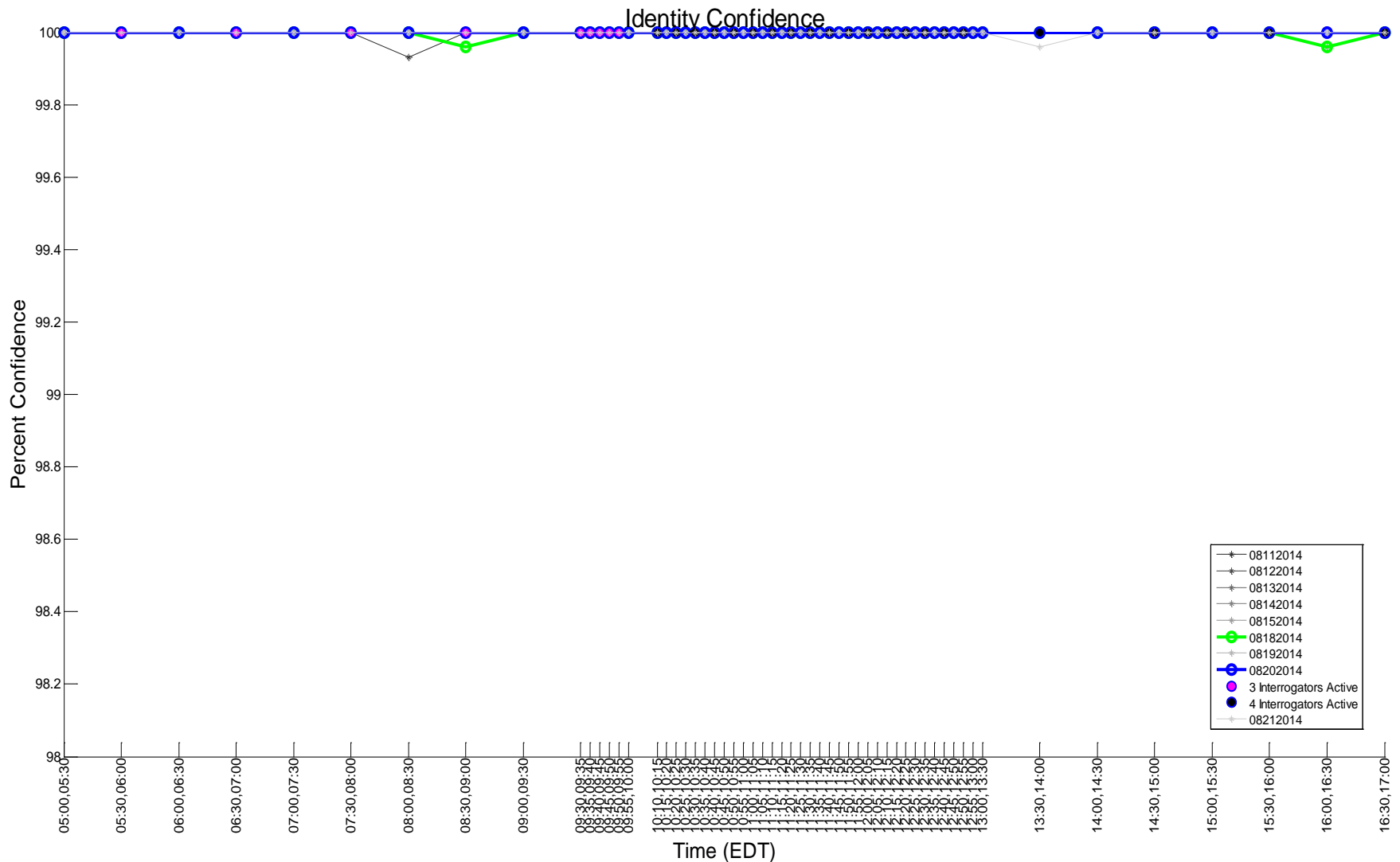


# Identity (3/A) Confidence – August 19<sup>th</sup>



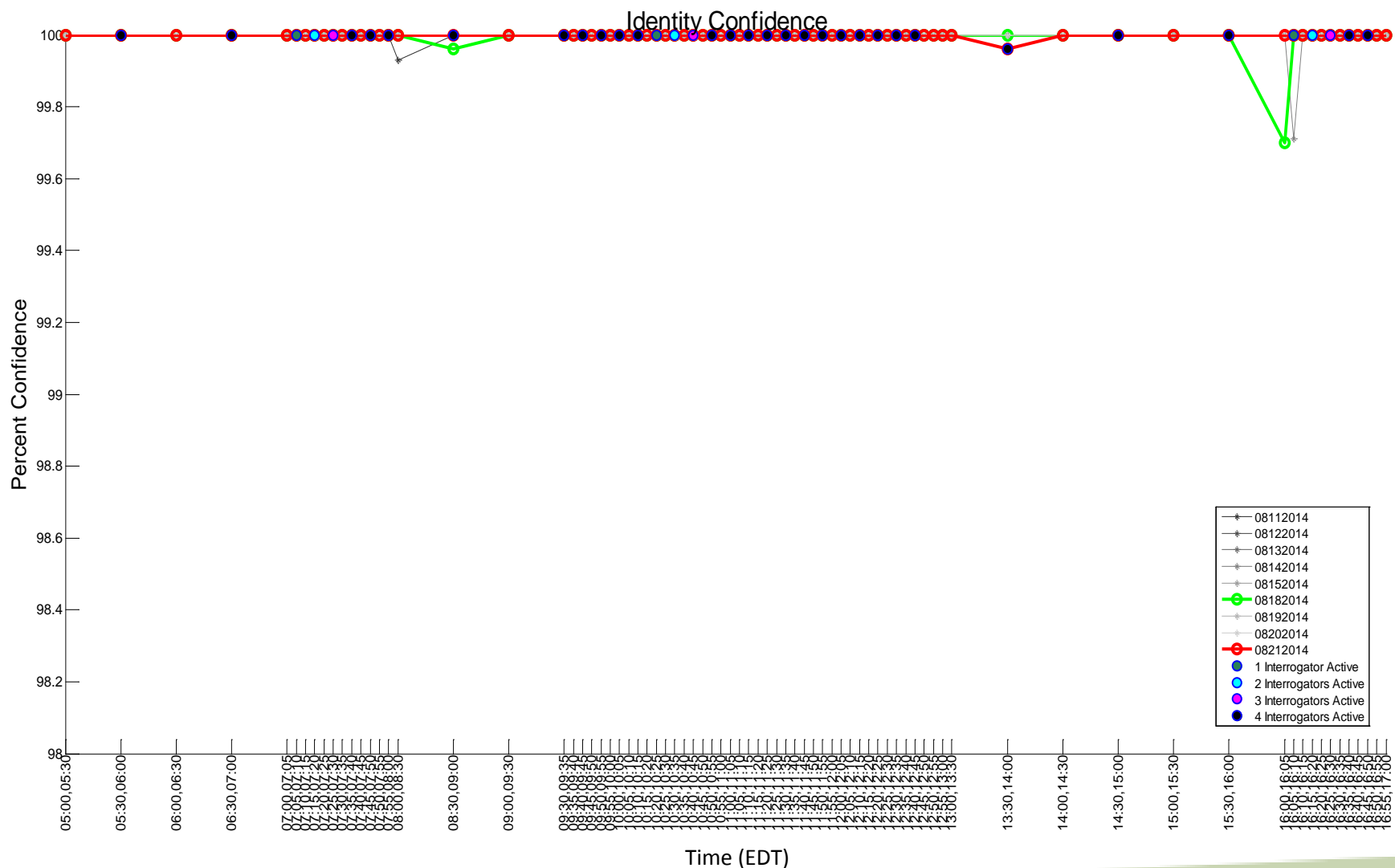
Geographic Filter: None  
 Target Filter: Exclude Targets < 190 NM

# Identity (3/A) Confidence – August 20<sup>th</sup>



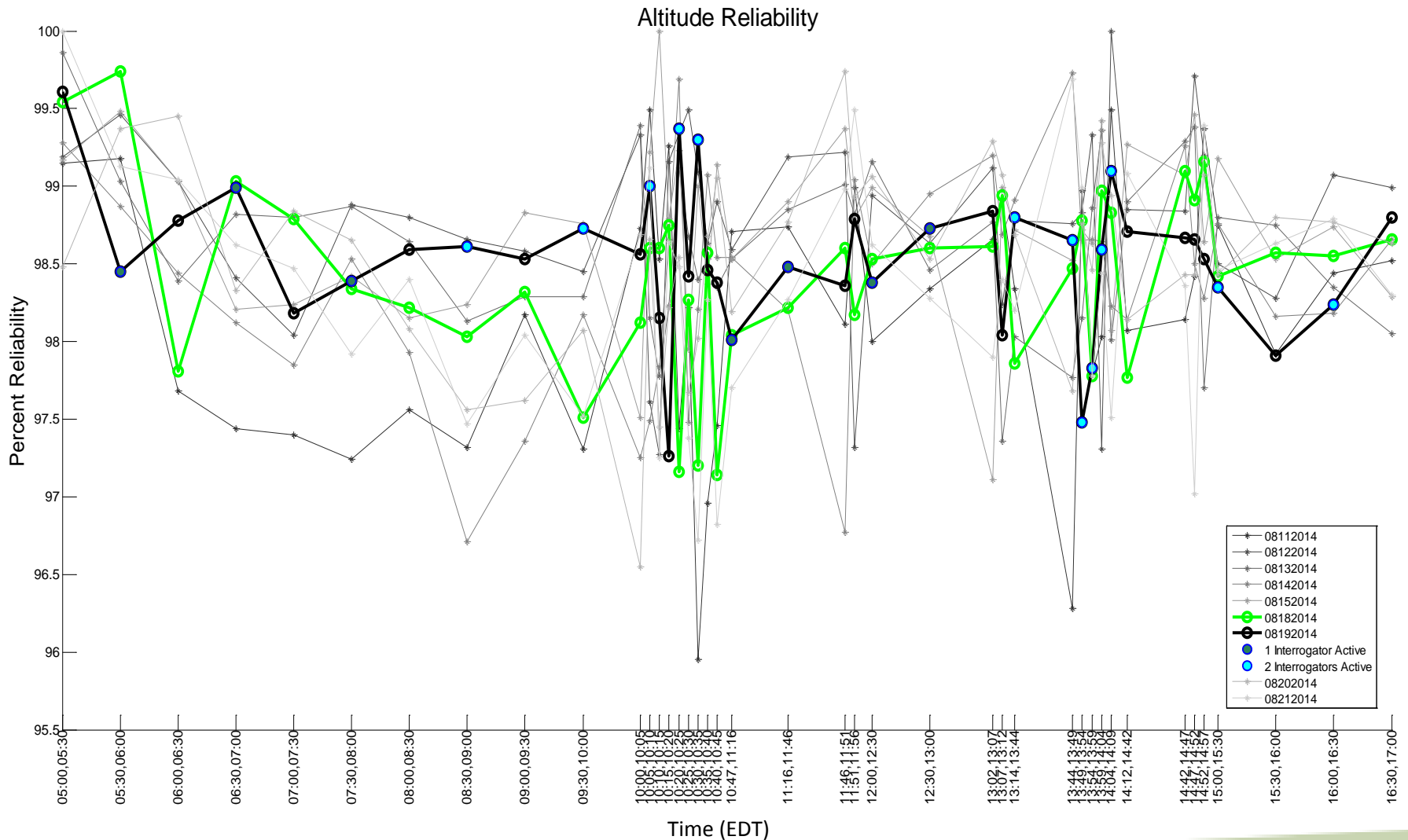
Geographic Filter: None  
Target Filter: Exclude Targets < 190 NM

# Identity (3/A) Confidence – August 21<sup>st</sup>

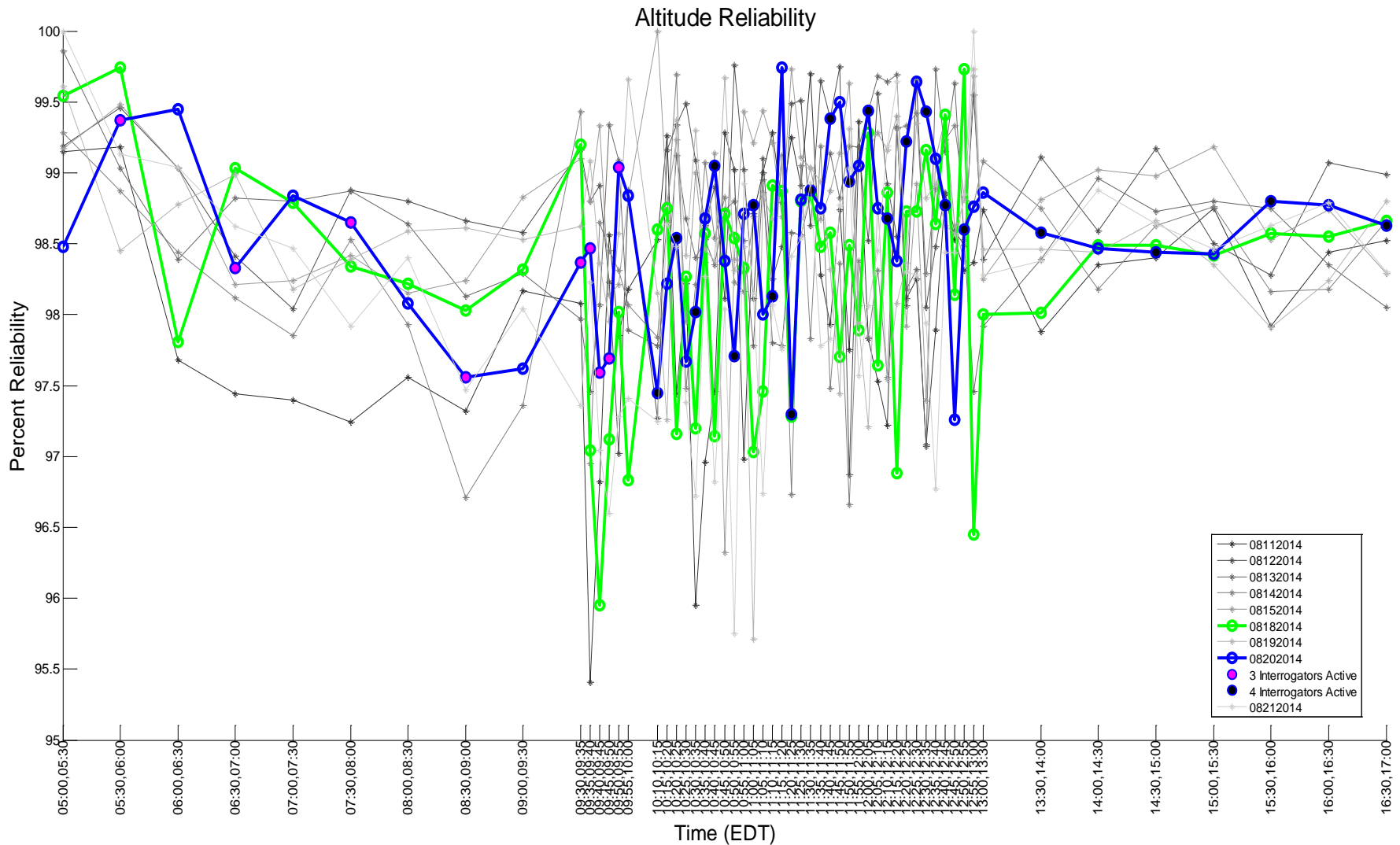


Geographic Filter: None  
Target Filter: Exclude Targets < 190 NM

# Altitude (C) Reliability – August 19<sup>th</sup>



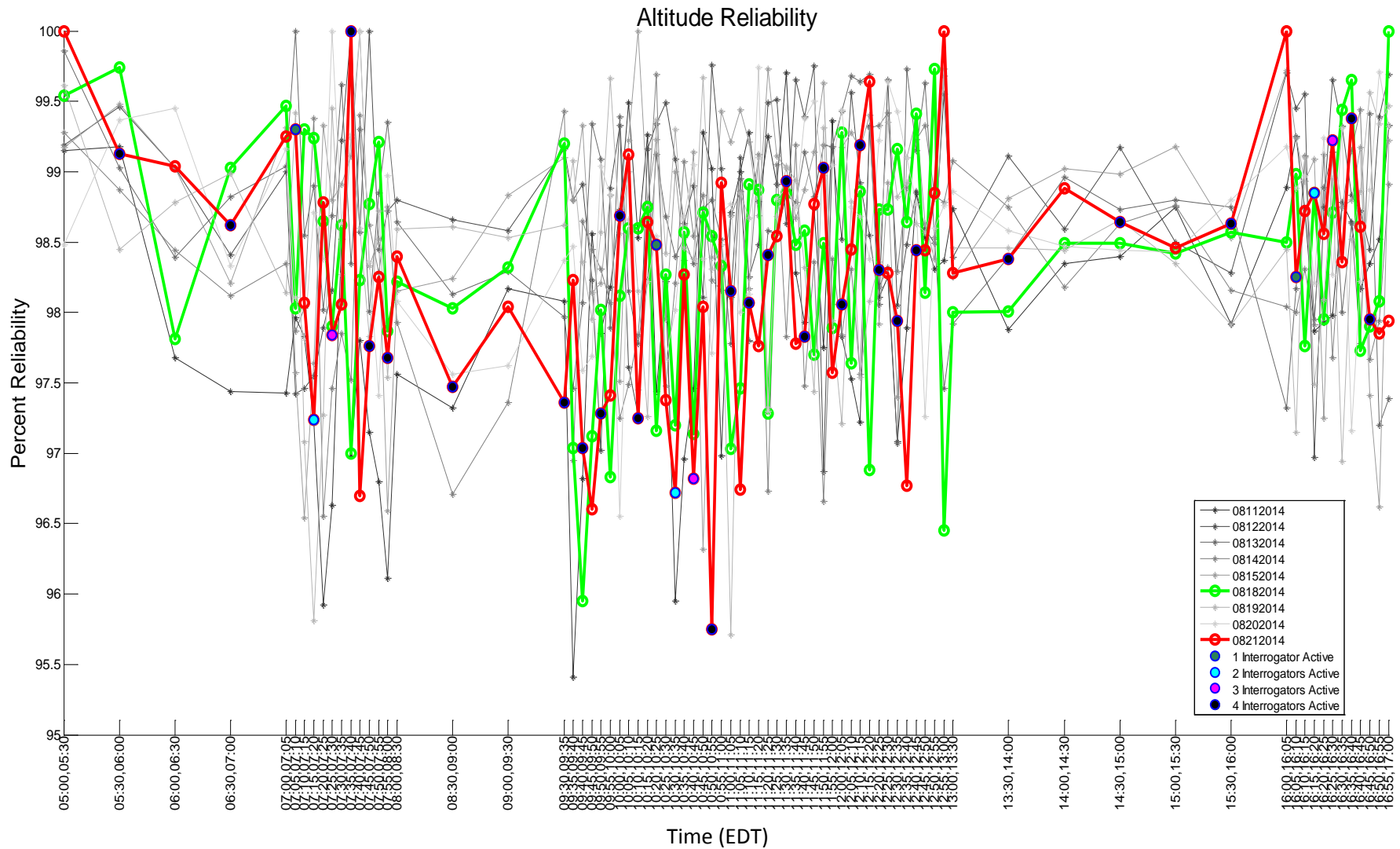
# Altitude (C) Reliability – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets < 190 NM

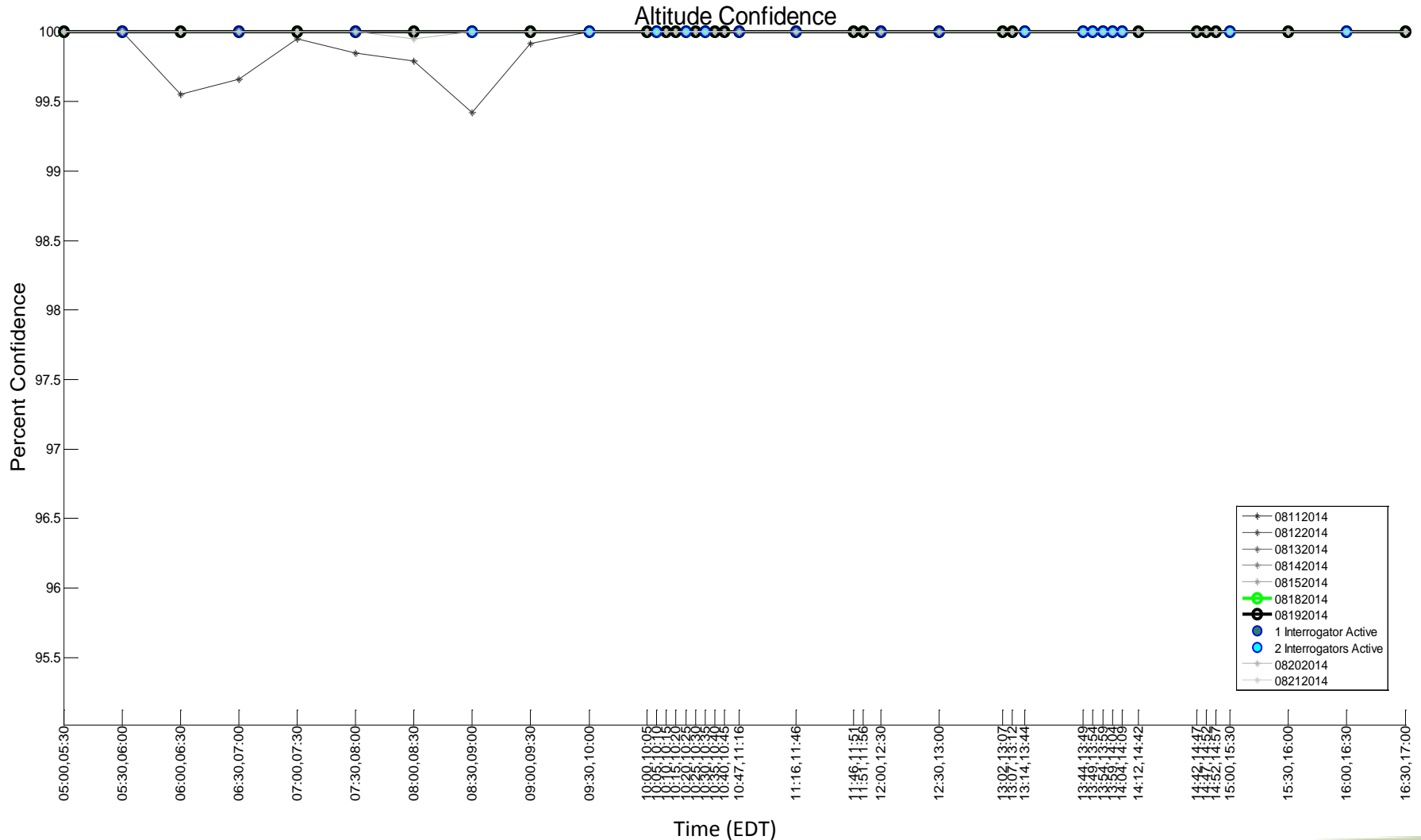
# Altitude (C) Reliability – August 21<sup>st</sup>



Geographic Filter: None

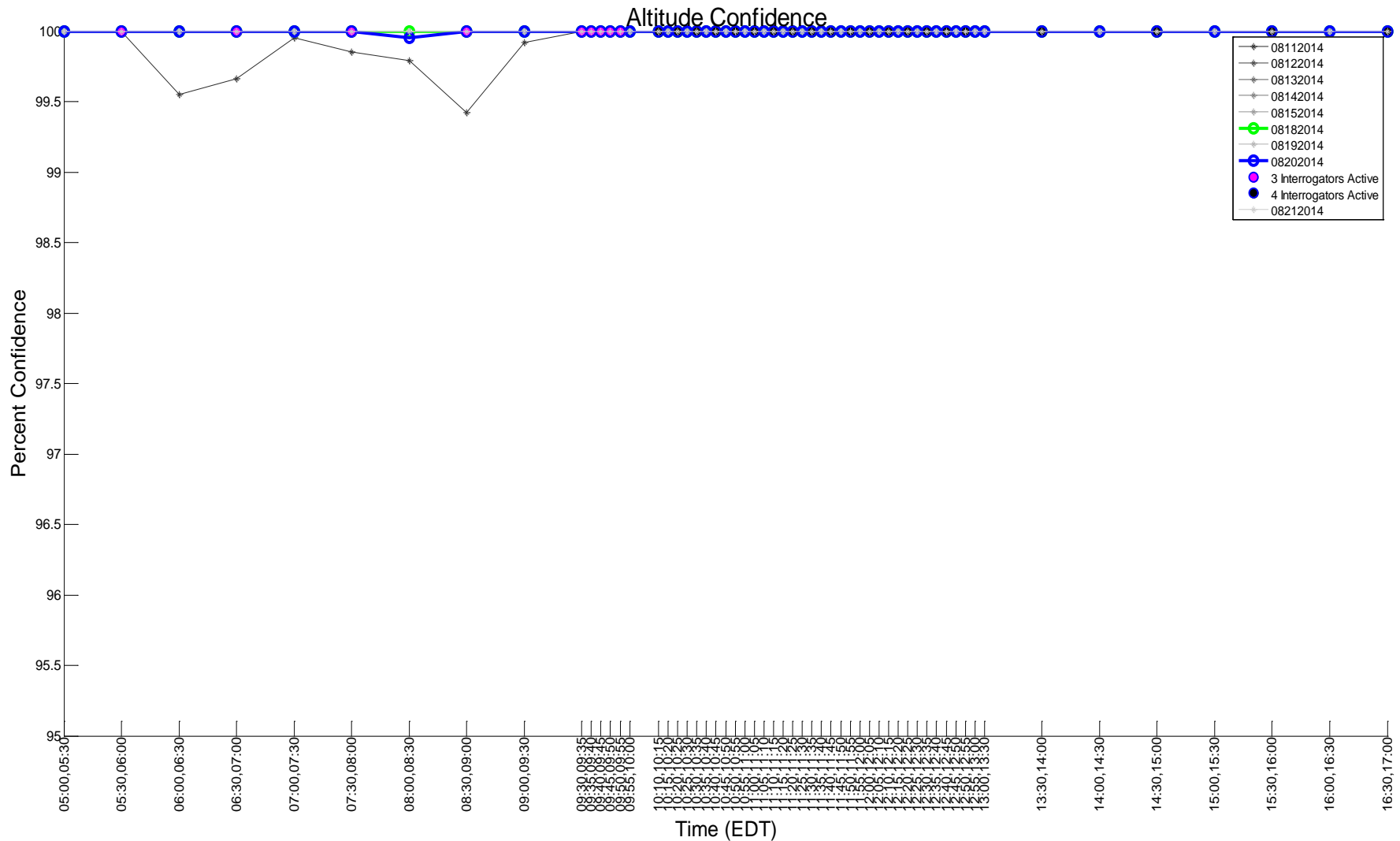
Target Filter: Exclude Targets < 190 NM

# Altitude (C) Confidence – August 19<sup>th</sup>



Geographic Filter: None  
 Target Filter: Exclude Targets < 190 NM

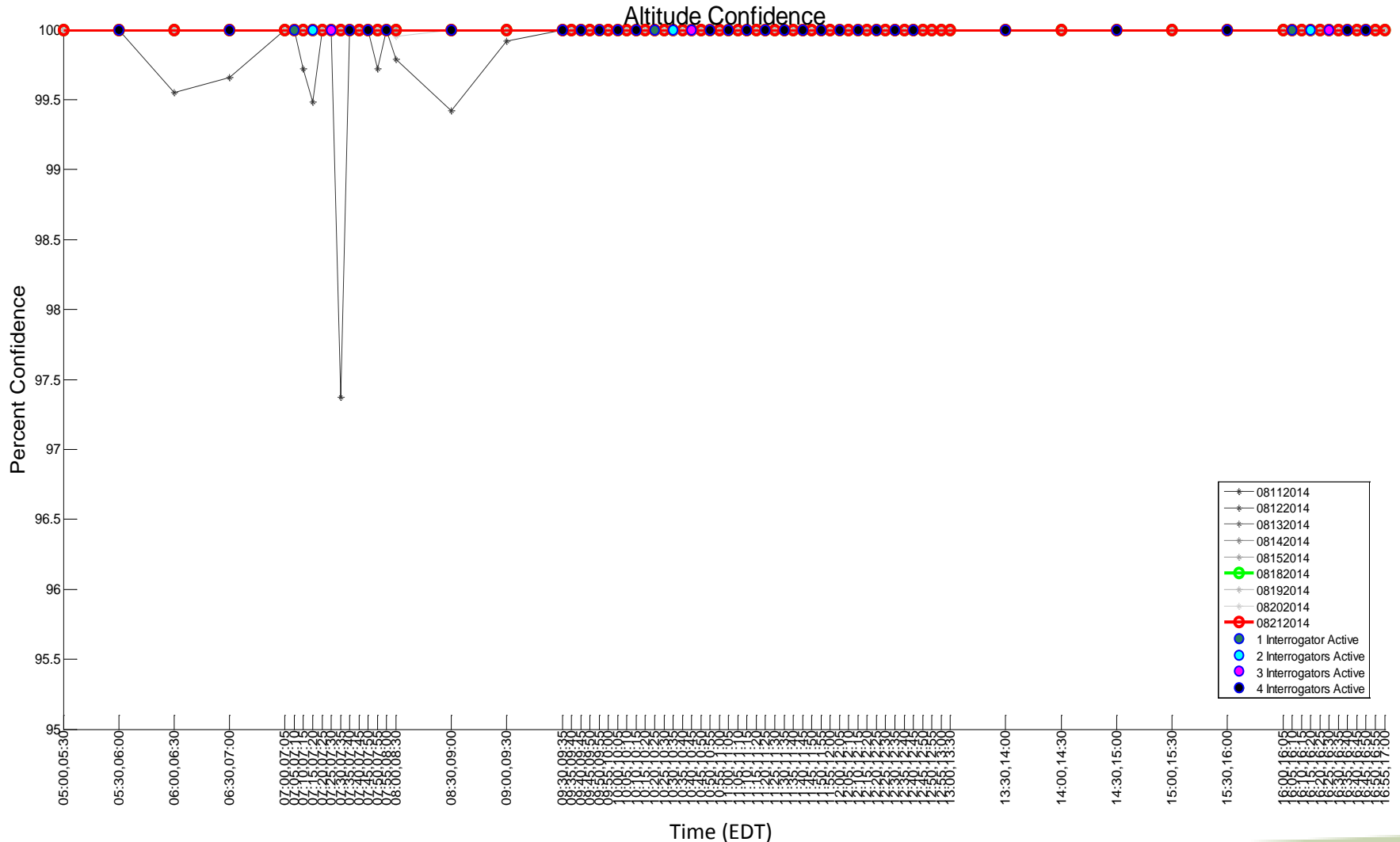
# Altitude (C) Confidence – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: Exclude Targets < 190 NM



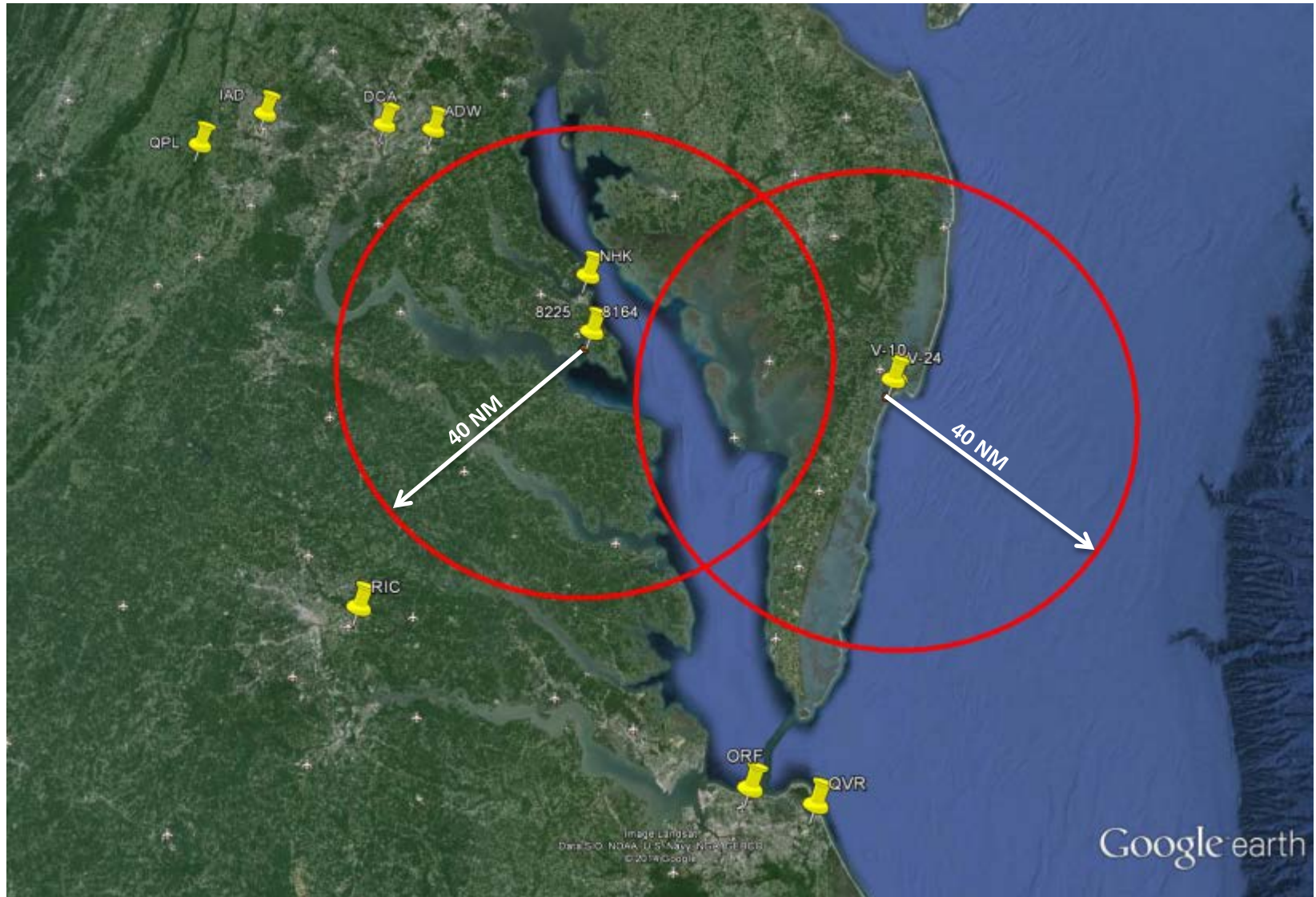
# Altitude (C) Confidence – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: Exclude Targets < 190 NM

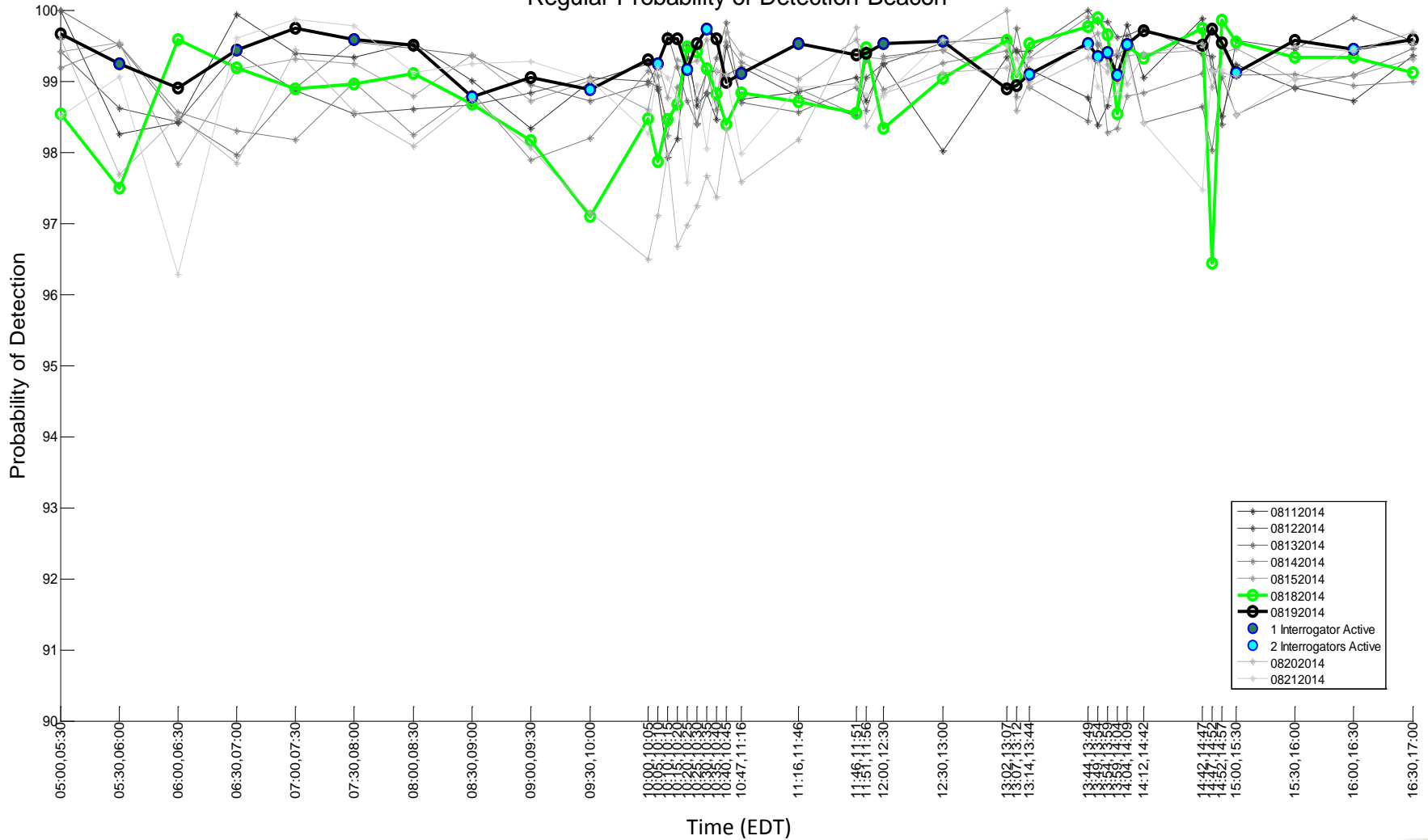
# Target Metrics within the Hotspot Region

# Hotspot Geography



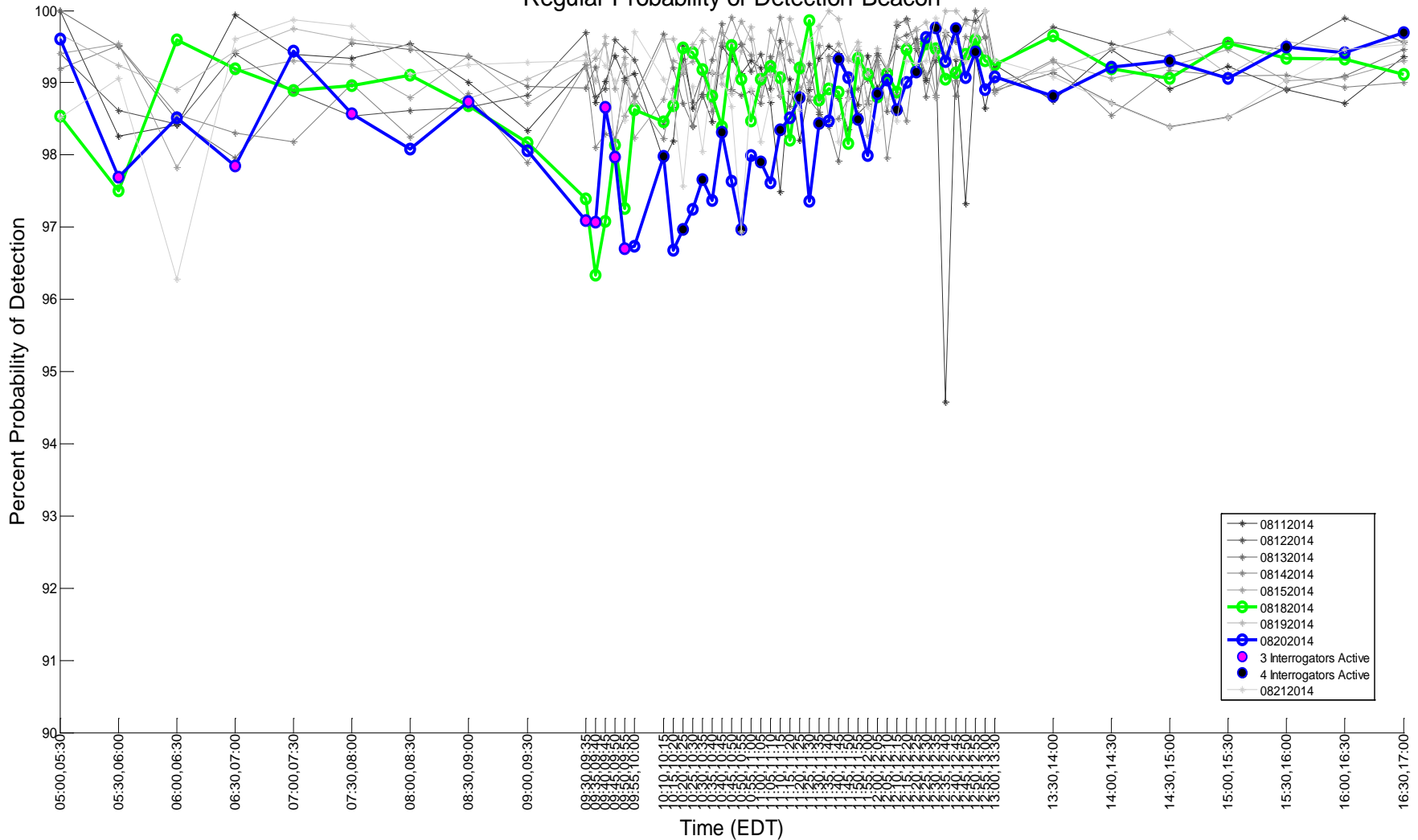
# Probability of Detection – August 19<sup>th</sup>

Regular Probability of Detection-Beacon

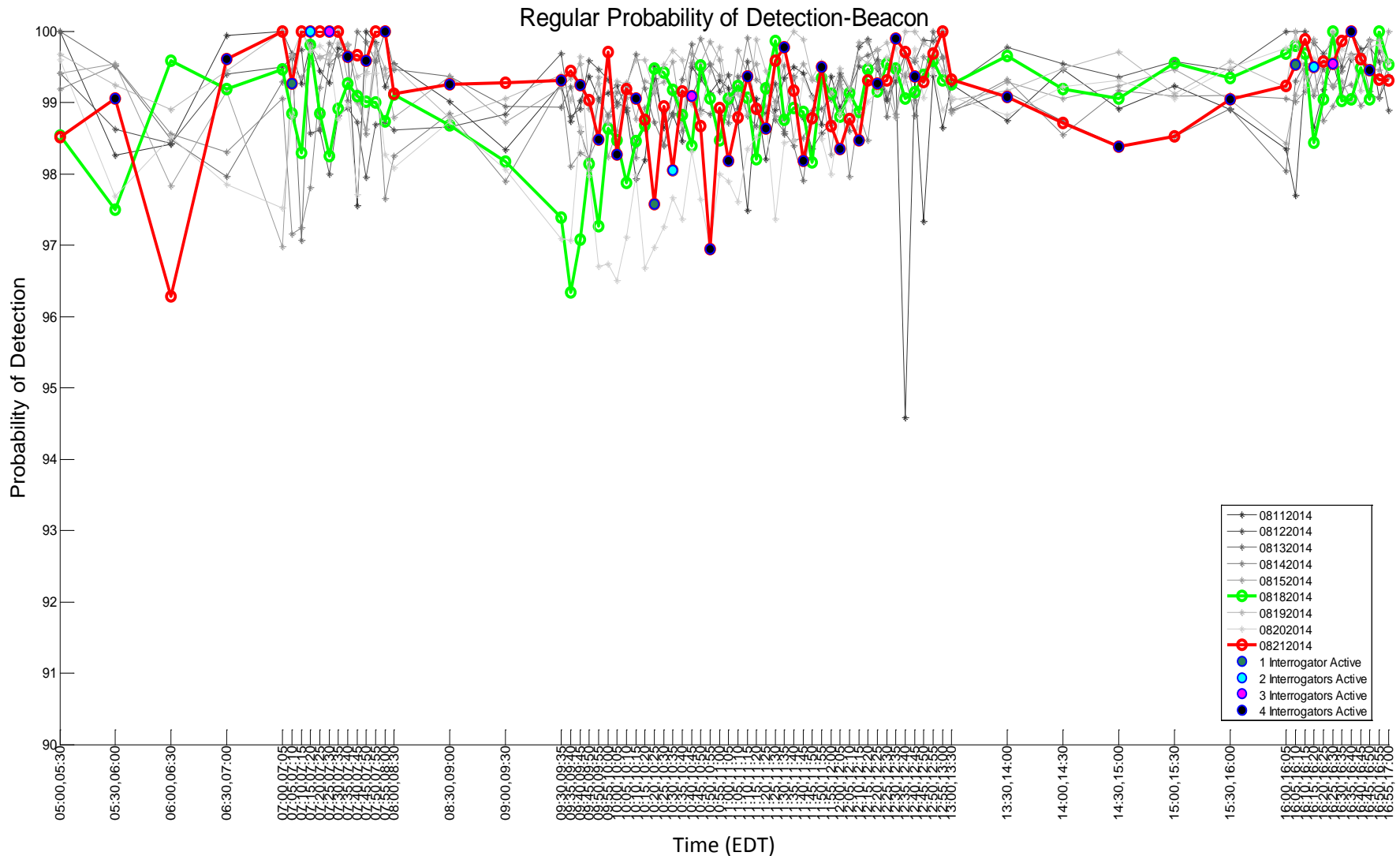


# Probability of Detection – August 20<sup>th</sup>

Regular Probability of Detection-Beacon

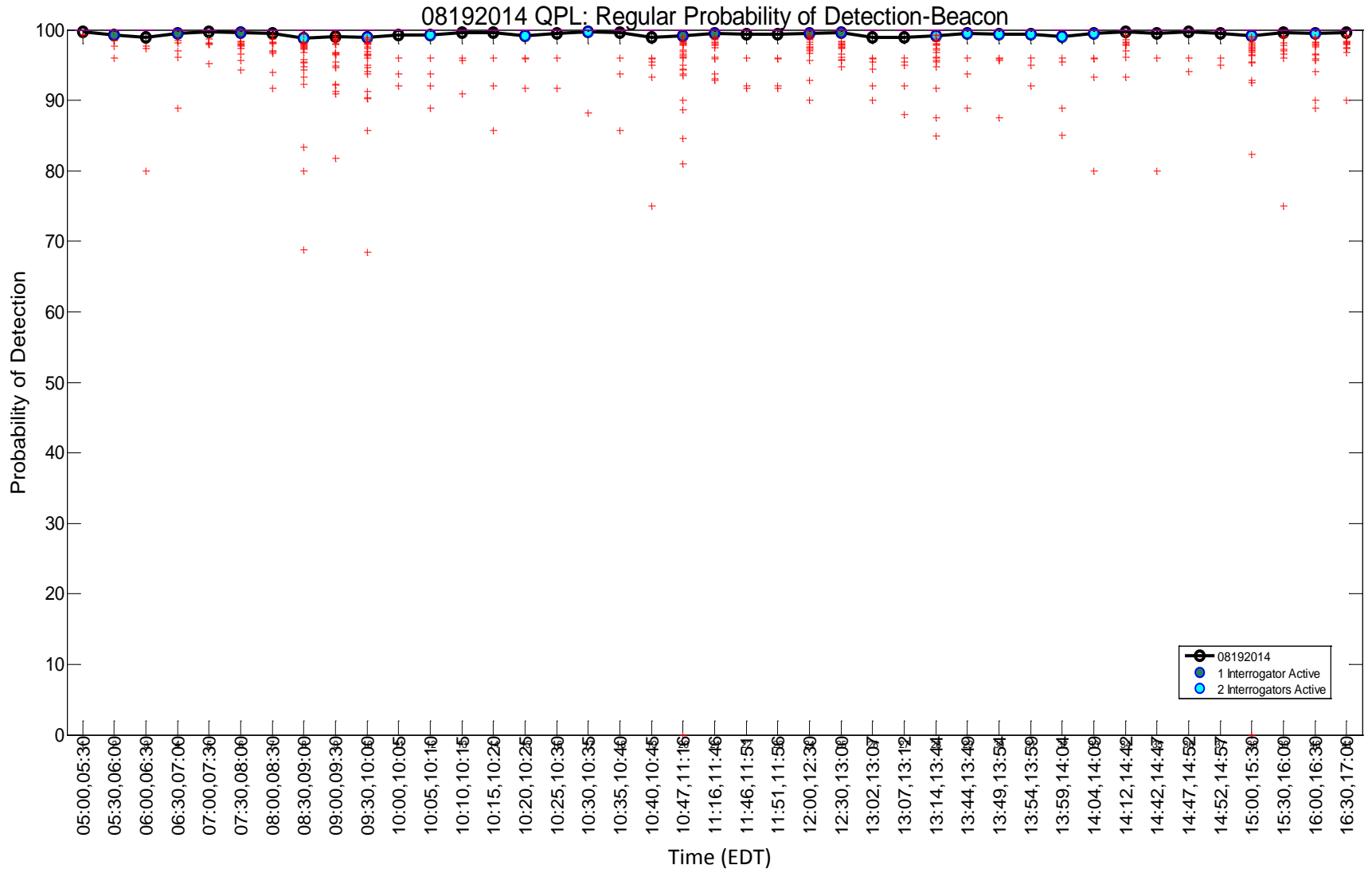


# Probability of Detection – August 21<sup>st</sup>



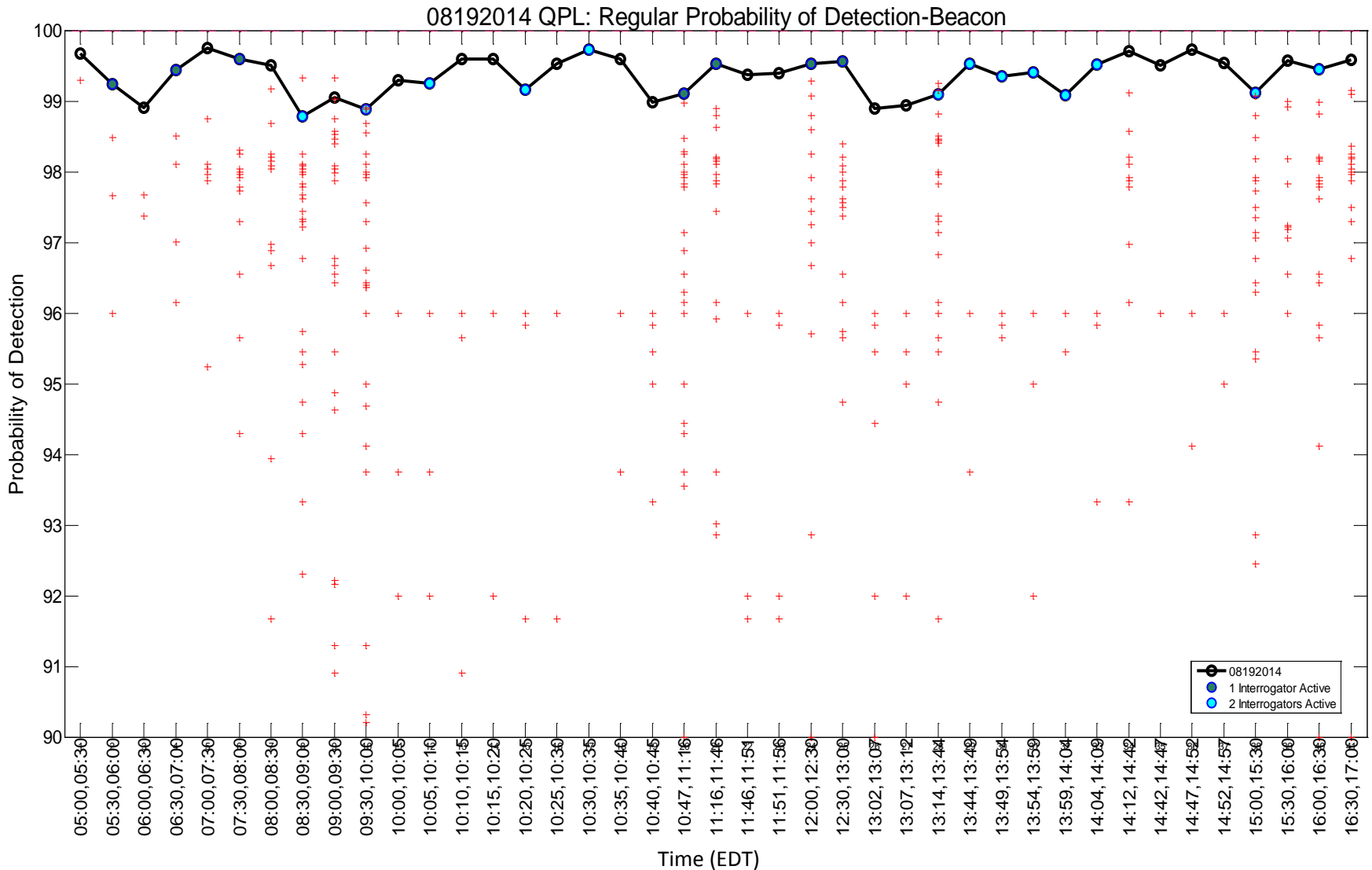
# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution



# Probability of Detection – August 19<sup>th</sup>

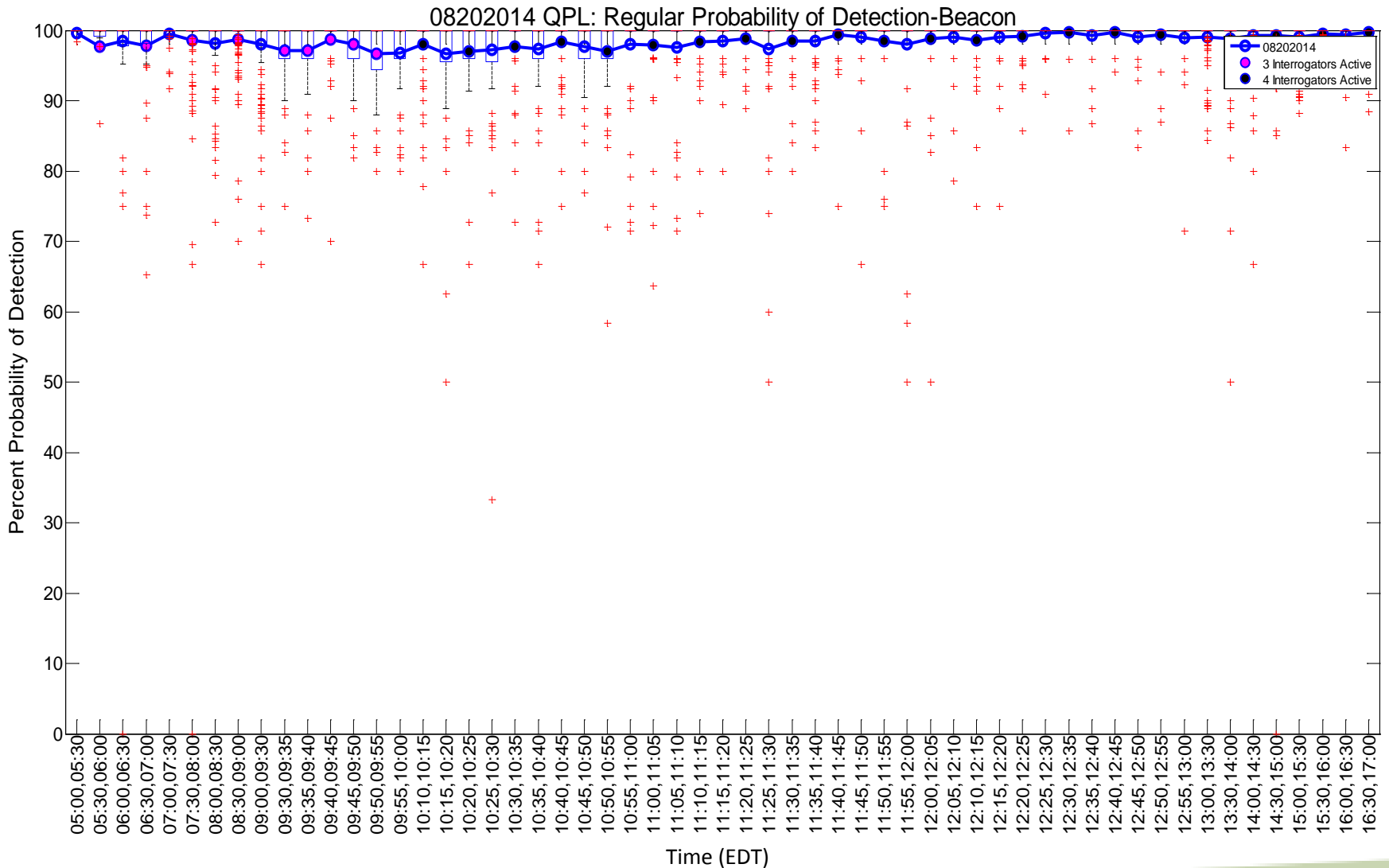
## Individual Aircraft Distribution (zoom-in)





# Probability of Detection – August 20<sup>th</sup>

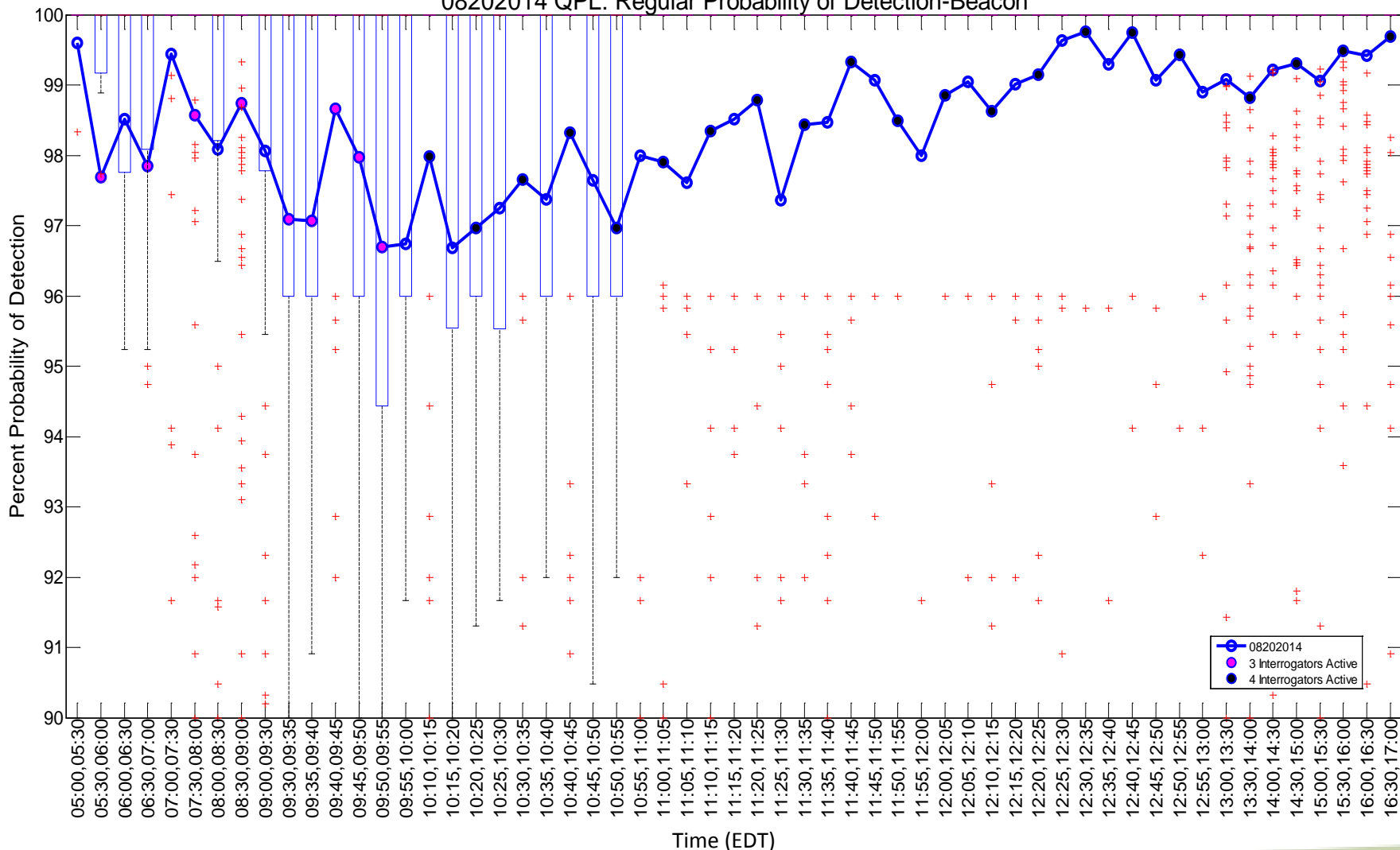
## Individual Aircraft Distribution



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

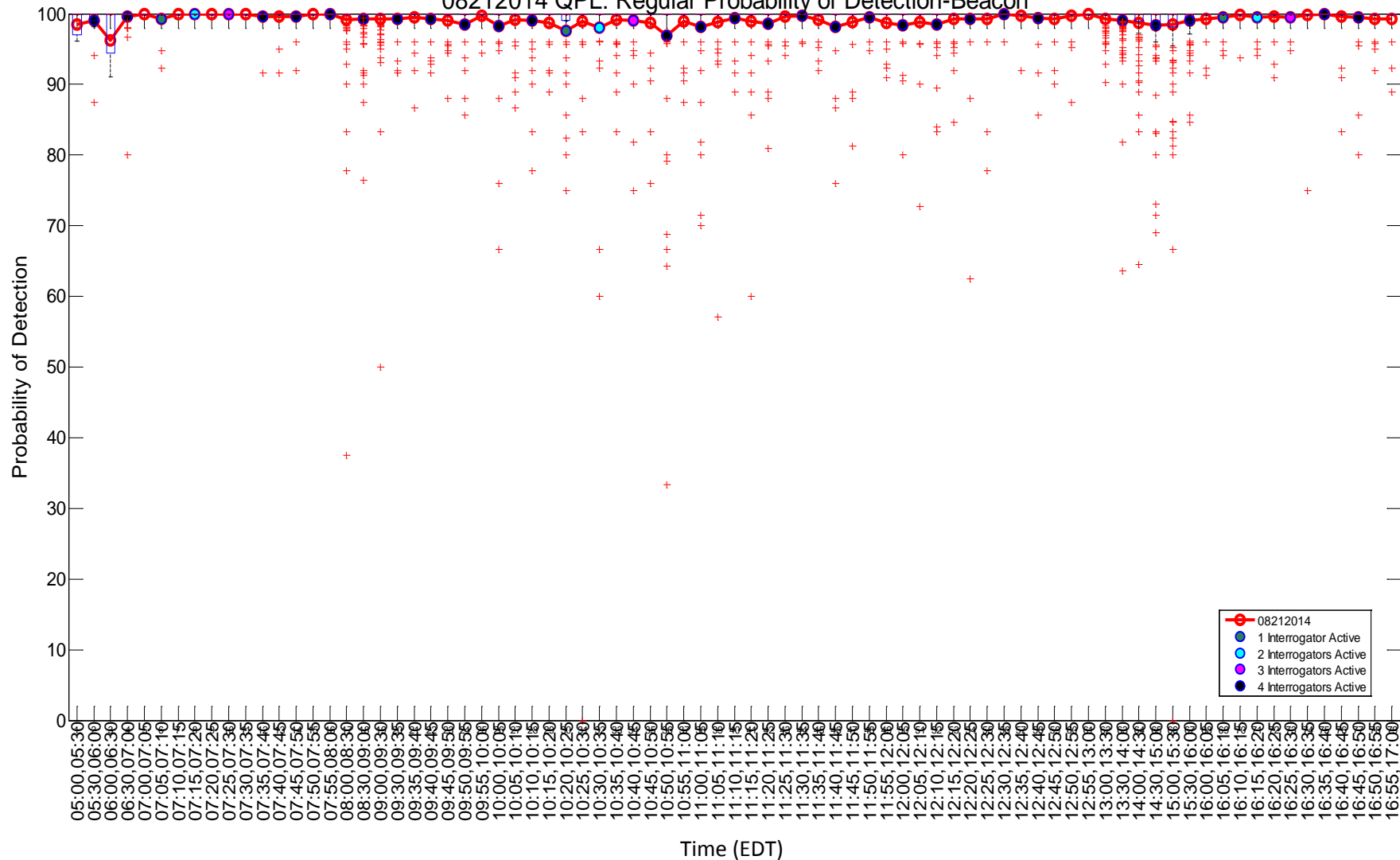
08202014 QPL: Regular Probability of Detection-Beacon



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

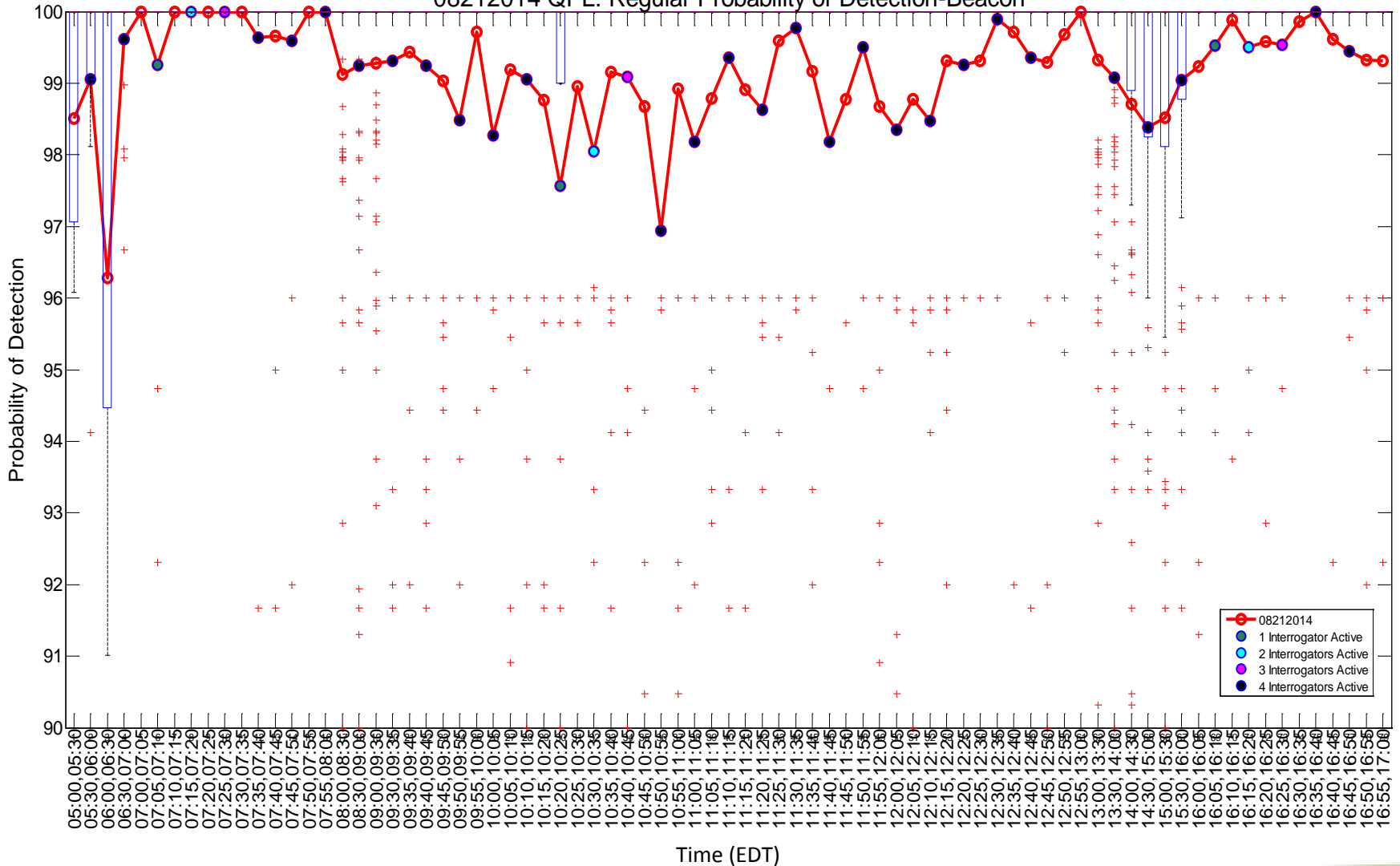
08212014 QPL: Regular Probability of Detection-Beacon



# Probability of Detection – August 21<sup>st</sup>

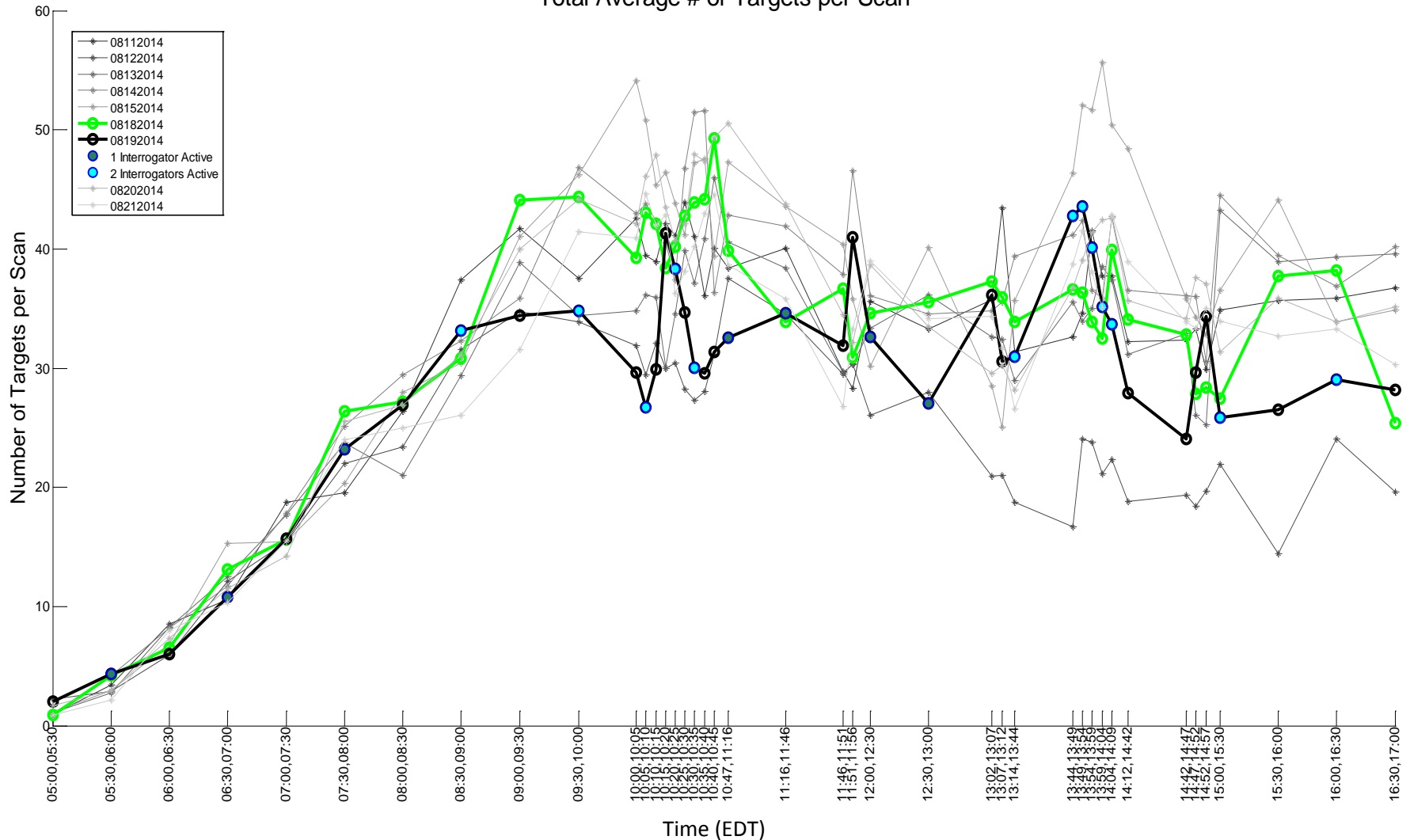
## Individual Aircraft Distribution (zoom-in)

08212014 QPL: Regular Probability of Detection-Beacon



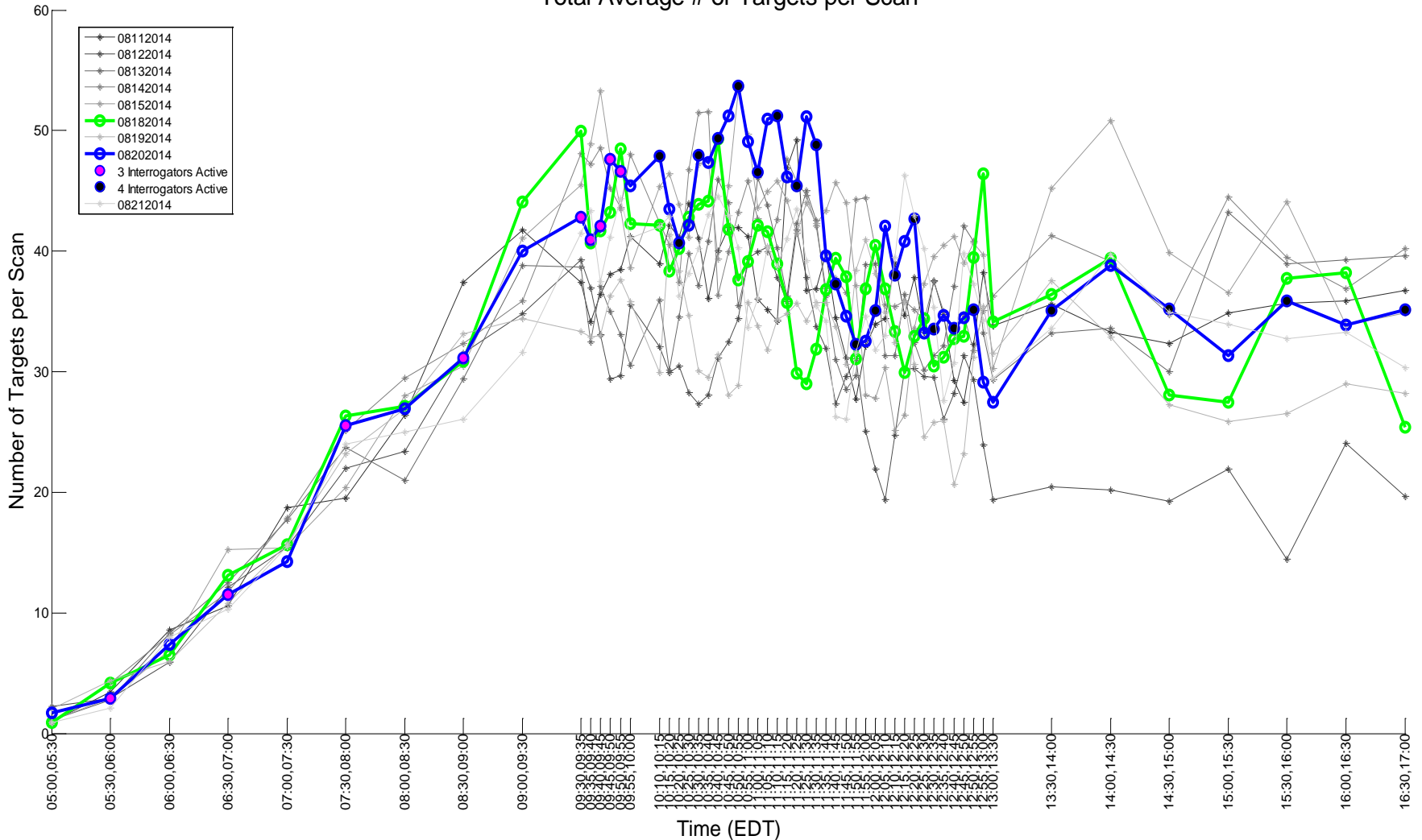
# Targets per Scan – August 19<sup>th</sup>

Total Average # of Targets per Scan



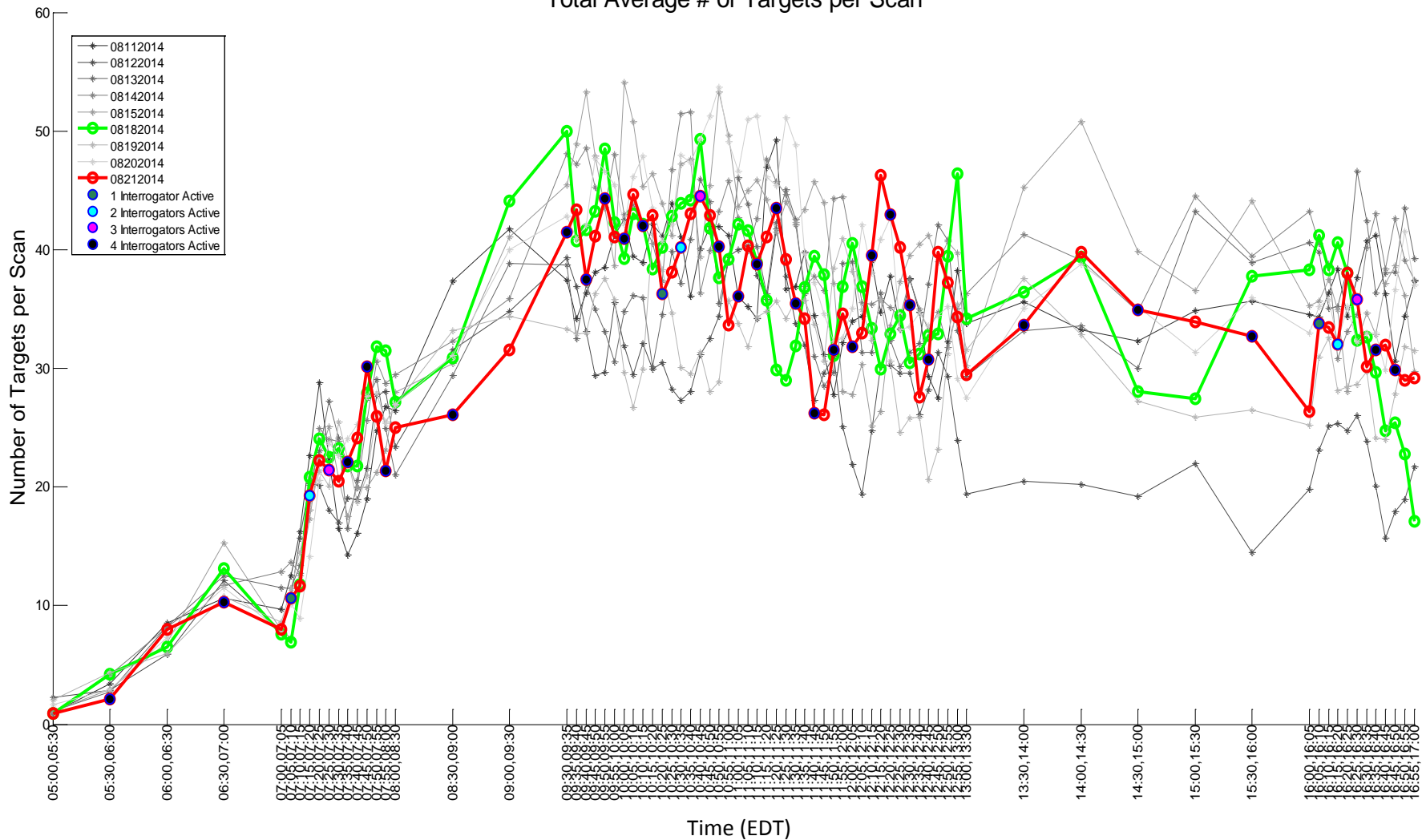
# Targets per Scan – August 20<sup>th</sup>

Total Average # of Targets per Scan

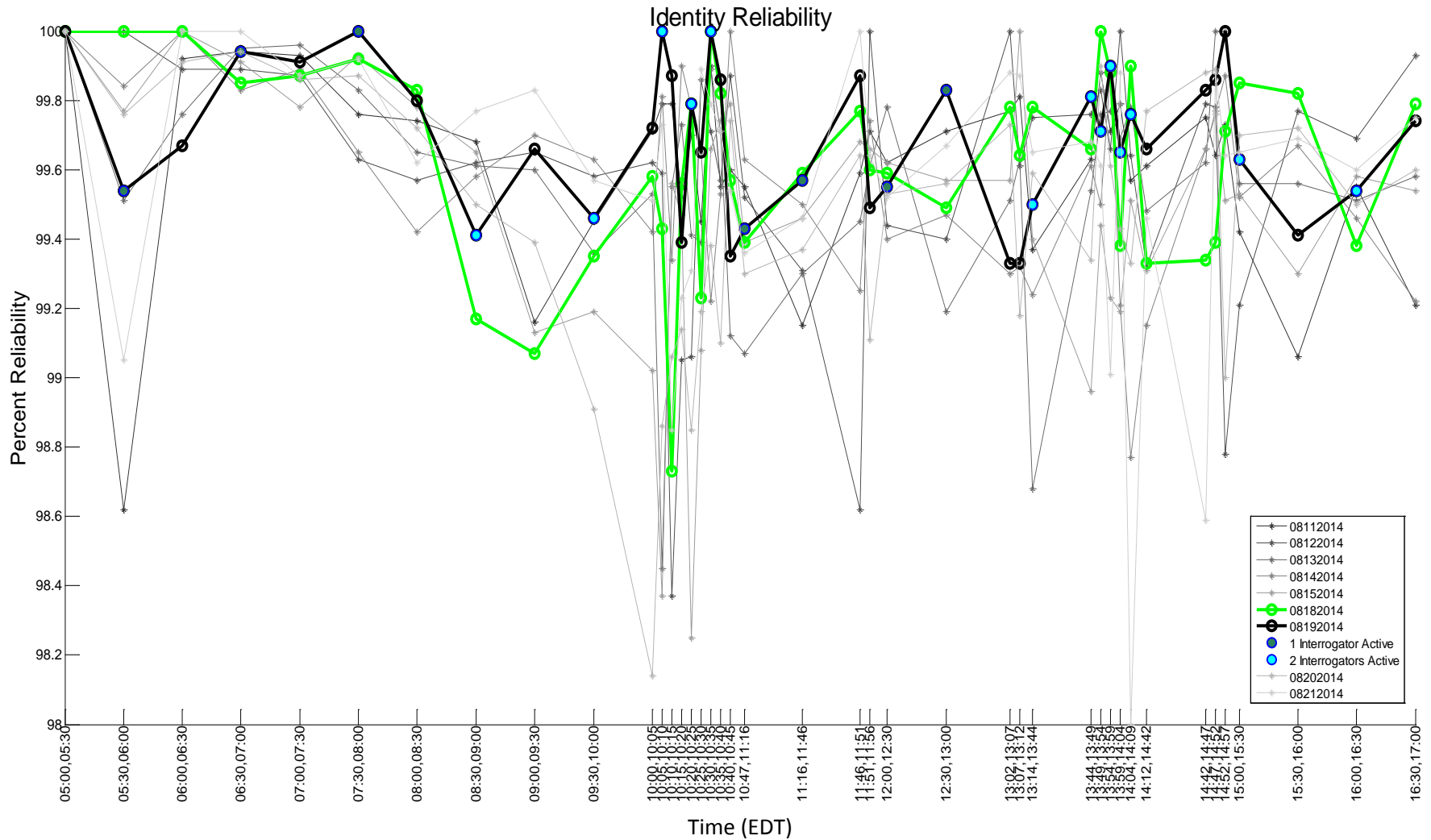


# Targets per Scan – August 21<sup>st</sup>

Total Average # of Targets per Scan

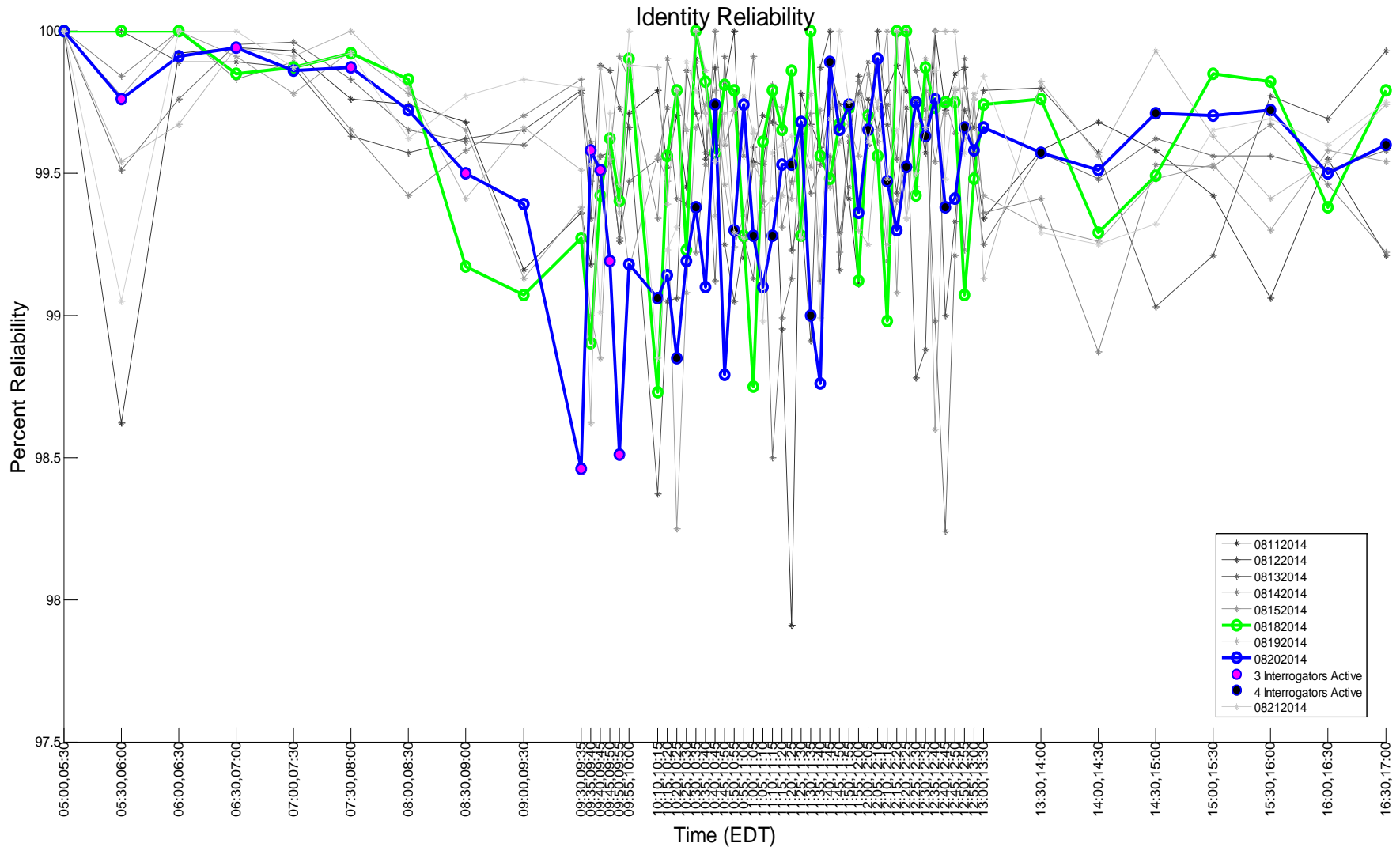


# Identity (3/A) Reliability – August 19<sup>th</sup>



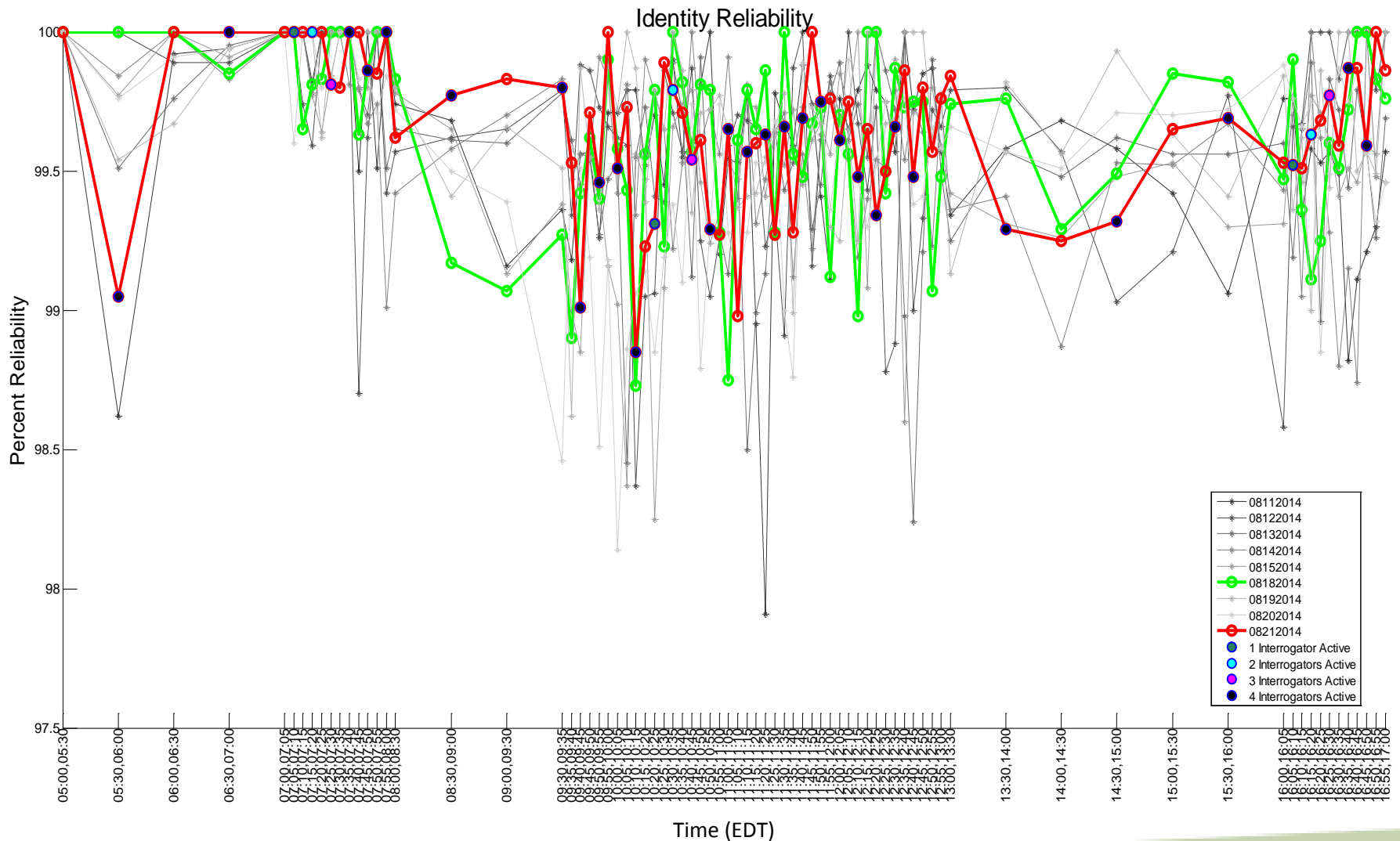


# Identity (3/A) Reliability – August 20<sup>th</sup>



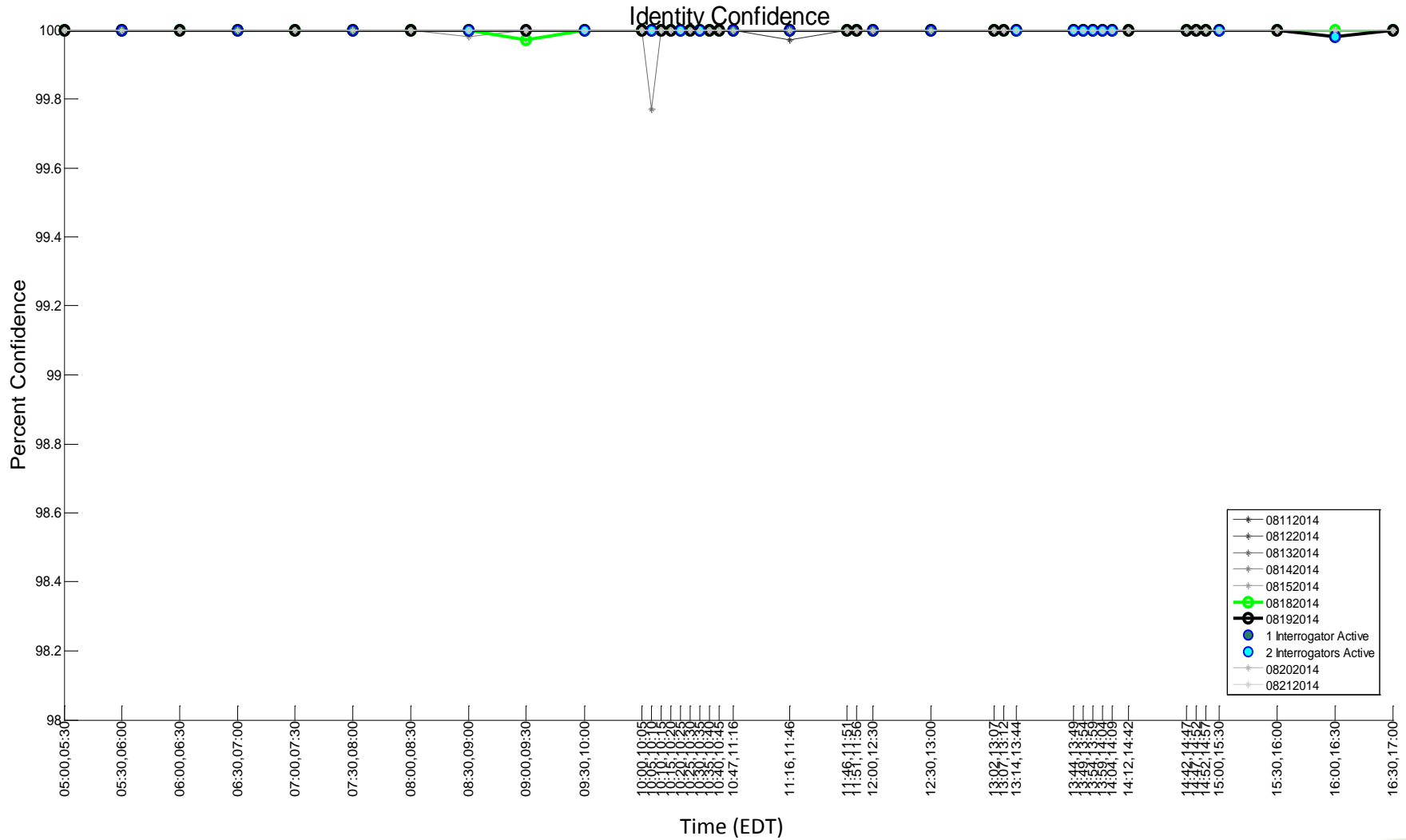
Geographic Filter: Hotspot Region  
Target Filter: None

# Identity (3/A) Reliability – August 21<sup>st</sup>



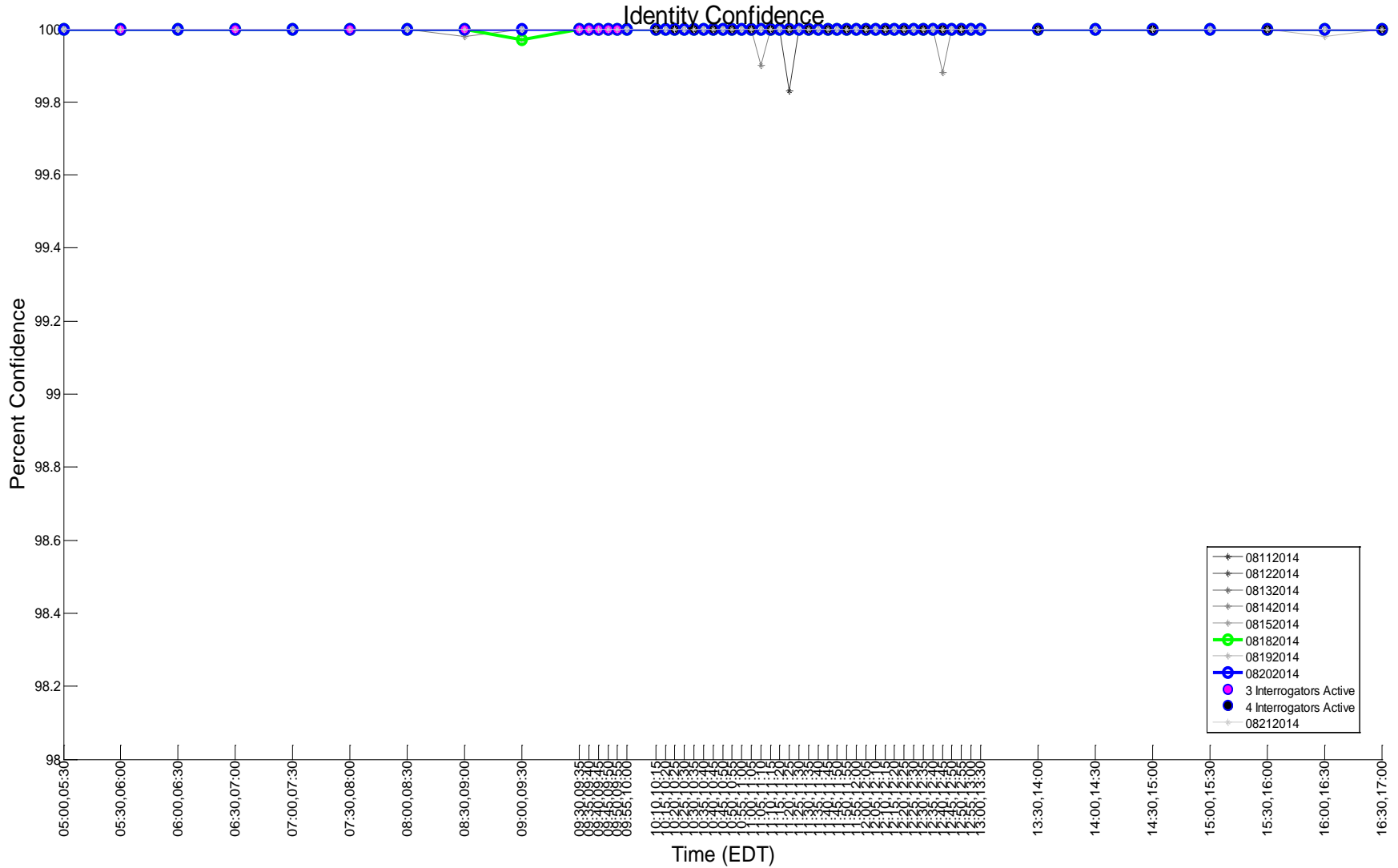
Geographic Filter: Hotspot Region  
Target Filter: None

# Identity (3/A) Confidence – August 19<sup>th</sup>



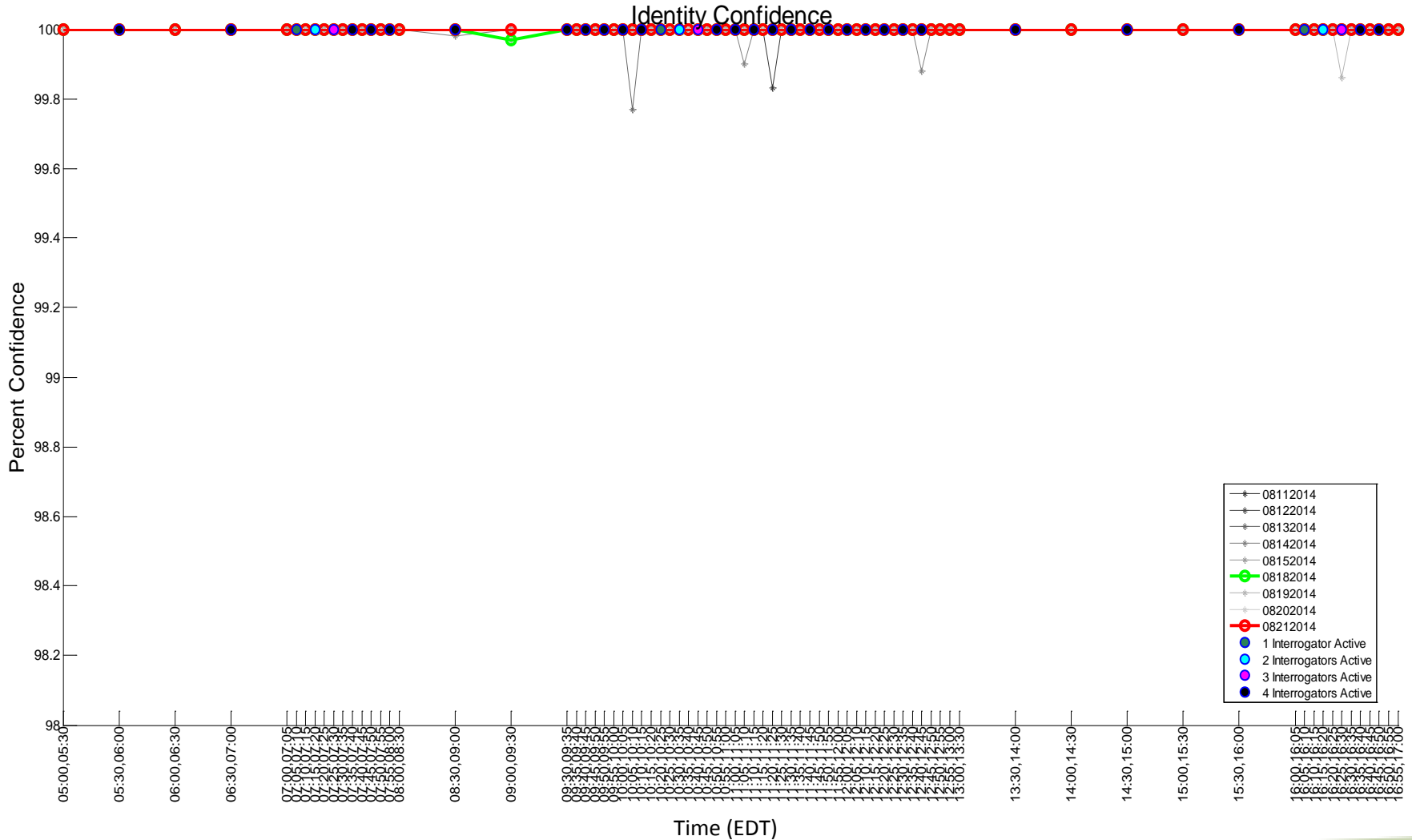
Geographic Filter: Hotspot Region  
 Target Filter: None

# Identity (3/A) Confidence – August 20<sup>th</sup>

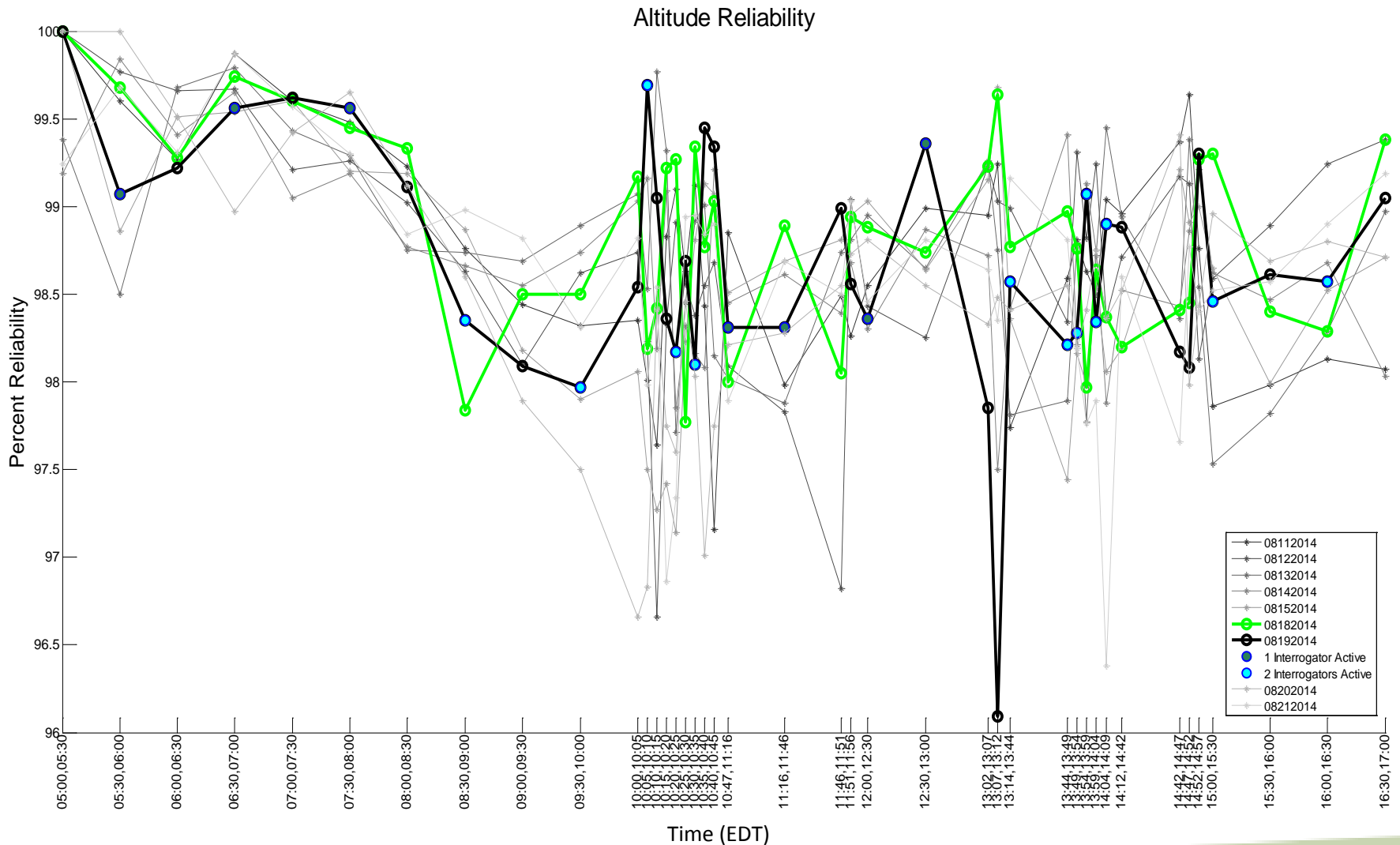


Geographic Filter: Hotspot Region  
Target Filter: None

# Identity (3/A) Confidence – August 21<sup>st</sup>

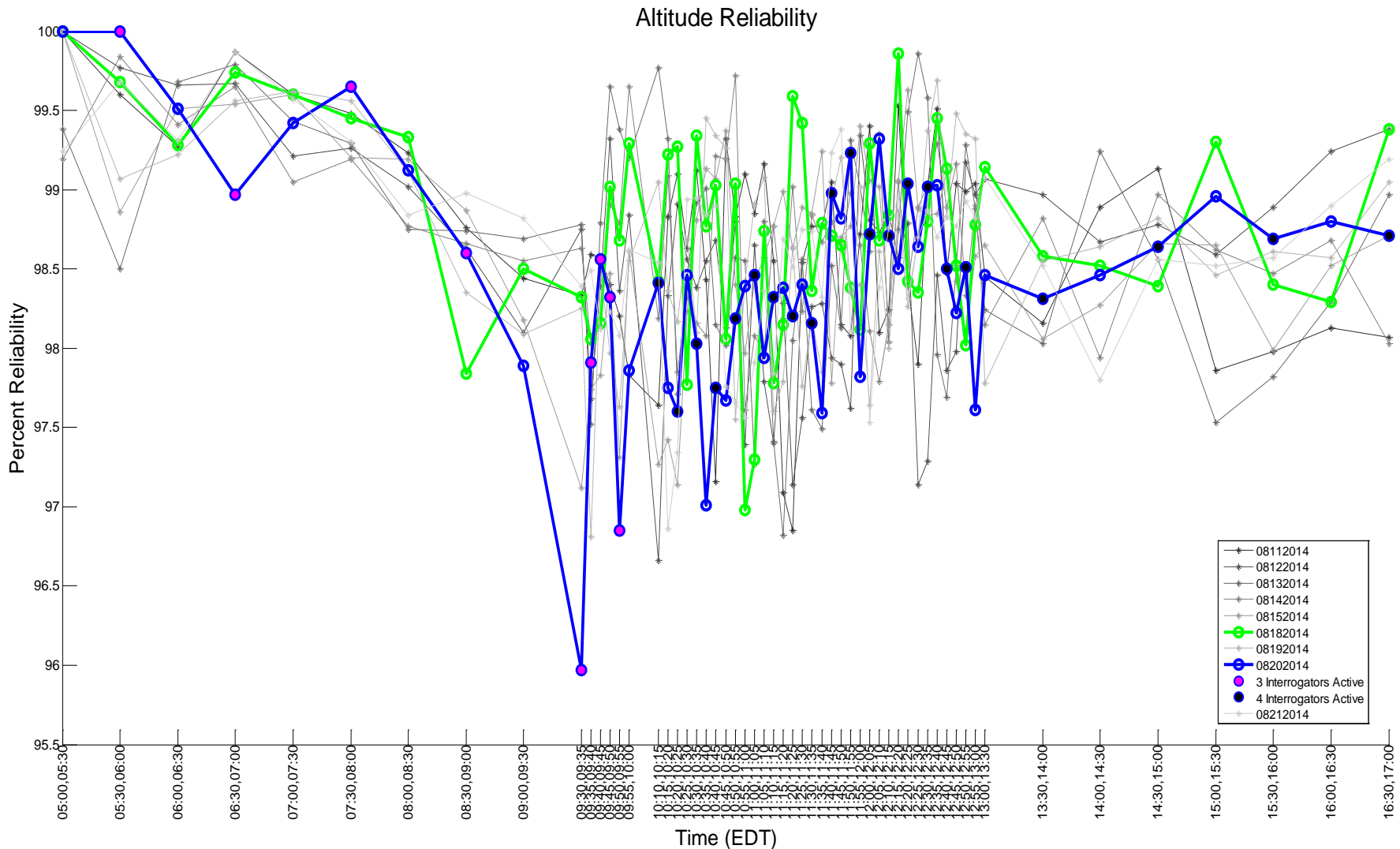


# Altitude (C) Reliability – August 19<sup>th</sup>

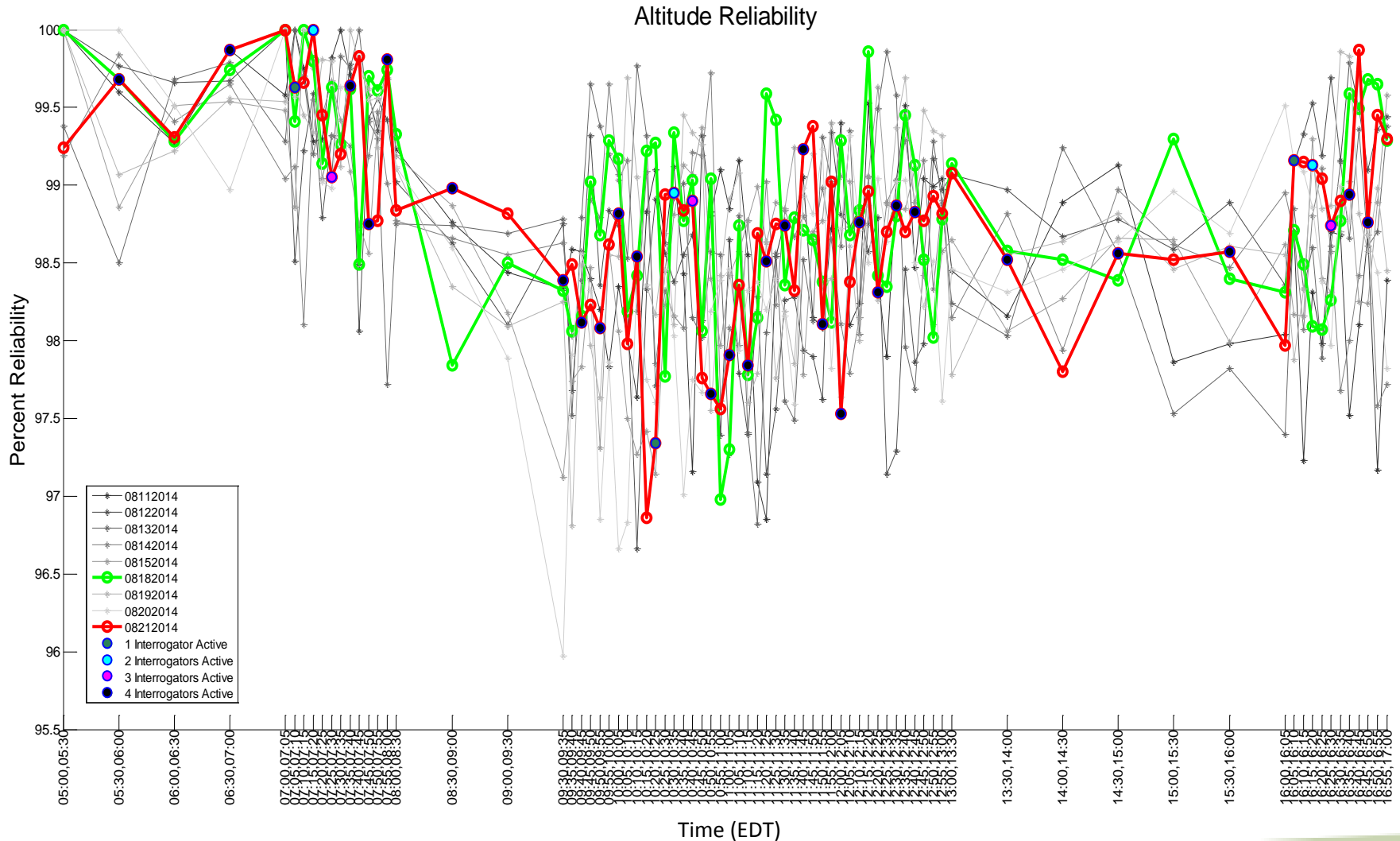


Geographic Filter: Hotspot Region  
Target Filter: None

# Altitude (C) Reliability – August 20<sup>th</sup>

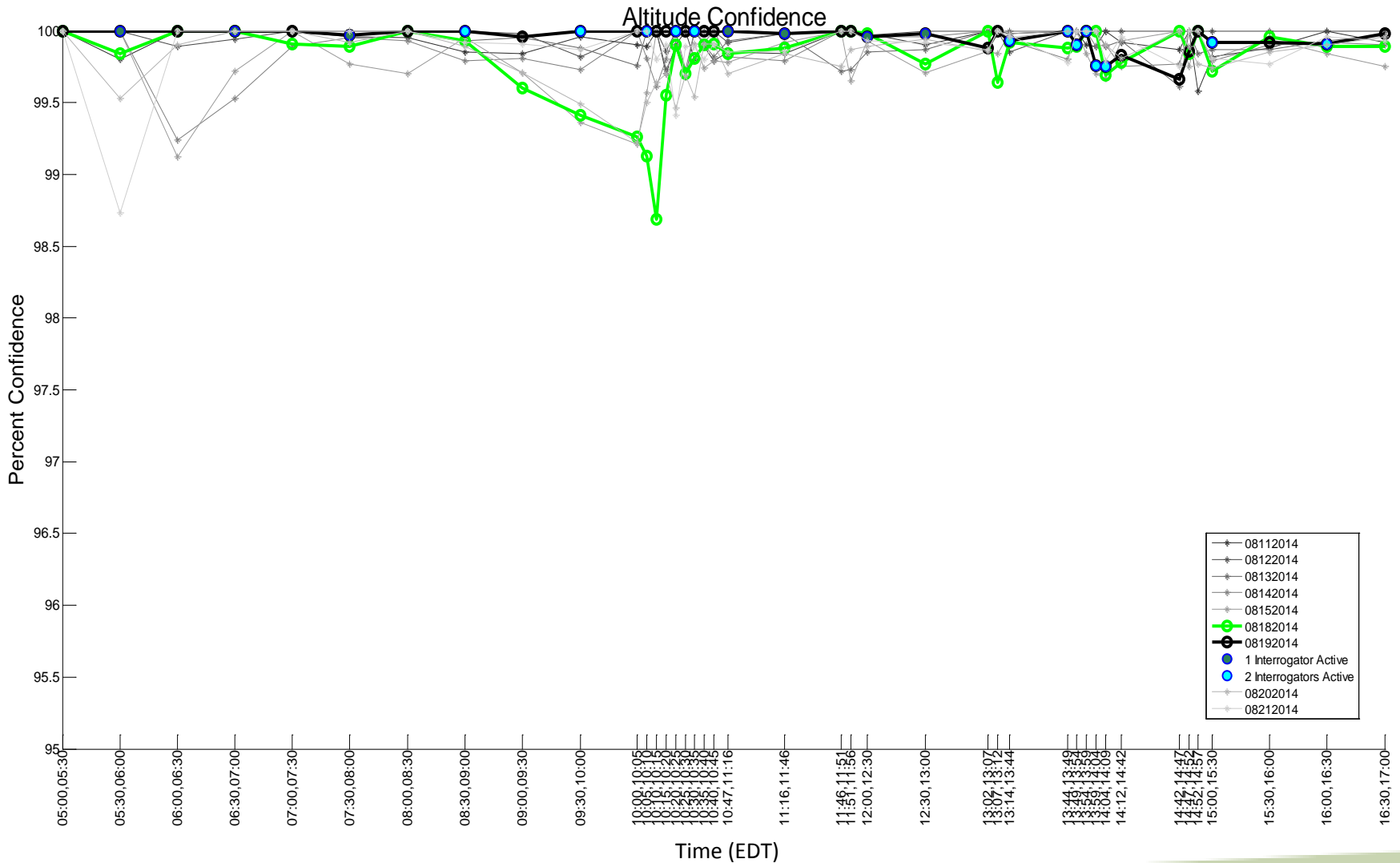


# Altitude (C) Reliability – August 21<sup>st</sup>



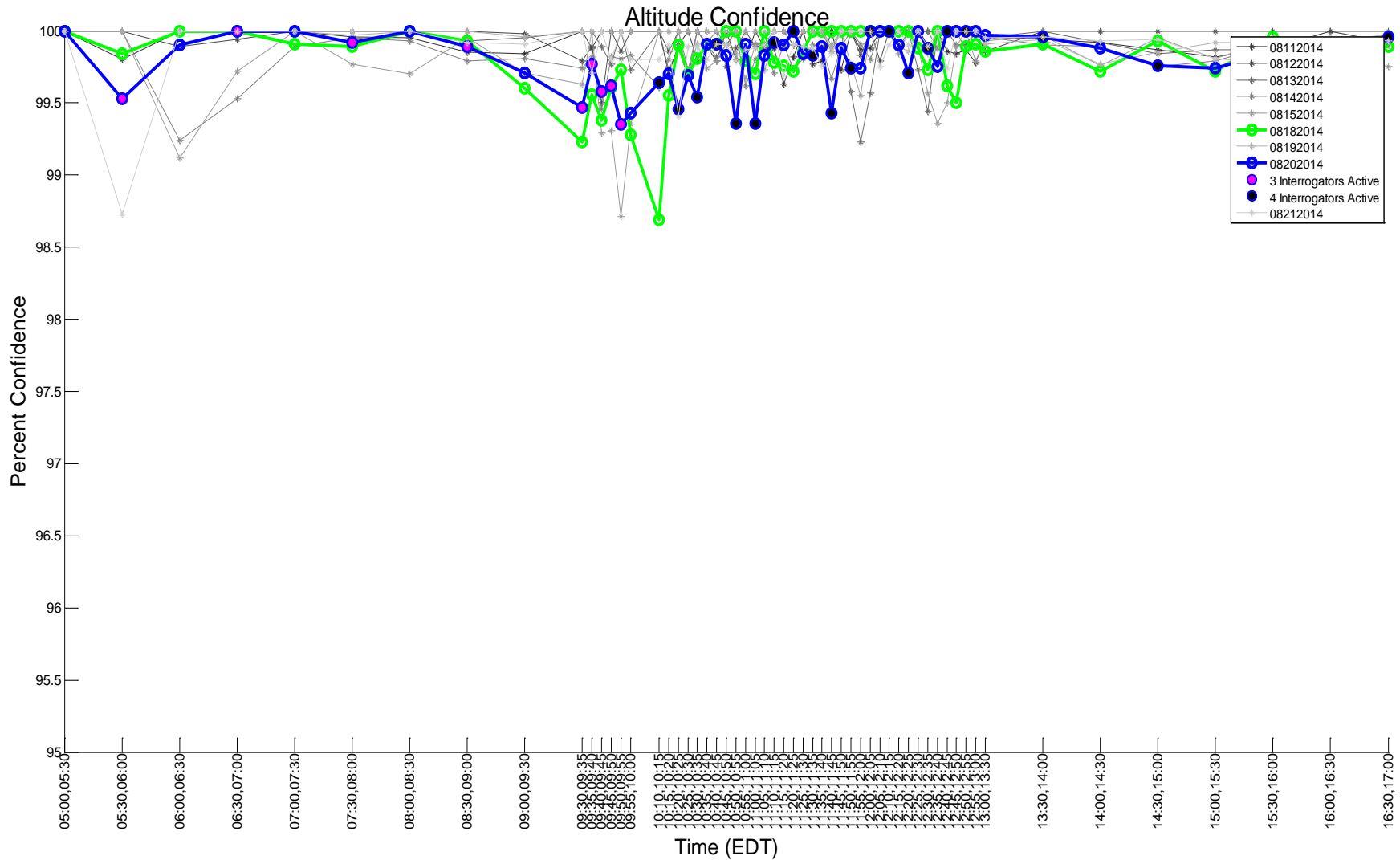


# Altitude (C) Confidence – August 19<sup>th</sup>



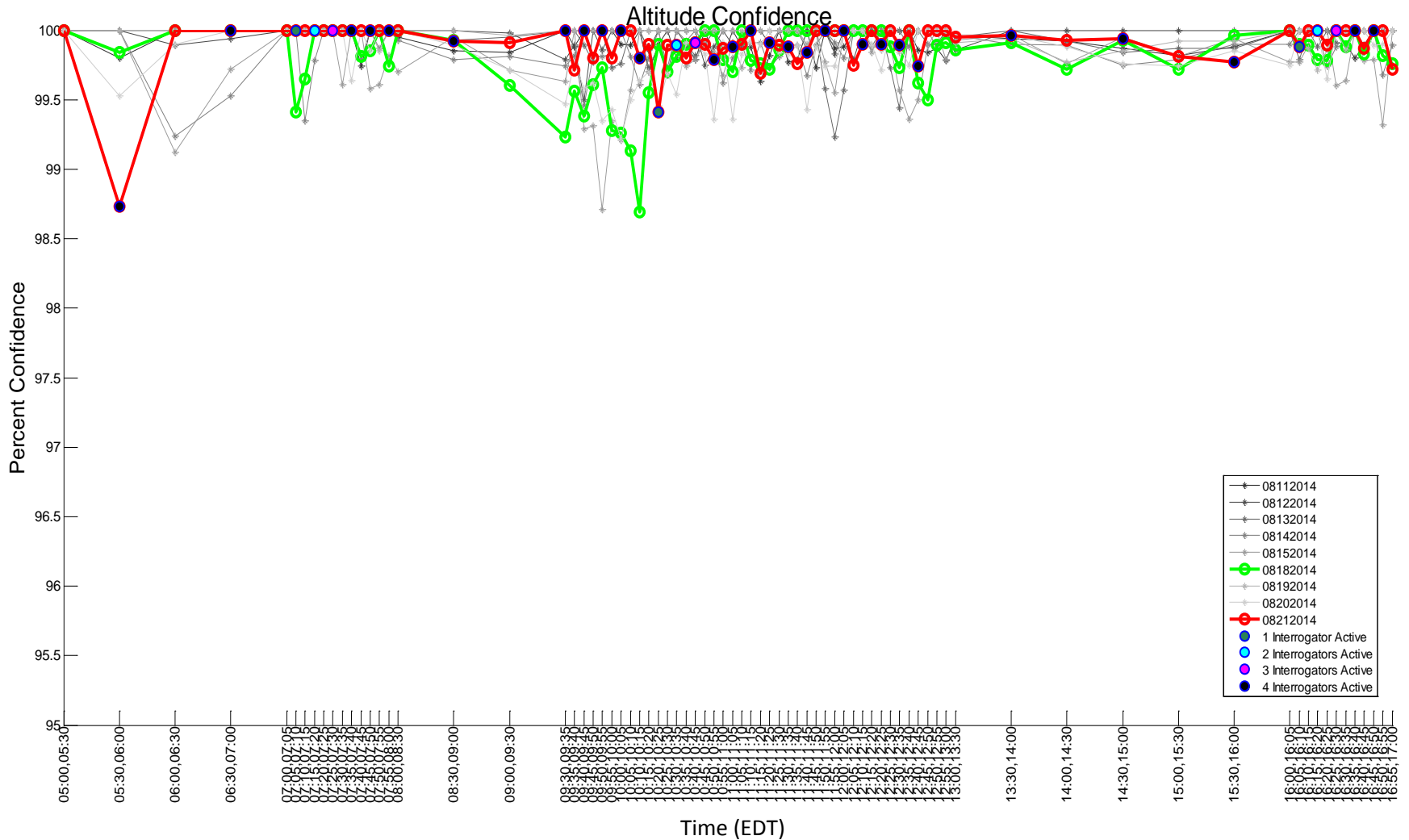
Geographic Filter: Hotspot Region  
 Target Filter: None

# Altitude (C) Confidence – August 20<sup>th</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

# Altitude (C) Confidence – August 21<sup>st</sup>





# Executive Summary

- ❑ The Probability of Detection, Identity Reliability and Confidence, Altitude Reliability and Confidence, False Targets, 0000 Codes, and Targets per Scan exhibit no observable adverse trend with respect to periods of radiation by the AN/UPX-41(C) interrogator.
- ❑ During AN/UPX-41(C) interrogator radiation, the variations or volatility of the aforementioned metrics are within the bounds of the variations of the same metrics on non-test days (baseline).

# Background

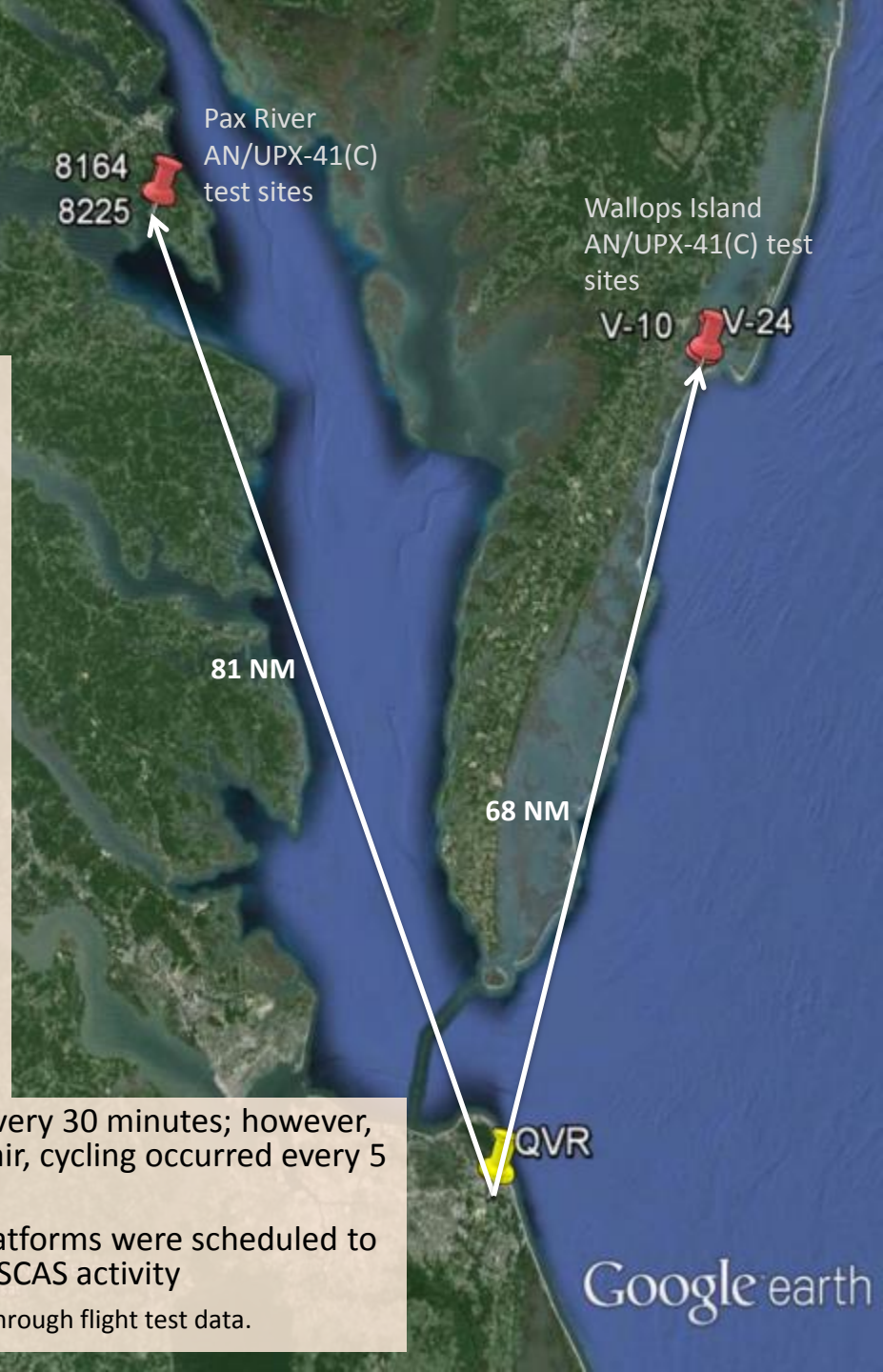
- ❑ The AN/UPX-41(C)\* Stage-4 operational transmit certification for AEGIS-Class ships was signed by NTIA on June 22, 2012 with geographic and platform number restrictions when operating in proximity to the NAS.†
- ❑ Additionally, the Stage-4 certification contained a requirement for a joint FAA-Navy test to validate the operational restrictions.
- ❑ The Volpe Center, in conjunction with the Navy, FAA Spectrum, and FAA aeronautical surveillance and collision avoidance systems (ASCAS) SMEs created a test plan to validate the operational restrictions.
- ❑ From August 18-21, 2014 the FAA and Navy conducted the above-mentioned joint test, under the management of the Volpe Center.
- ❑ Since the test, the Volpe Center has analyzed recorded data to look for instances of harmful interference that would affect ASCAS system performance.

\*AN/UPX-41(C) Digital Interrogator System when operated in conjunction with the OE-120 antenna, the AN/UPX-29(V) Identification Friend or Foe (IFF) system, and the AN/UPX-24 software interface Version 2.1.2, controlled by the Cooperative Engagement Capability (CEC), in Naval surface vessels

†See SPS-18778\_1 Navy AN-UPX-41 V5.5 St4

# Test Plan Refresher

- ❑ **Baseline week: August 11<sup>th</sup> – 15<sup>th</sup>**
  - Baseline recording of data from 5 AM – 5 PM
    - No AN/UPX-41(C) systems Active
- ❑ **Test week: August 18<sup>th</sup> – 21<sup>st</sup>**
  - August 18<sup>th</sup> – Baseline recording of data from 5 AM – 5 PM
    - No AN/UPX-41(C) systems Active
  - August 19<sup>th</sup> – Record data from 5 AM – 5 PM
    - Cycle 1 and 2 AN/UPX-41(C) systems Active and OFF
  - August 20<sup>th</sup> – Record data from 5 AM – 5 PM
    - Cycle 3 and 4 AN/UPX-41(C) systems Active and OFF
  - August 21<sup>st</sup> – Record data from 5 AM – 5 PM
    - Cycle 1, 2, 3, and 4 AN/UPX-41(C) systems Active and OFF
- ❑ Cycling of AN/UPX-41(C) systems Active/OFF occurred every 30 minutes; however, if N39 (Tech Center signal recording aircraft) was in the air, cycling occurred every 5 minutes
- ❑ During the test week, non-essential DoD interrogator platforms were scheduled to be inactive in order to get an accurate baseline of civil ASCAS activity
  - This did not occur. Non-test platform radiation was discovered through flight test data.



# Data Recording

- ❑ During the August test, Enroute Common Gateway (ECG) data was recorded at the Tech Center from the QVR site.
- ❑ The Radar Beacon Analysis Tool (RBAT) was used to analyze ECG data to produce statistics for the following list of parameters:
  - Targets per Scan
  - Probability of Detection
  - Identity Reliability
  - Identity Confidence
  - Altitude Reliability
  - Altitude Confidence
  - False Target Percentage
  - 0000 Code Percentage



# Data Analysis Methodology

- ❑ Applied time bins that corresponded to the AN/UPX-41(C) Active/OFF periods from test days (August 19<sup>th</sup>-21<sup>st</sup>) to baseline days to produce baseline statistics
- ❑ Data was first analyzed without any geographic or target filters
  - In analyzing possible cases of interference, it was determined that targets at low elevation angles exhibited relatively low probabilities of detection regardless of Active/OFF period
  - This behavior was not conducive to pinpointing interference events
- ❑ Analysis of targets at elevation angles greater than 0.5° degrees was prepared
  - Interference events would be easier to see if targets that were already behaving poorly were excluded from the analysis
- ❑ Targets that are beyond 230 NM from the SSR site were analyzed
  - Replies from targets at the edge of the coverage area are more likely to be lost to overpowering FRUIT
- ❑ Next, data was analyzed using a geographic filter that represented the area of AN/UPX-41(C) systems' sidelobes (subsequently referred to as the Hotspot area) – the area where transponder occupancy due to AN/UPX-41(C) would be the greatest
  - Assumption: AN/UPX-41(C) sidelobes extend 40 NM
  - Recent developments from flight test data show that P2 pulse can be seen up to 40 NM; however, only caused N39 ownship transponder suppressions up to 20 NM

# Analysis Limitations

- ❑ The theoretical or textbook definition of probability of detection is a function of interrogation/reply round reliability.
- ❑ However, probability of detection in RBAT is the percentage of target updates versus total number of beam dwells over all targets.
- ❑ Therefore, the ability for probability of detection calculated by RBAT to properly represent theoretical probability of detection is minimized as the sample size decreases (either through geographical or time constraints) since it no longer reliably reflects the target population mean.
- ❑ Example: A target population of two where both targets miss one update out of ten scans (approximately 50 seconds) results in a probability of detection of 90%. While this is unacceptable by QARS blip/scan minimums, we have no knowledge of the updates that occurred outside of the given time constraint . If both targets received ten out of ten updates for the previous as well as the next 10 scans, the probability of detection is now 96.7%.

# Analysis Objective

- ❑ We are attempting to observe distinct patterns of change in the metrics of interest between times when the AN/UPX-41(C) systems are OFF and when they are Active.
- ❑ While geographic and time filters reduces target update sample sizes such that a small sample size itself influences the metric of interest, it is more important to focus on the change from Off to Active since both the Off and Active periods have the same constraints applied.

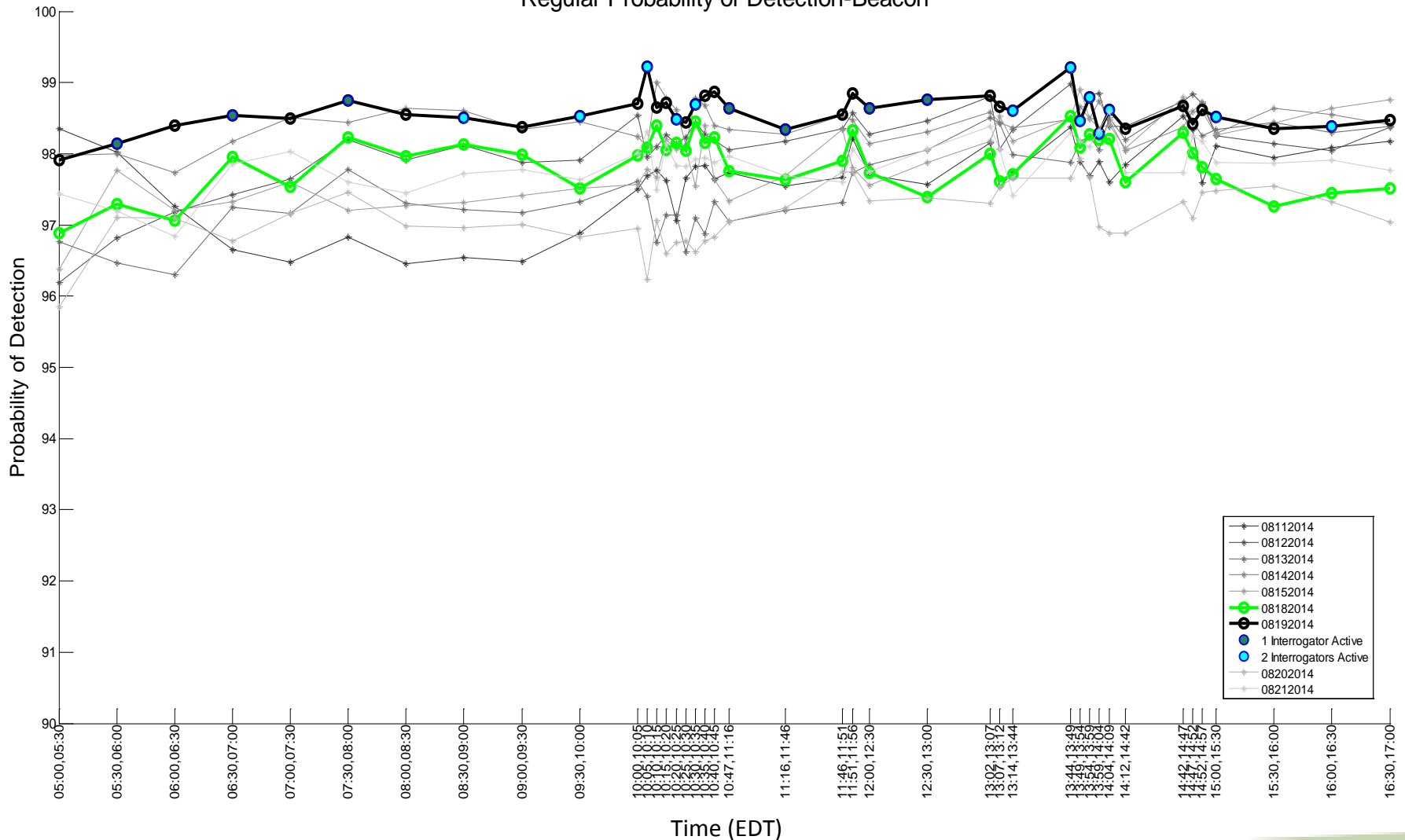
# Plot Guide

- ❑ There are four sets of plots that correspond to the data analysis methodology discussed previously
  1. No filters
  2. Filter on targets with elevation angle greater than 0.5 degrees
  3. Filter on targets with range greater than 190 NM from SSR
  4. Filter on targets within Hotspot
- ❑ Plots with multiple days of data utilize the time filters from the Active/Off periods for the date given in the slide's title
- ❑ Plots that use boxplots
  - The edges of the box are the 25<sup>th</sup> and 75<sup>th</sup> percentiles. The maximum whisker length represents approximately 2.7 sigma (99.3%). Points in red are shown as outliers.
  - For five minute time bins, there are only 25 QVR scans and, if you miss one target update, Pd will automatically drop to 96% (24 out of 25 possible target reports).
  - Horizontal axis 30-min and 5-min time bins are not scaled according to duration

# Target Metrics with No Filter

# Probability of Detection – August 19<sup>th</sup>

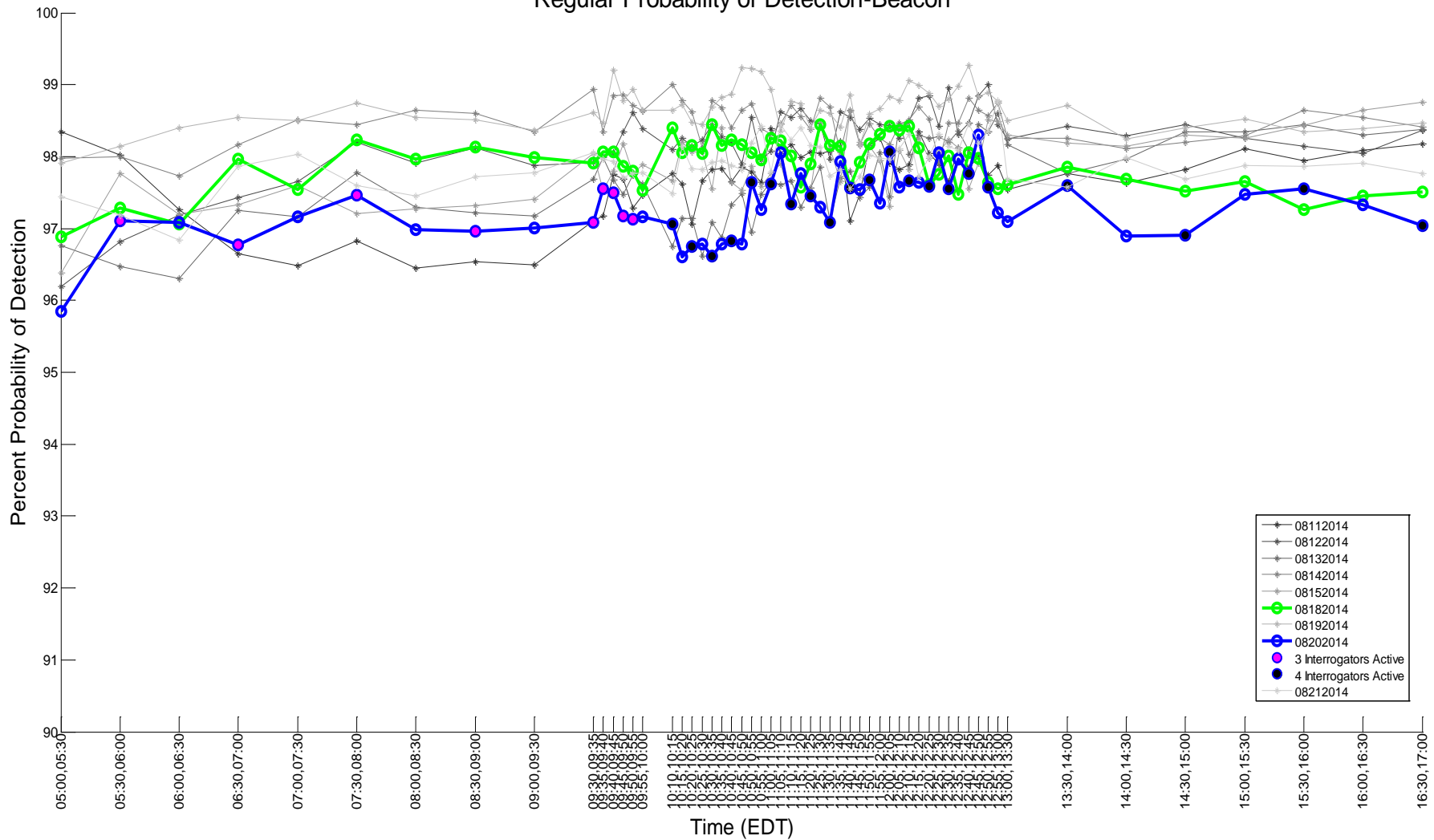
## Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

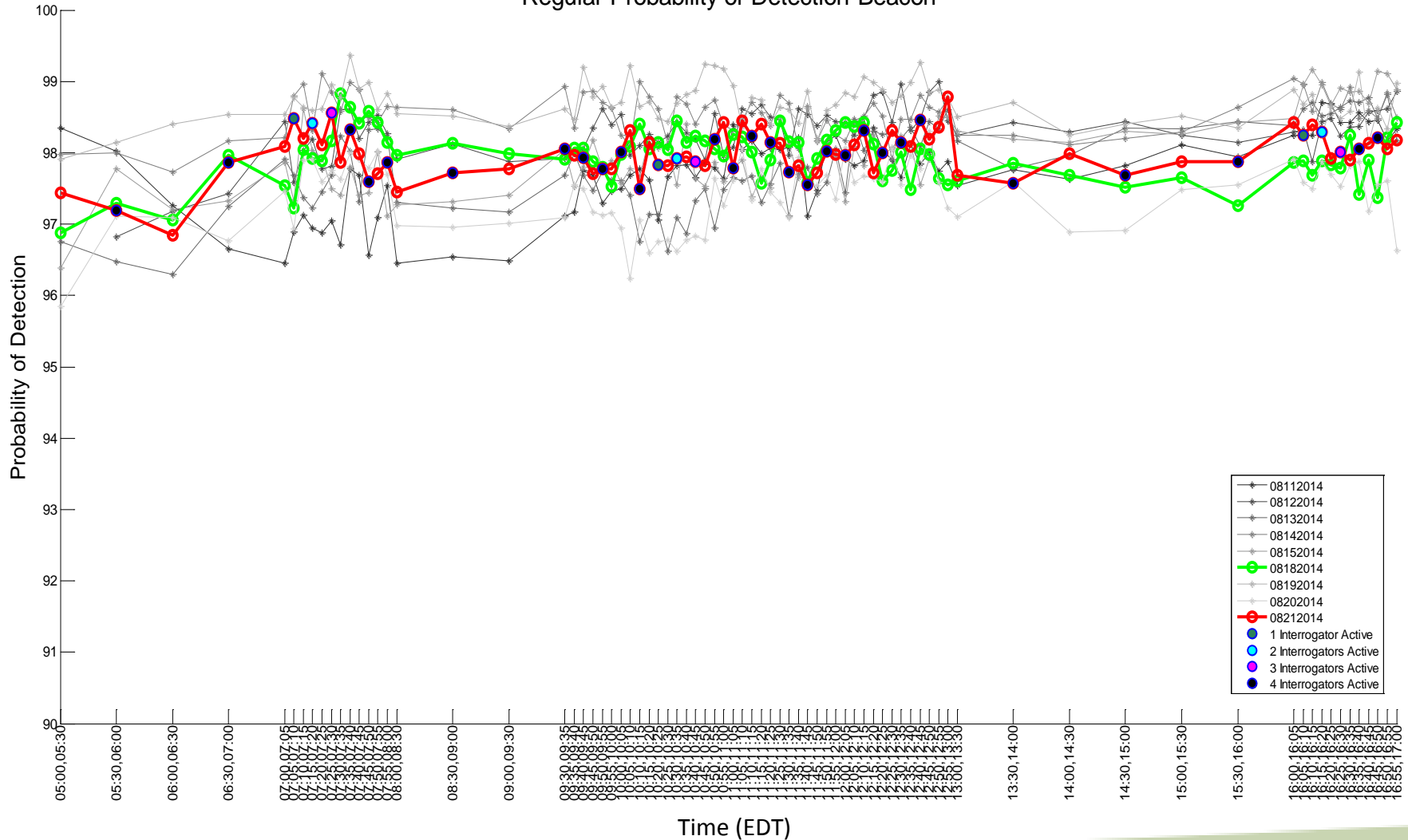
Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

Regular Probability of Detection-Beacon

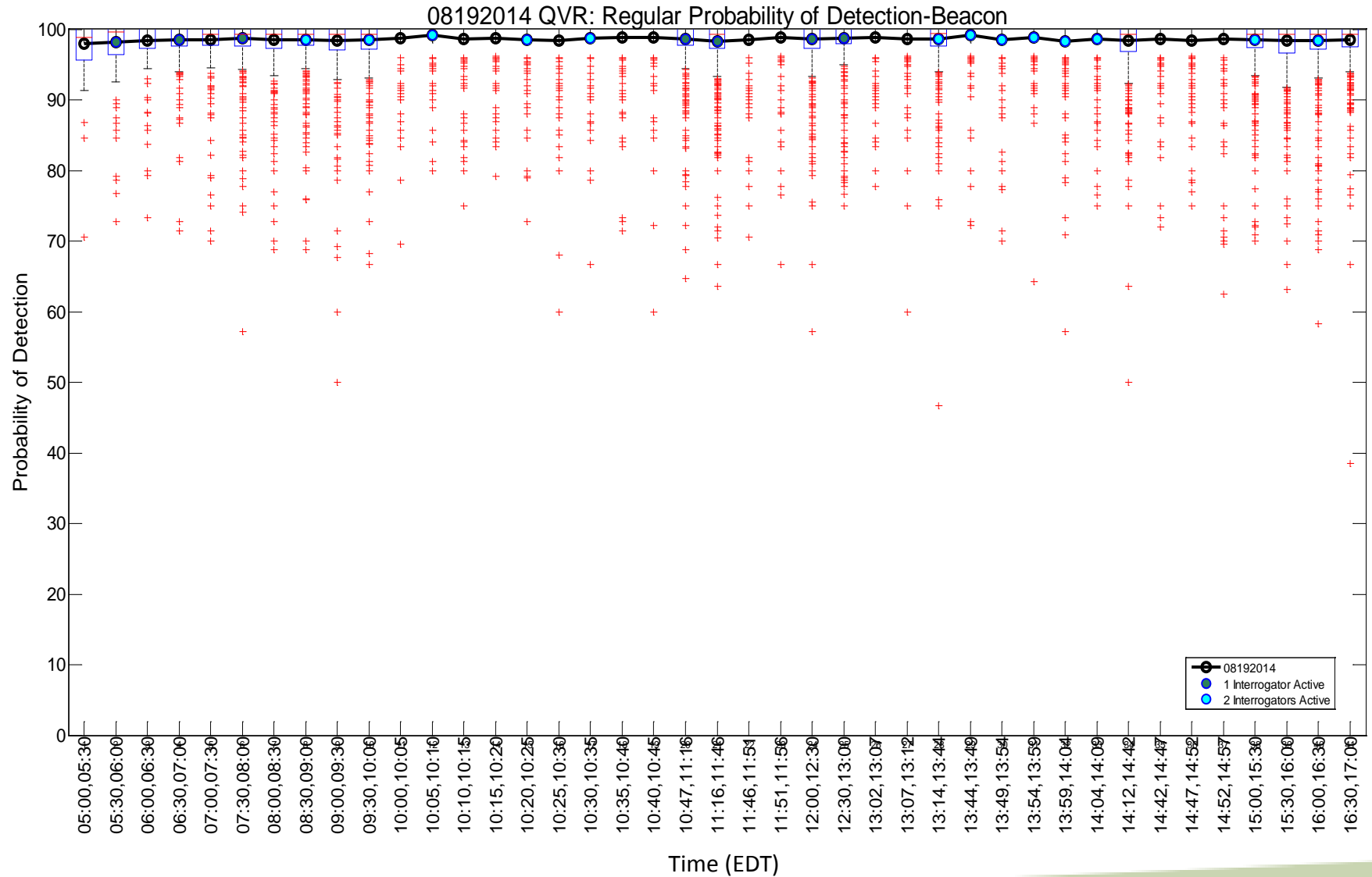


Geographic Filter: None  
Target Filter: None



# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution

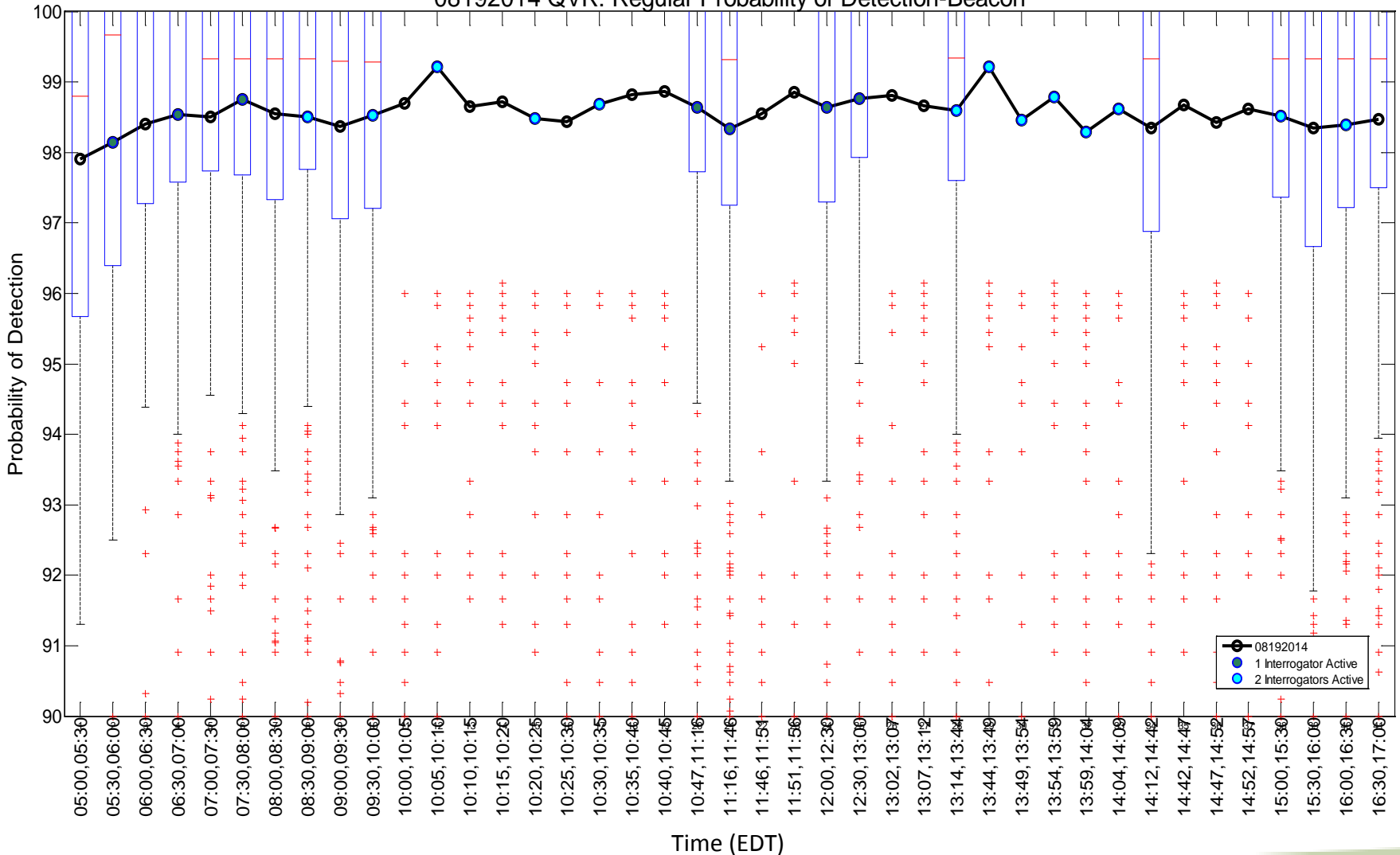


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08192014 QVR: Regular Probability of Detection-Beacon

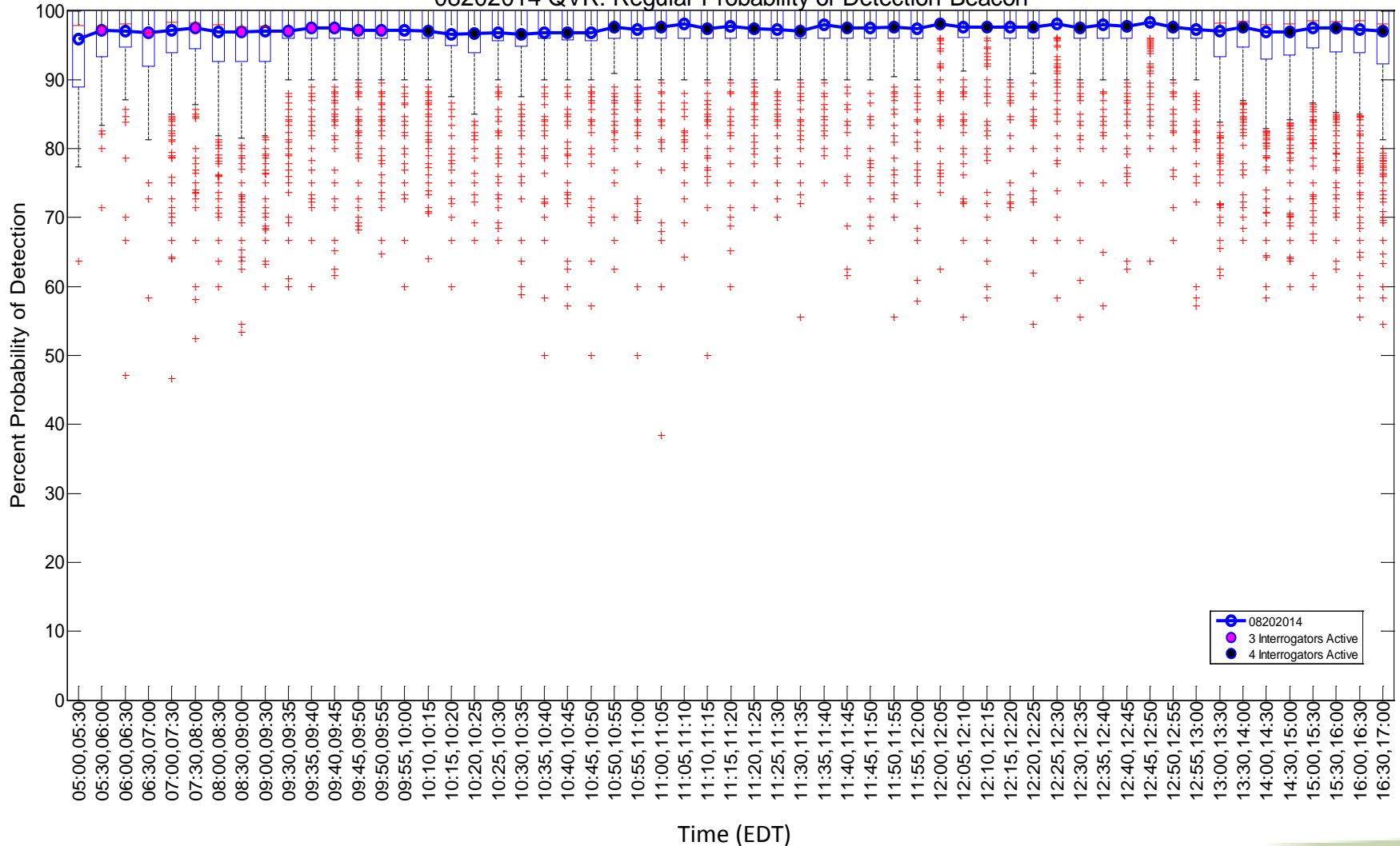


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

08202014 QVR: Regular Probability of Detection-Beacon

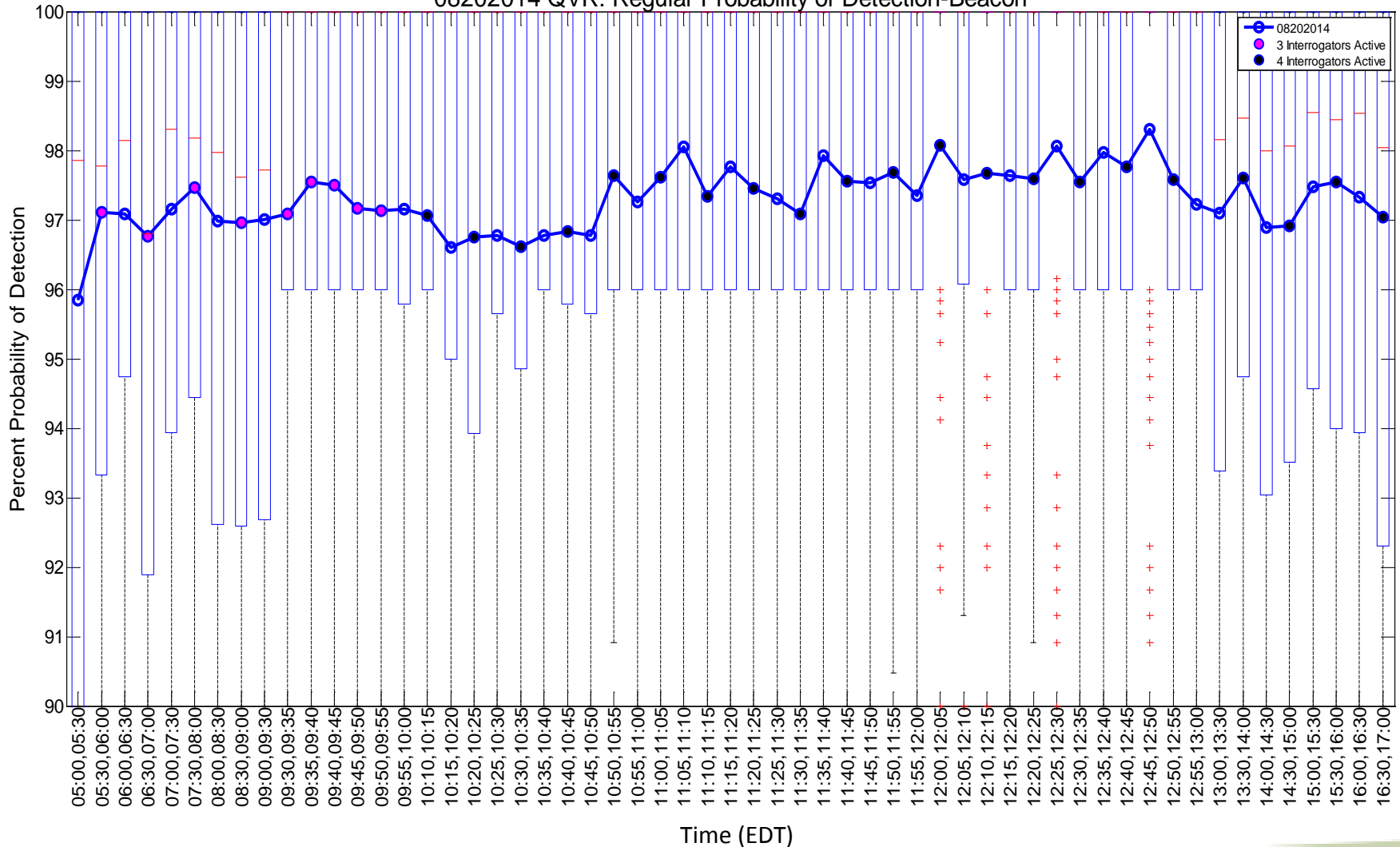


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

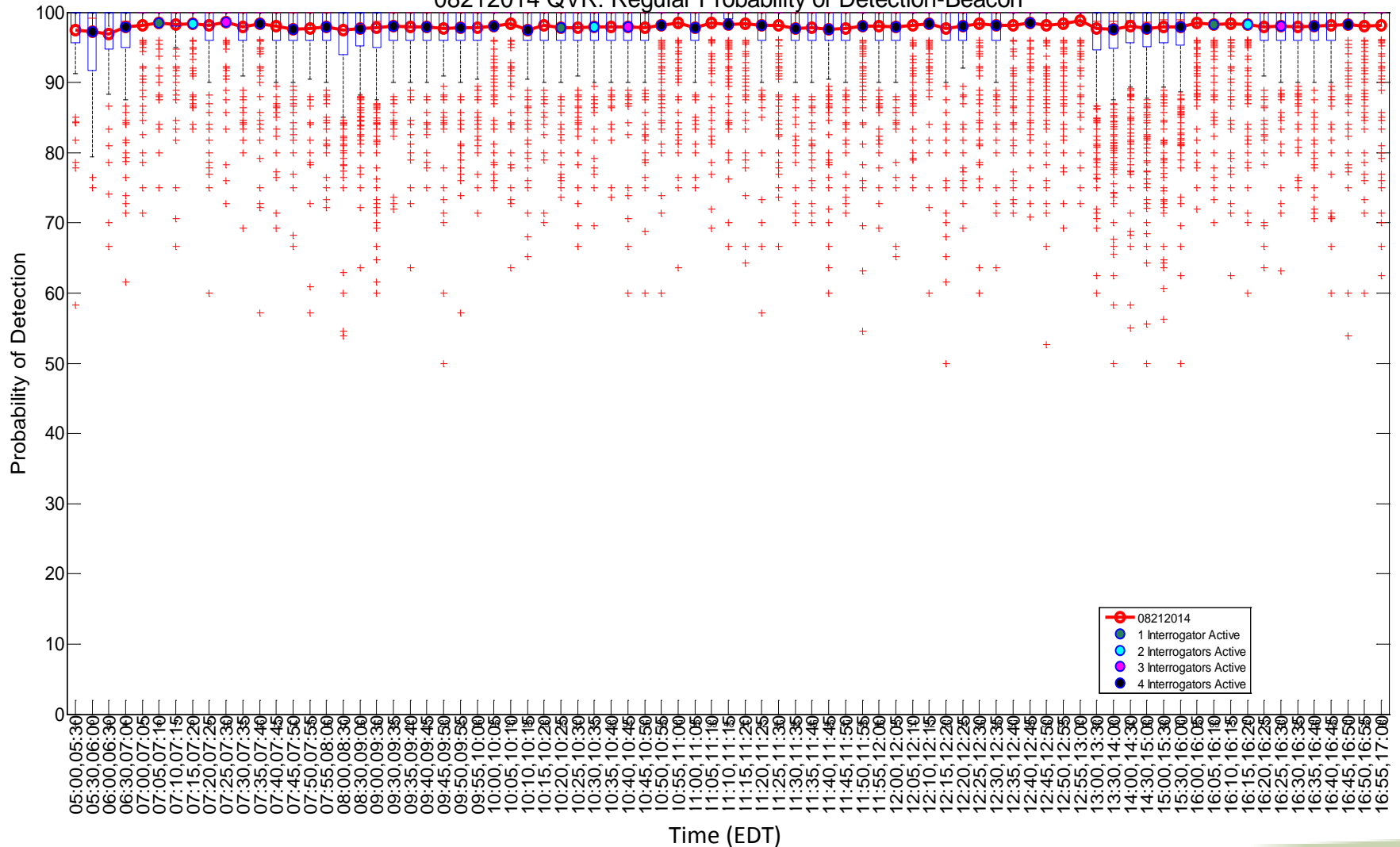
08202014 QVR: Regular Probability of Detection-Beacon



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

08212014 QVR: Regular Probability of Detection-Beacon

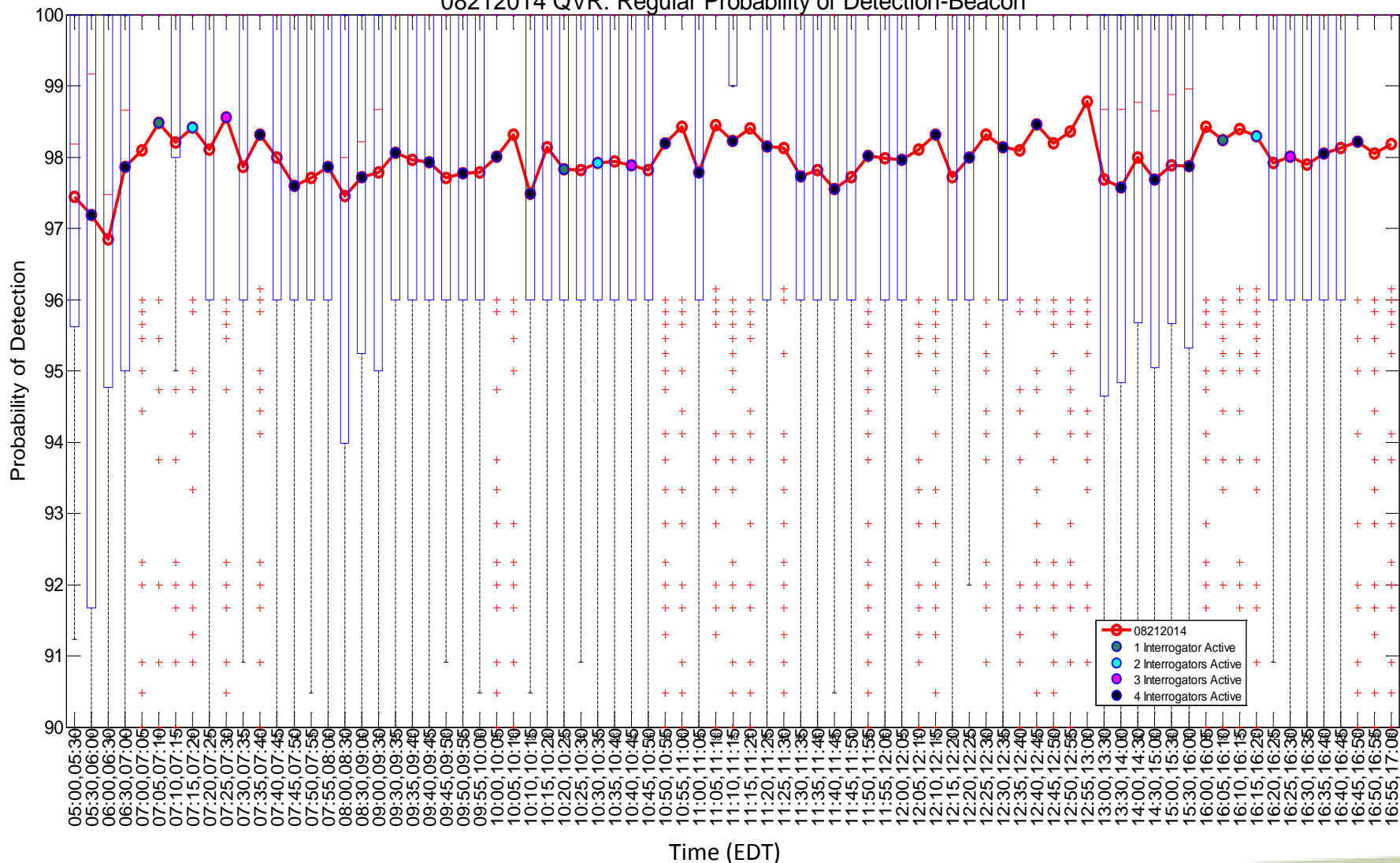


Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

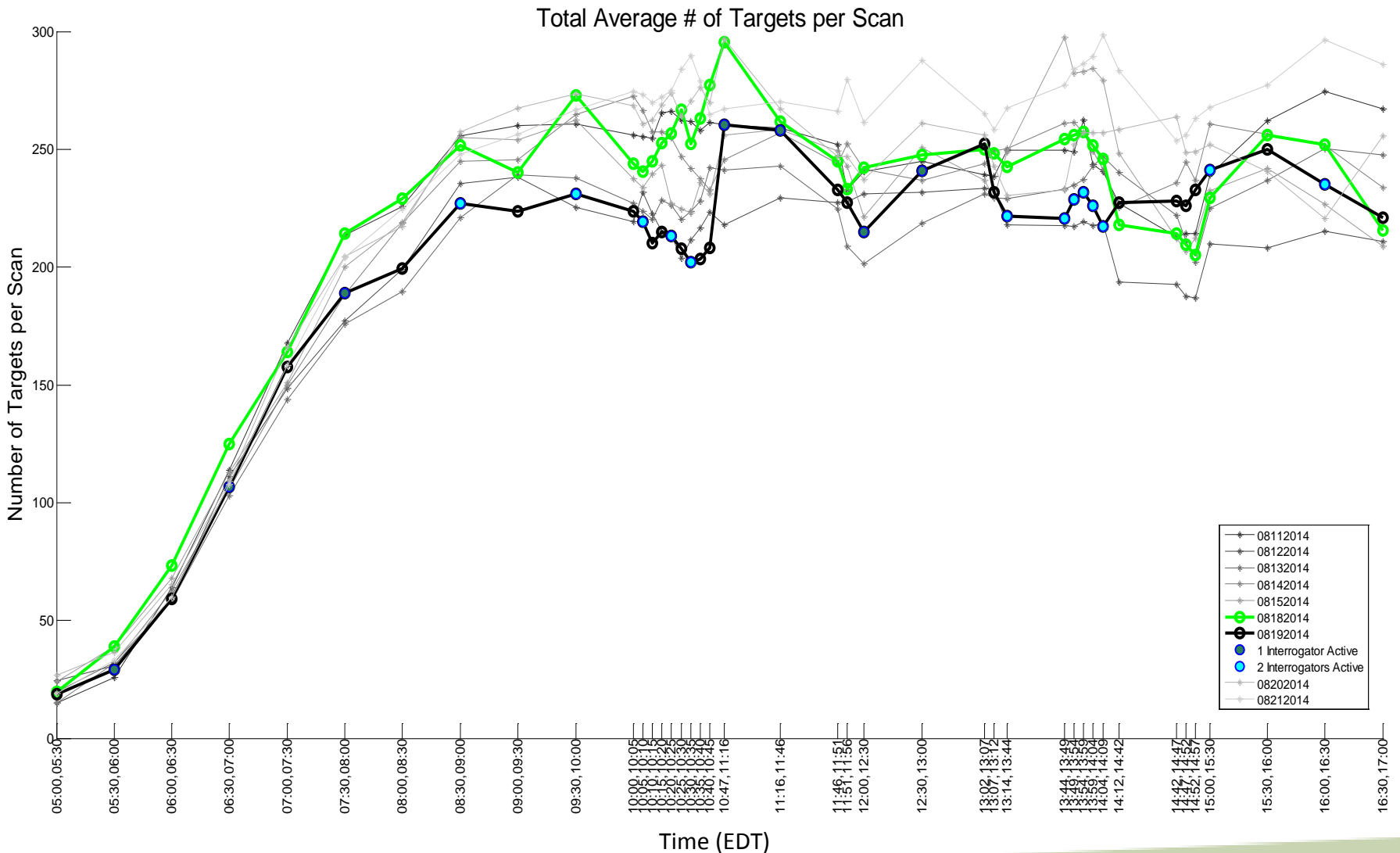
## Individual Aircraft Distribution (zoom-in)

08212014 QVR: Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: None

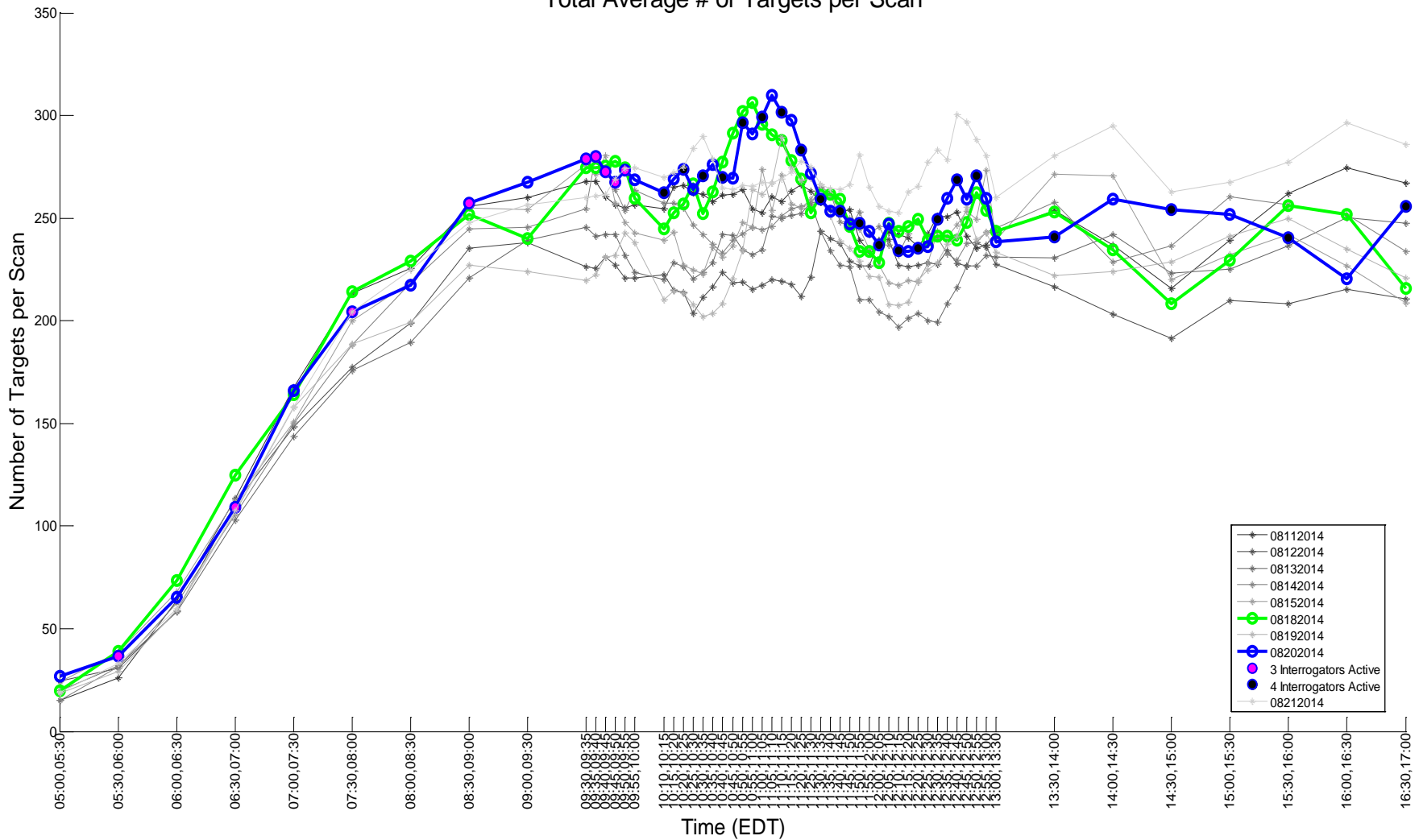
# Targets per Scan – August 19<sup>th</sup>



Geographic Filter: None  
Target Filter: None

# Targets per Scan – August 20<sup>th</sup>

Total Average # of Targets per Scan

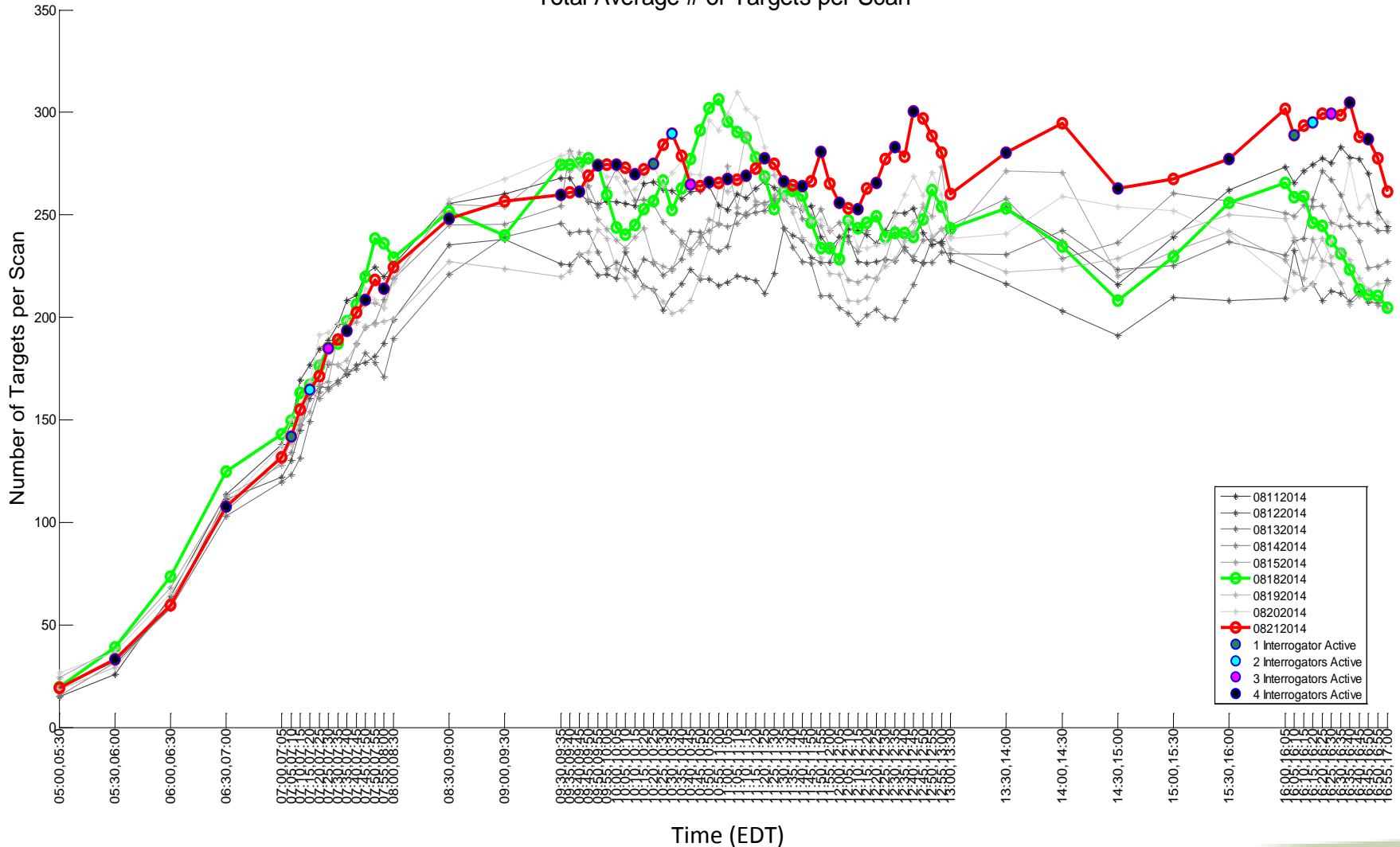


Geographic Filter: None  
Target Filter: None



# Targets per Scan – August 21<sup>st</sup>

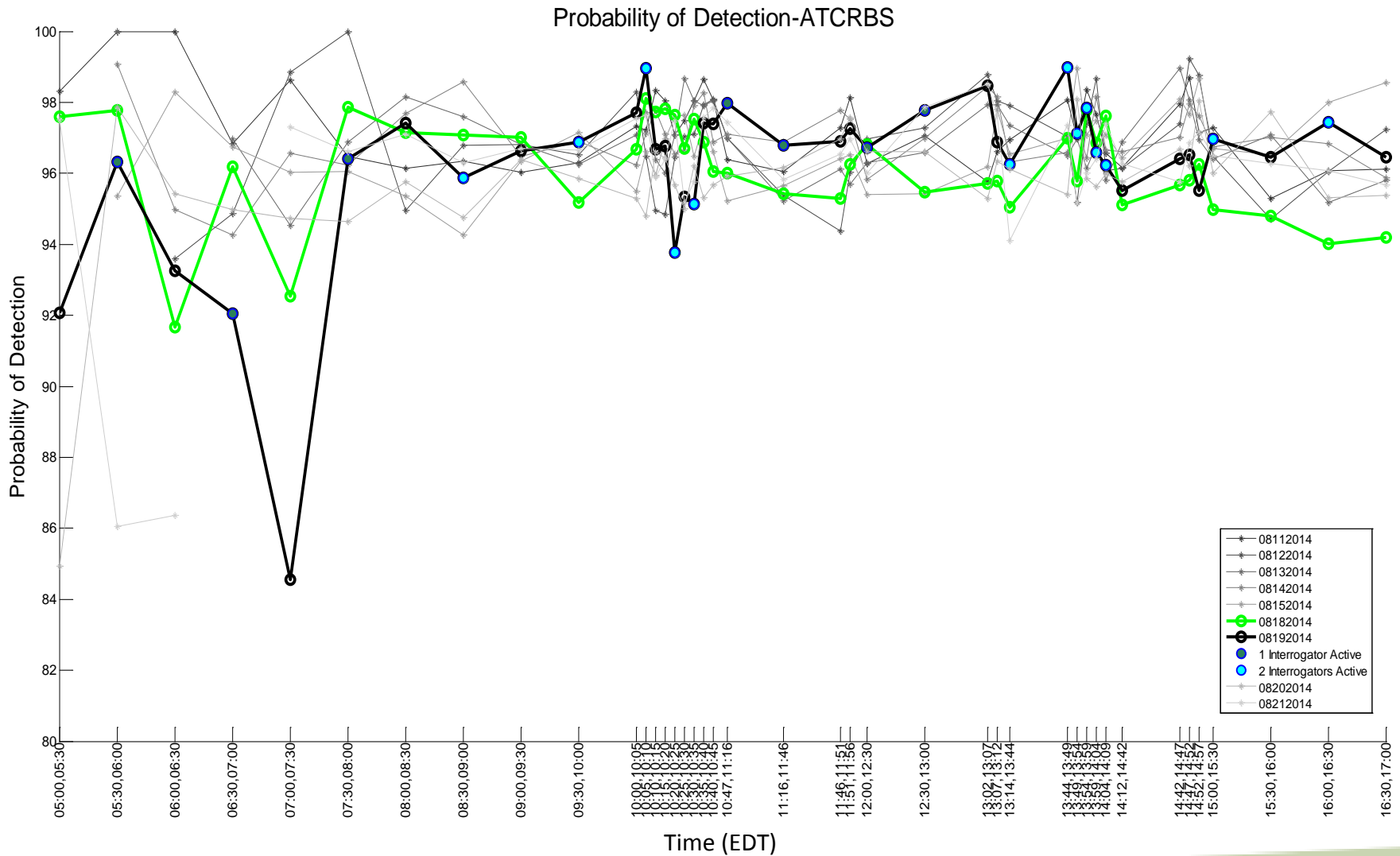
Total Average # of Targets per Scan



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

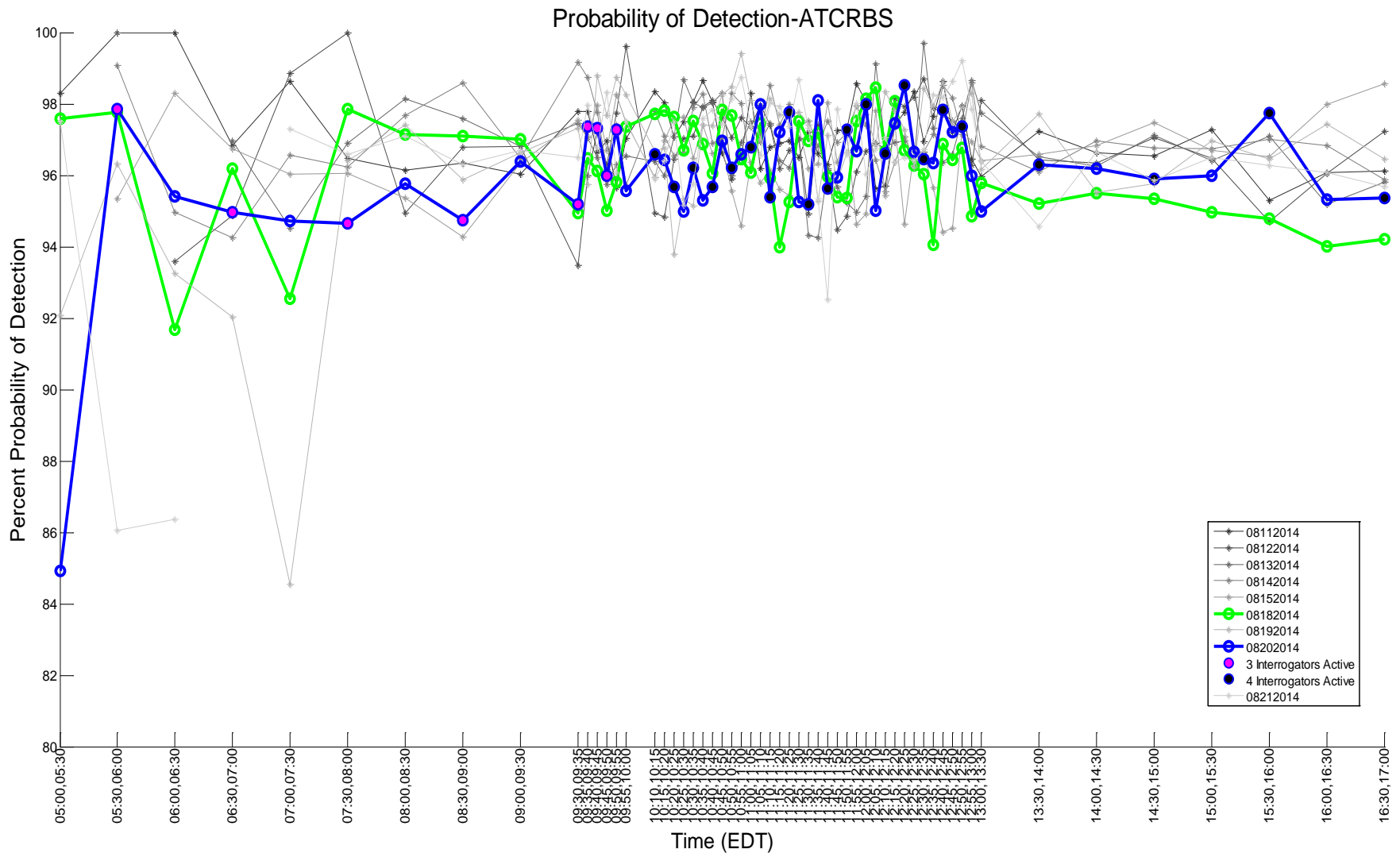
## ATCRBS Targets - Discrete



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

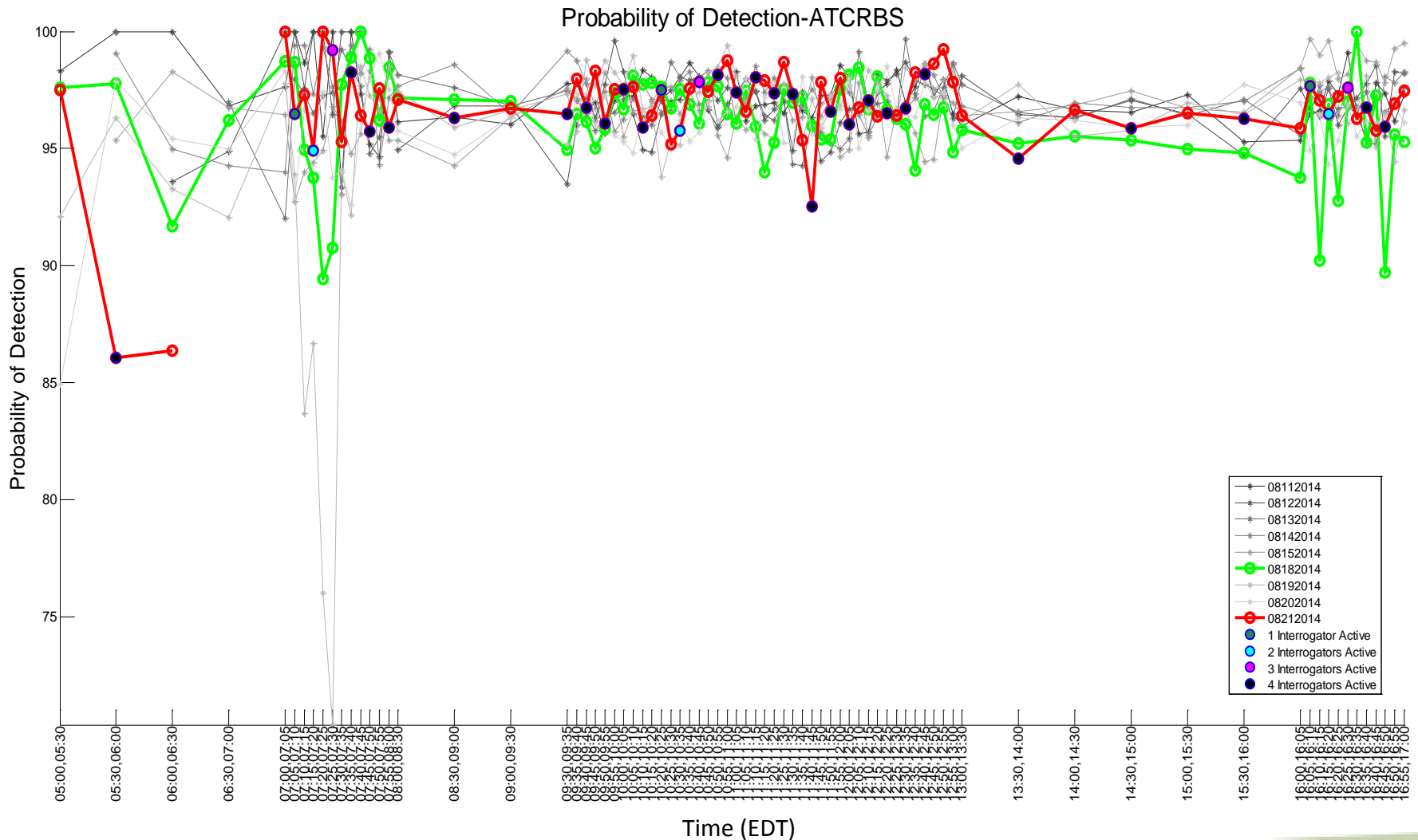
## ATCRBS Targets - Discrete



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

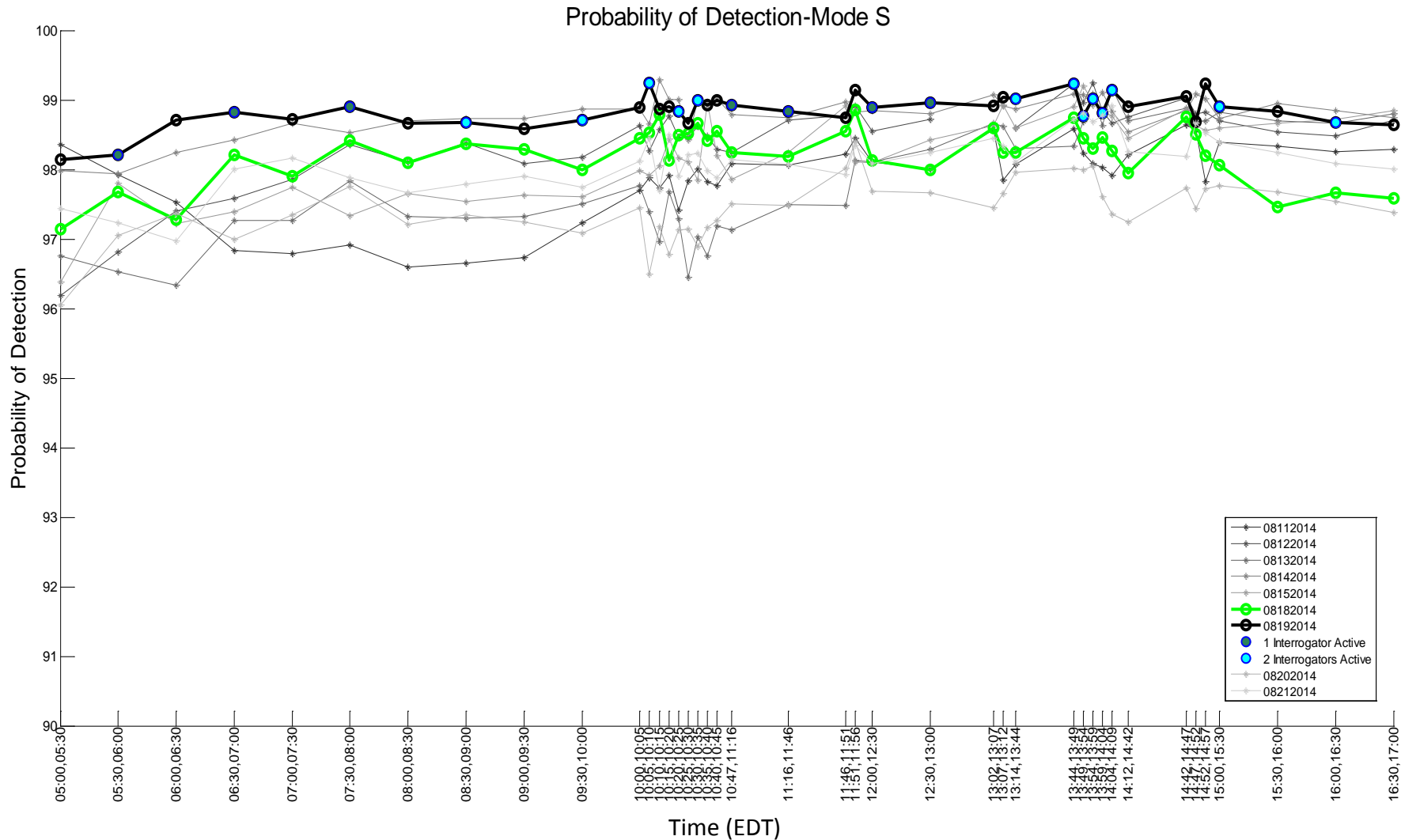
## ATCRBS Targets - Discrete



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

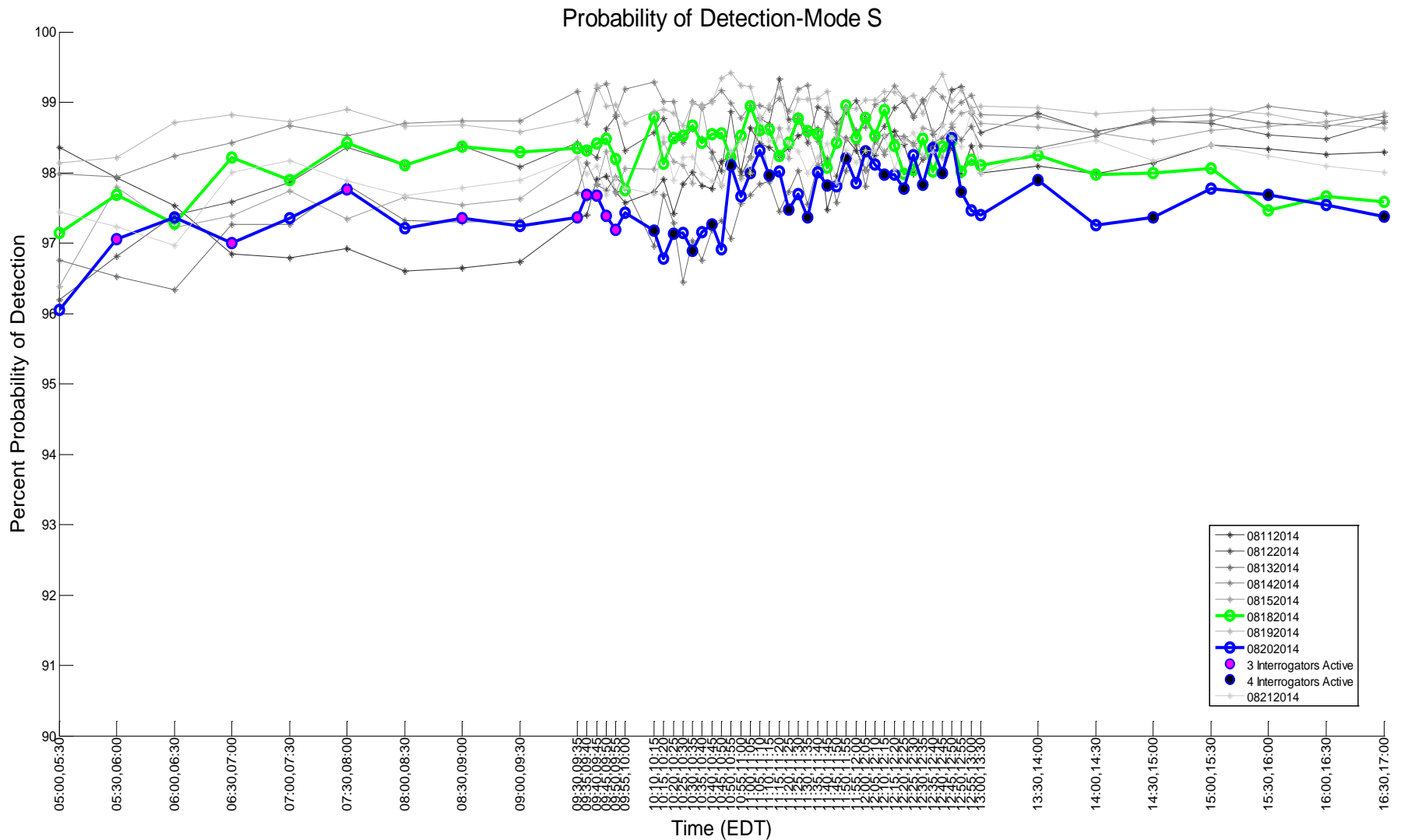
## Mode S Targets



Geographic Filter: None  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

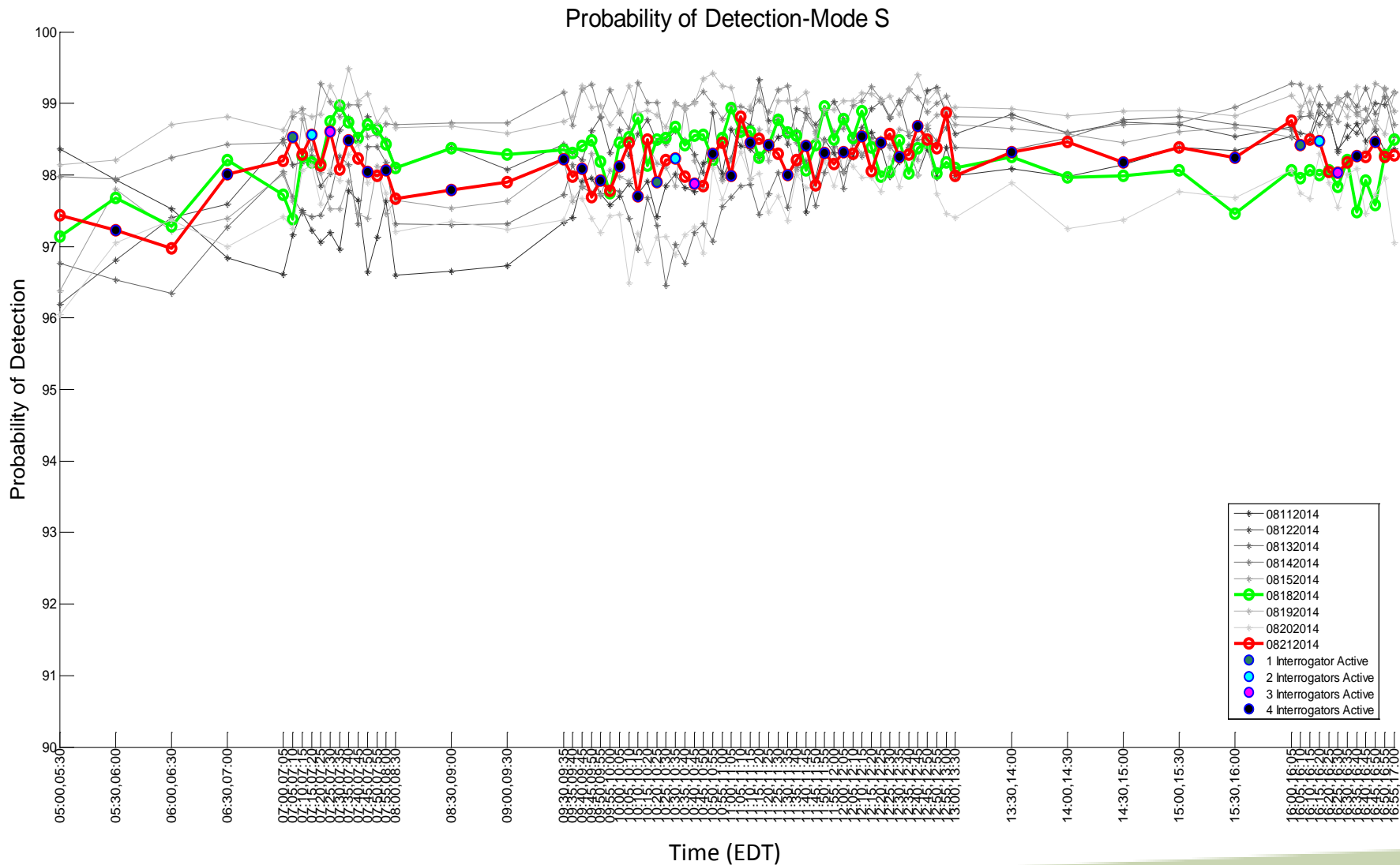
## Mode S Targets



Geographic Filter: None  
Target Filter: None

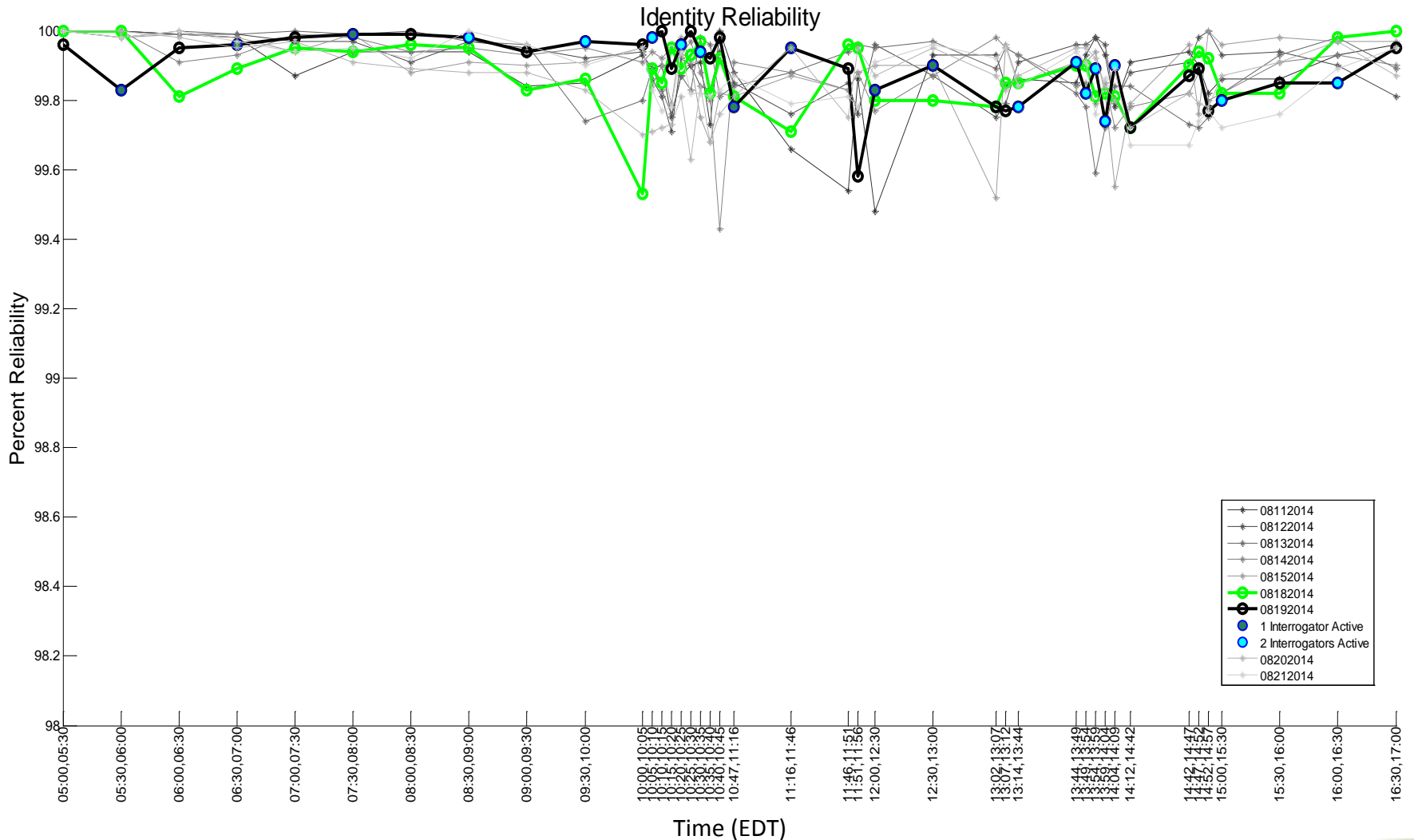
# Probability of Detection – August 21<sup>st</sup>

## Mode S Targets



Geographic Filter: None  
Target Filter: None

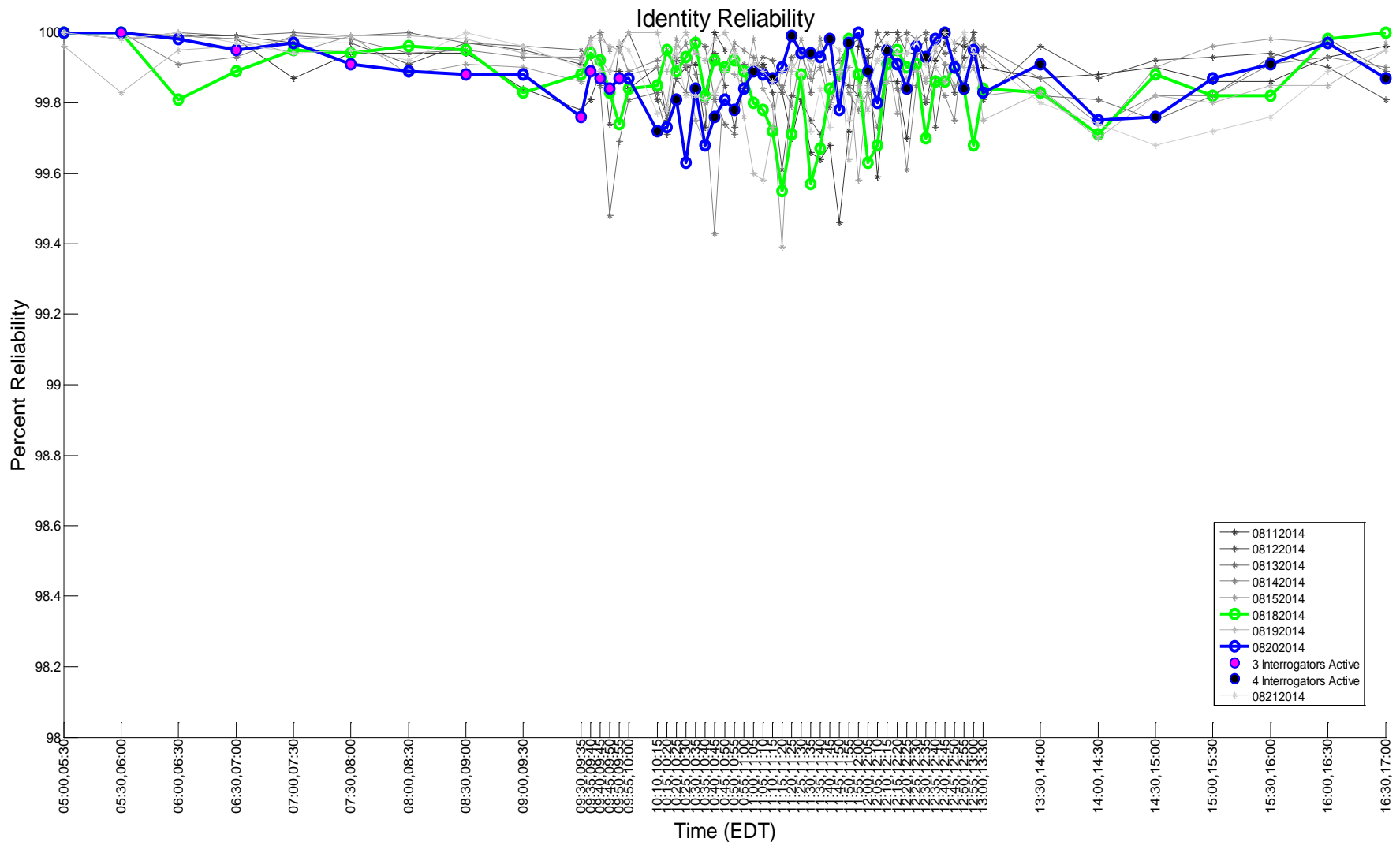
# Identity (3/A) Reliability – August 19th



Geographic Filter: None  
 Target Filter: None

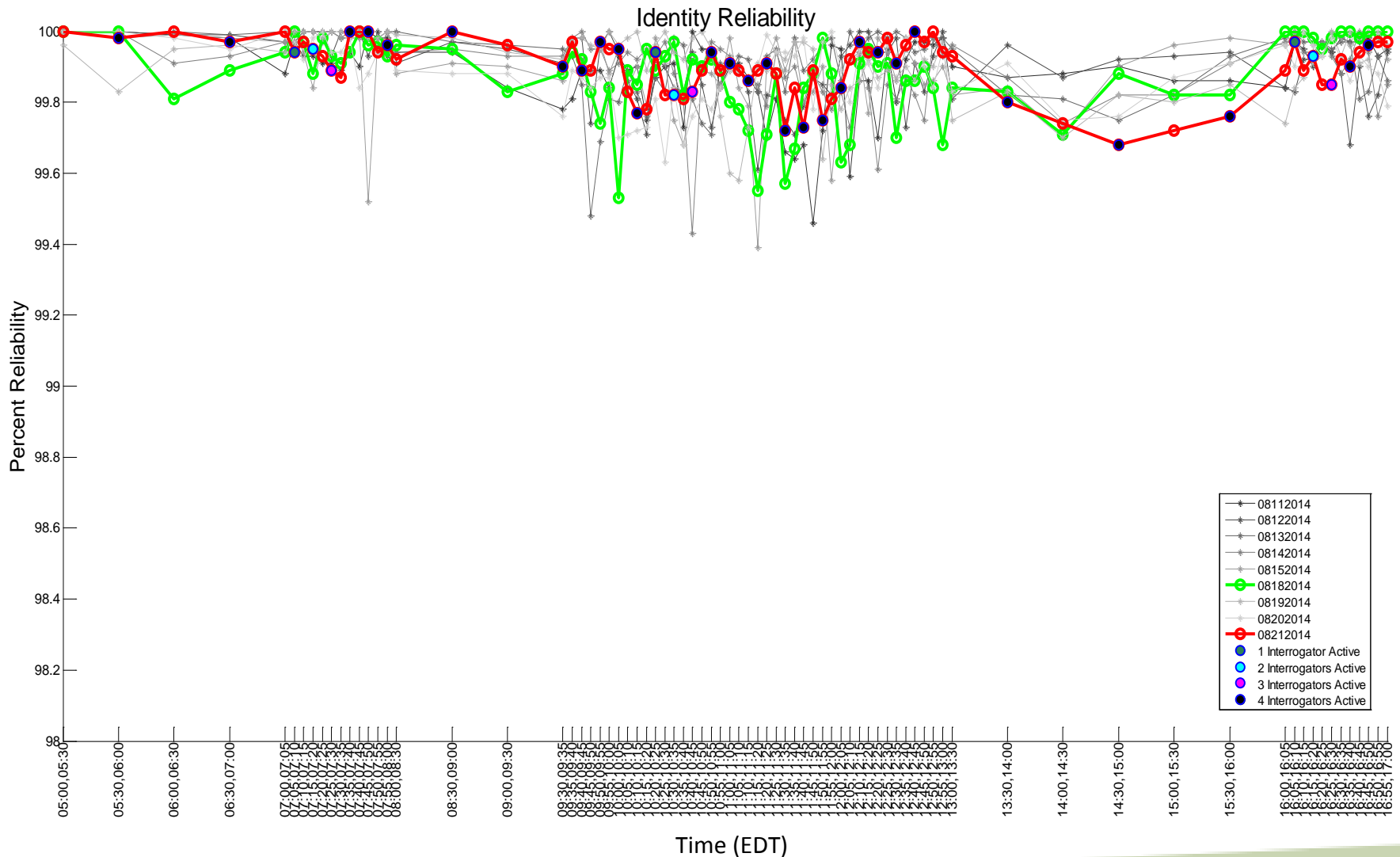


# Identity (3/A) Reliability – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

# Identity (3/A) Reliability – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

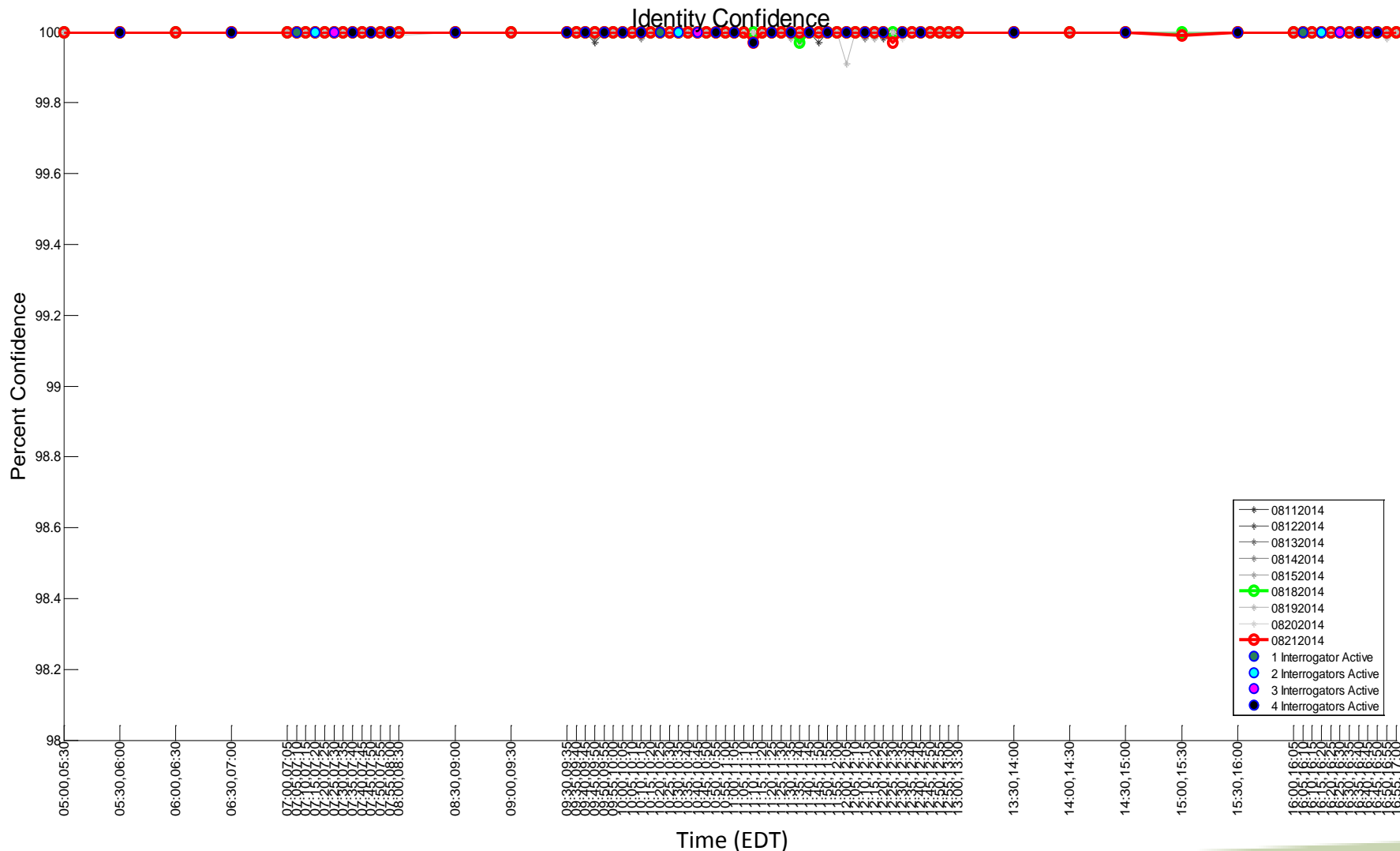
# Identity (3/A) Confidence – August 19th



Geographic Filter: None  
Target Filter: None

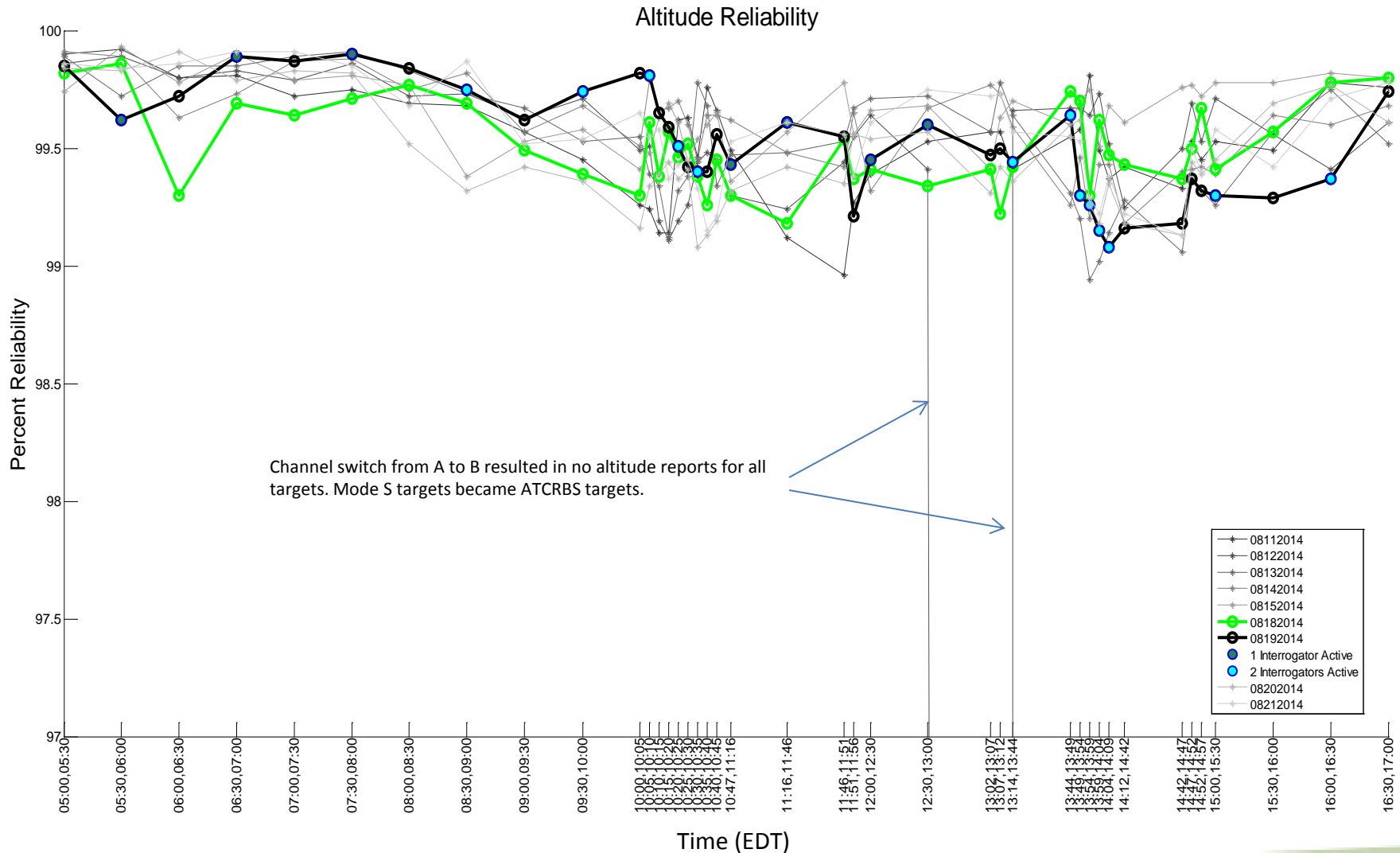


# Identity (3/A) Confidence – August 21<sup>st</sup>

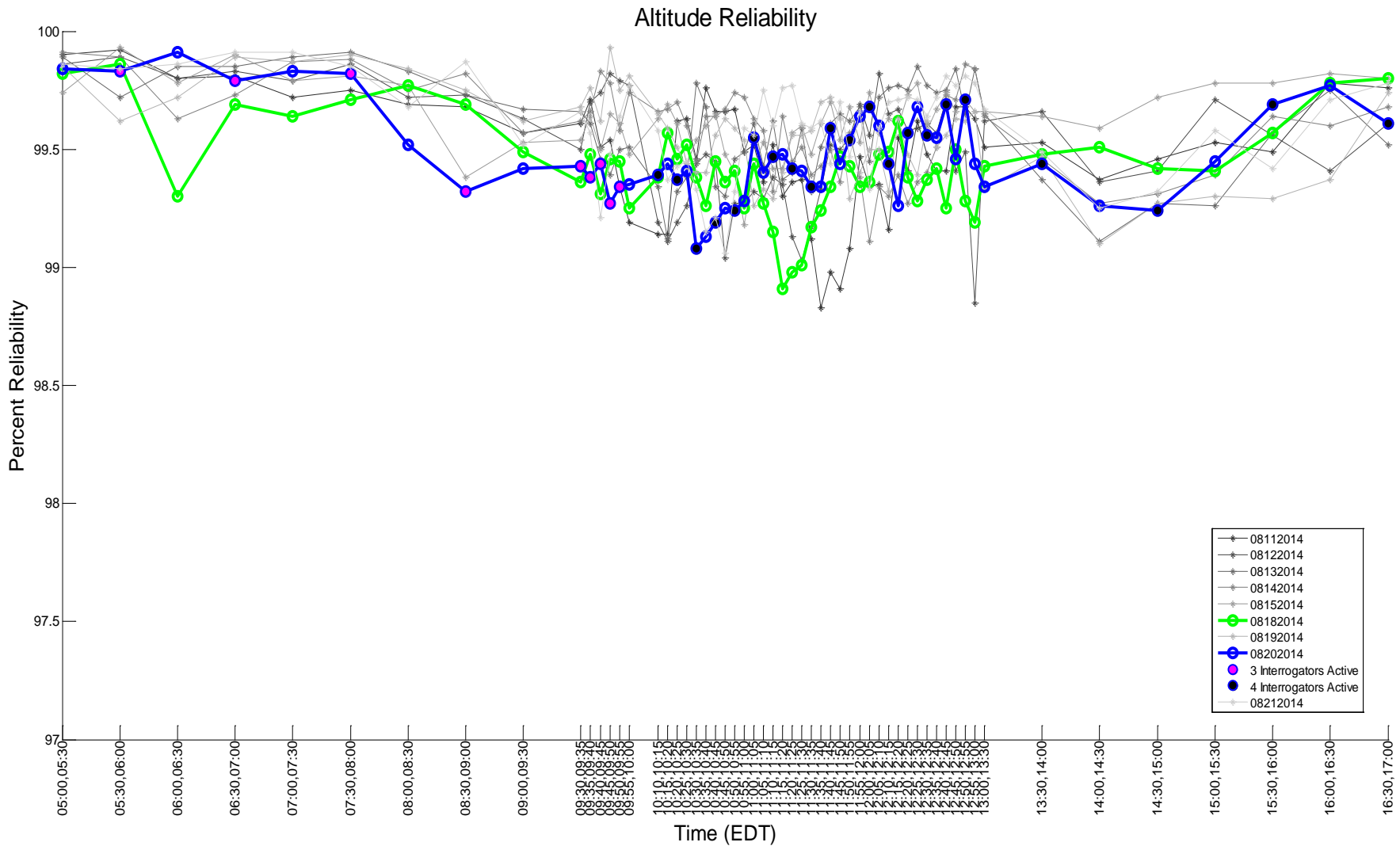


Geographic Filter: None  
Target Filter: None

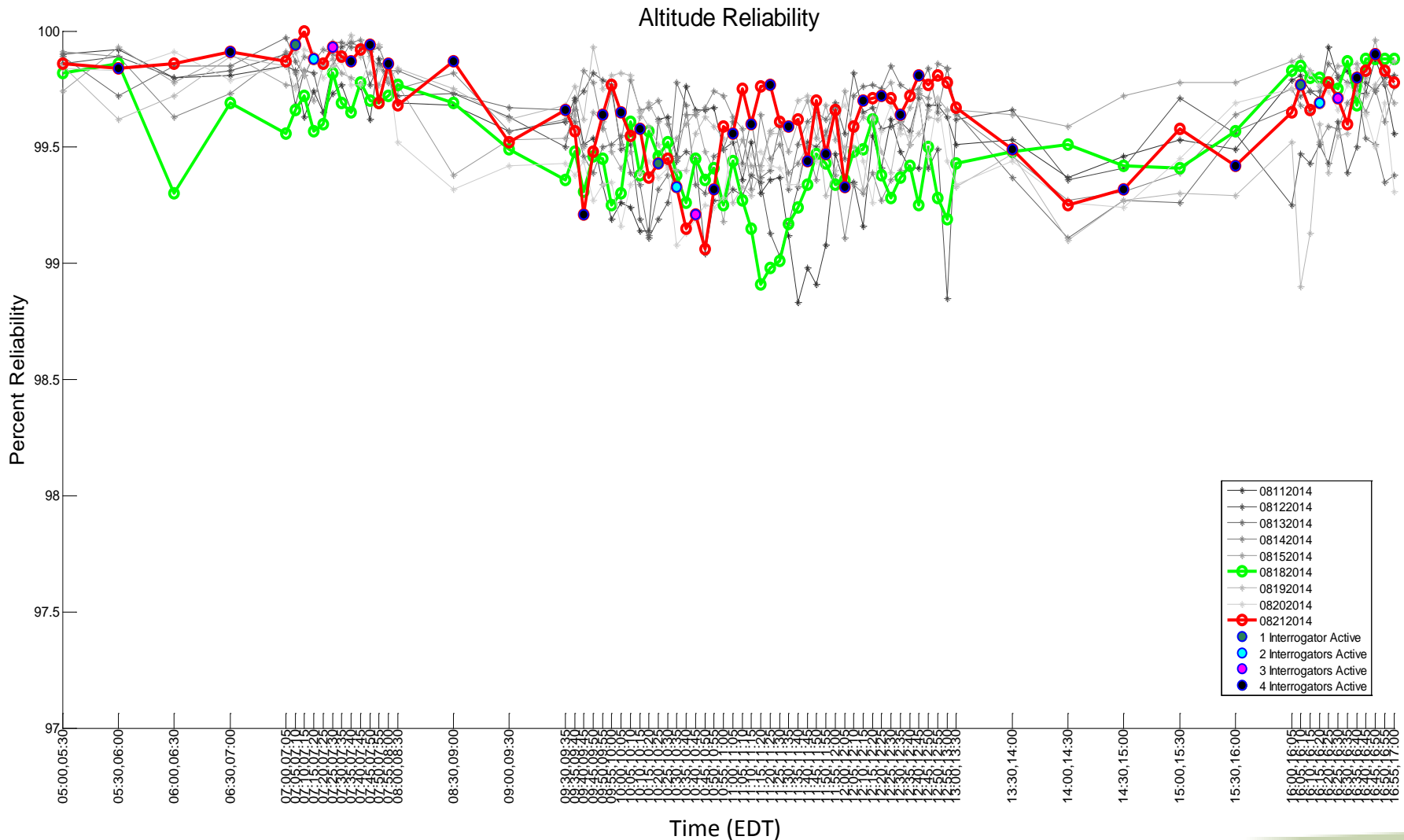
# Altitude (C) Reliability – August 19th



# Altitude (C) Reliability – August 20<sup>th</sup>



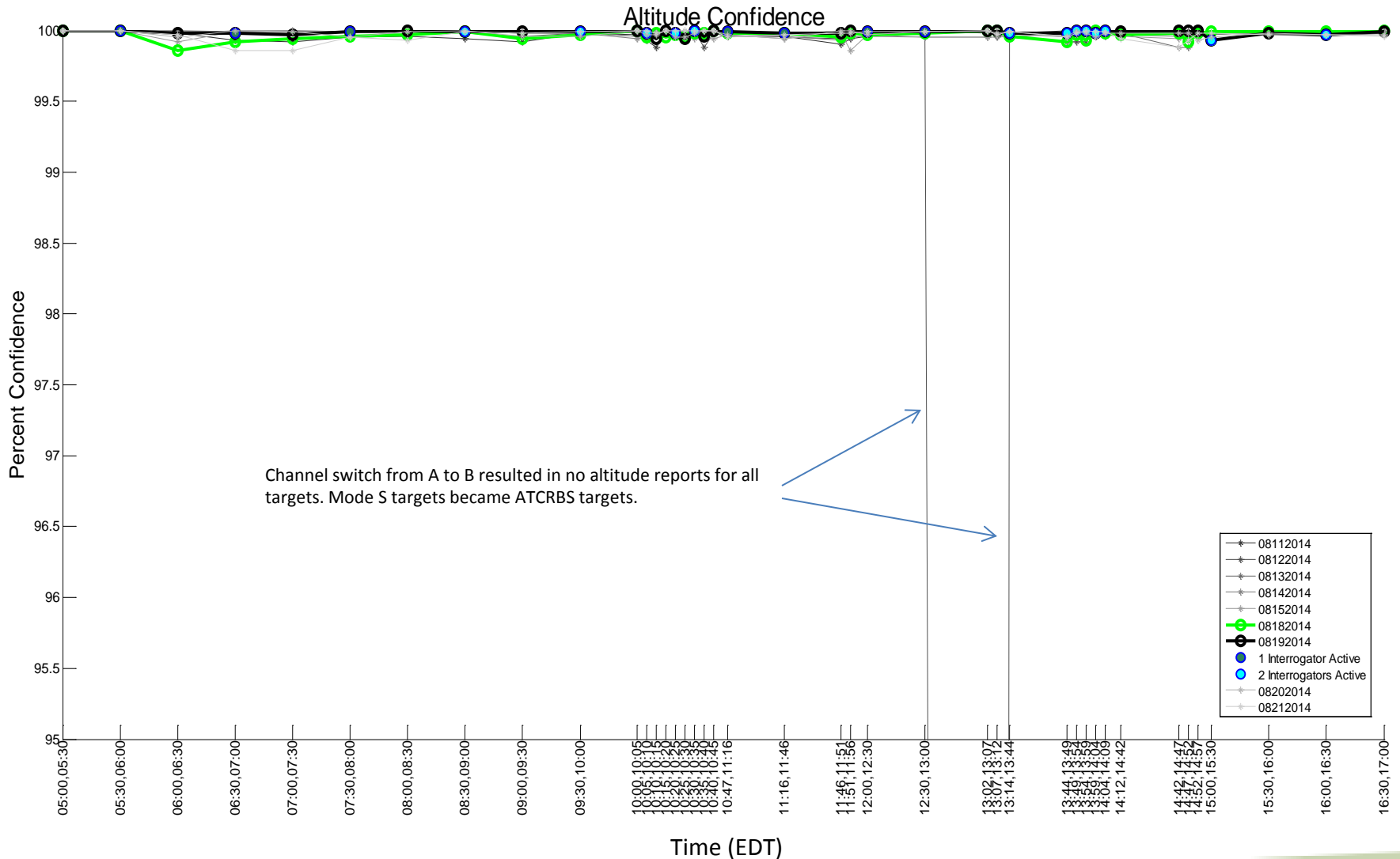
# Altitude (C) Reliability – August 21<sup>st</sup>



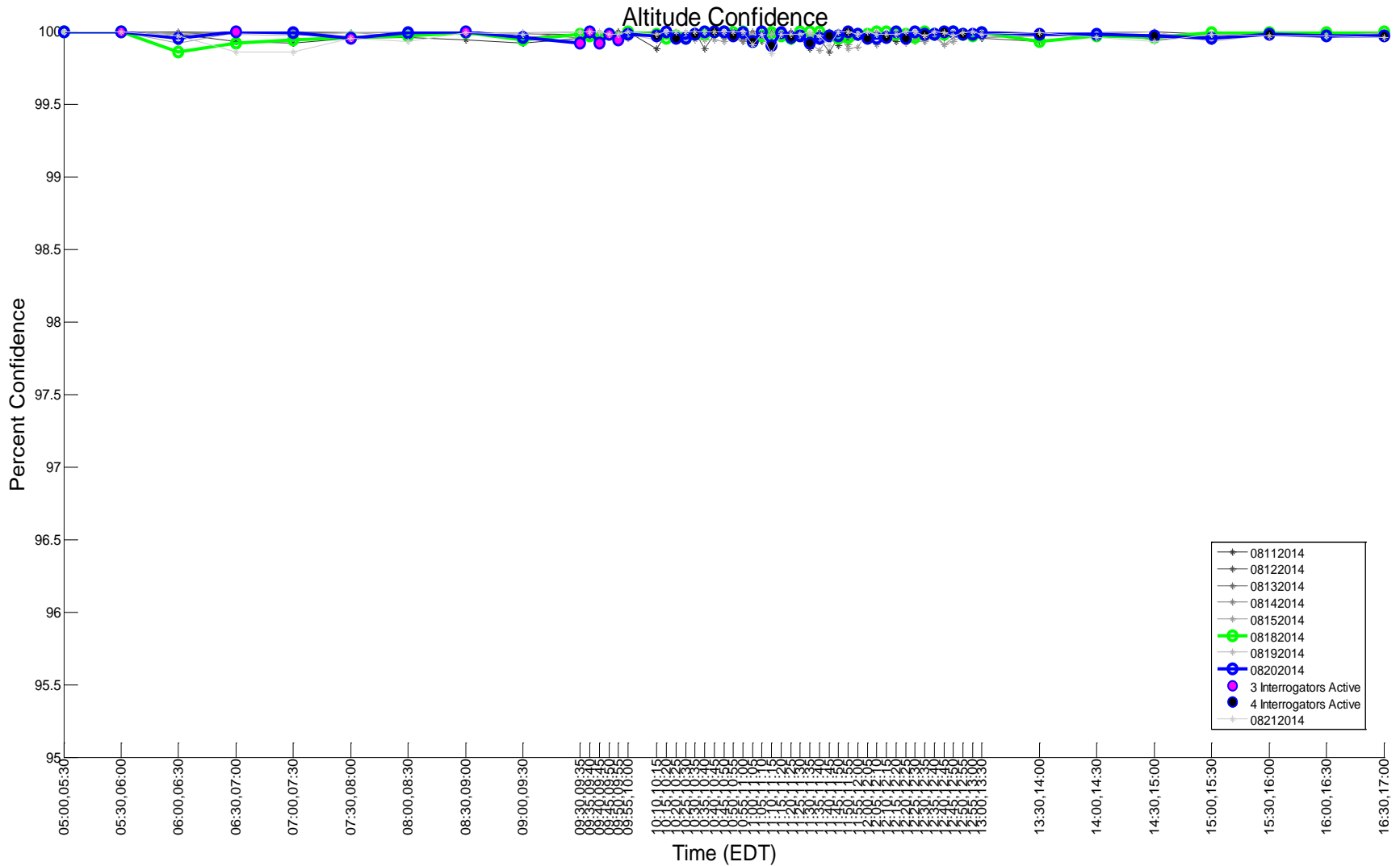
Geographic Filter: None  
Target Filter: None



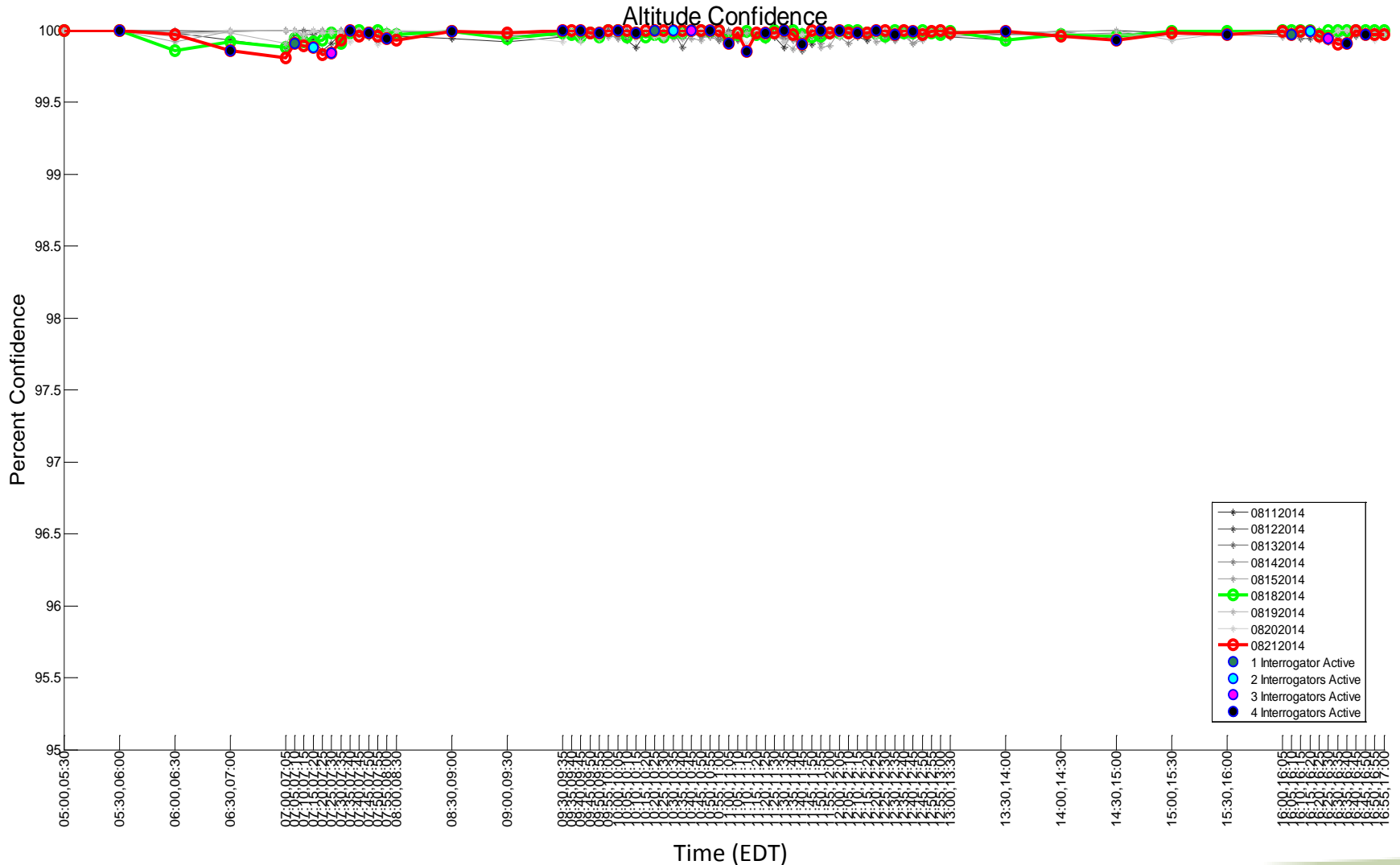
# Altitude (C) Confidence – August 19th



# Altitude (C) Confidence – August 20<sup>th</sup>

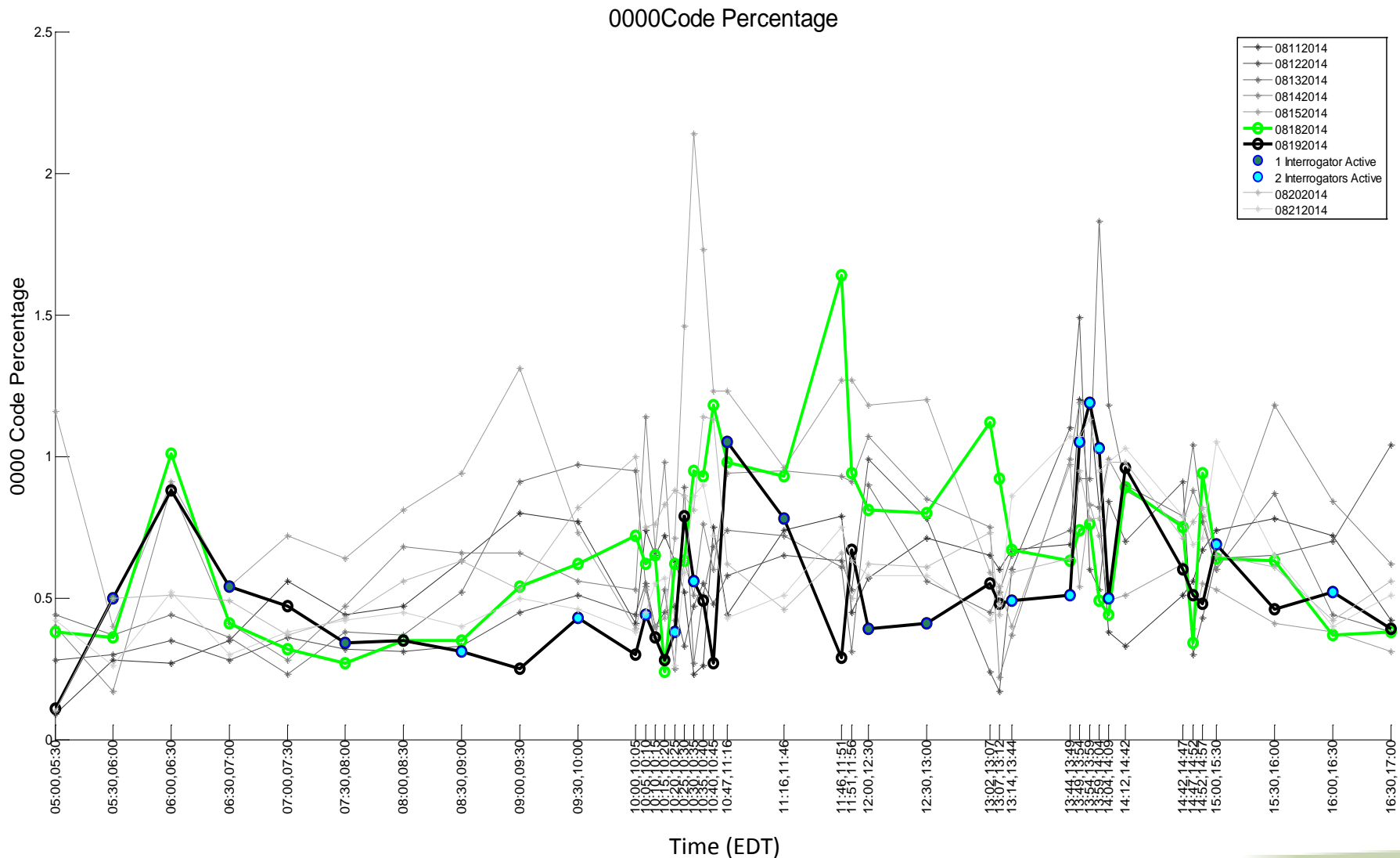


# Altitude (C) Confidence – August 21<sup>st</sup>



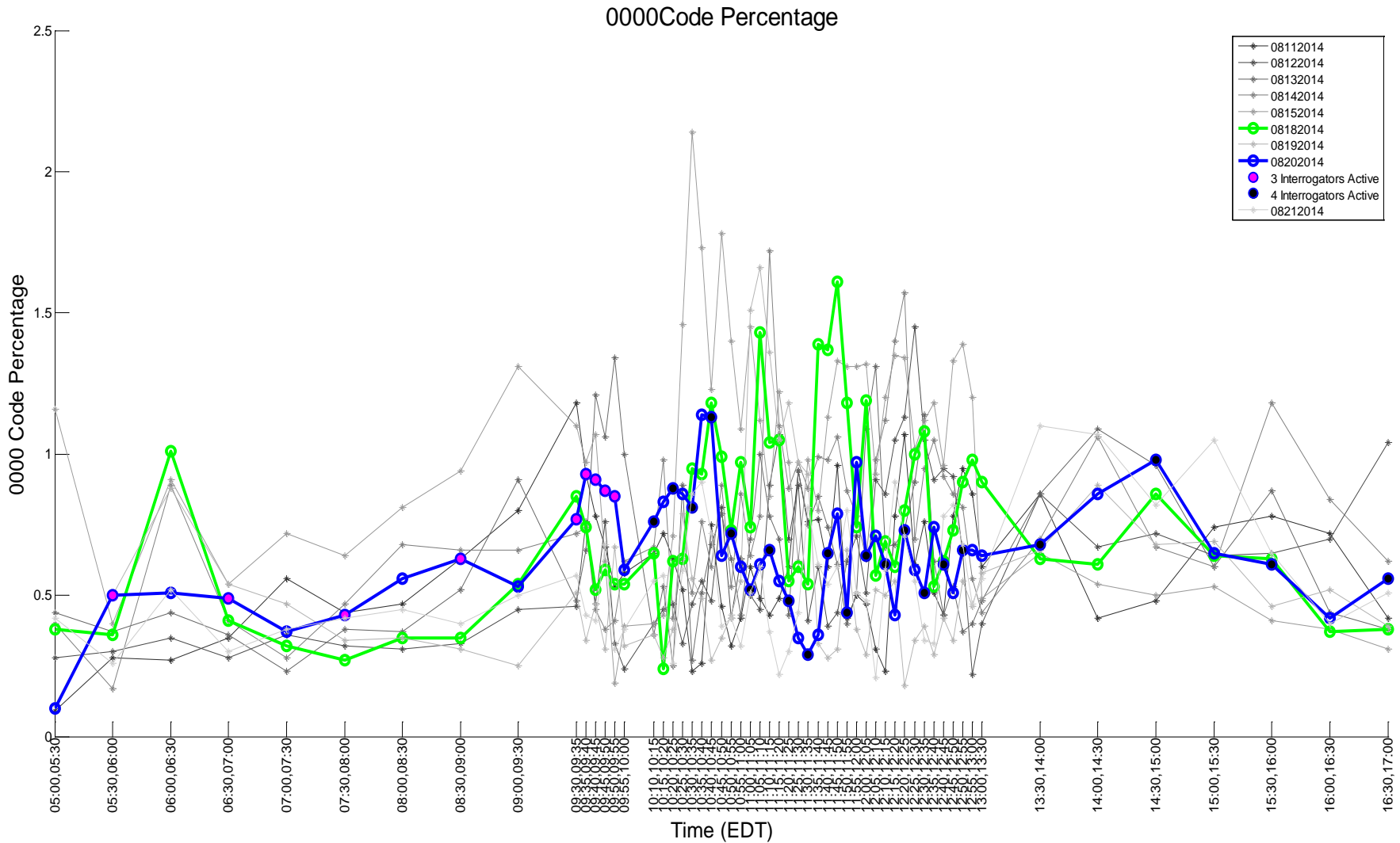
Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 19th



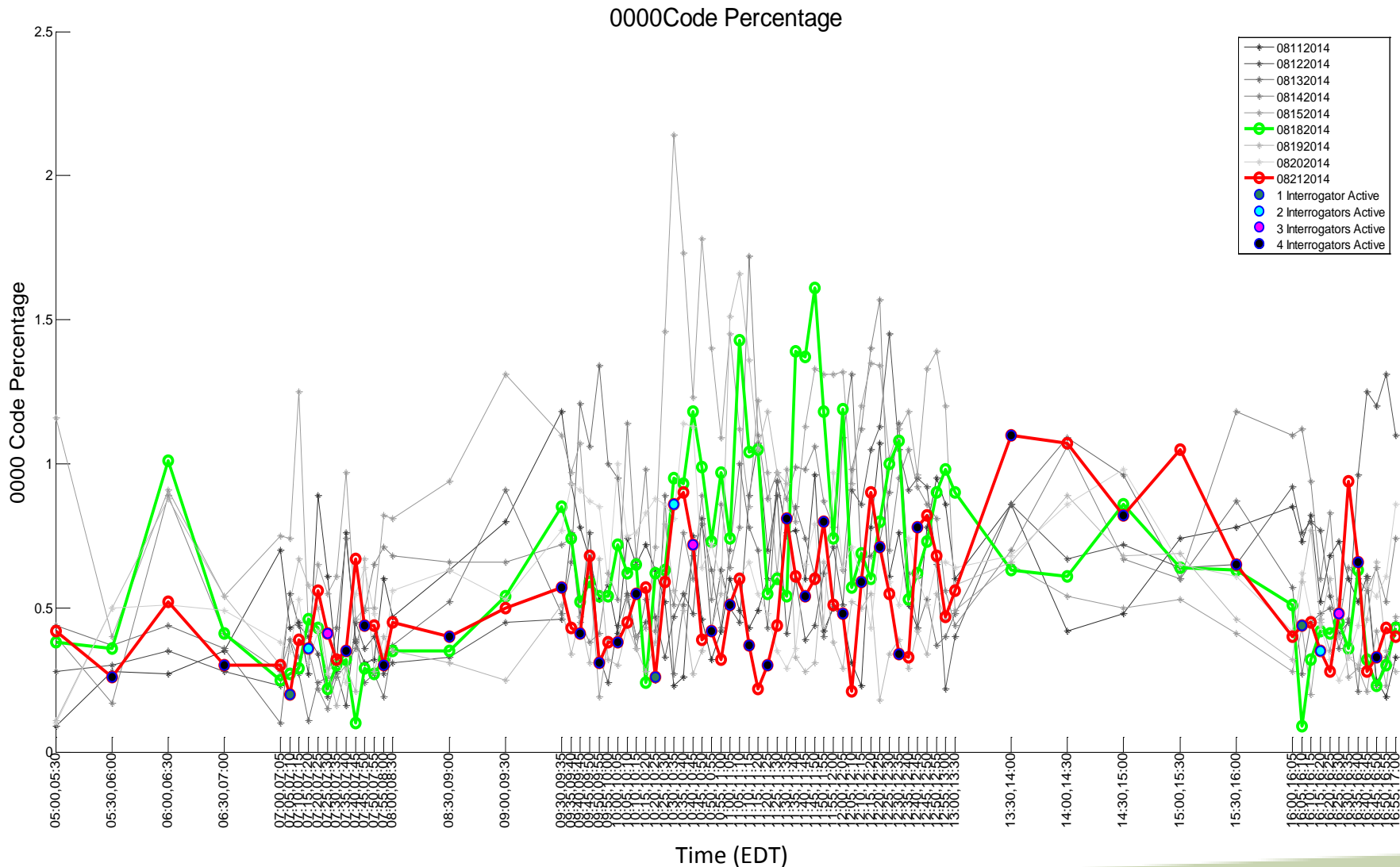
Geographic Filter: None  
Target Filter: None

# 0000 Codes – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: None

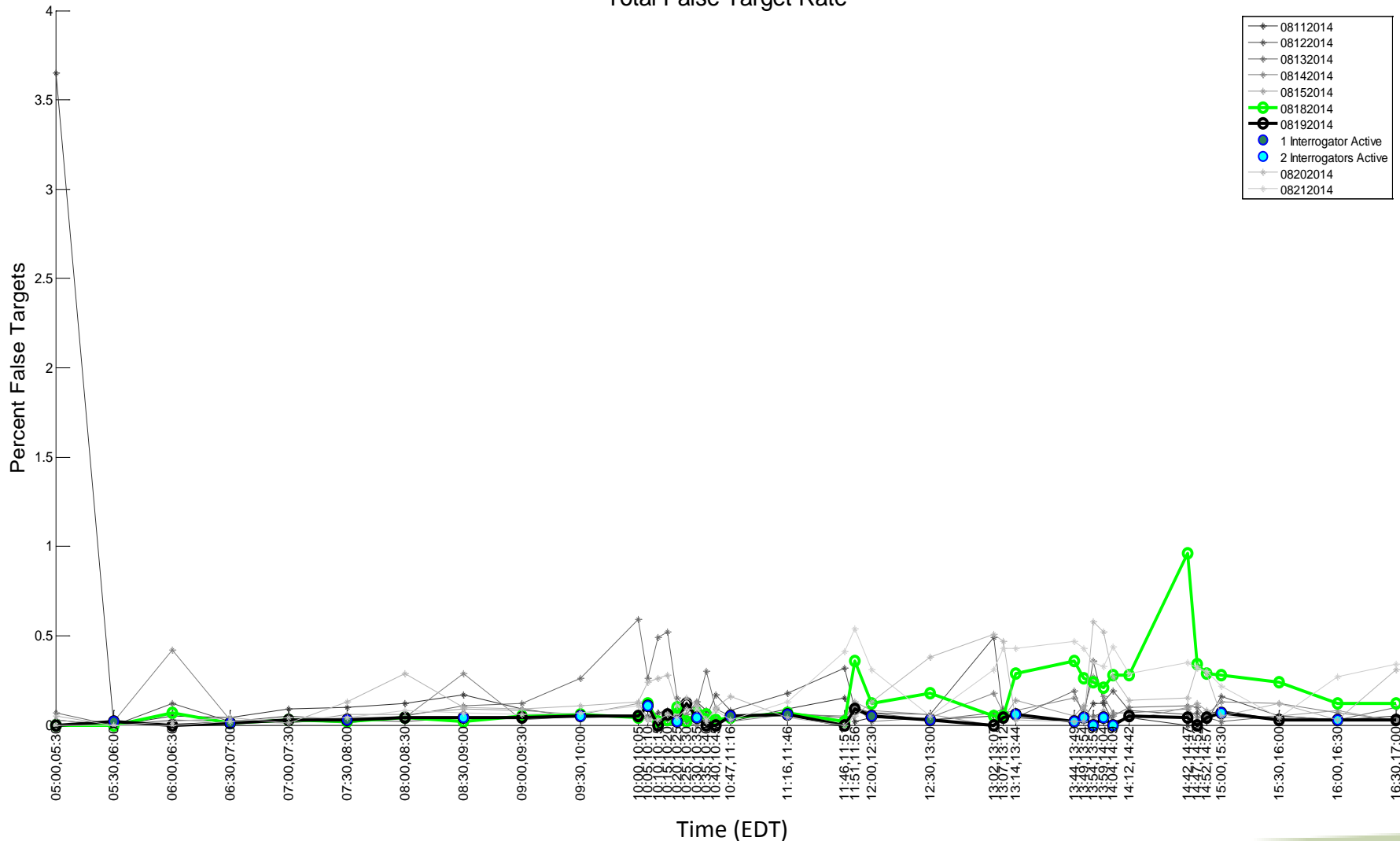
# 0000 Codes – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: None

# False Targets – August 19th

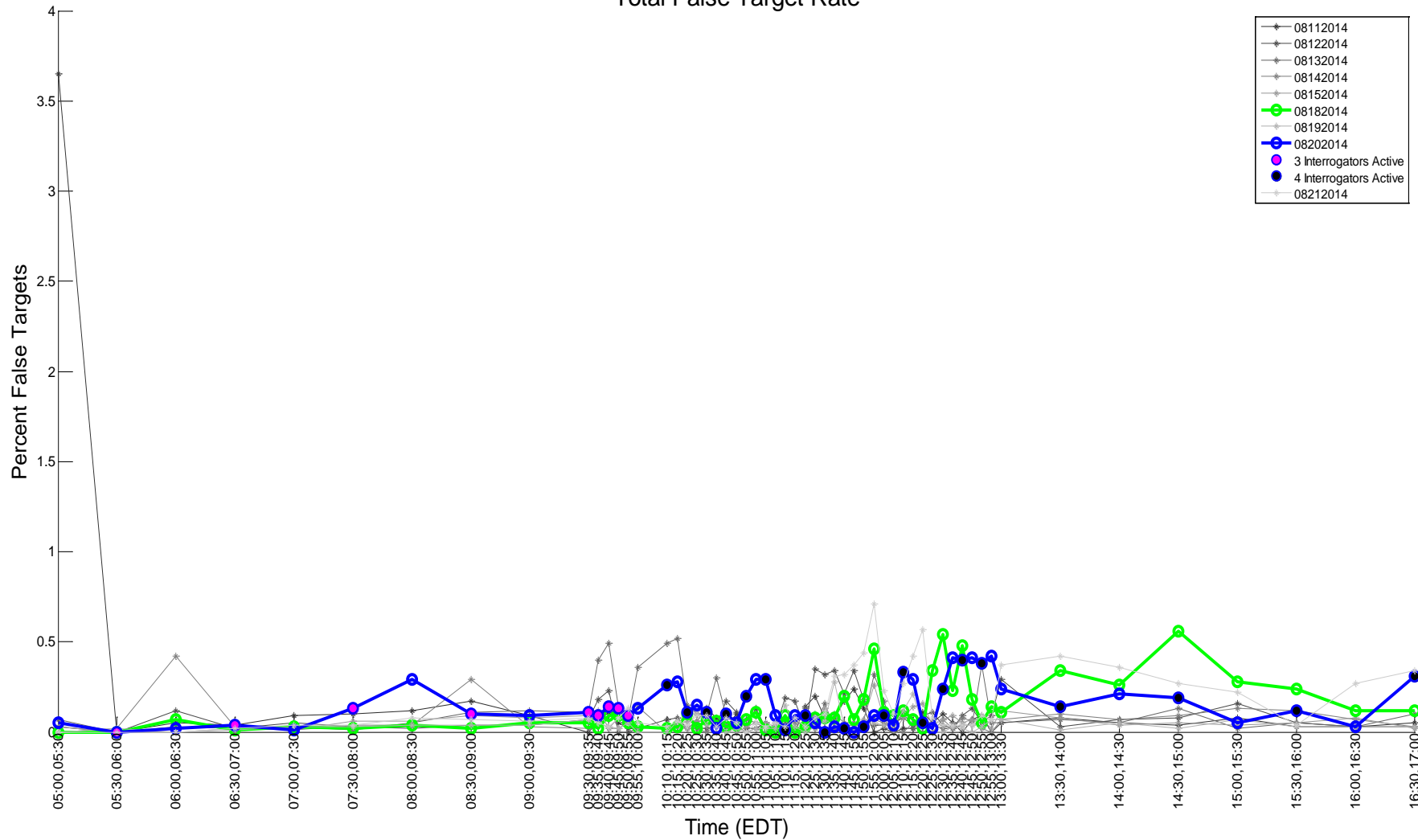
Total False Target Rate



Geographic Filter: None  
Target Filter: None

# False Targets – August 20<sup>th</sup>

Total False Target Rate

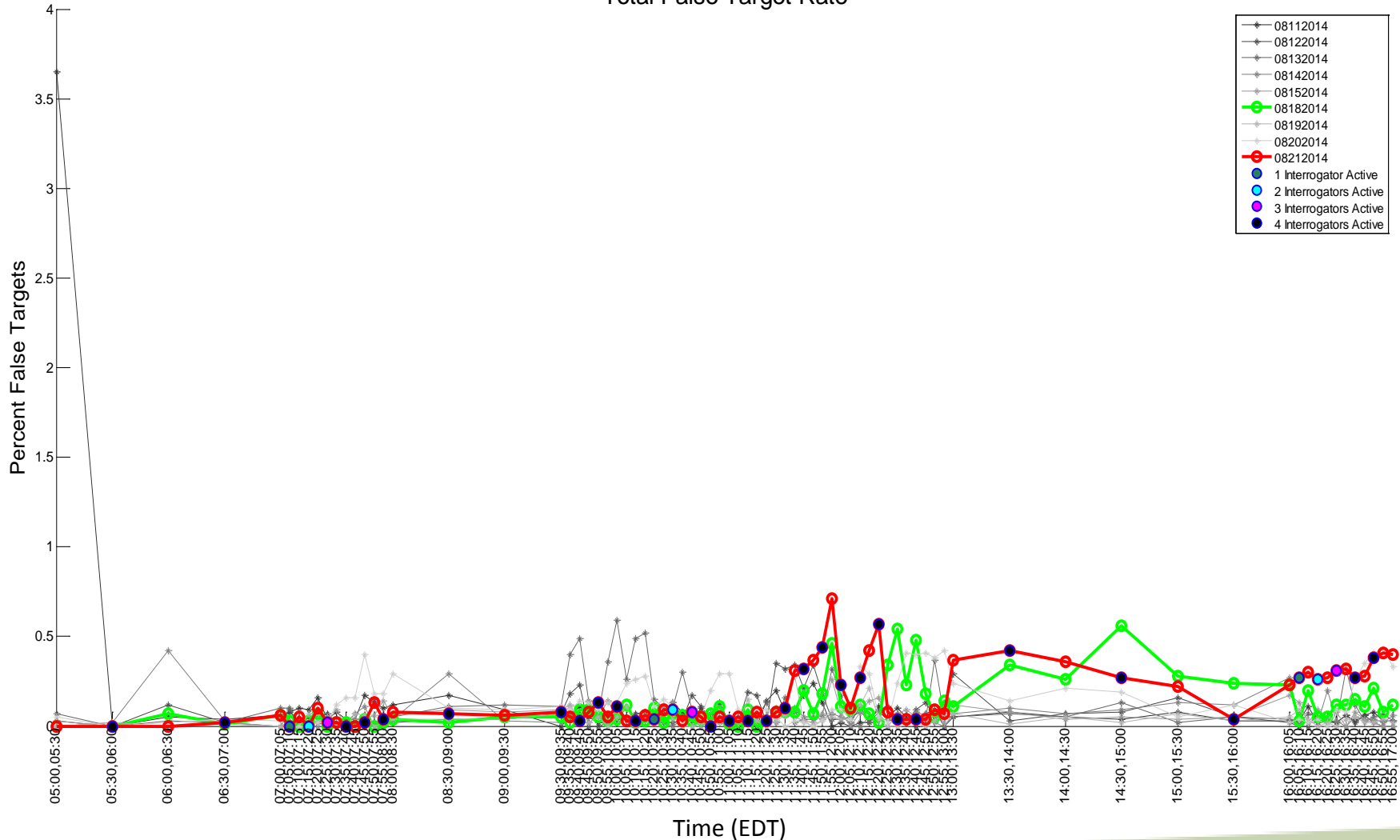


Geographic Filter: None  
Target Filter: None



# False Targets – August 21<sup>st</sup>

Total False Target Rate

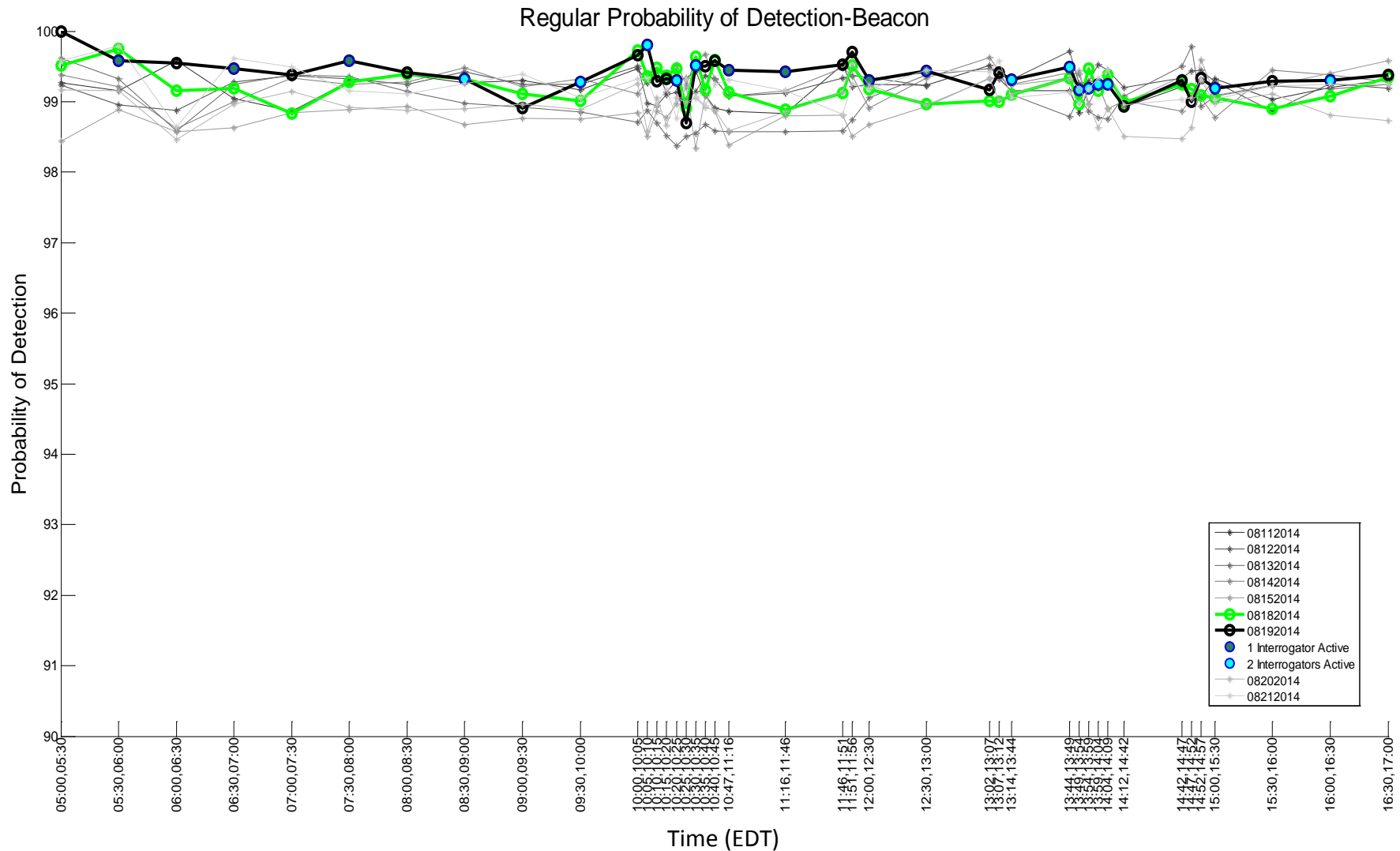


Geographic Filter: None  
Target Filter: None

# Target Metrics with Elevation Angle Greater than 0.5 Degrees

*\* Number of Targets Unavailable*

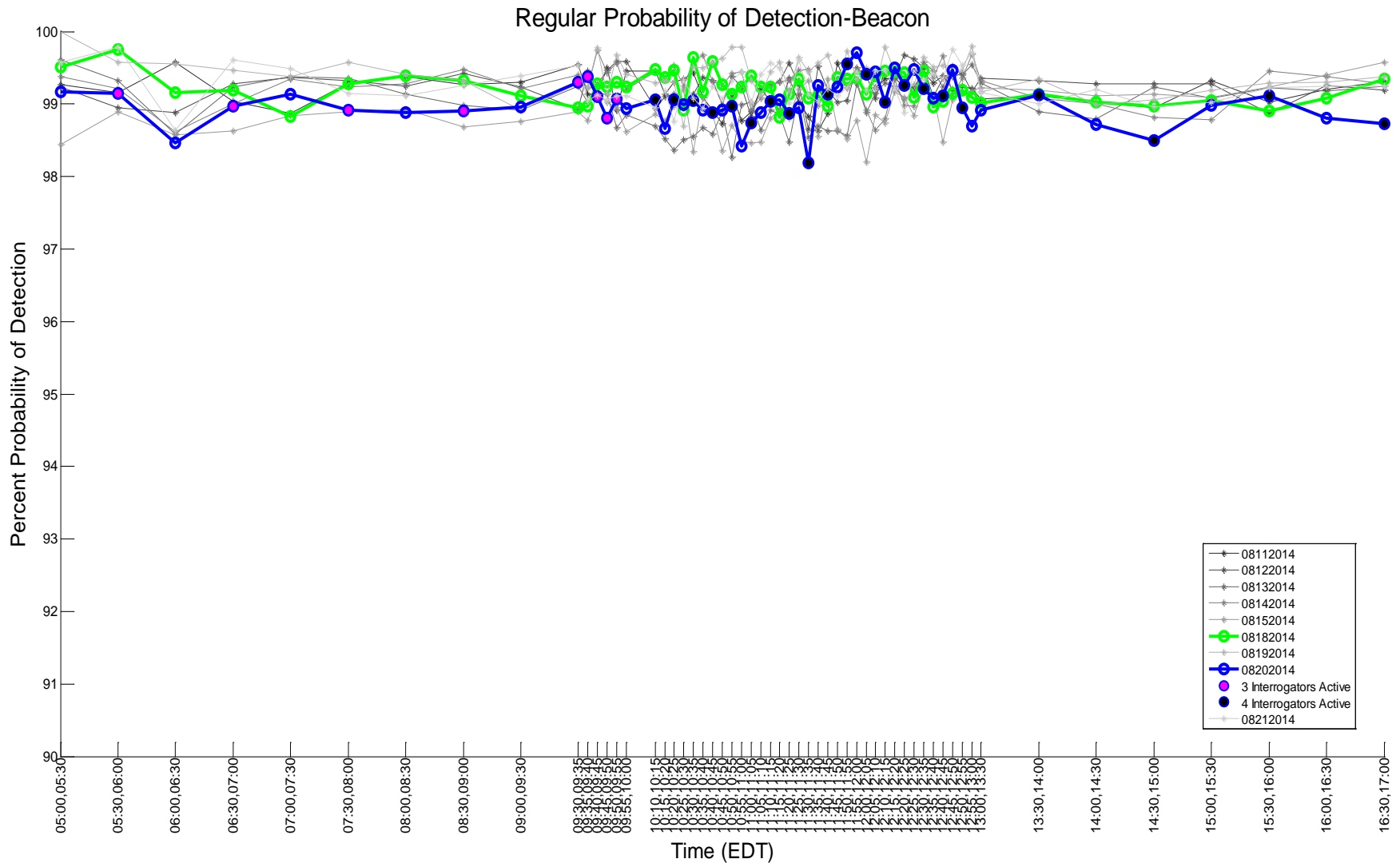
# Probability of Detection – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 20<sup>th</sup>

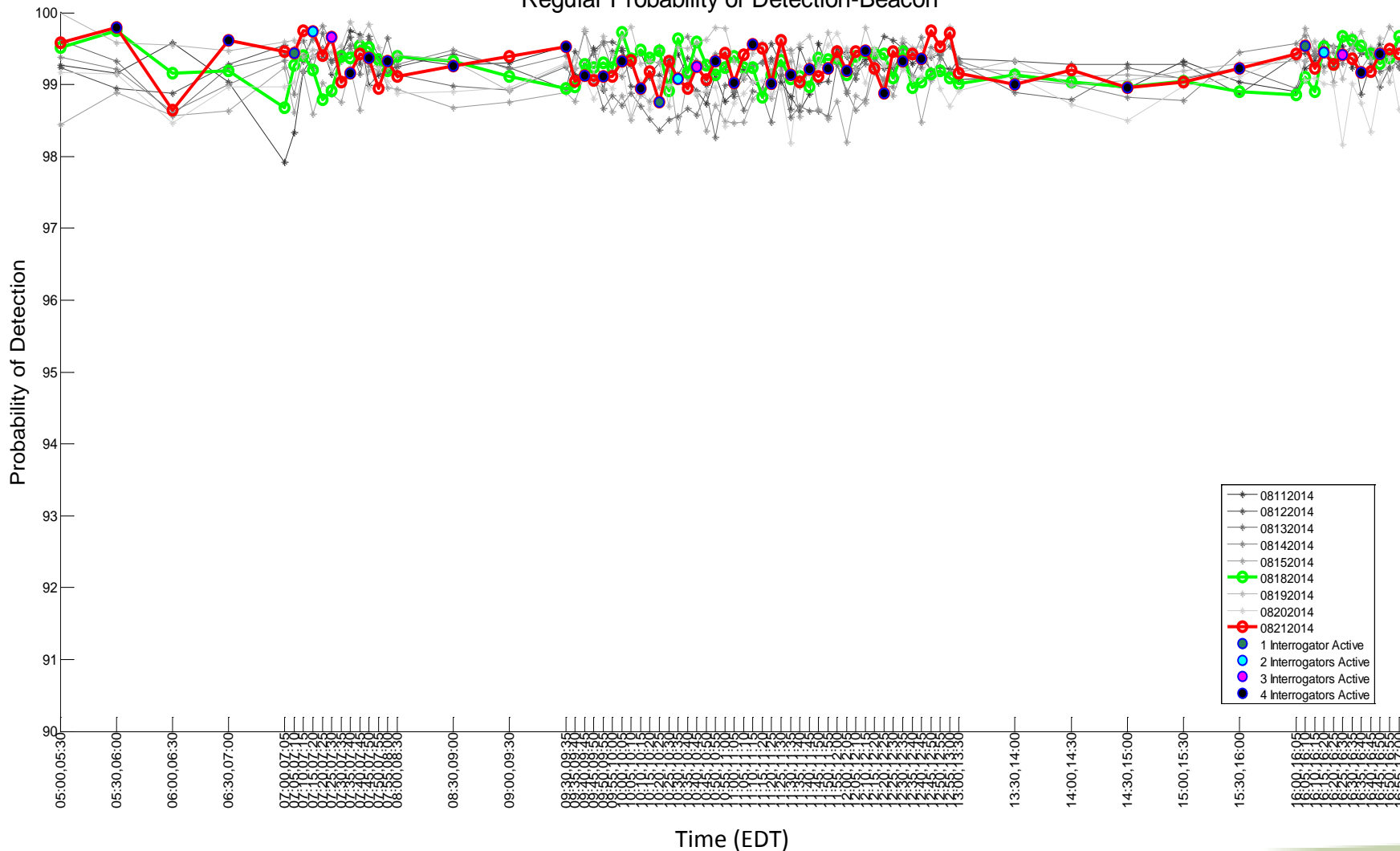


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 21<sup>st</sup>

Regular Probability of Detection-Beacon



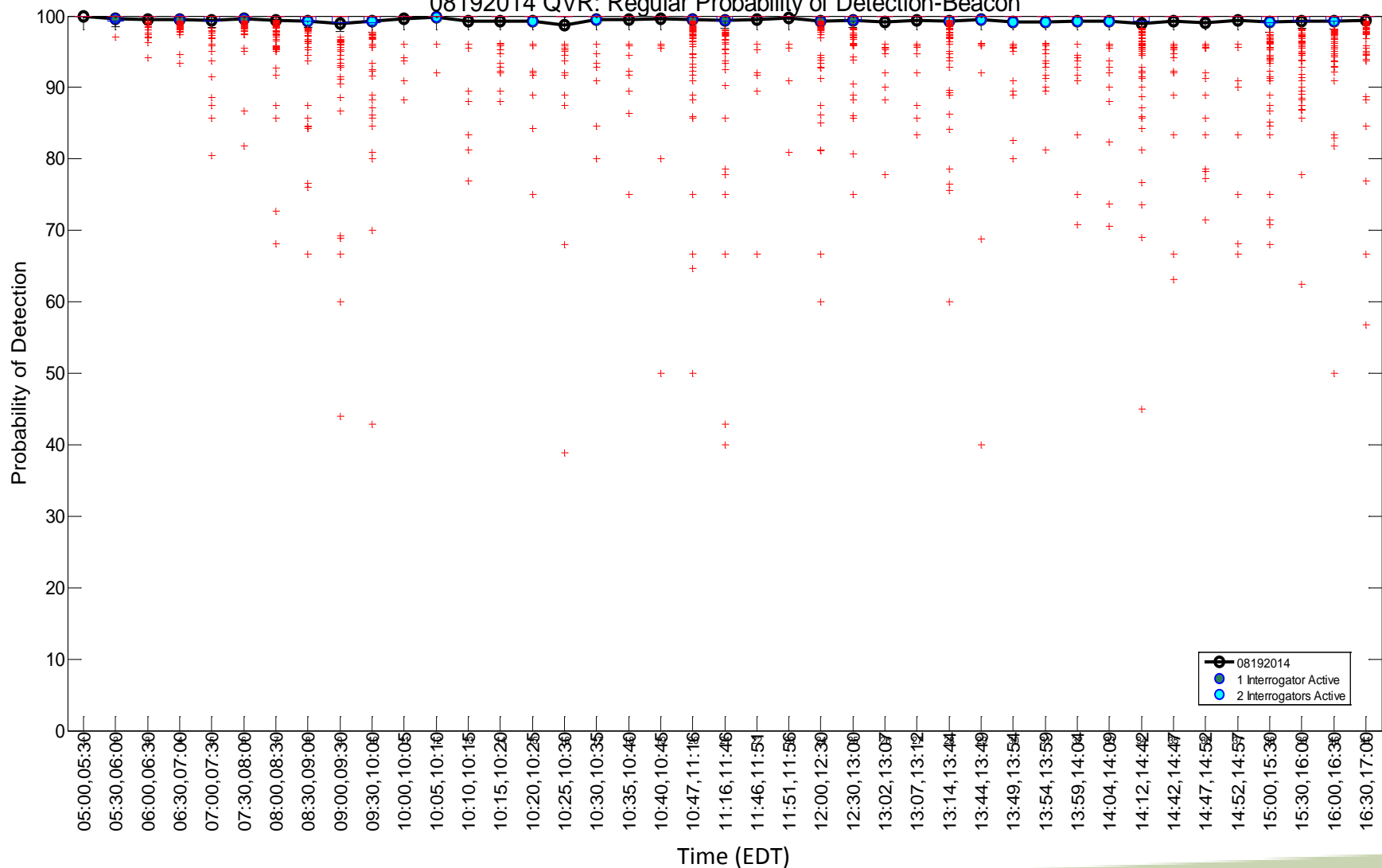
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution

08192014 QVR: Regular Probability of Detection-Beacon



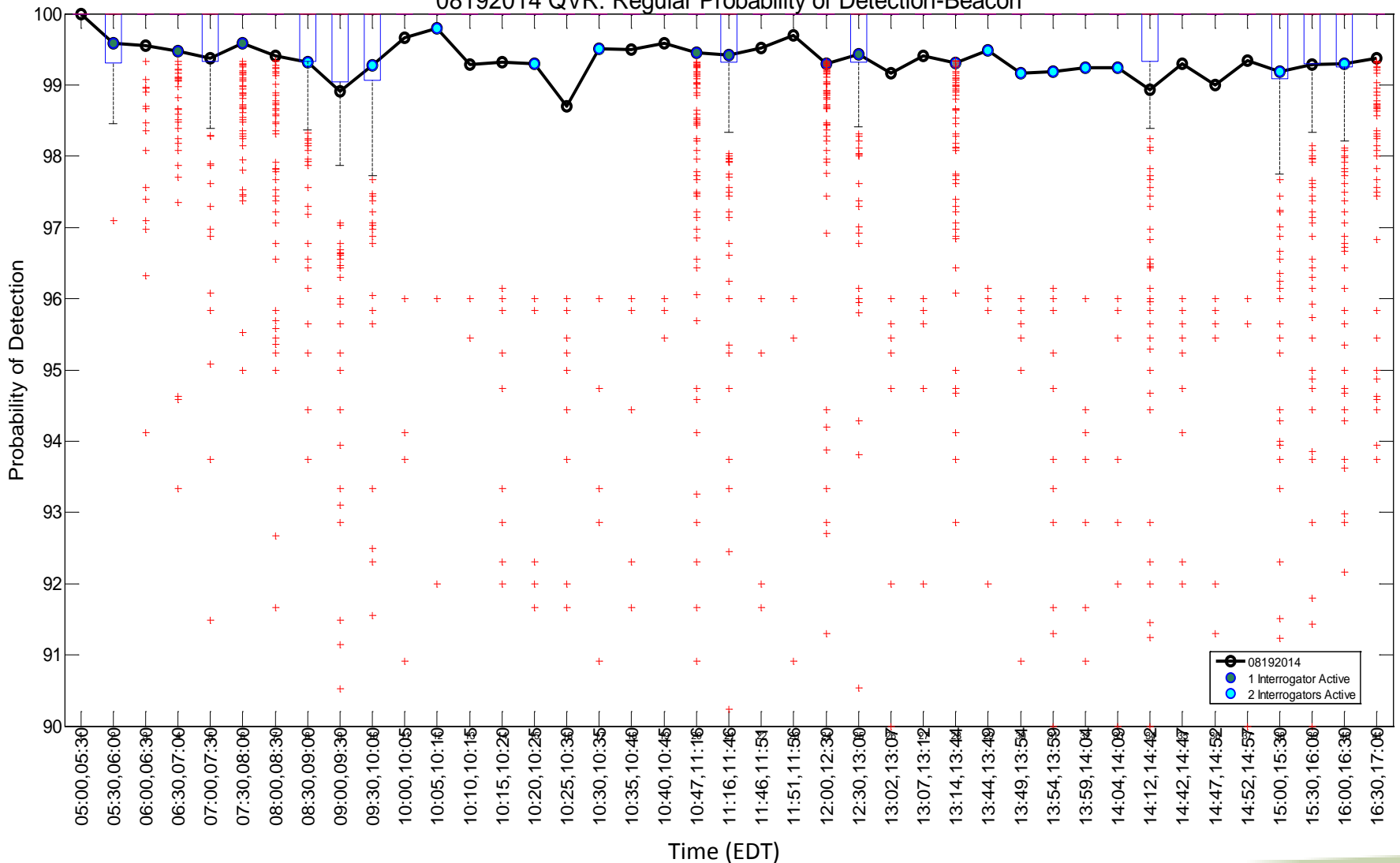
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08192014 QVR: Regular Probability of Detection-Beacon



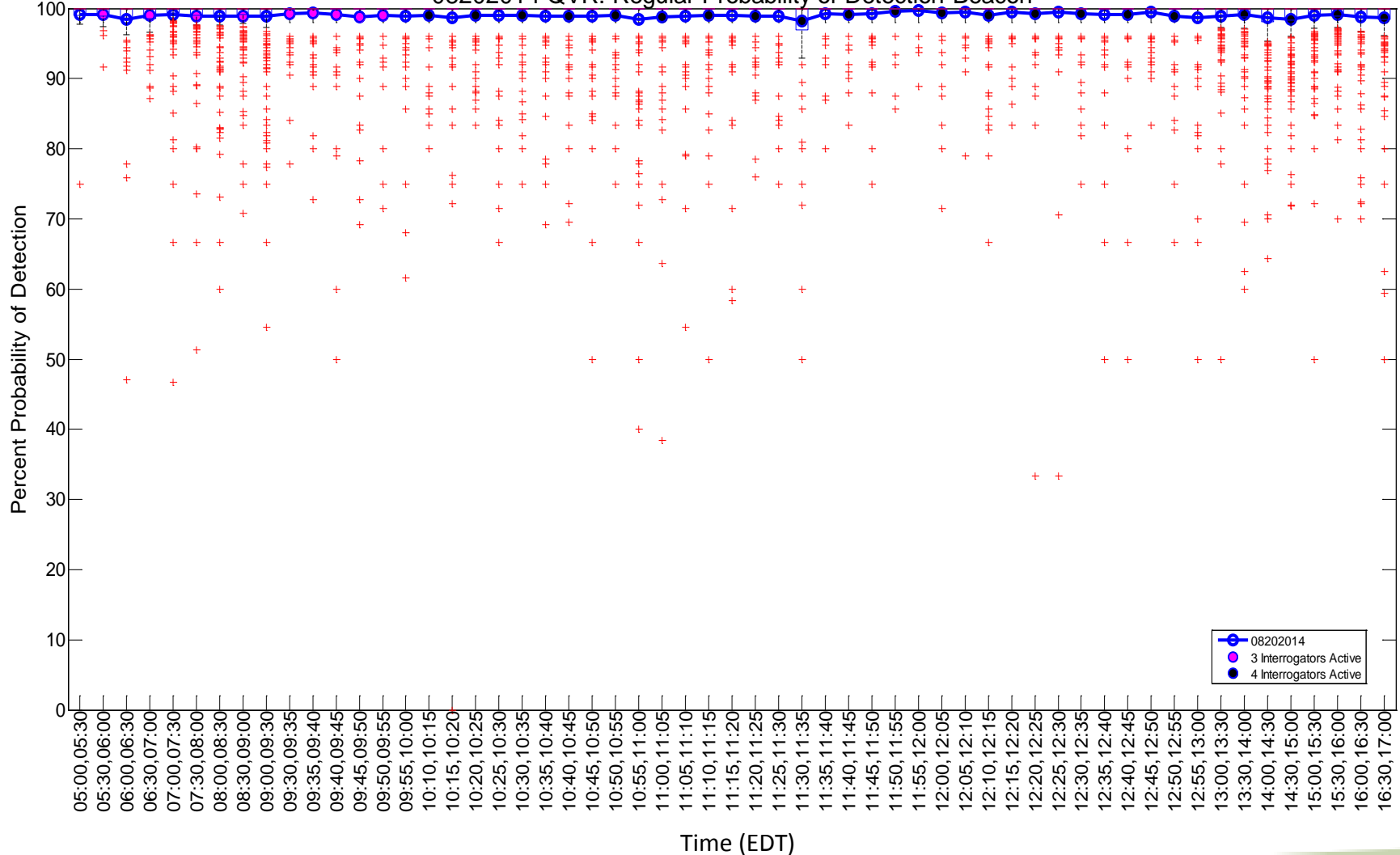
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

08202014 QVR: Regular Probability of Detection-Beacon



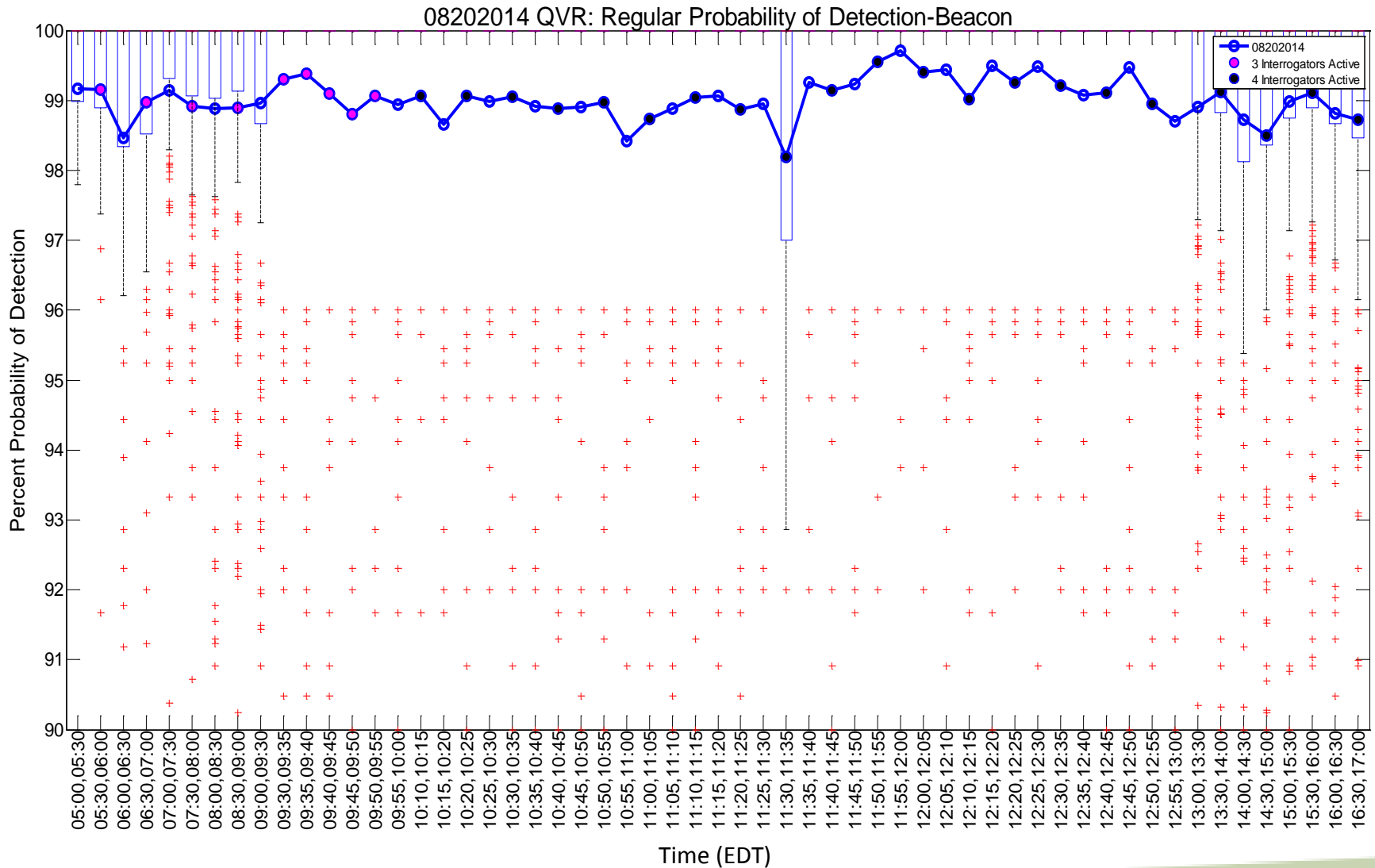
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

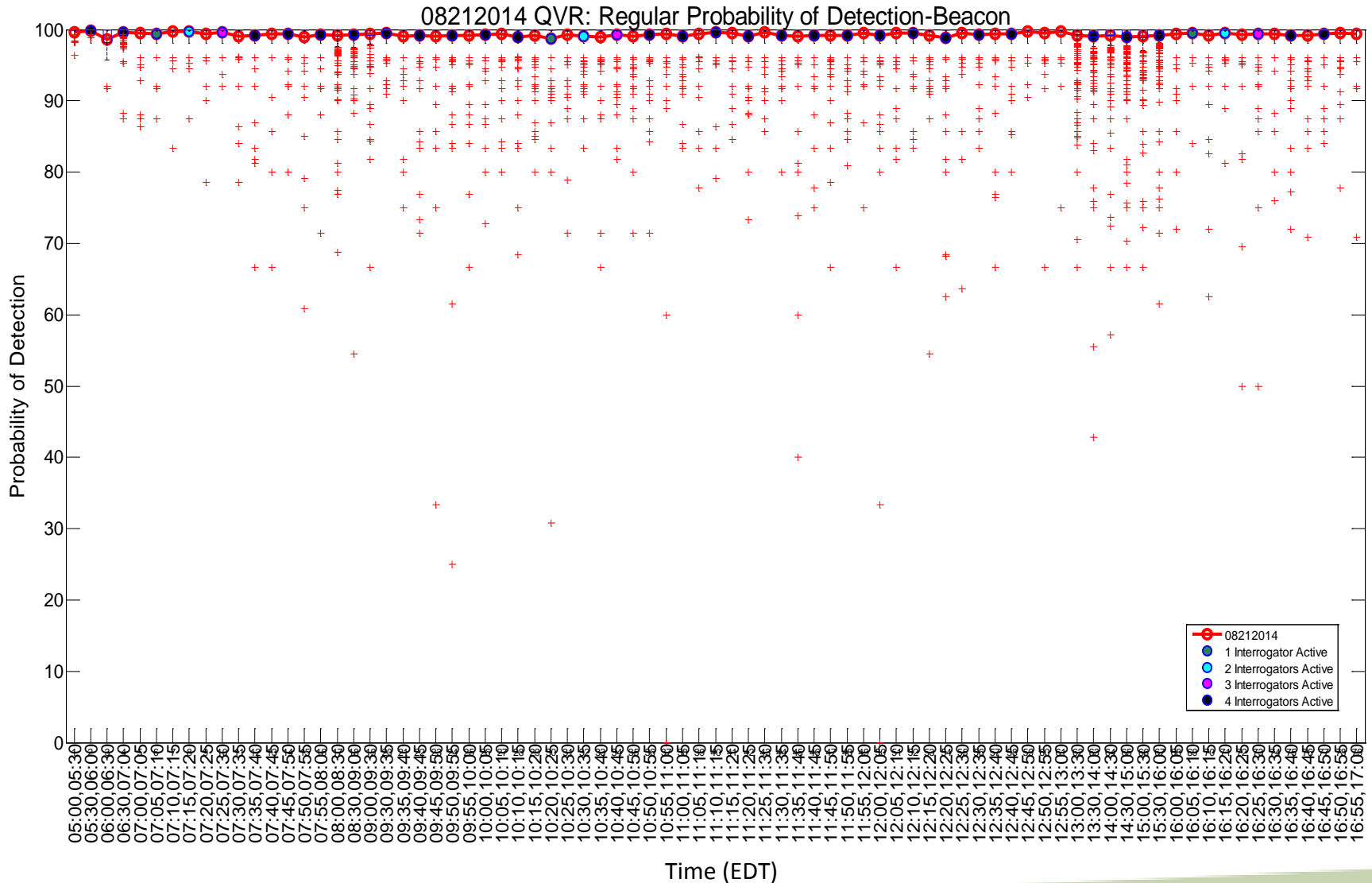


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution



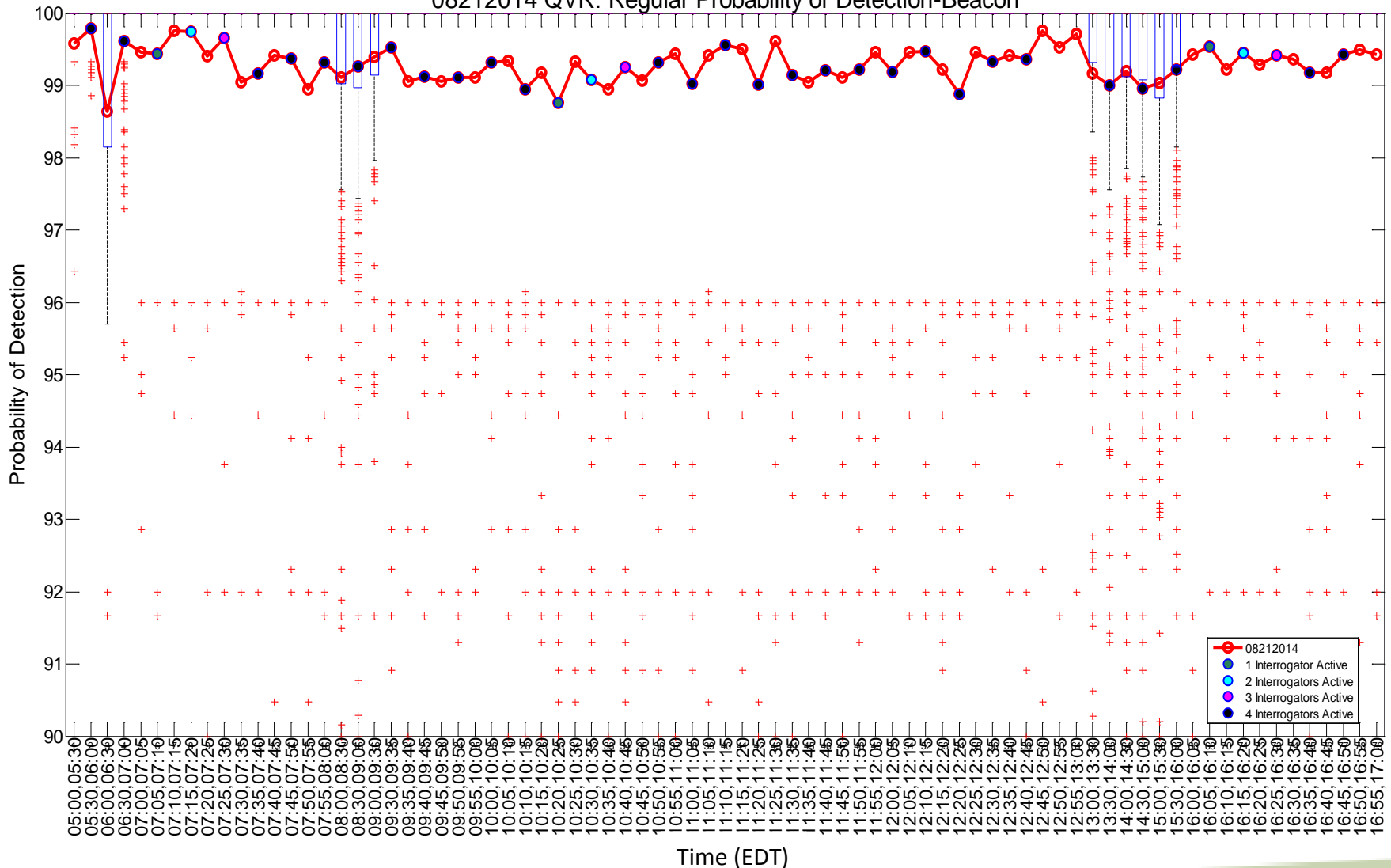
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)

08212014 QVR: Regular Probability of Detection-Beacon

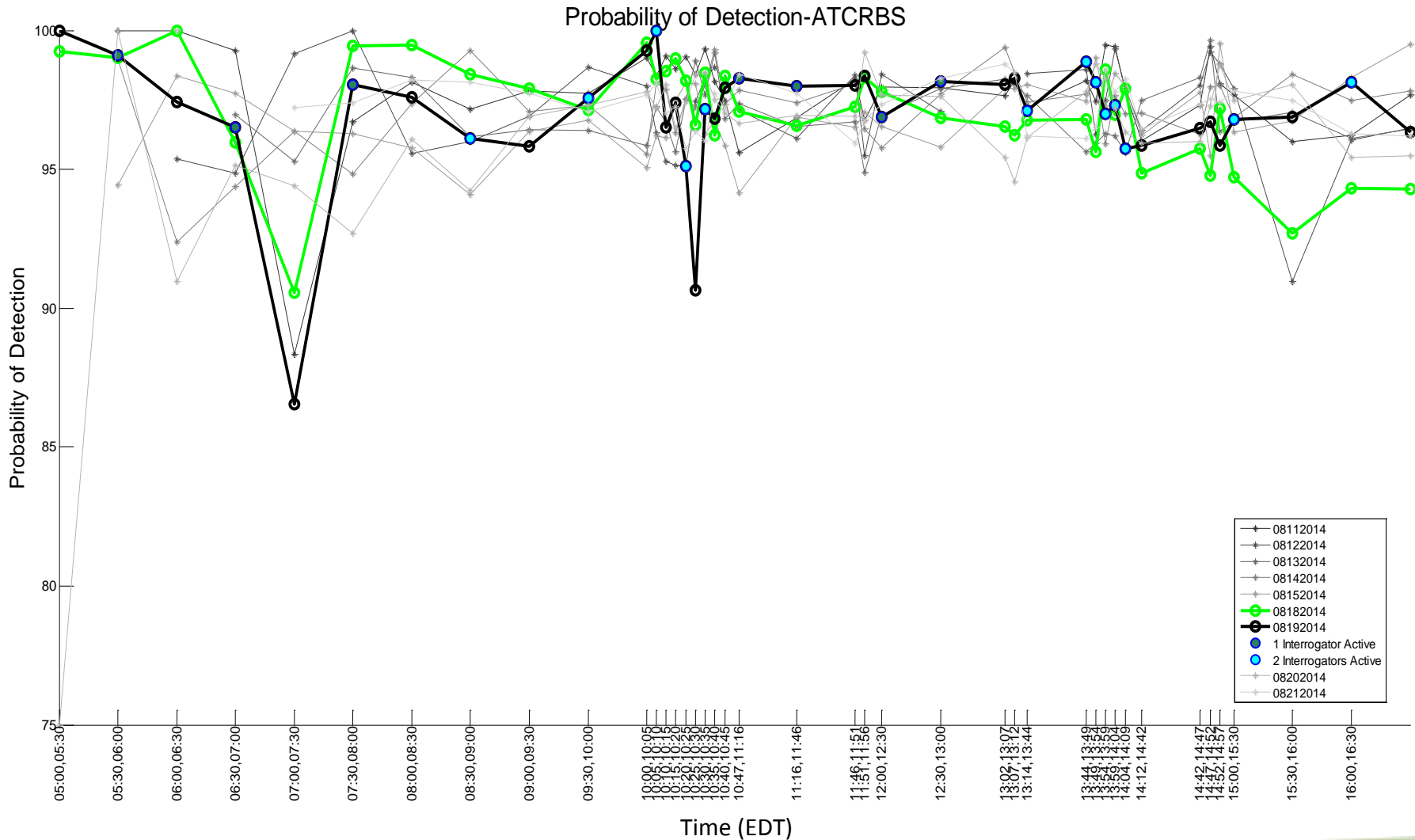


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 19<sup>th</sup>

## ATCRBS Targets - Discrete

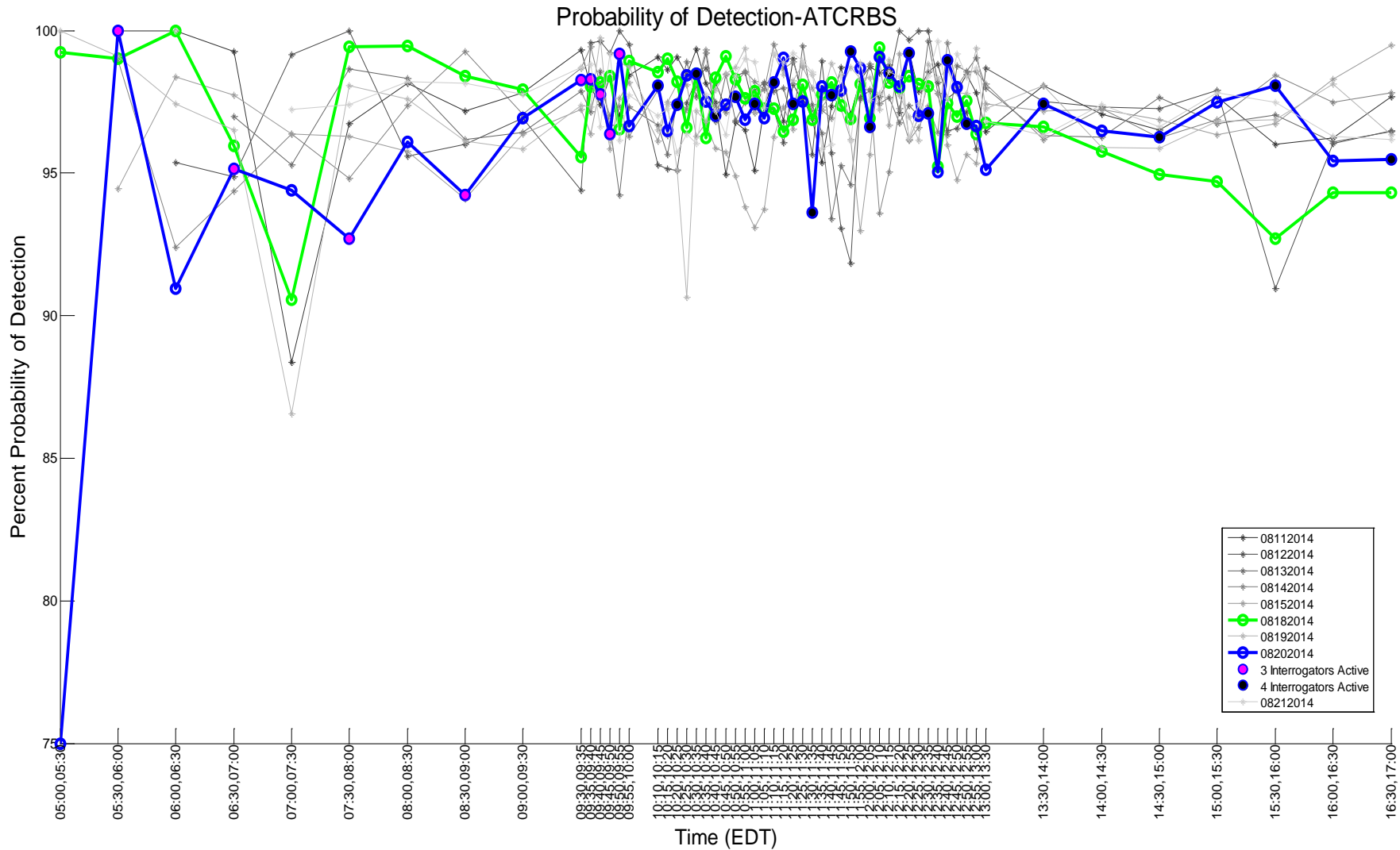


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 20<sup>th</sup>

## ATCRBS Targets - Discrete

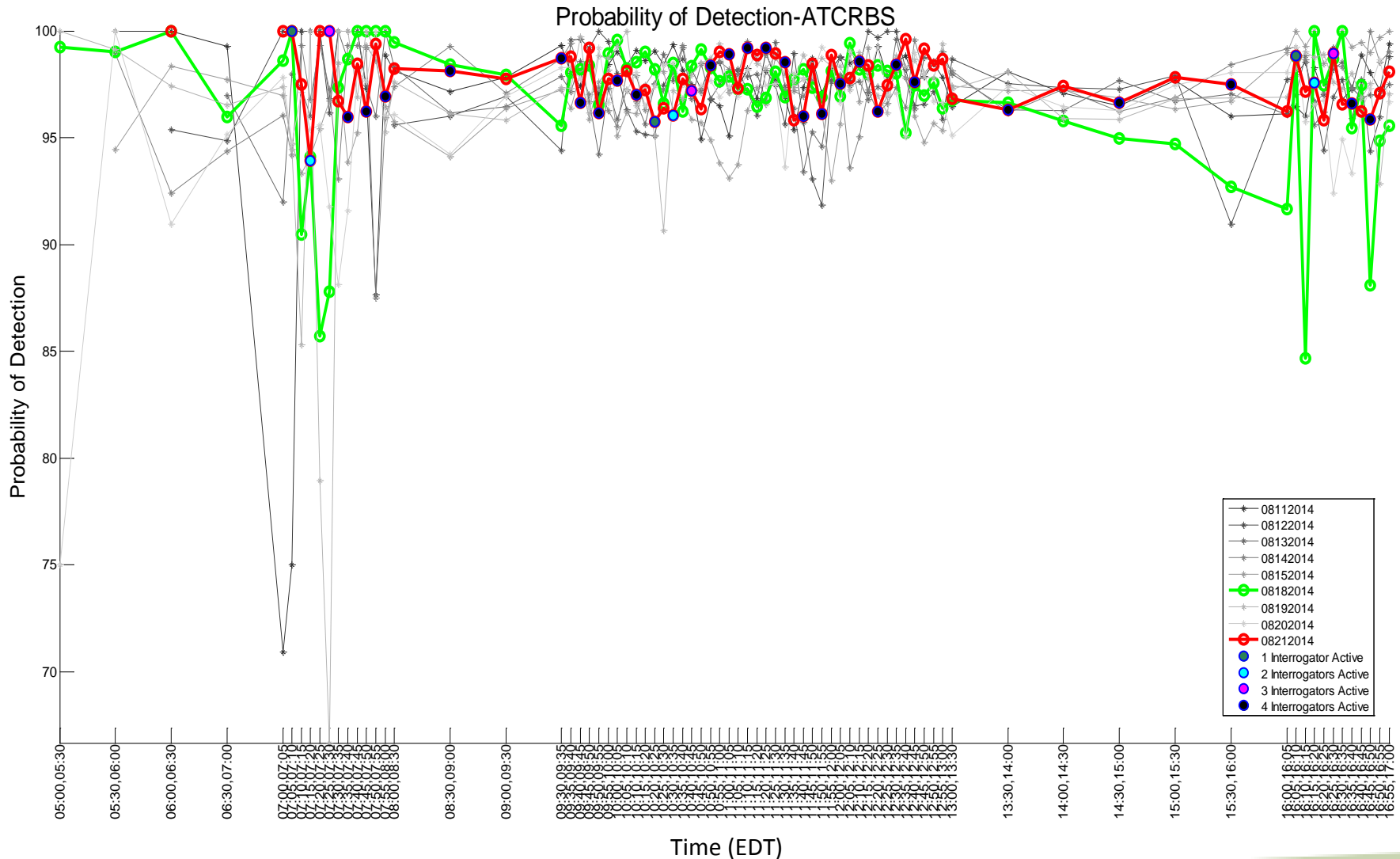


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 21<sup>st</sup>

## ATCRBS Targets - Discrete

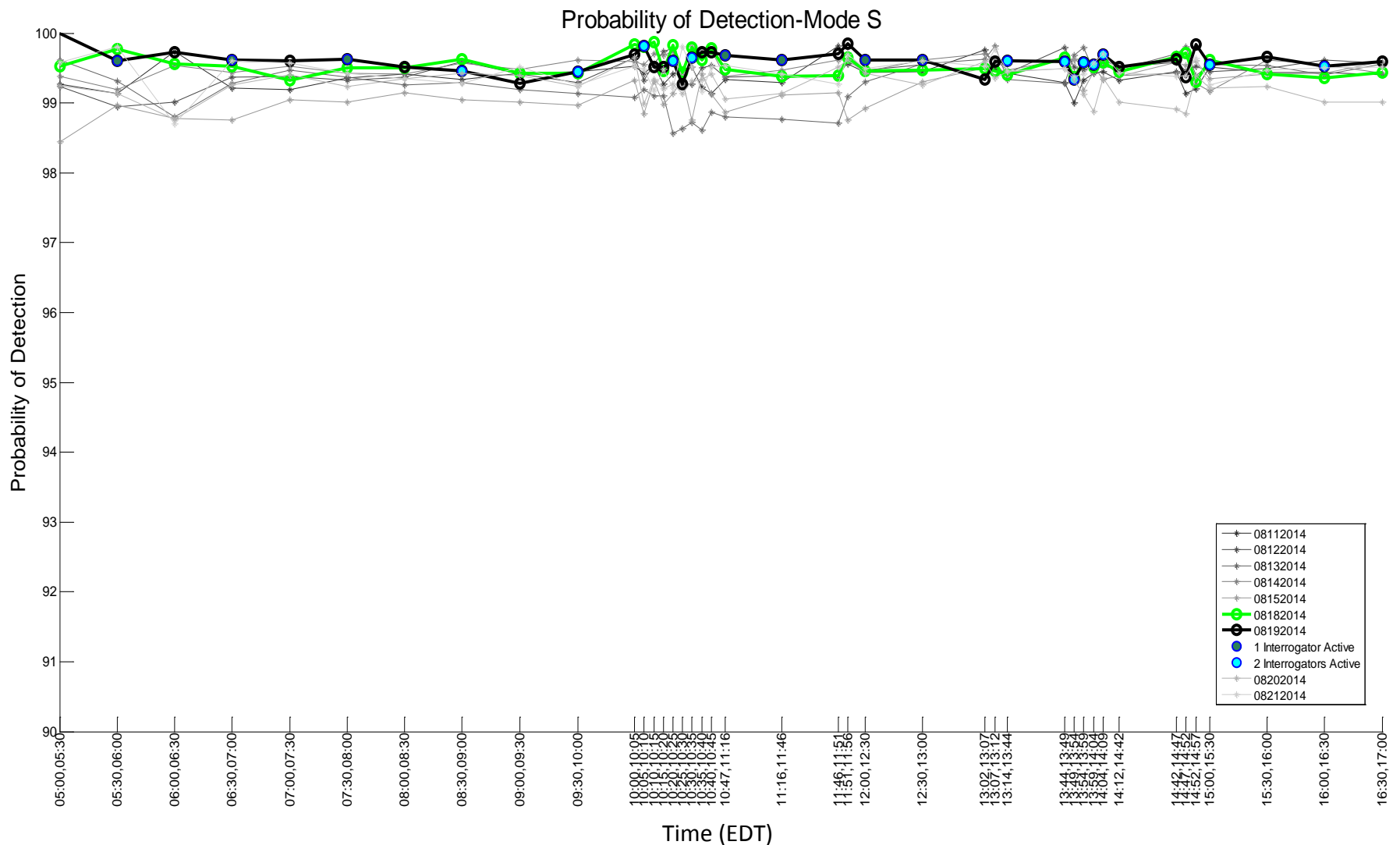


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 19<sup>th</sup>

## Mode S Targets

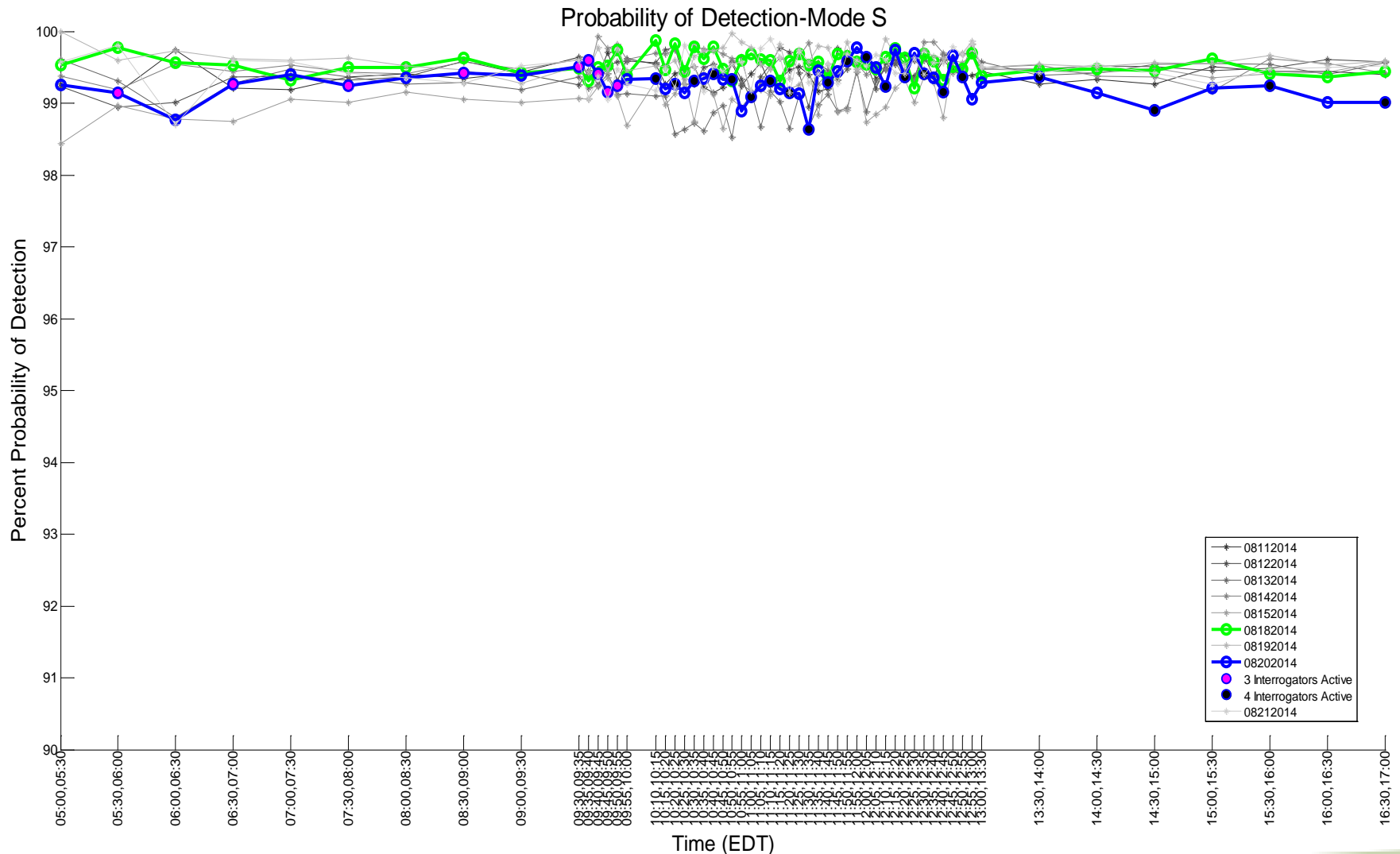


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Probability of Detection – August 20<sup>th</sup>

## Mode S Targets



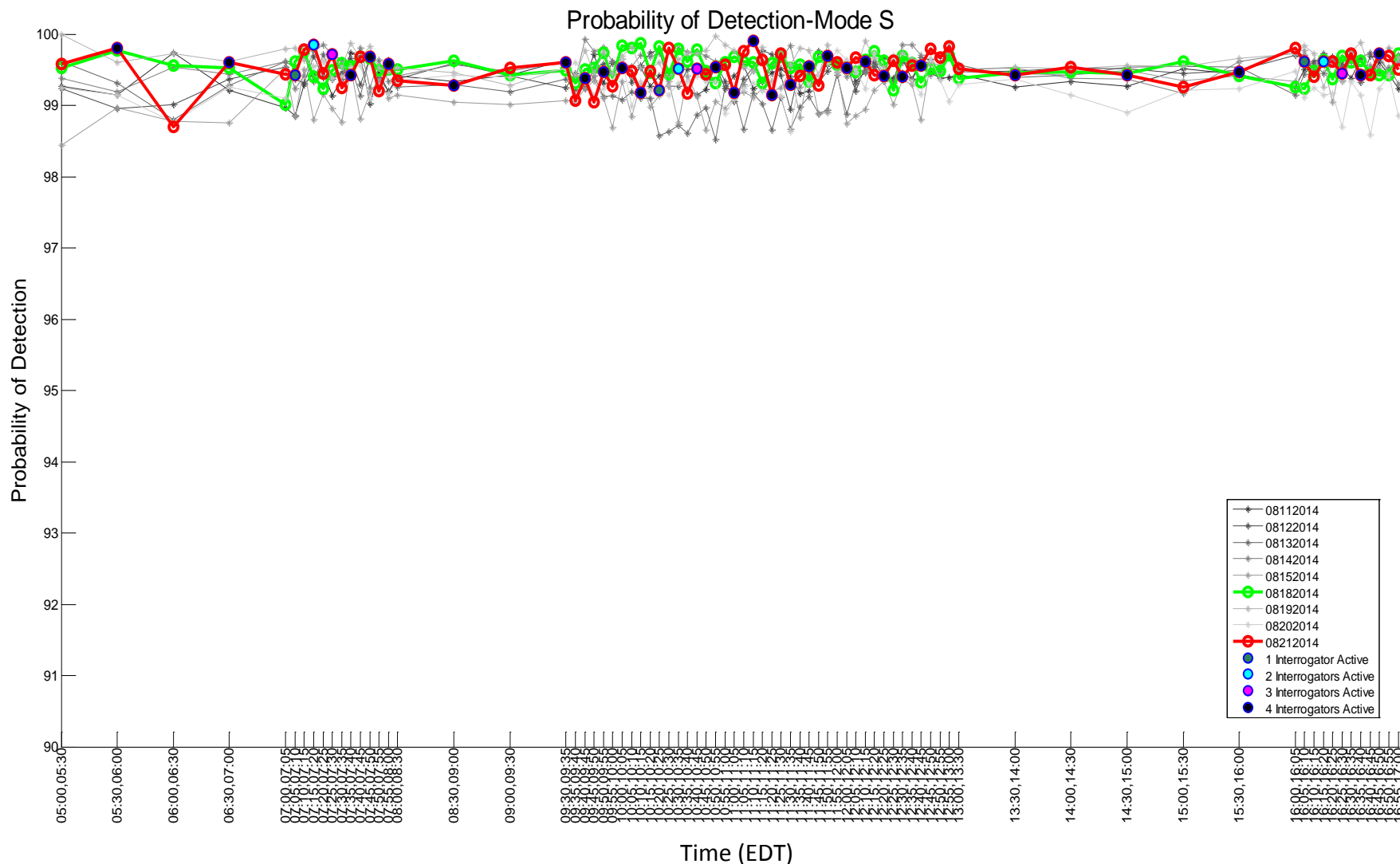
Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°



# Probability of Detection – August 21<sup>st</sup>

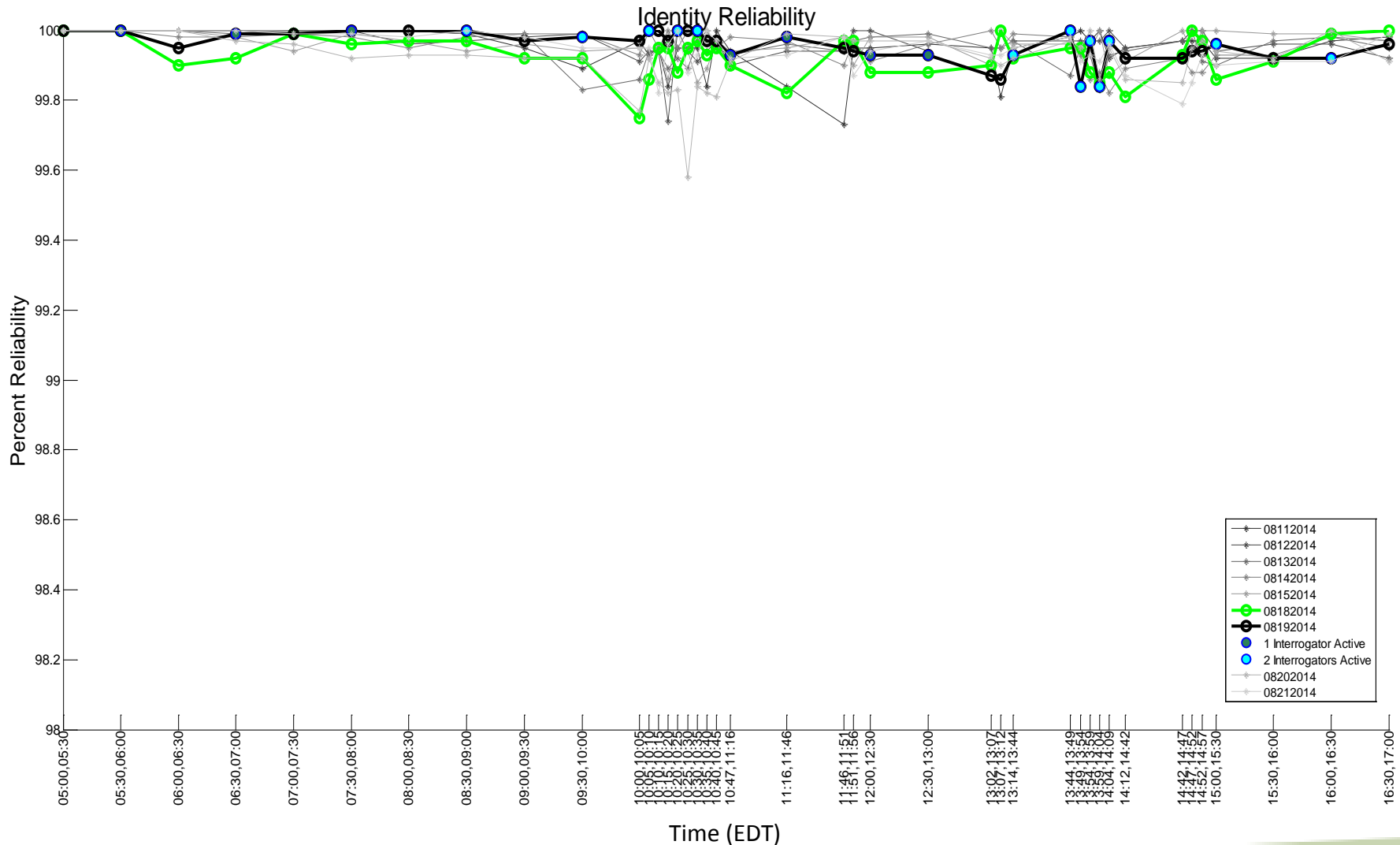
## Mode S Targets



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

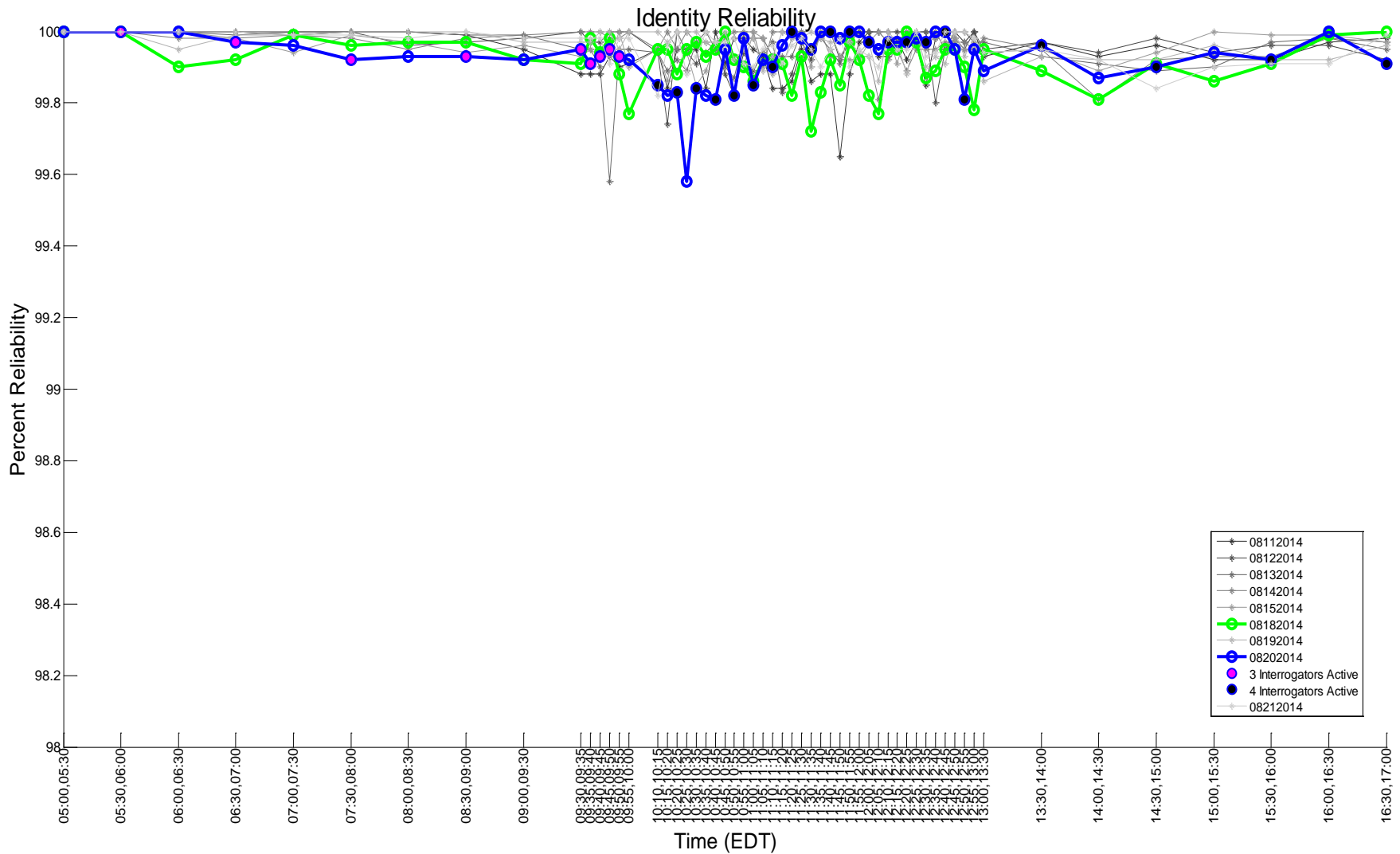
# Identity (3/A) Reliability – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

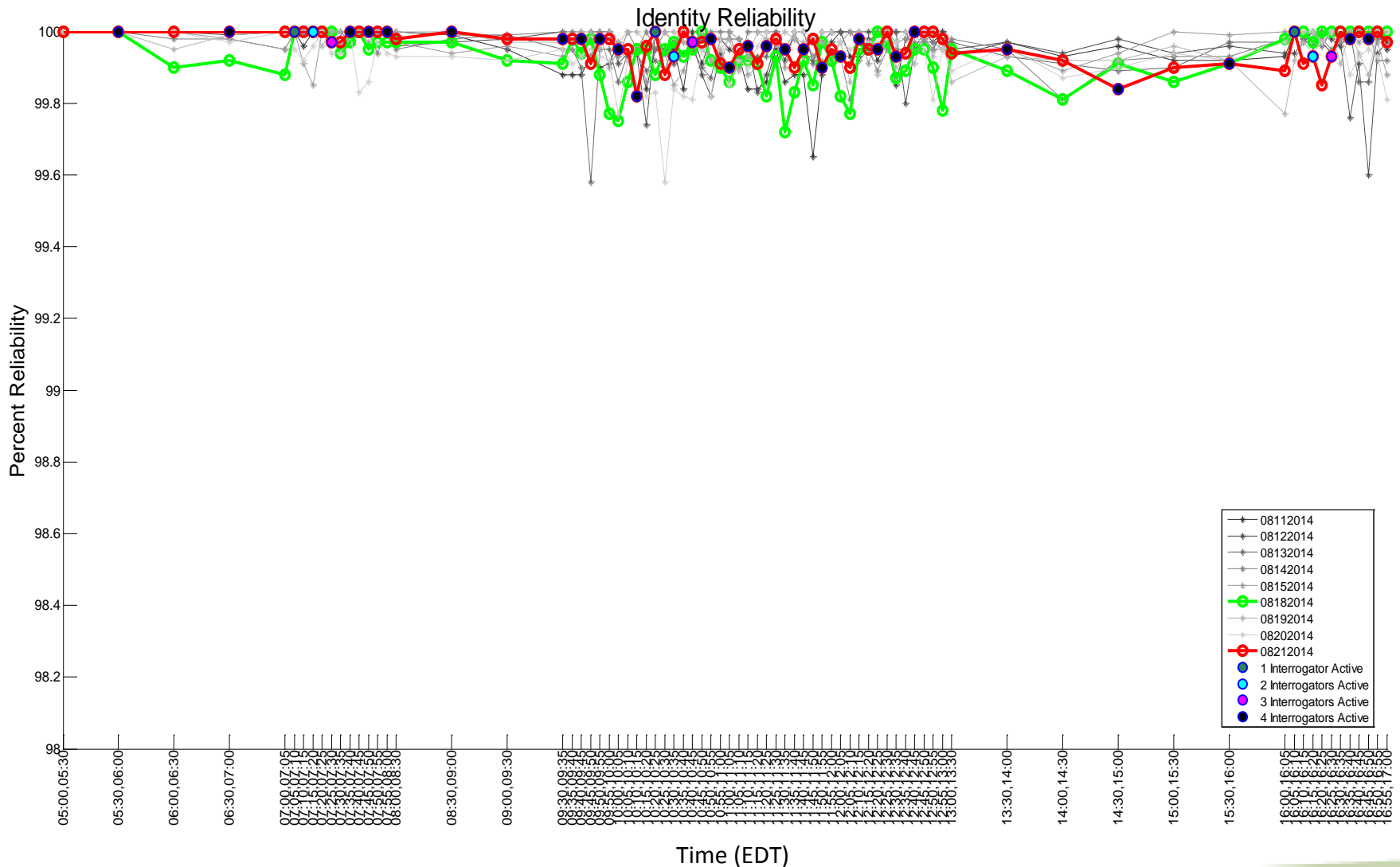
# Identity (3/A) Reliability – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

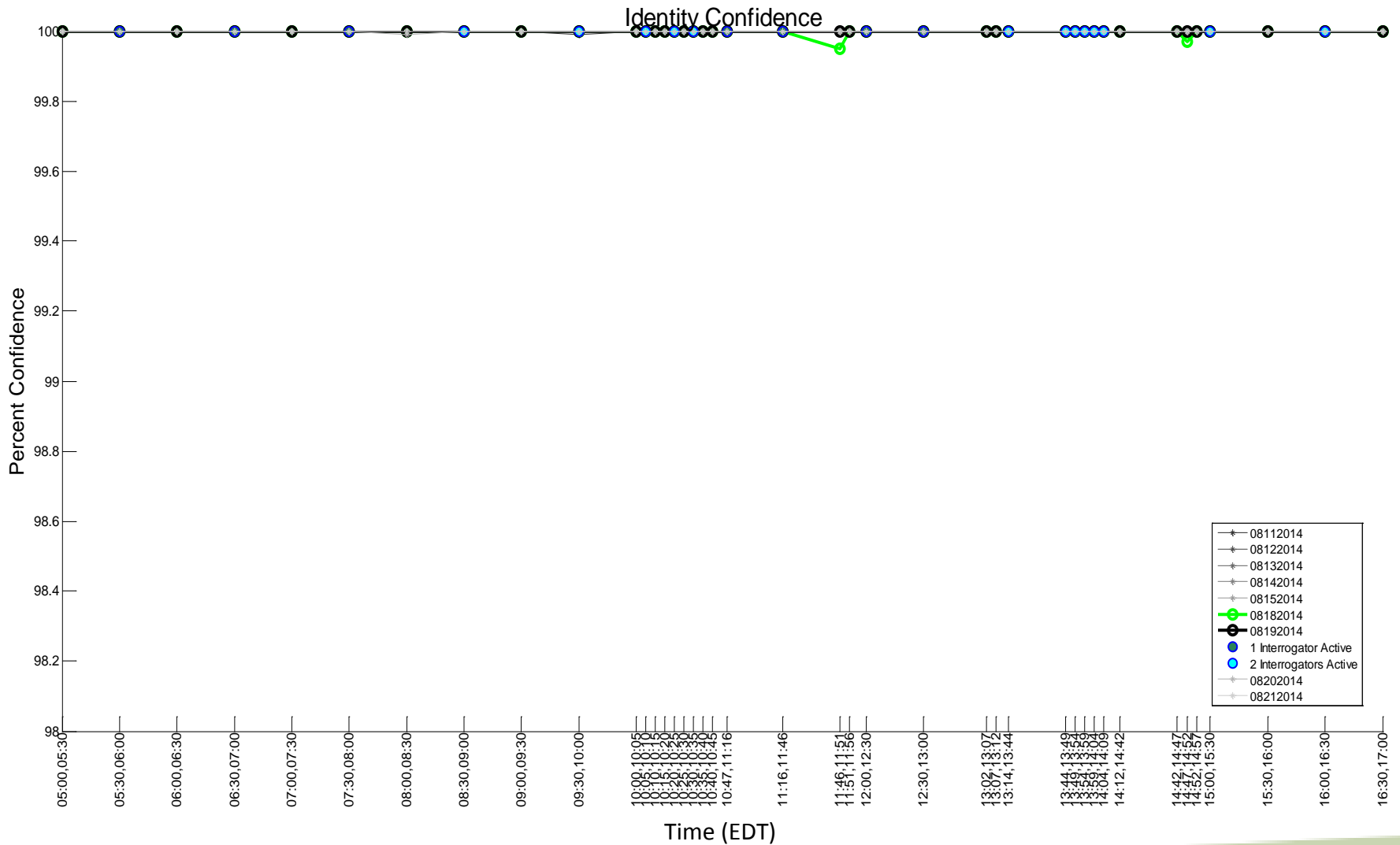
# Identity (3/A) Reliability – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

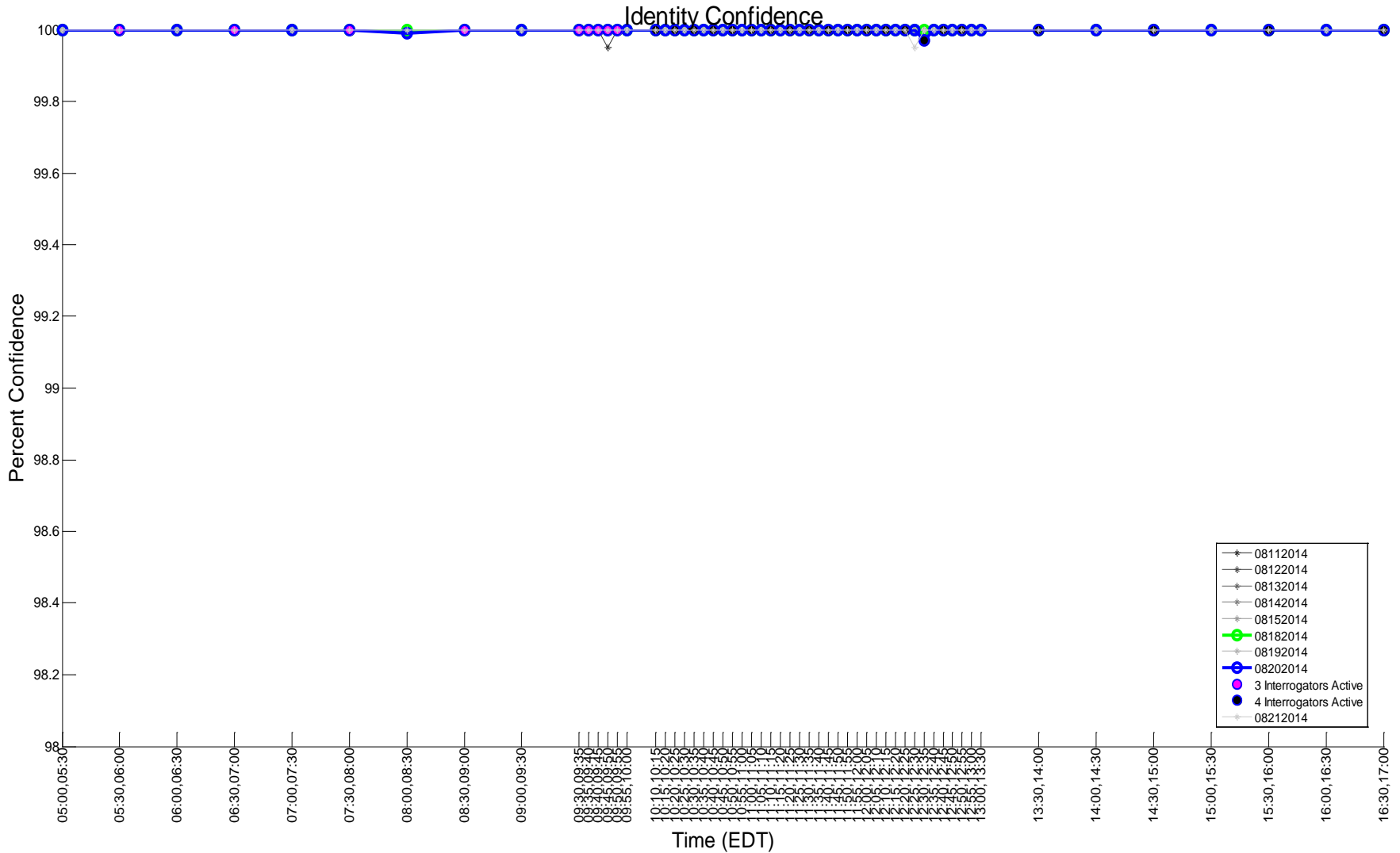
# Identity (3/A) Confidence – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

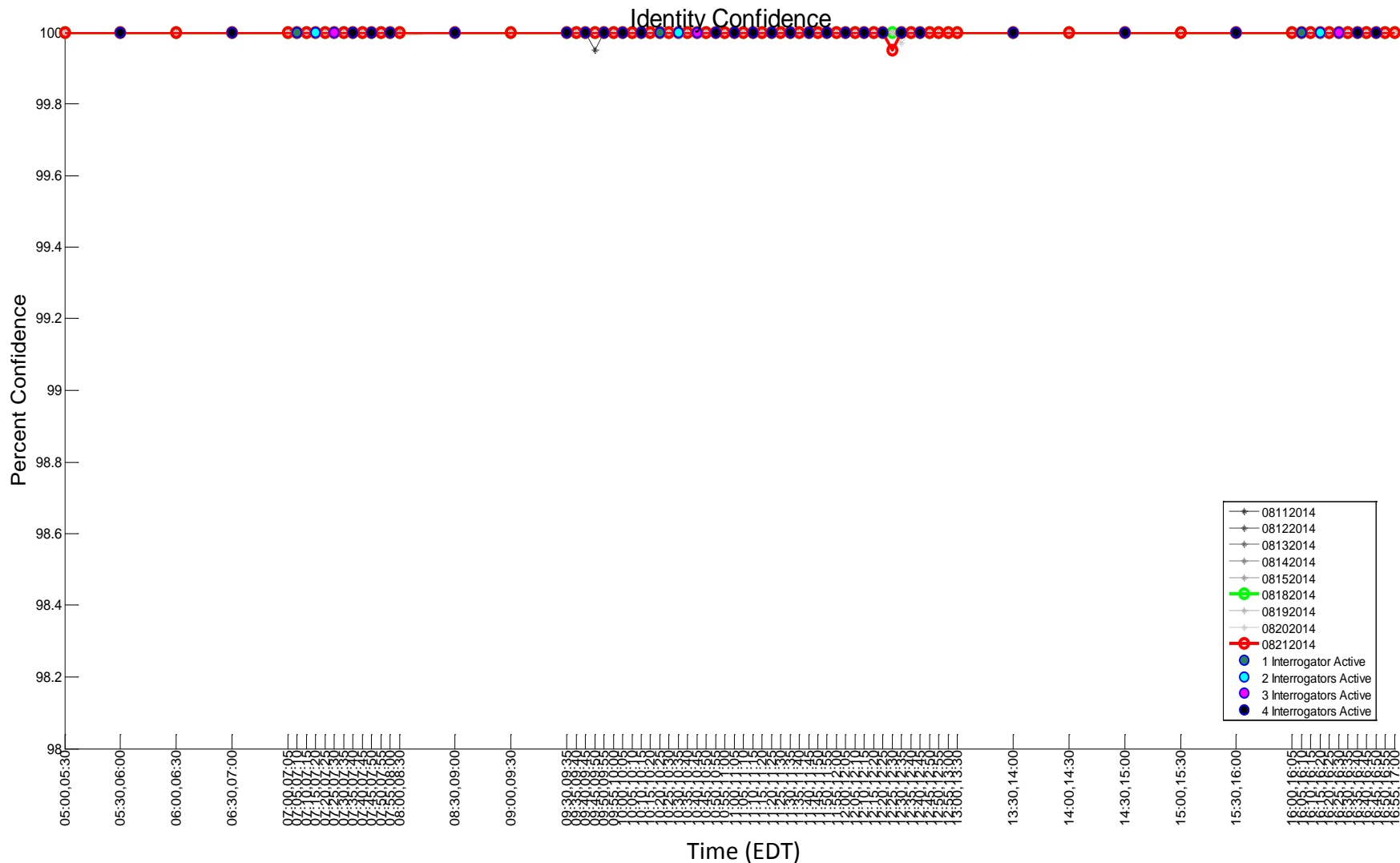
# Identity (3/A) Confidence – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

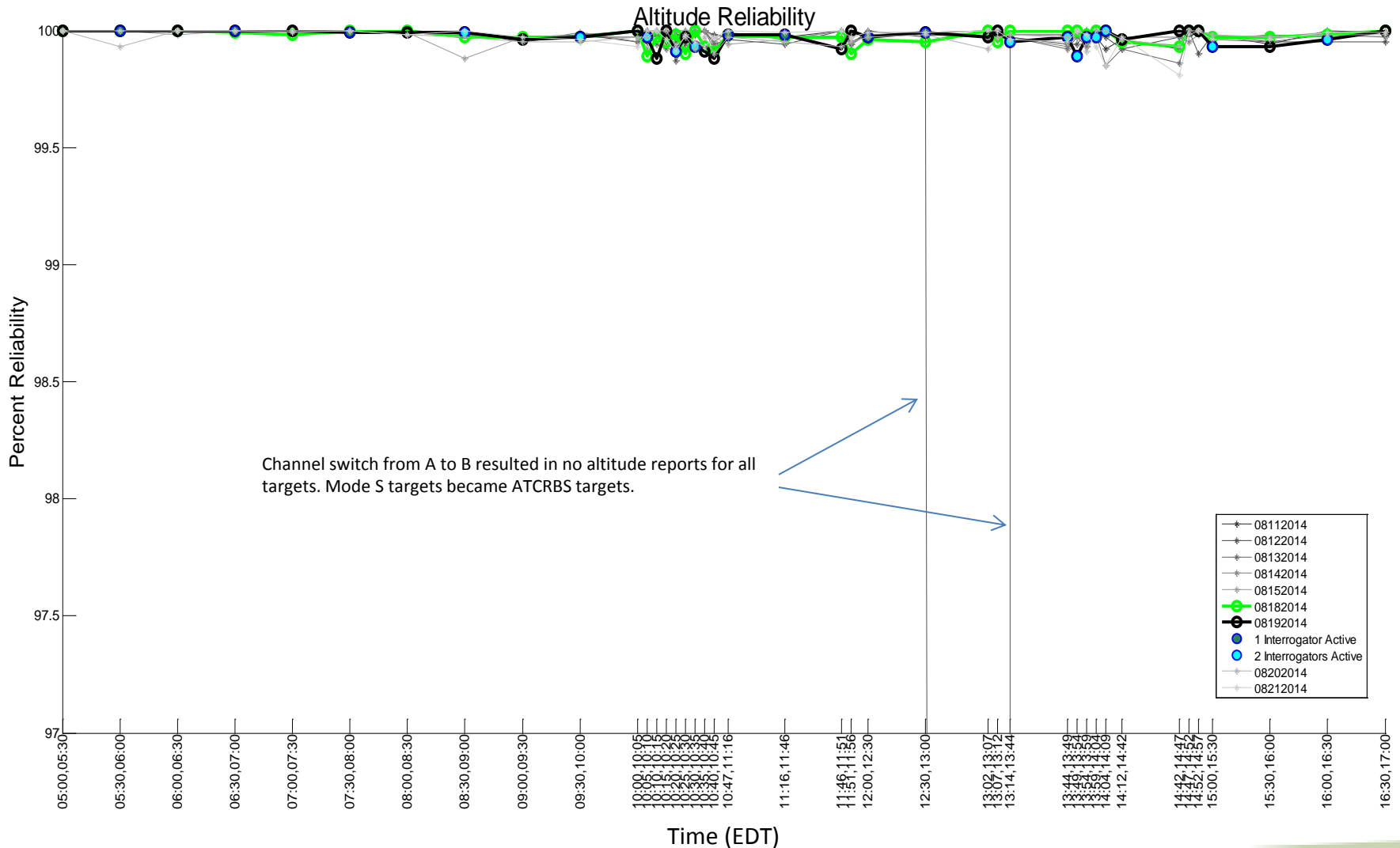
# Identity (3/A) Confidence – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Altitude (C) Reliability – August 19<sup>th</sup>

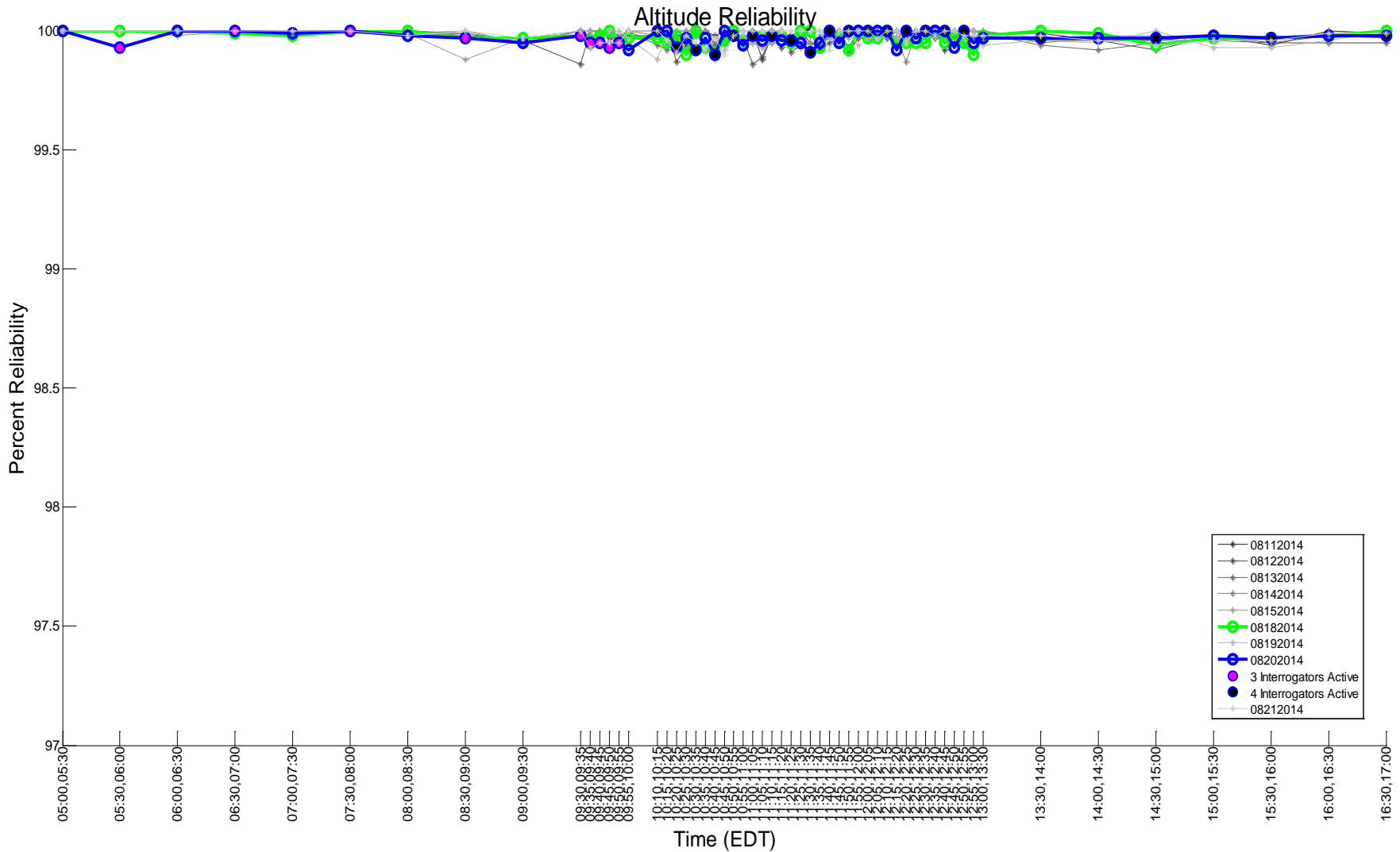


Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°



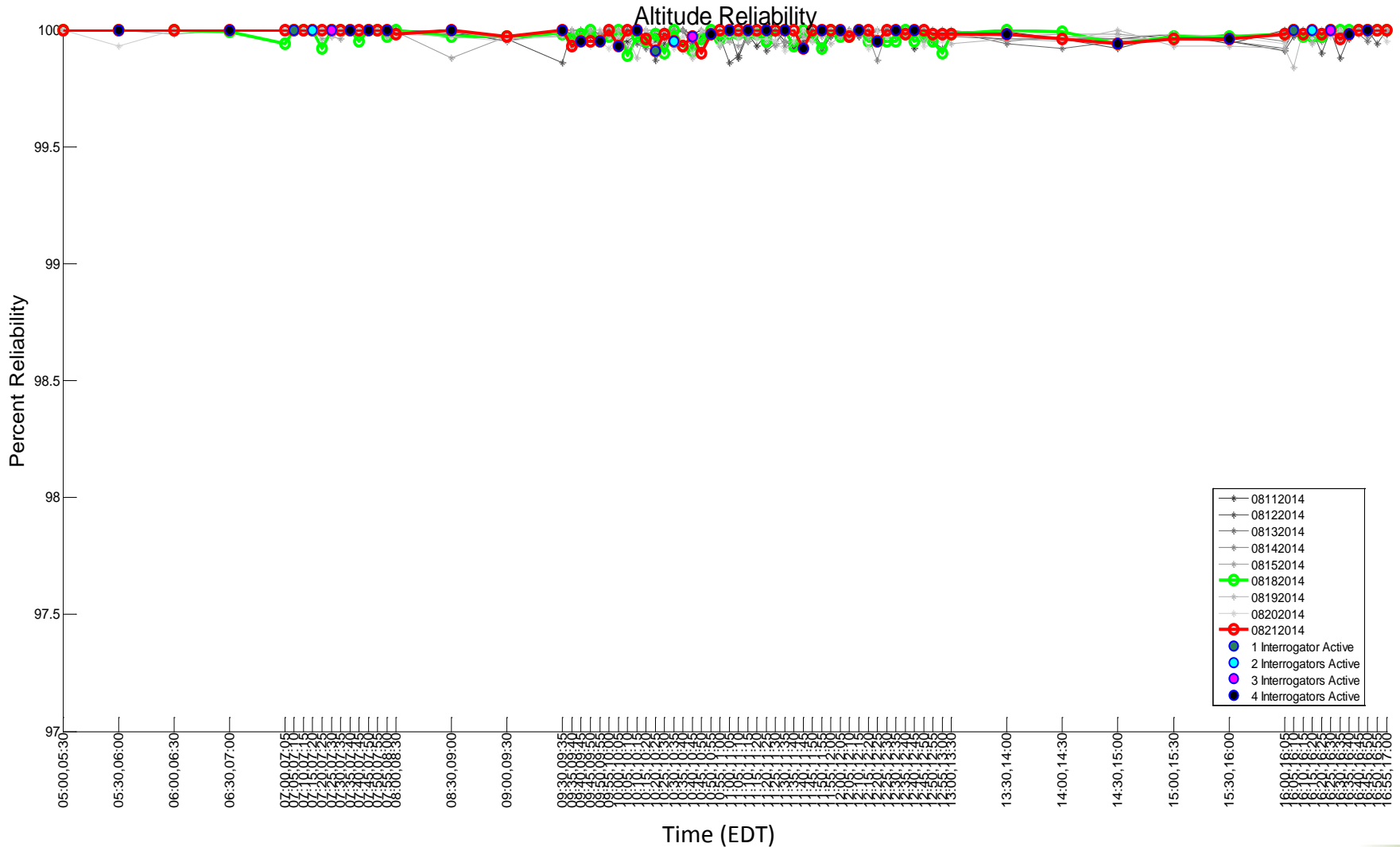
# Altitude (C) Reliability – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

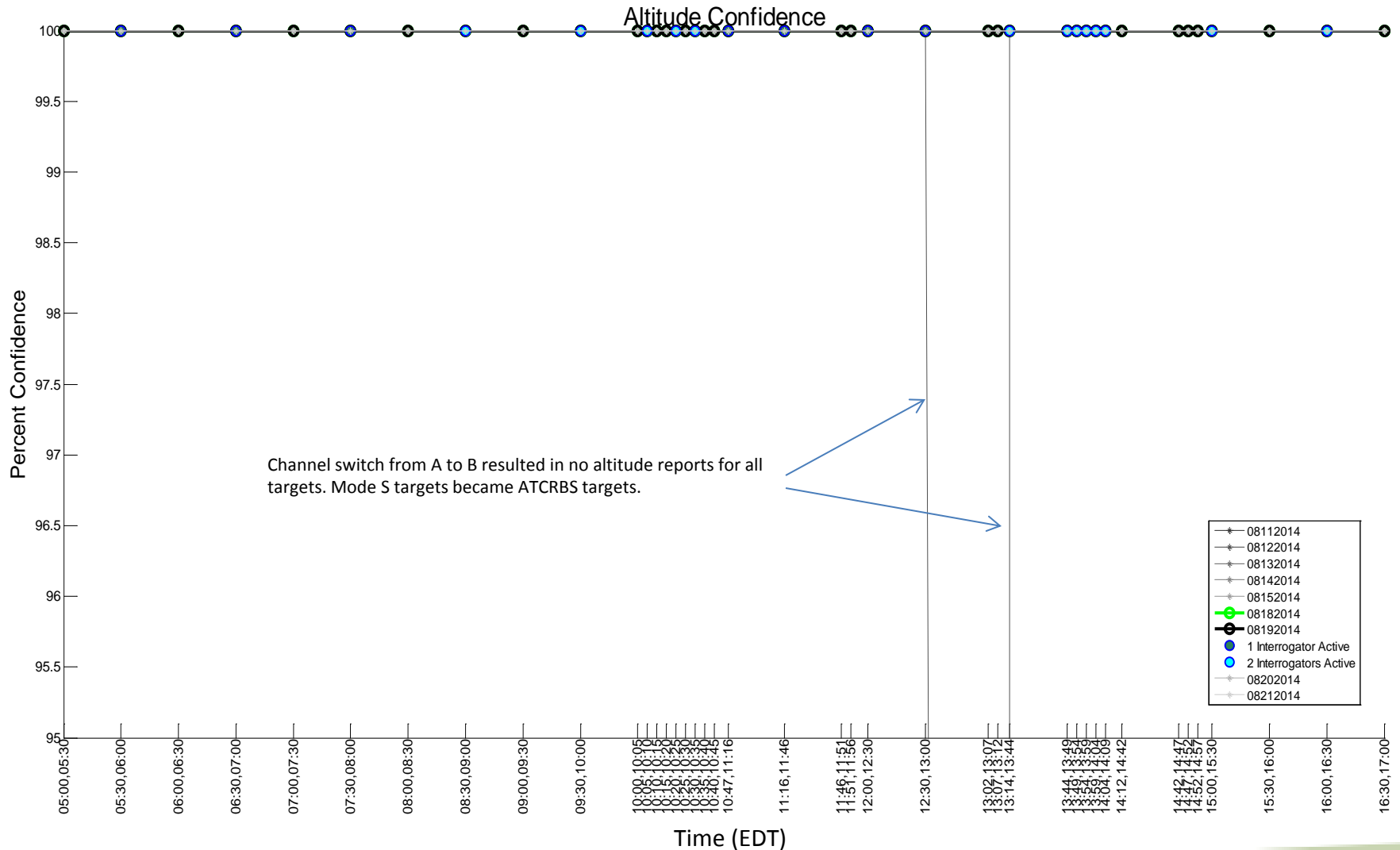
# Altitude (C) Reliability – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

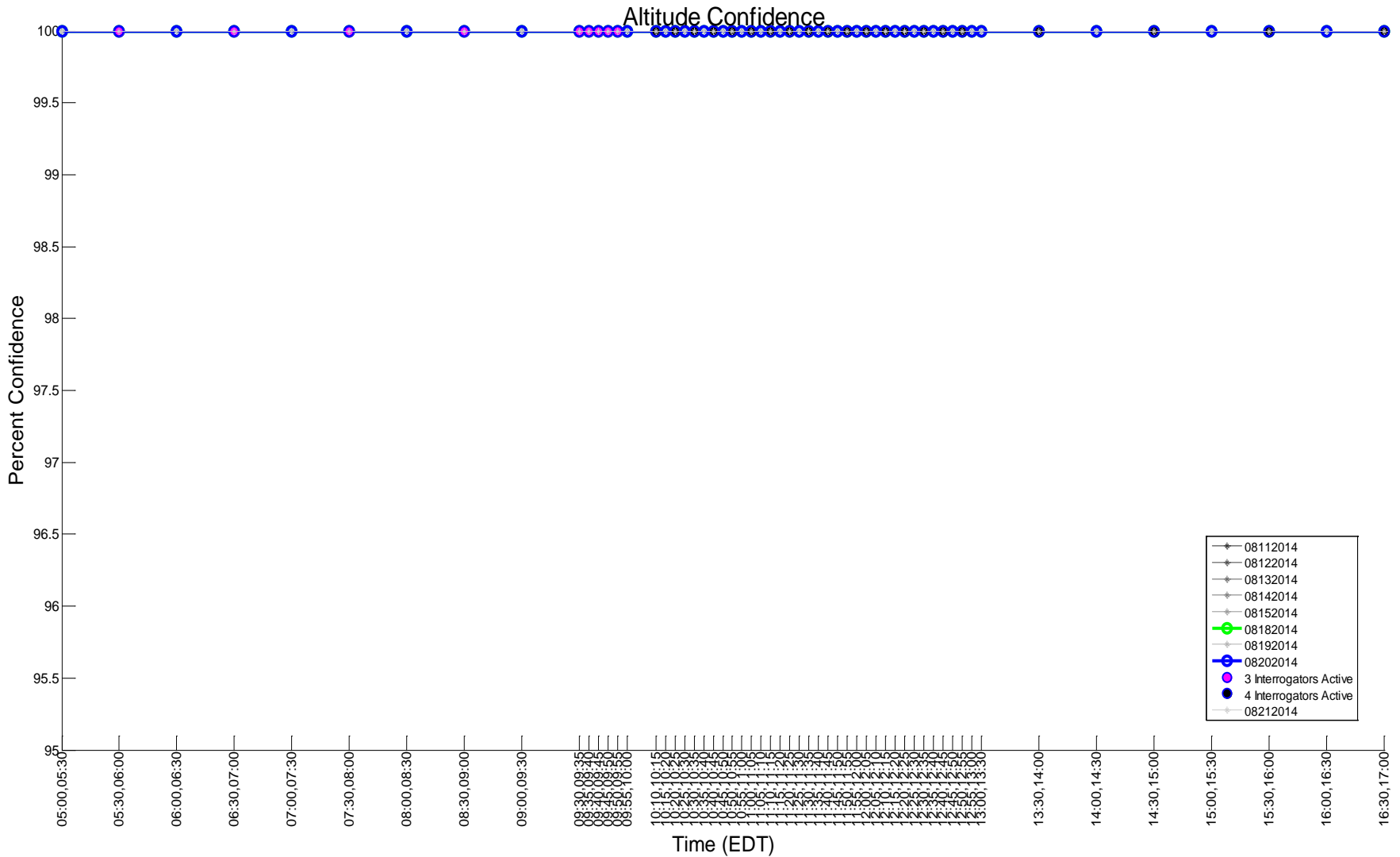
# Altitude (C) Confidence – August 19<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

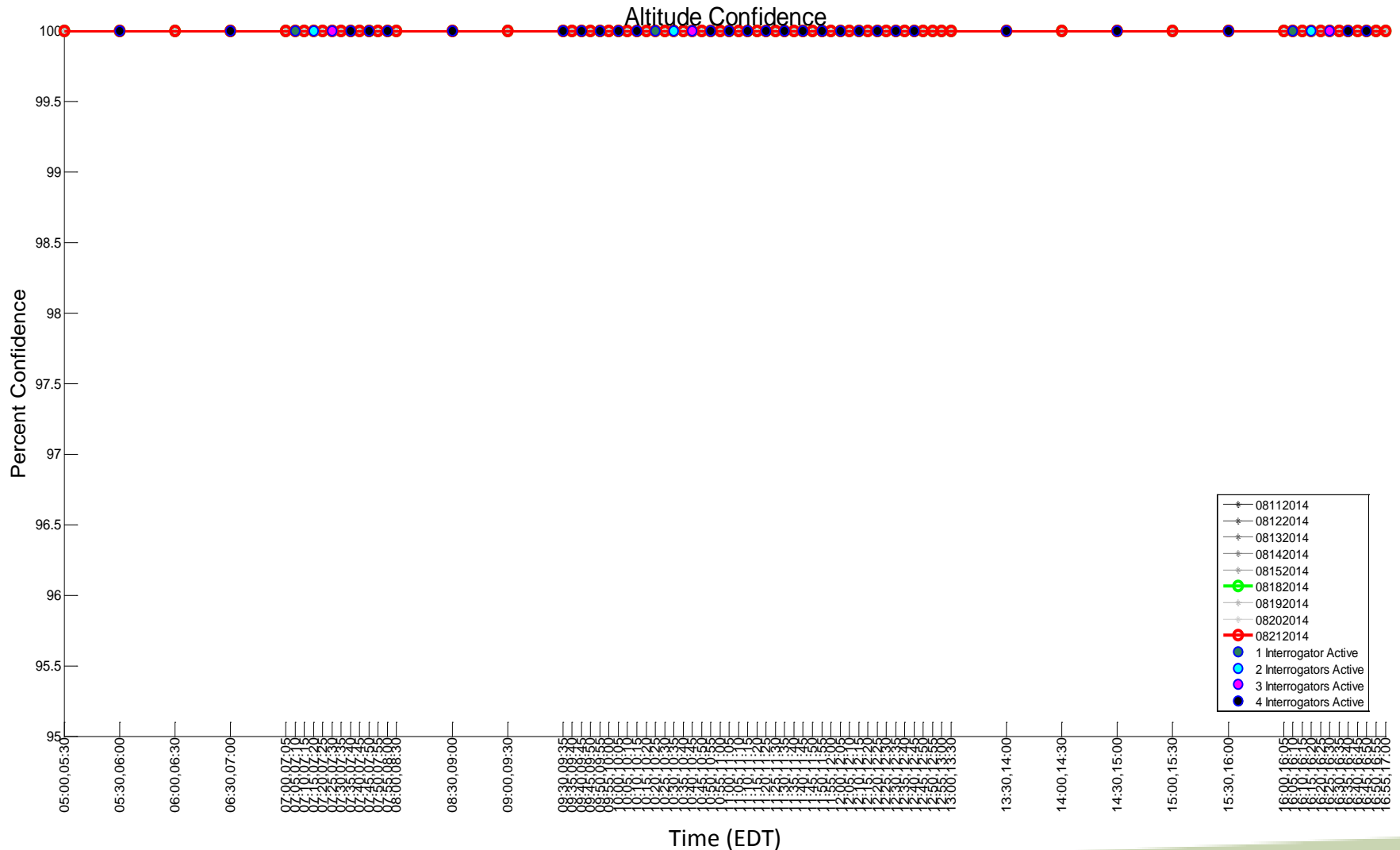
# Altitude (C) Confidence – August 20<sup>th</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

# Altitude (C) Confidence – August 21<sup>st</sup>



Geographic Filter: None

Target Filter: Exclude Targets with Elevation angle < 0.5°

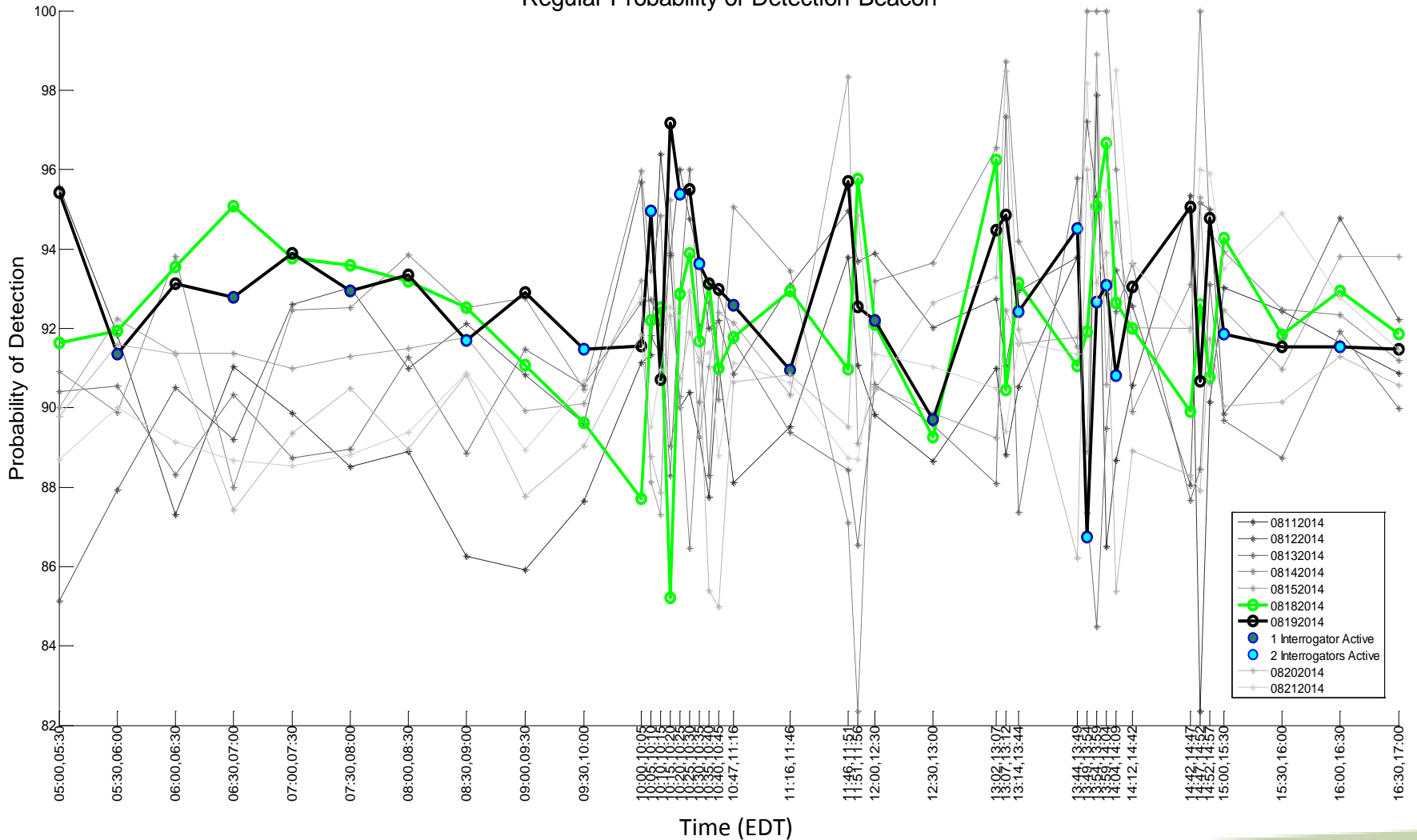
# Target Metrics with Range greater than 230 NM from SSR

*\* ATCRBS and Mode S Probability of Detection Breakdowns Unavailable*

*\*Number of Targets Unavailable*

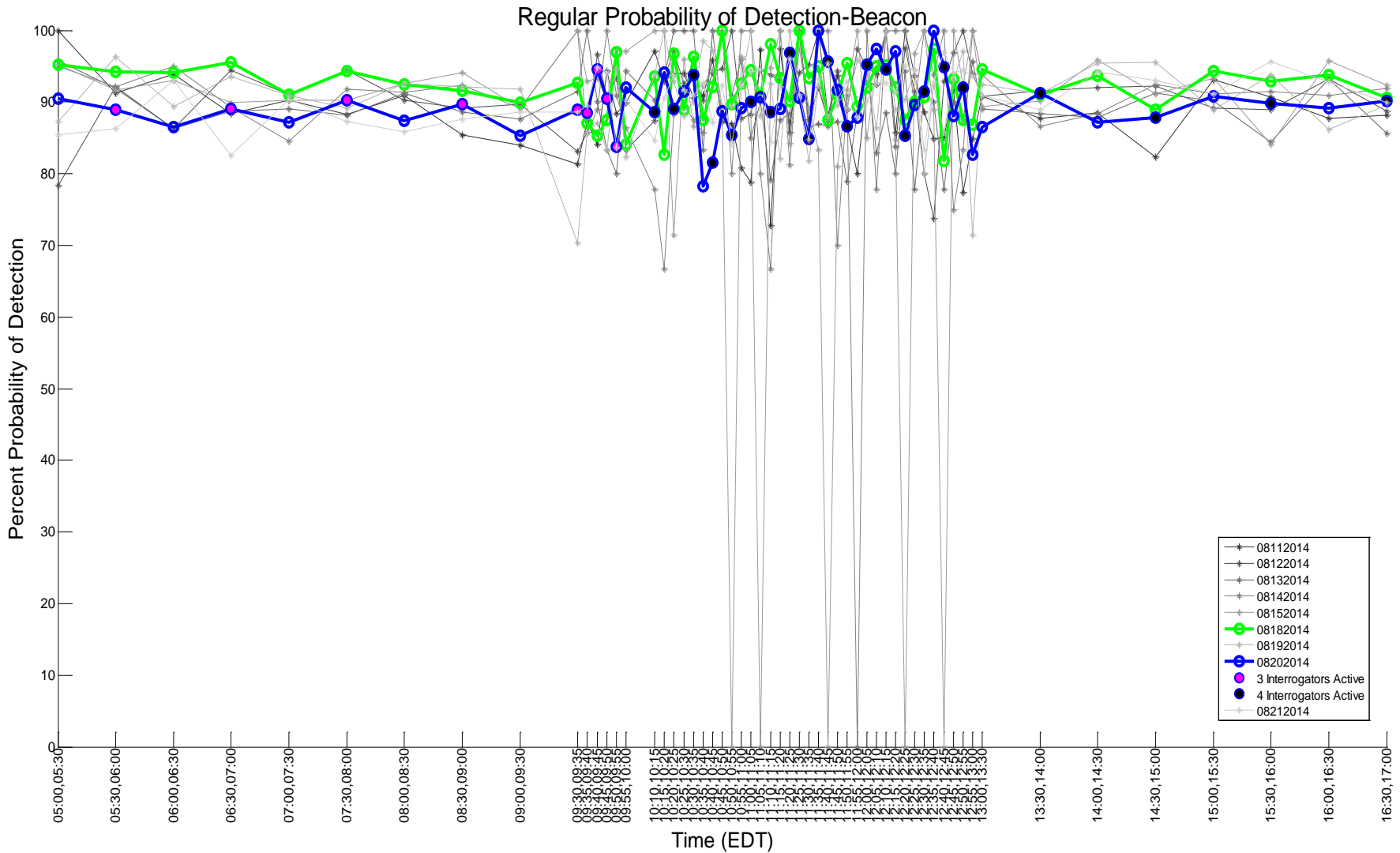
# Probability of Detection – August 19<sup>th</sup>

Regular Probability of Detection-Beacon



Geographic Filter: None  
Target Filter: Exclude Targets < 230 NM

# Probability of Detection – August 20<sup>th</sup>

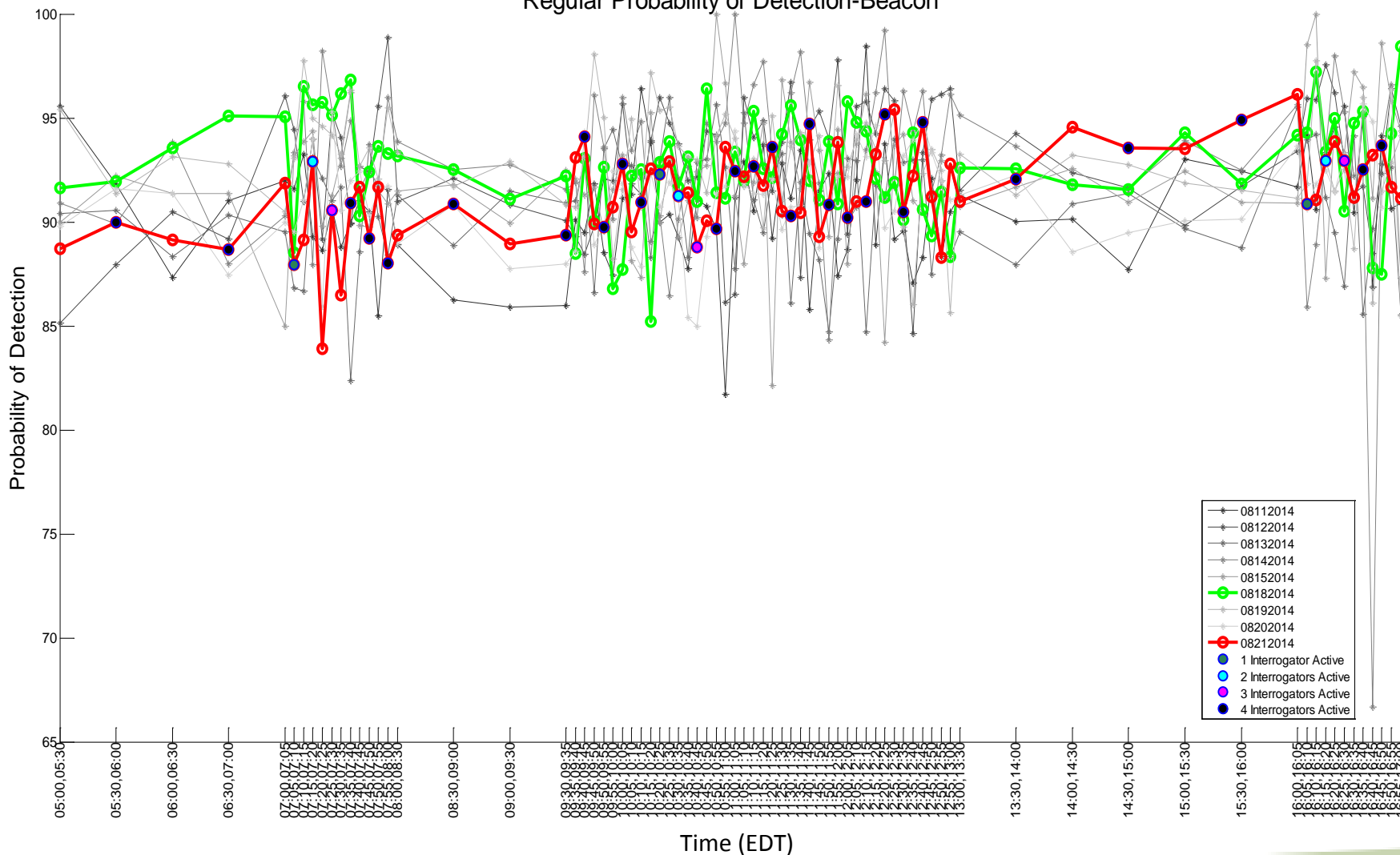


Geographic Filter: None  
Target Filter: Exclude Targets < 230 NM



# Probability of Detection – August 21<sup>st</sup>

## Regular Probability of Detection-Beacon

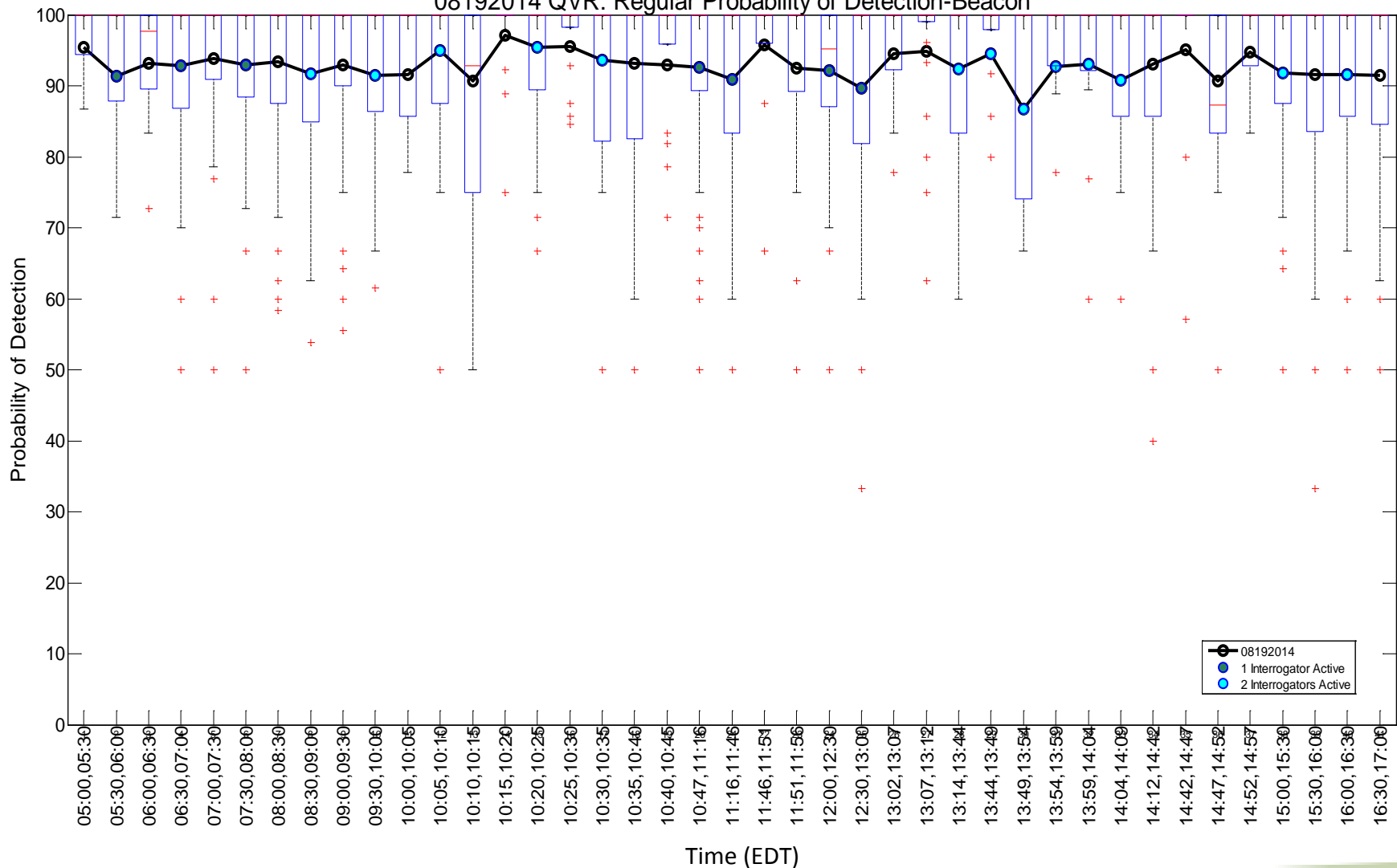


Geographic Filter: None  
Target Filter: Exclude Targets < 230 NM

# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution

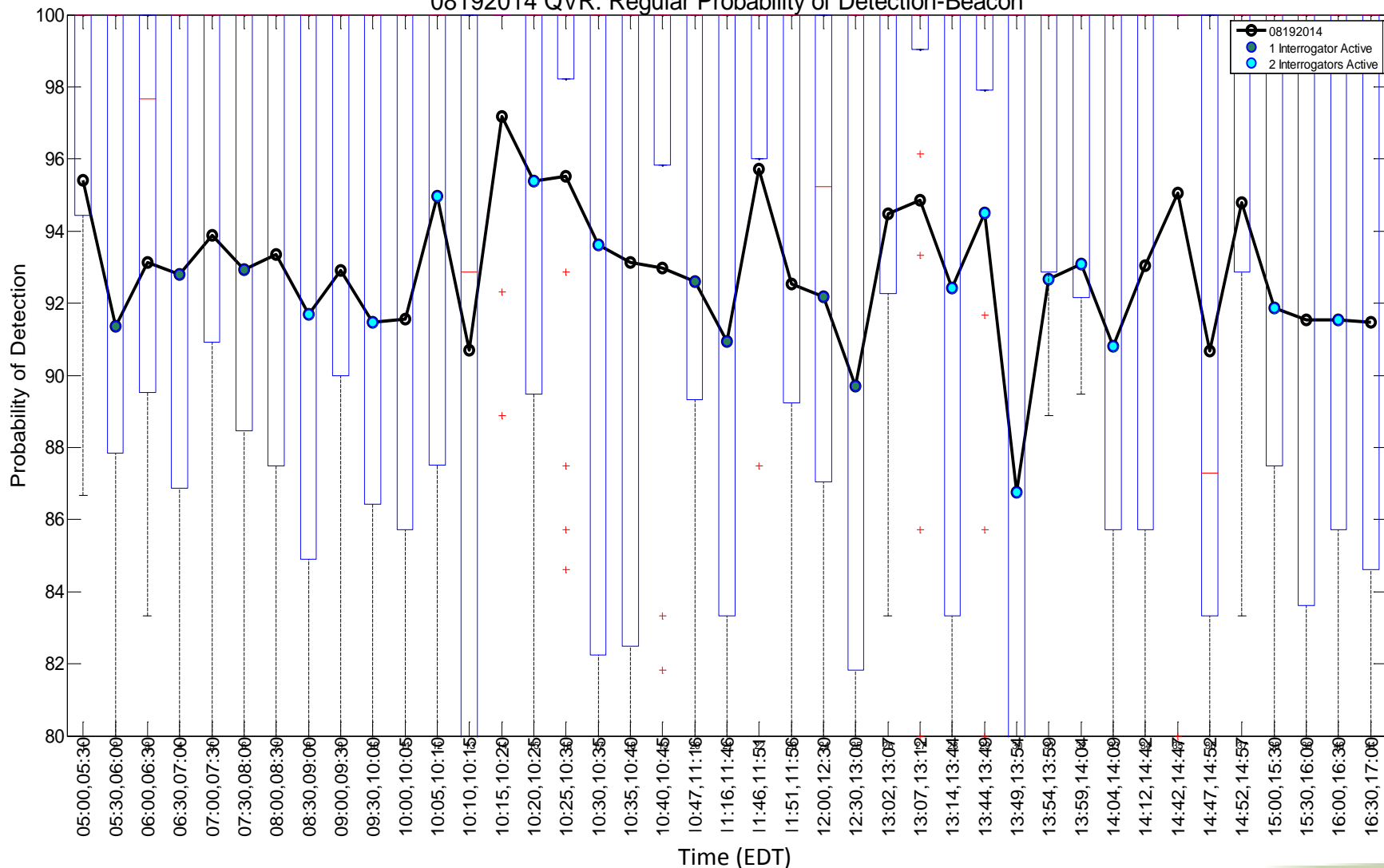
08192014 QVR: Regular Probability of Detection-Beacon



# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08192014 QVR: Regular Probability of Detection-Beacon



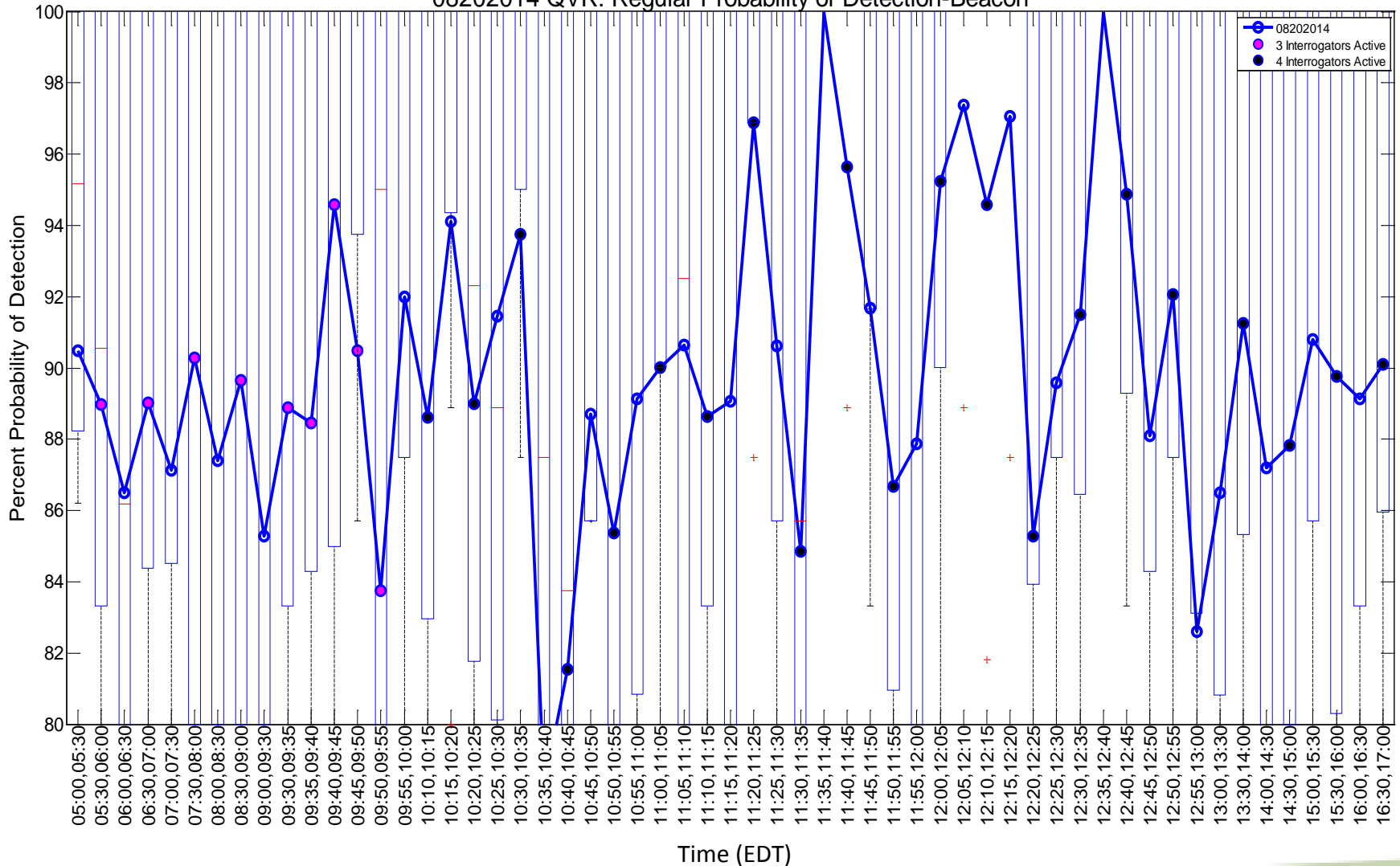
Geographic Filter: None  
 Target Filter: Exclude Targets < 230 NM



# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

08202014 QVR: Regular Probability of Detection-Beacon



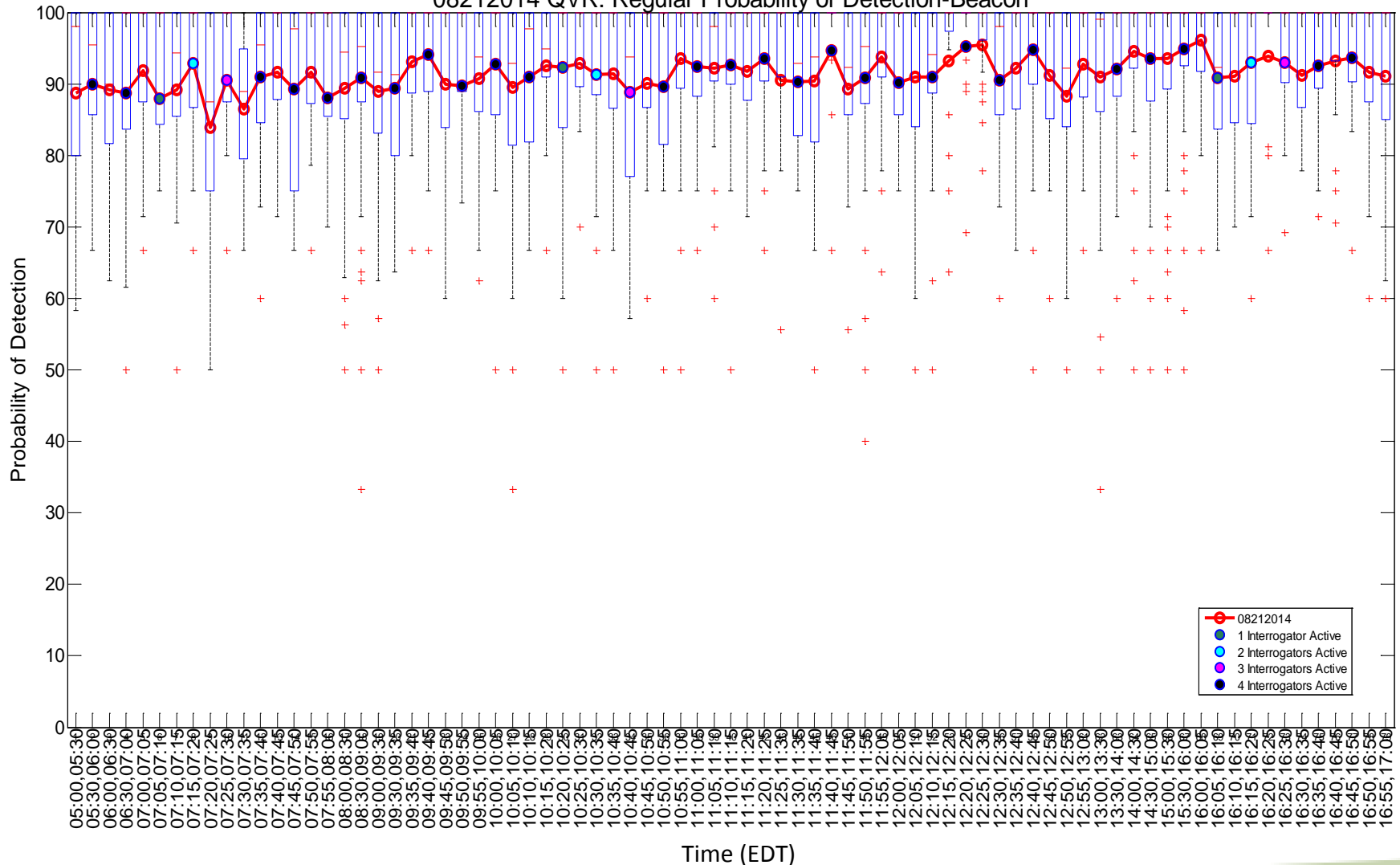
Geographic Filter: None

Target Filter: Exclude Targets < 230 NM

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

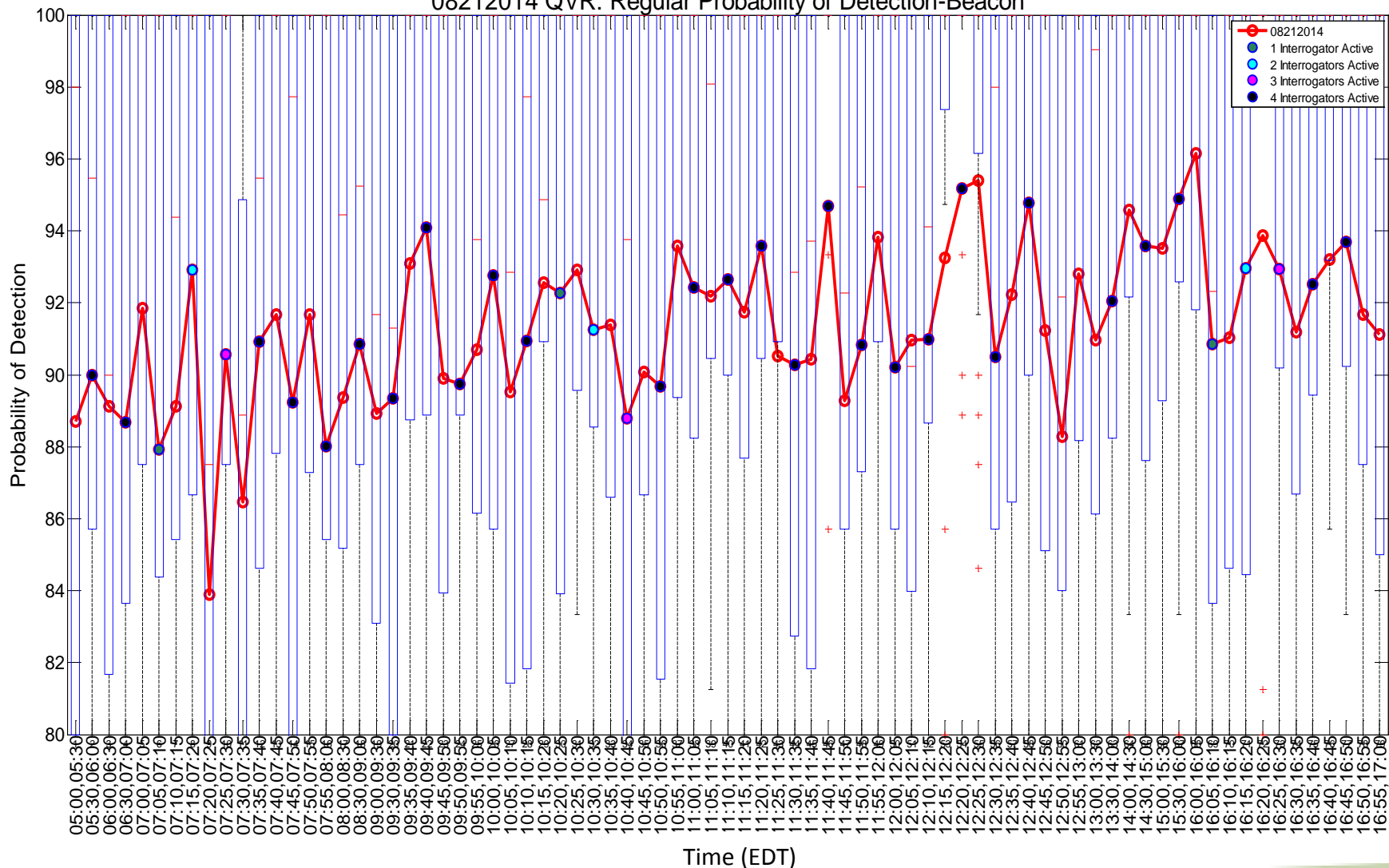
08212014 QVR: Regular Probability of Detection-Beacon



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)

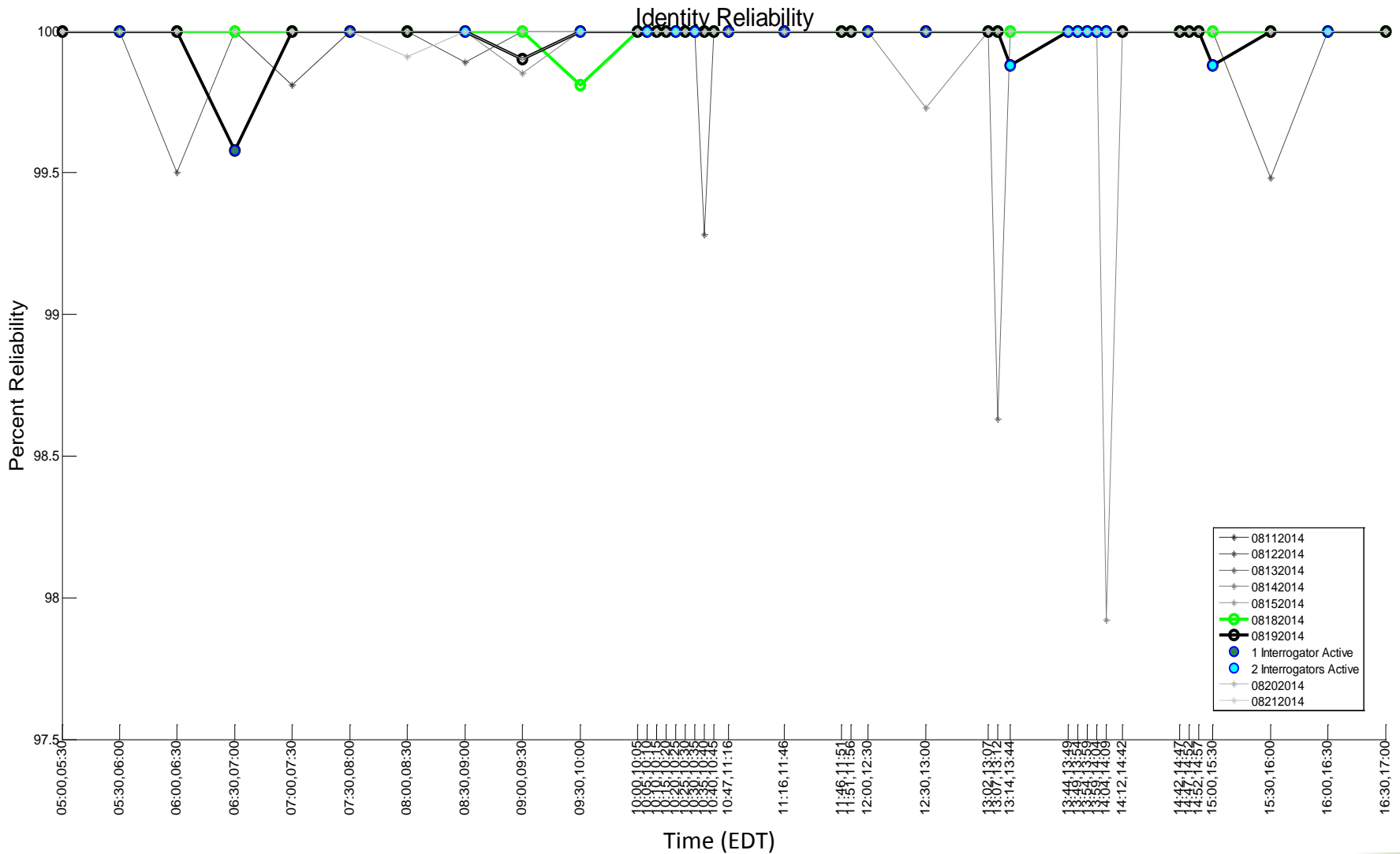
08212014 QVR: Regular Probability of Detection-Beacon



Geographic Filter: None

Target Filter: Exclude Targets < 230 NM

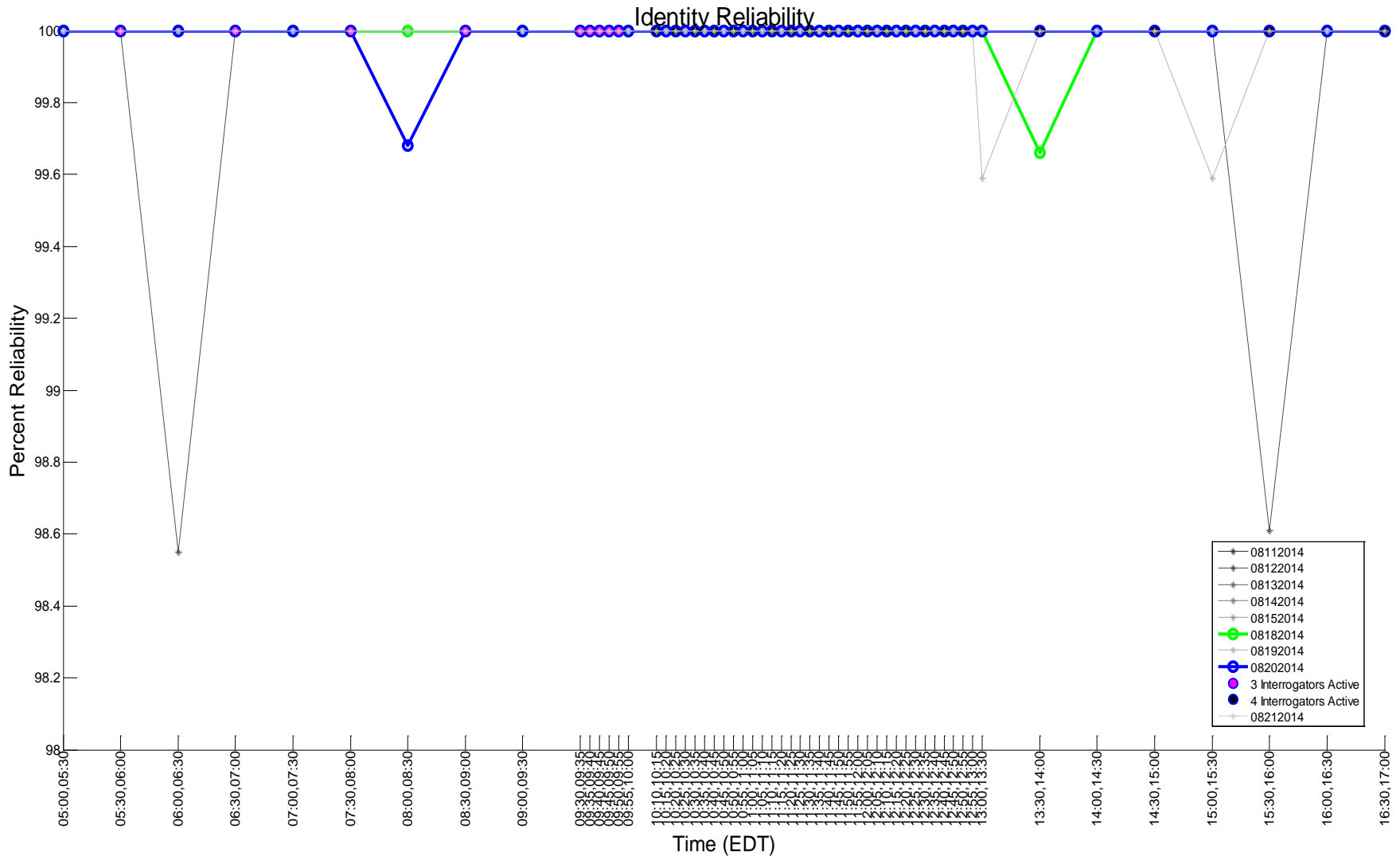
# Identity (3/A) Reliability – August 19<sup>th</sup>



Geographic Filter: None  
 Target Filter: Exclude Targets < 230 NM

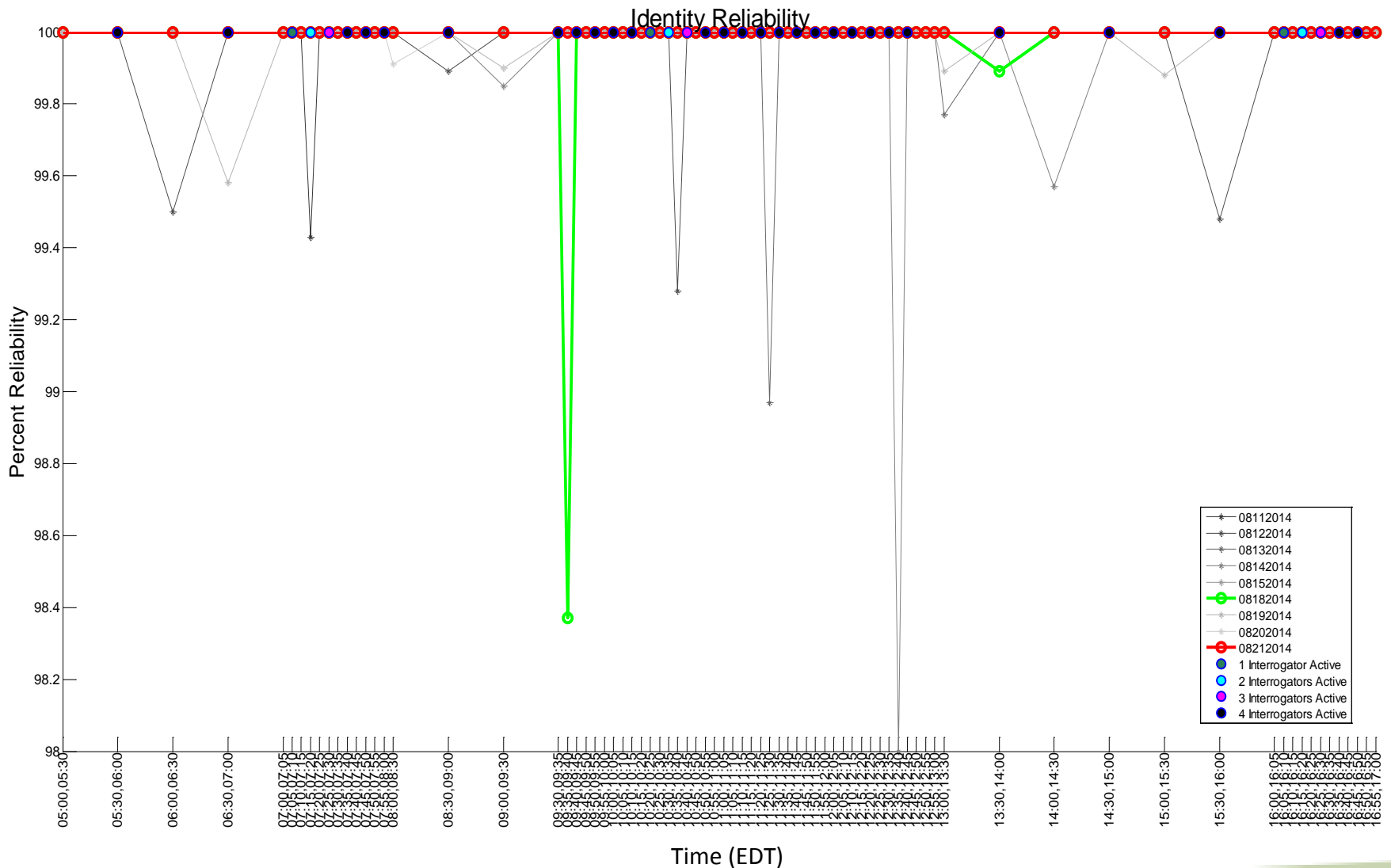


# Identity (3/A) Reliability – August 20<sup>th</sup>



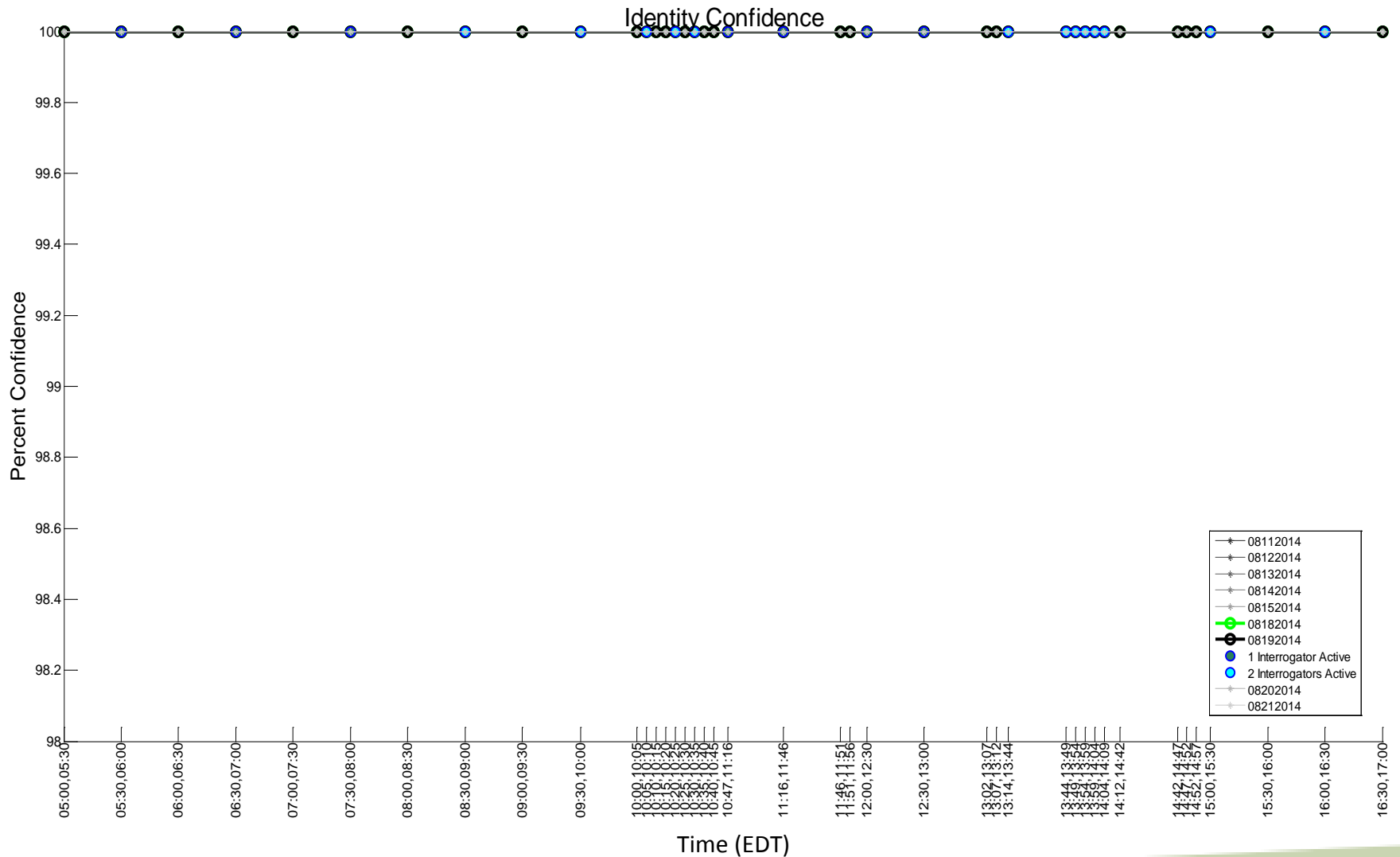
Geographic Filter: None  
 Target Filter: Exclude Targets < 230 NM

# Identity (3/A) Reliability – August 21<sup>st</sup>



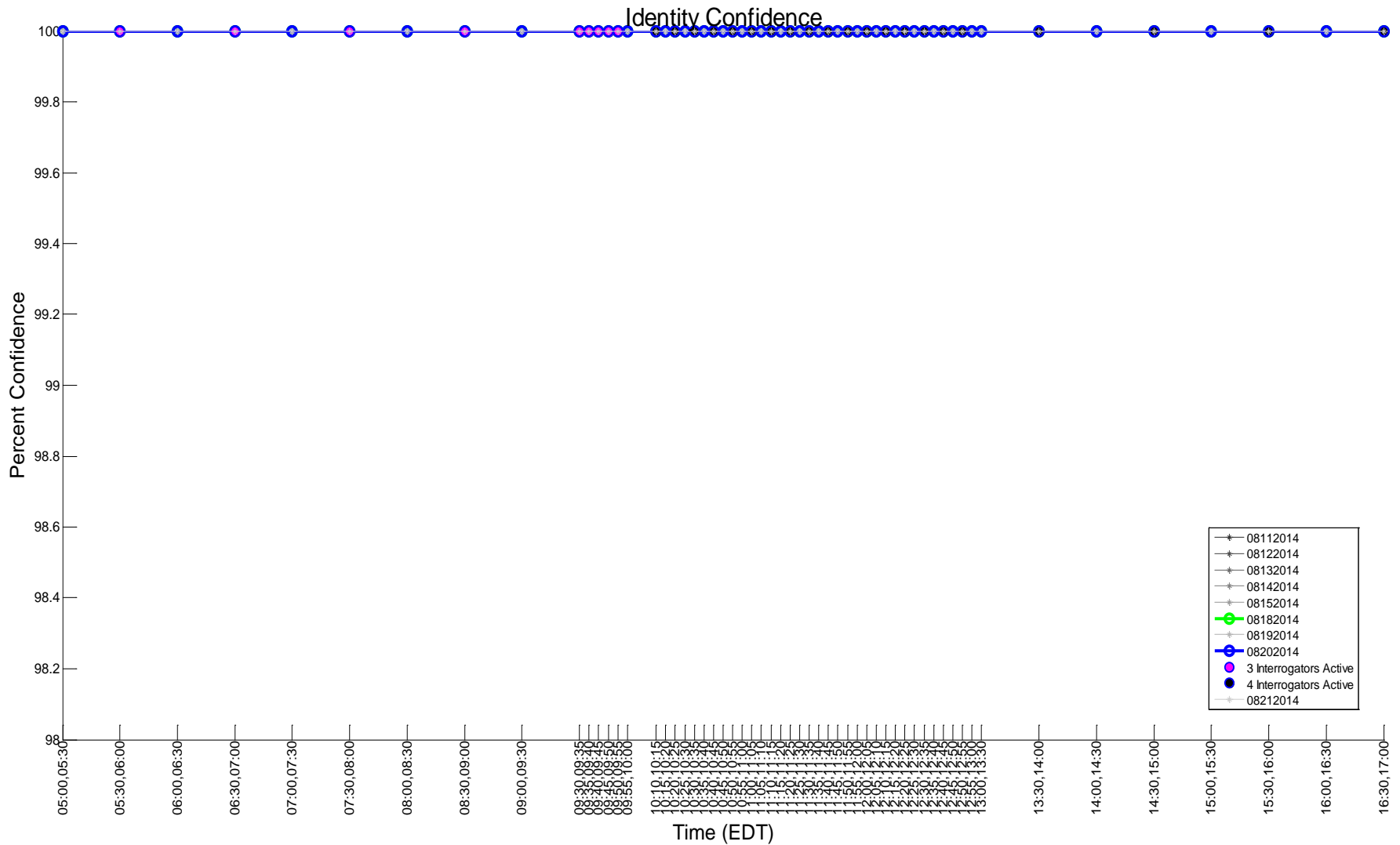
Geographic Filter: None  
Target Filter: Exclude Targets < 230 NM

# Identity (3/A) Confidence – August 19<sup>th</sup>



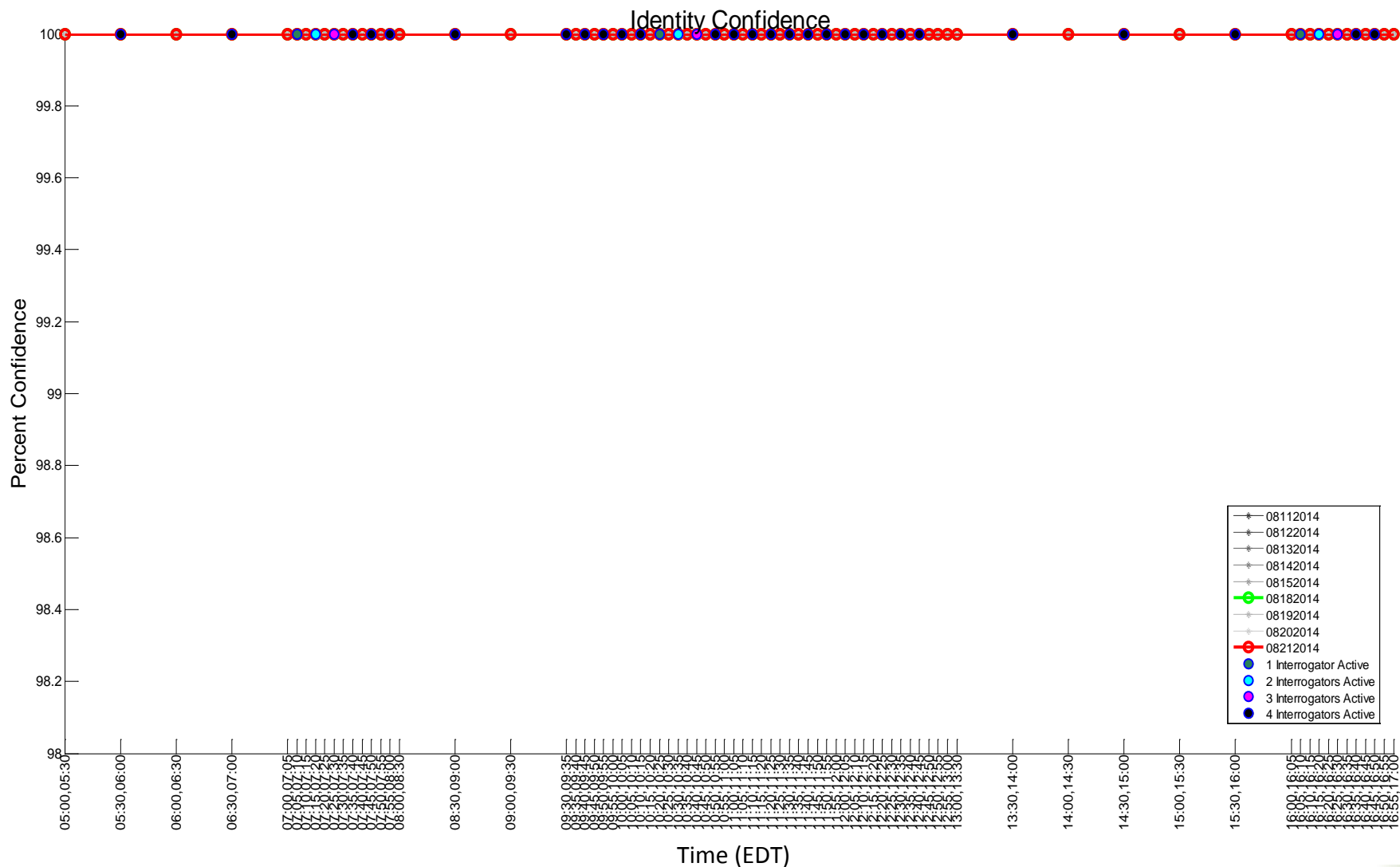
Geographic Filter: None  
 Target Filter: Exclude Targets < 230 NM

# Identity (3/A) Confidence – August 20<sup>th</sup>



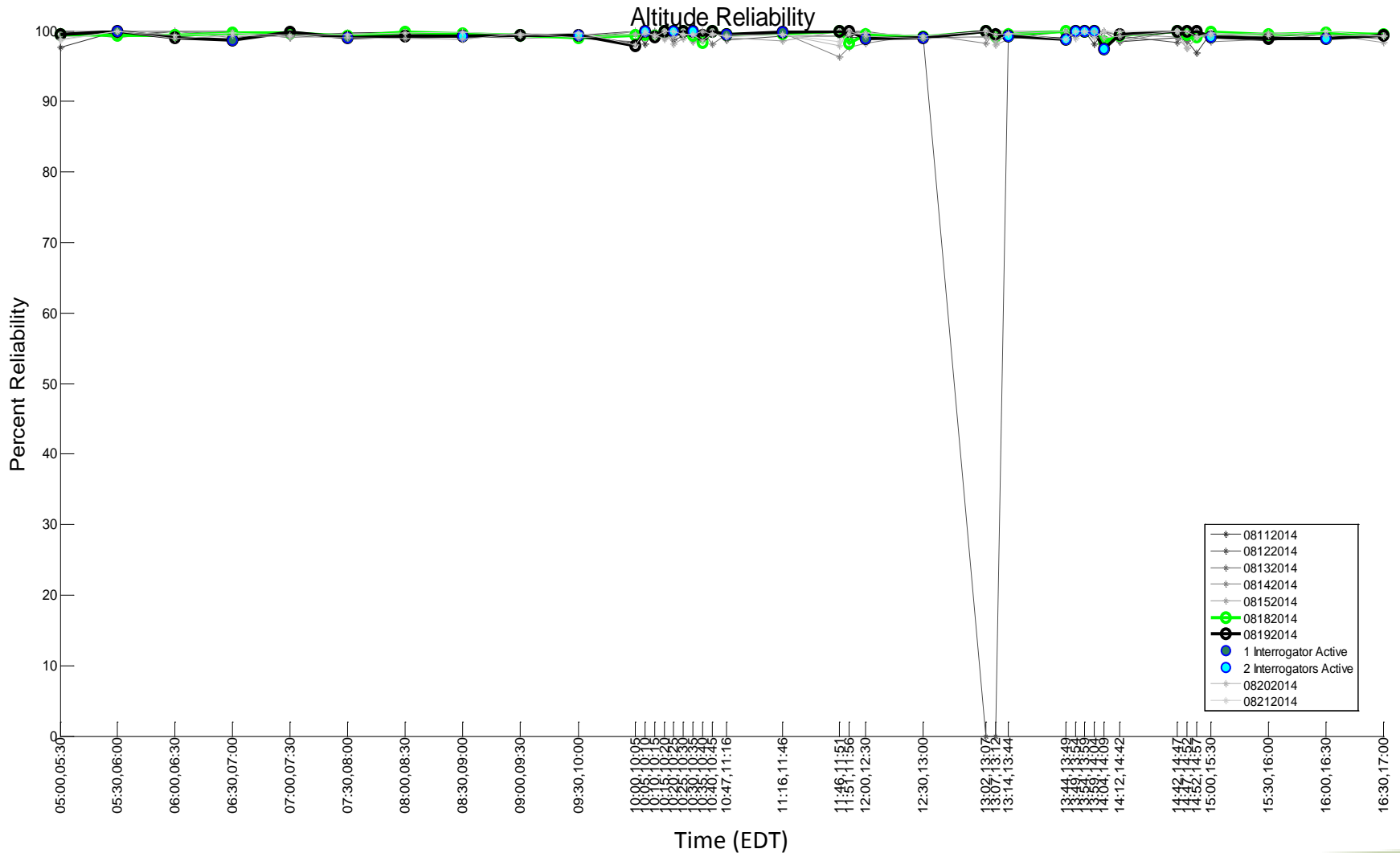
Geographic Filter: None  
Target Filter: Exclude Targets < 230 NM

# Identity (3/A) Confidence – August 21<sup>st</sup>



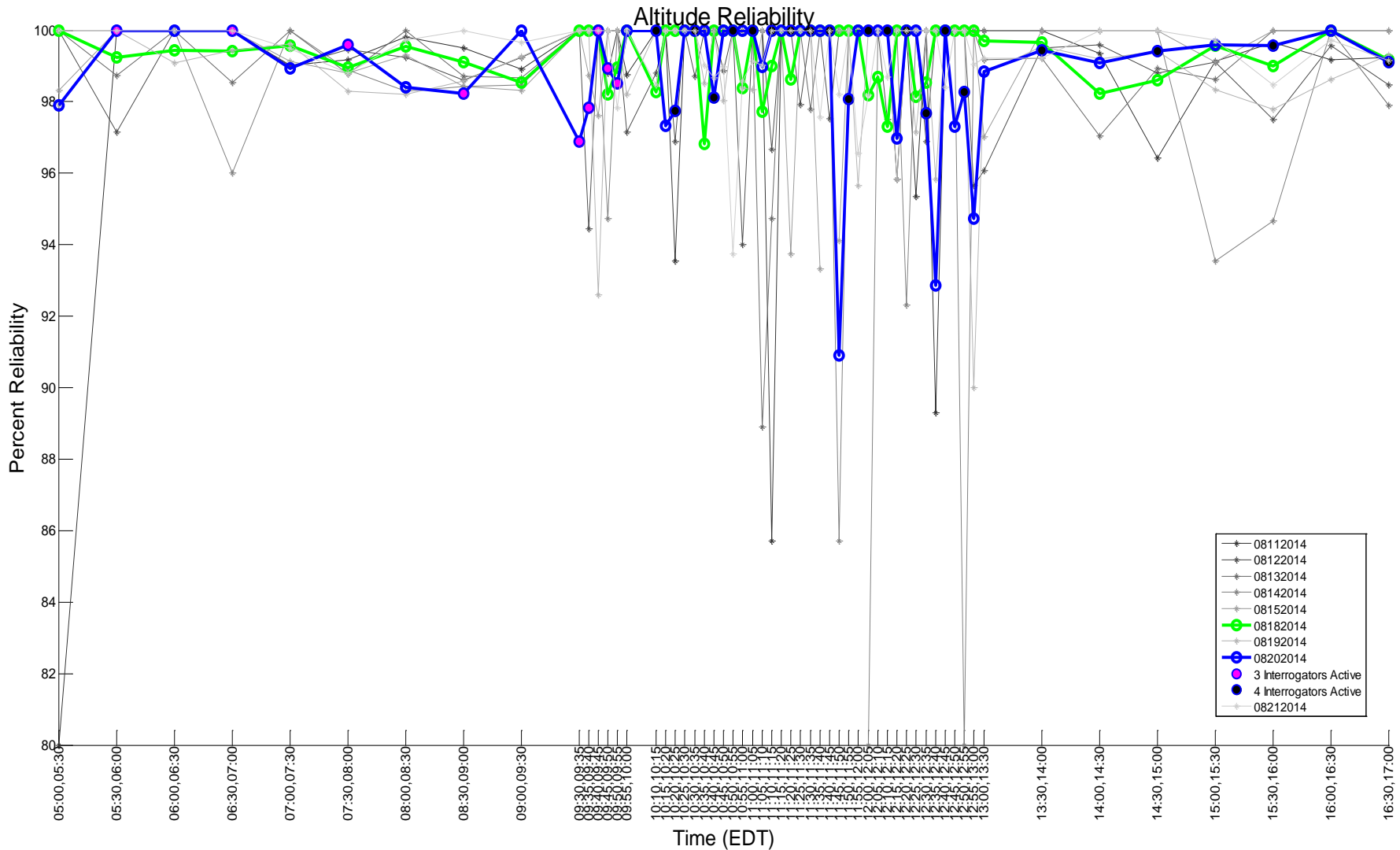
Geographic Filter: None  
Target Filter: Exclude Targets < 230 NM

# Altitude (C) Reliability – August 19<sup>th</sup>



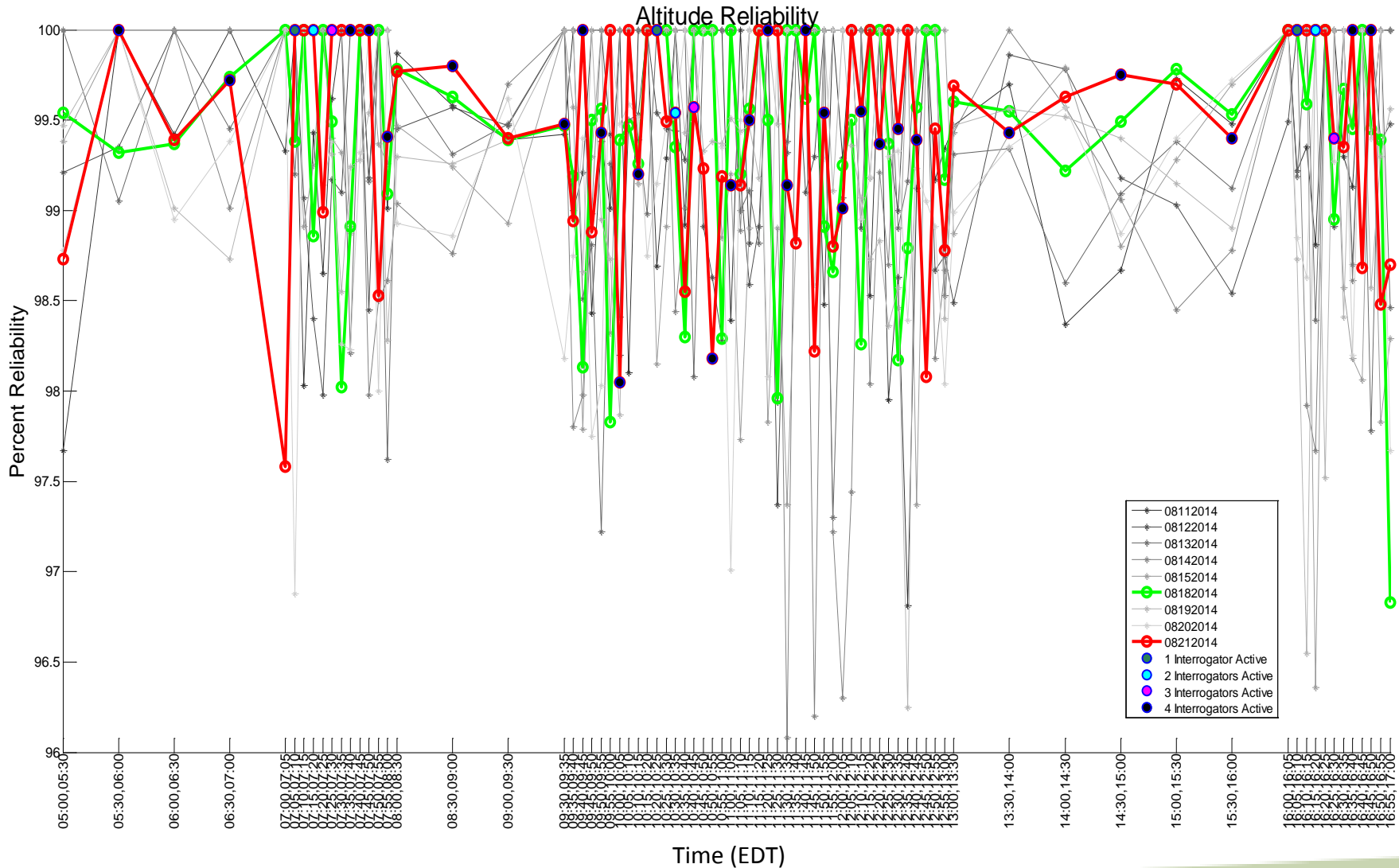
Geographic Filter: None  
Target Filter: Exclude Targets < 230 NM

# Altitude (C) Reliability – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: Exclude Targets < 230 NM

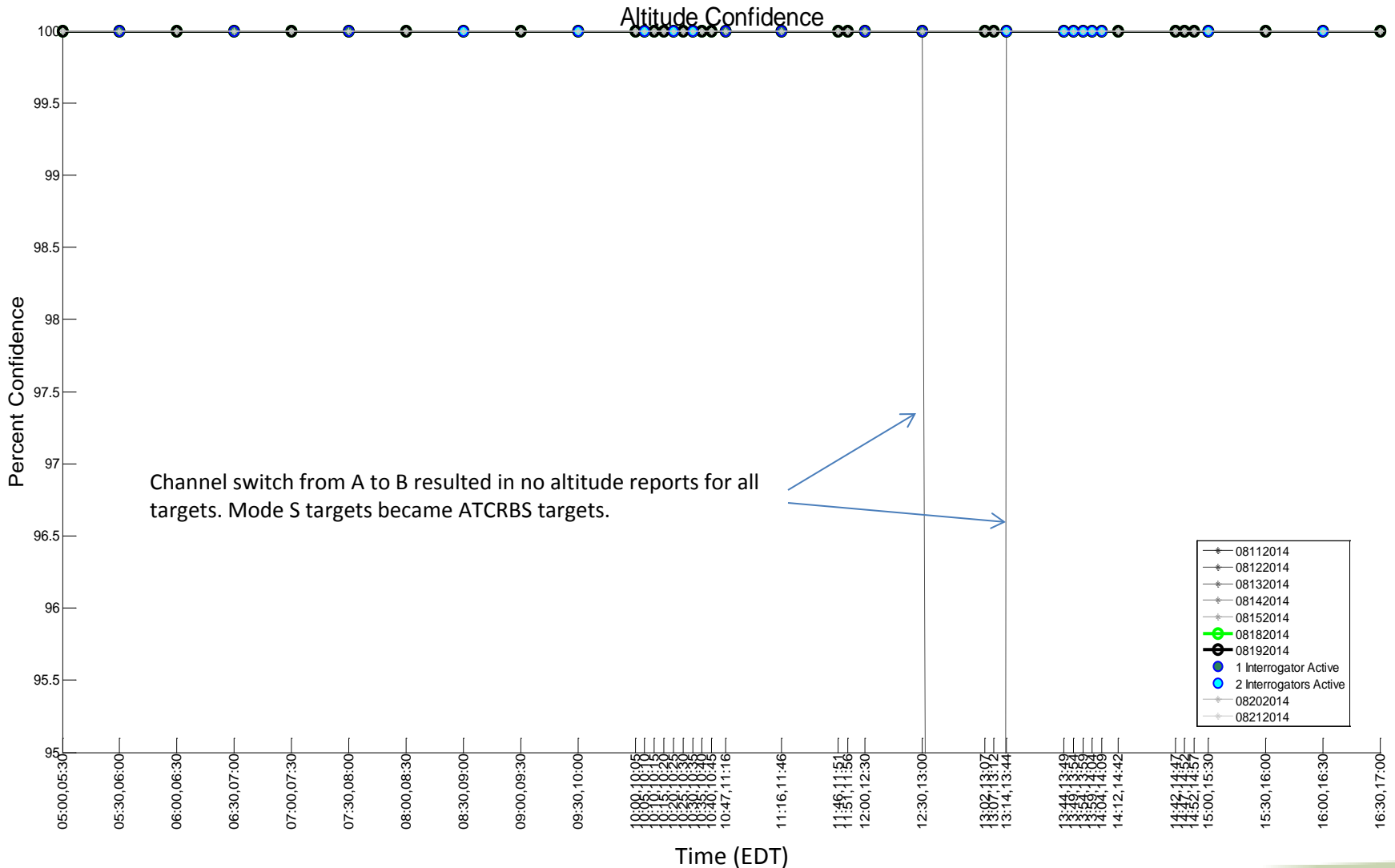
# Altitude (C) Reliability – August 21<sup>st</sup>



Geographic Filter: None  
Target Filter: Exclude Targets < 230 NM

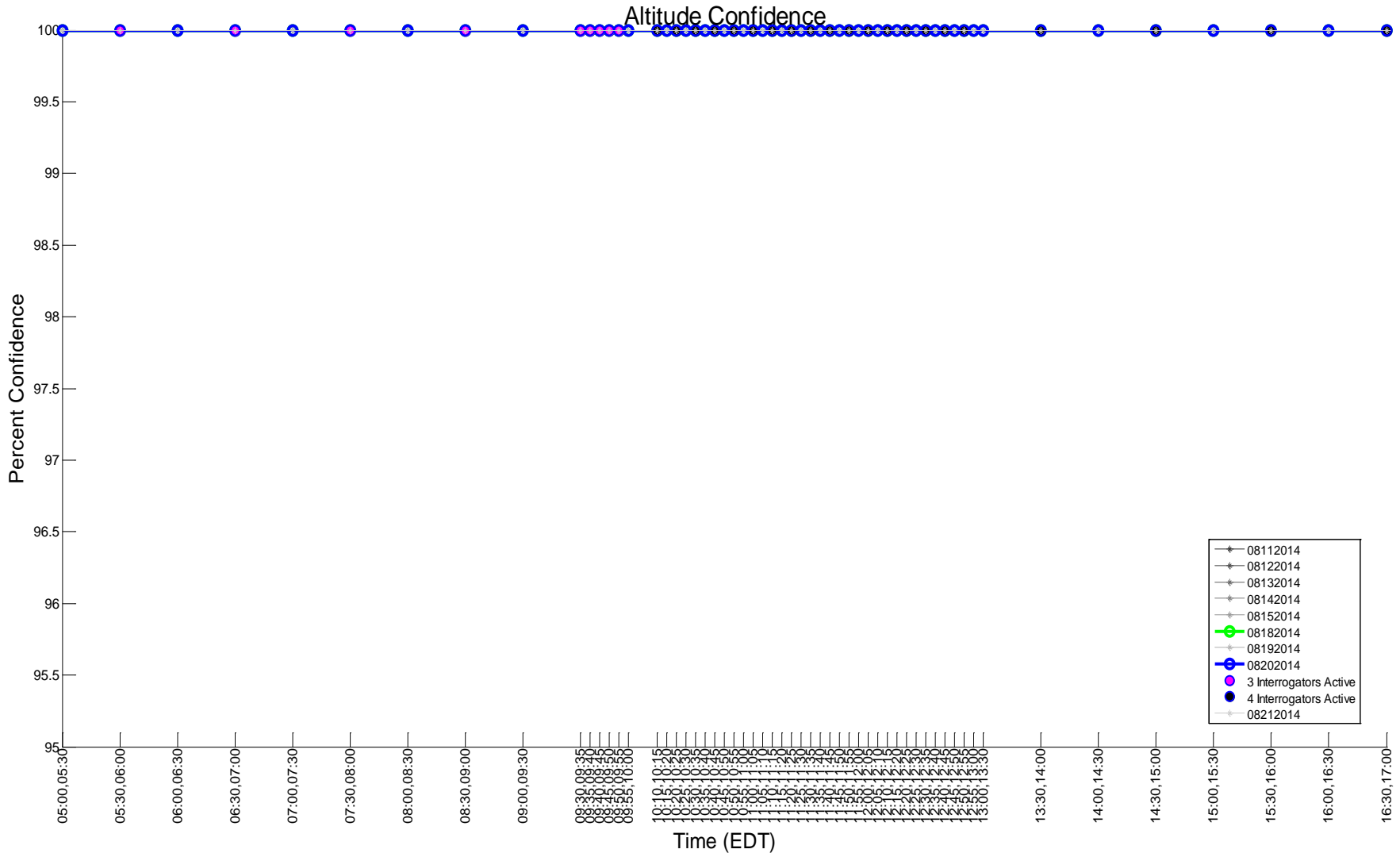


# Altitude (C) Confidence – August 19<sup>th</sup>



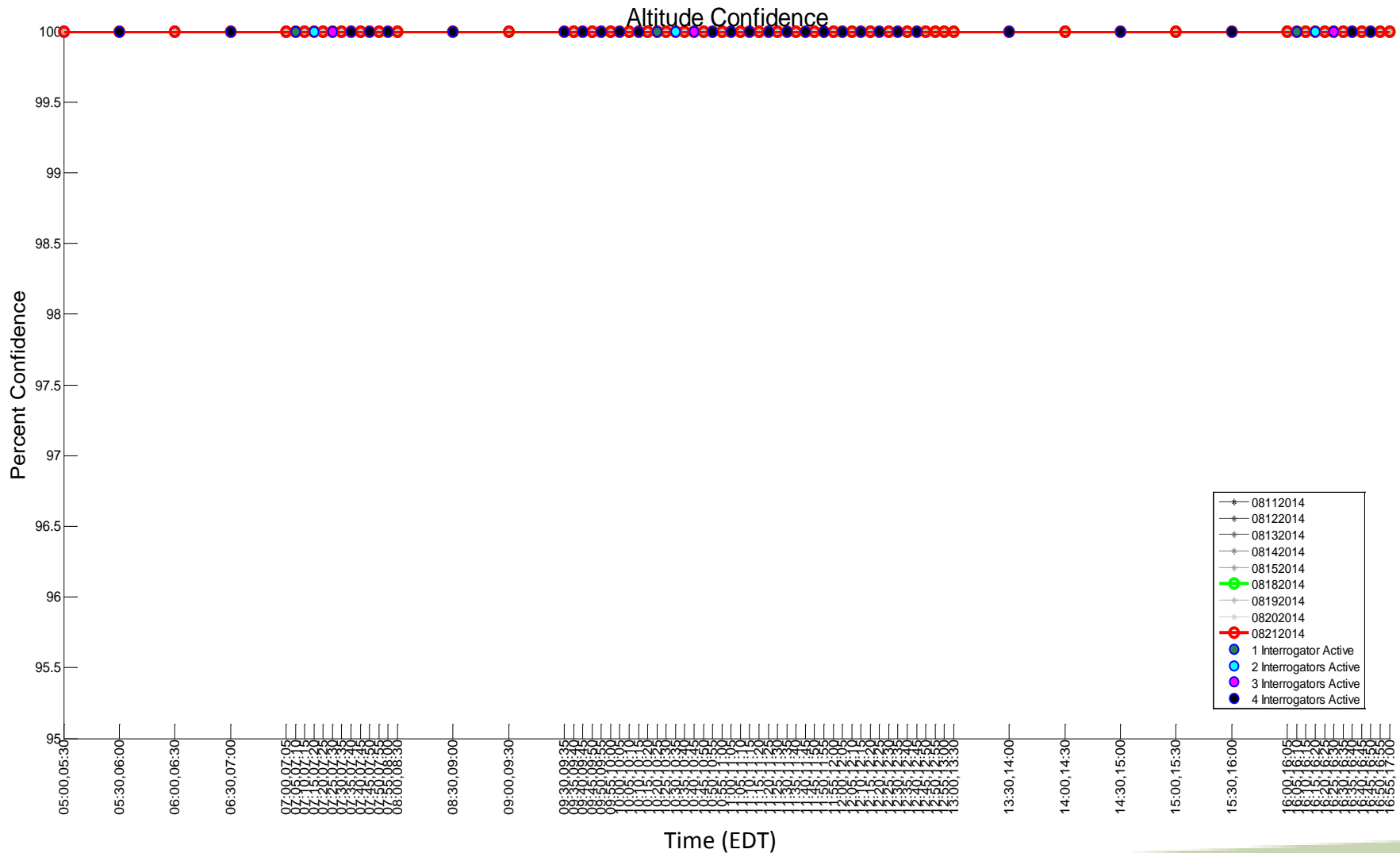
Channel switch from A to B resulted in no altitude reports for all targets. Mode S targets became ATCRBS targets.

# Altitude (C) Confidence – August 20<sup>th</sup>



Geographic Filter: None  
Target Filter: Exclude Targets < 230 NM

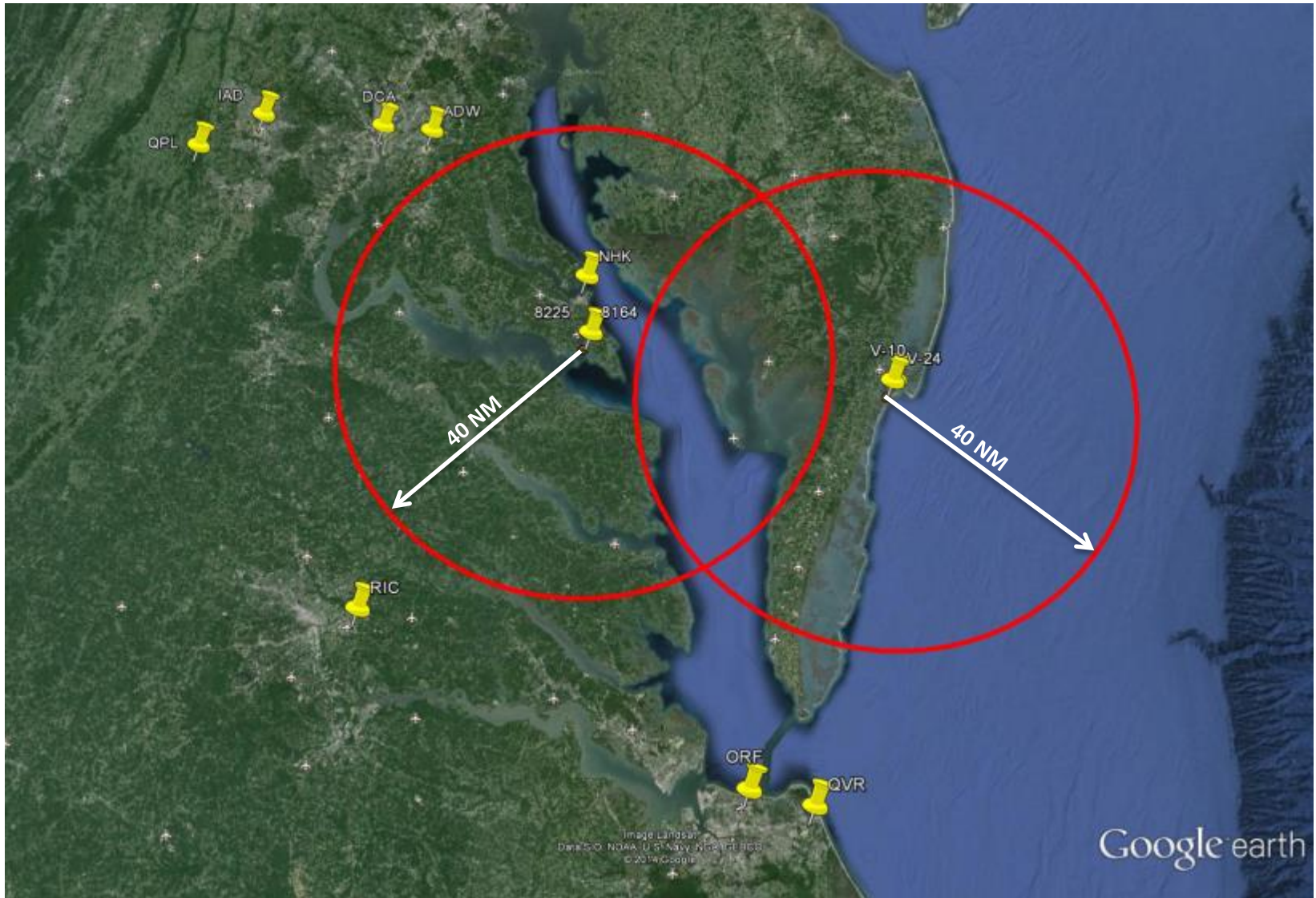
# Altitude (C) Confidence – August 21<sup>st</sup>



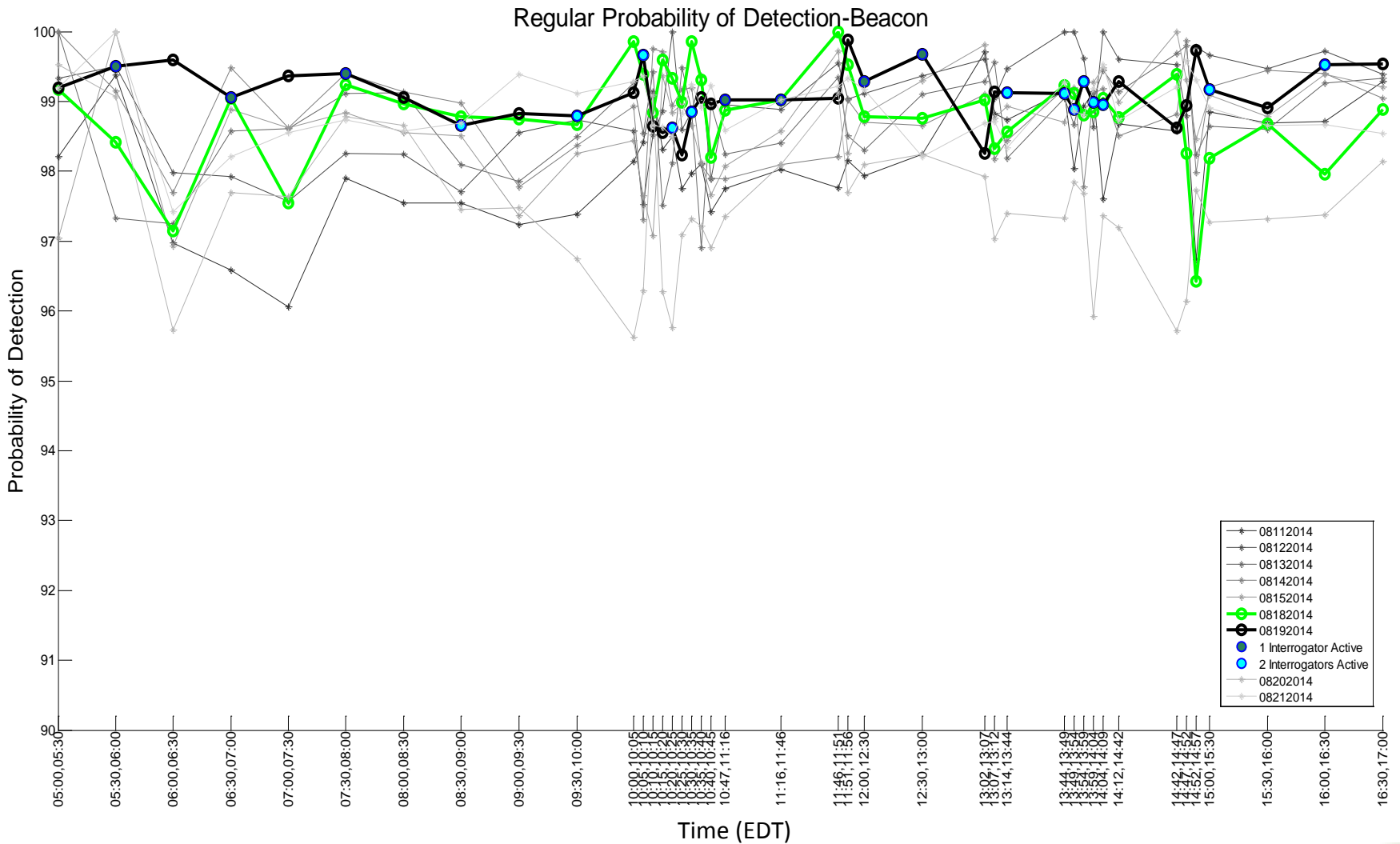
Geographic Filter: None  
Target Filter: Exclude Targets < 230 NM

# Target Metrics within the Hotspot Region

# Hotspot Geography



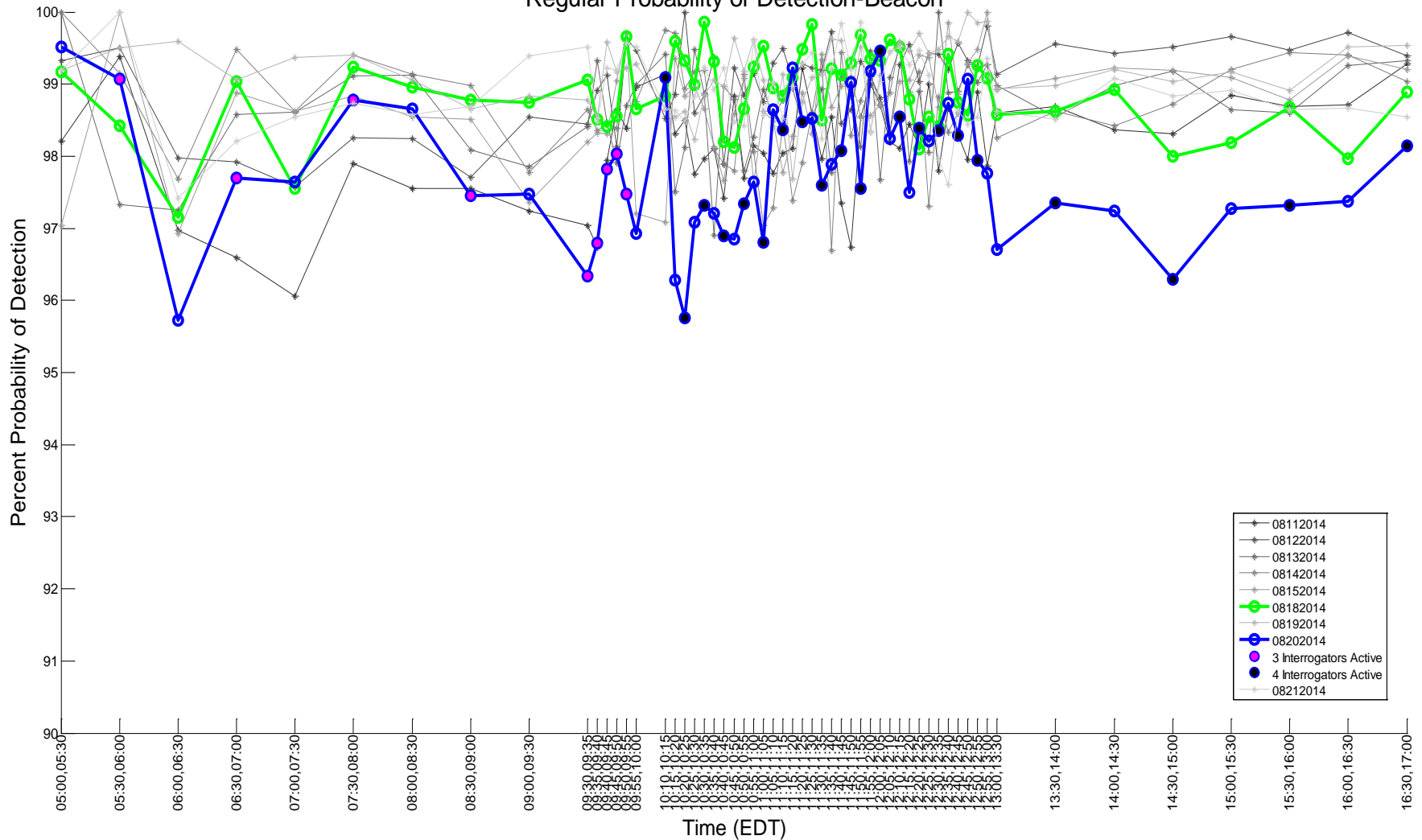
# Probability of Detection – August 19<sup>th</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

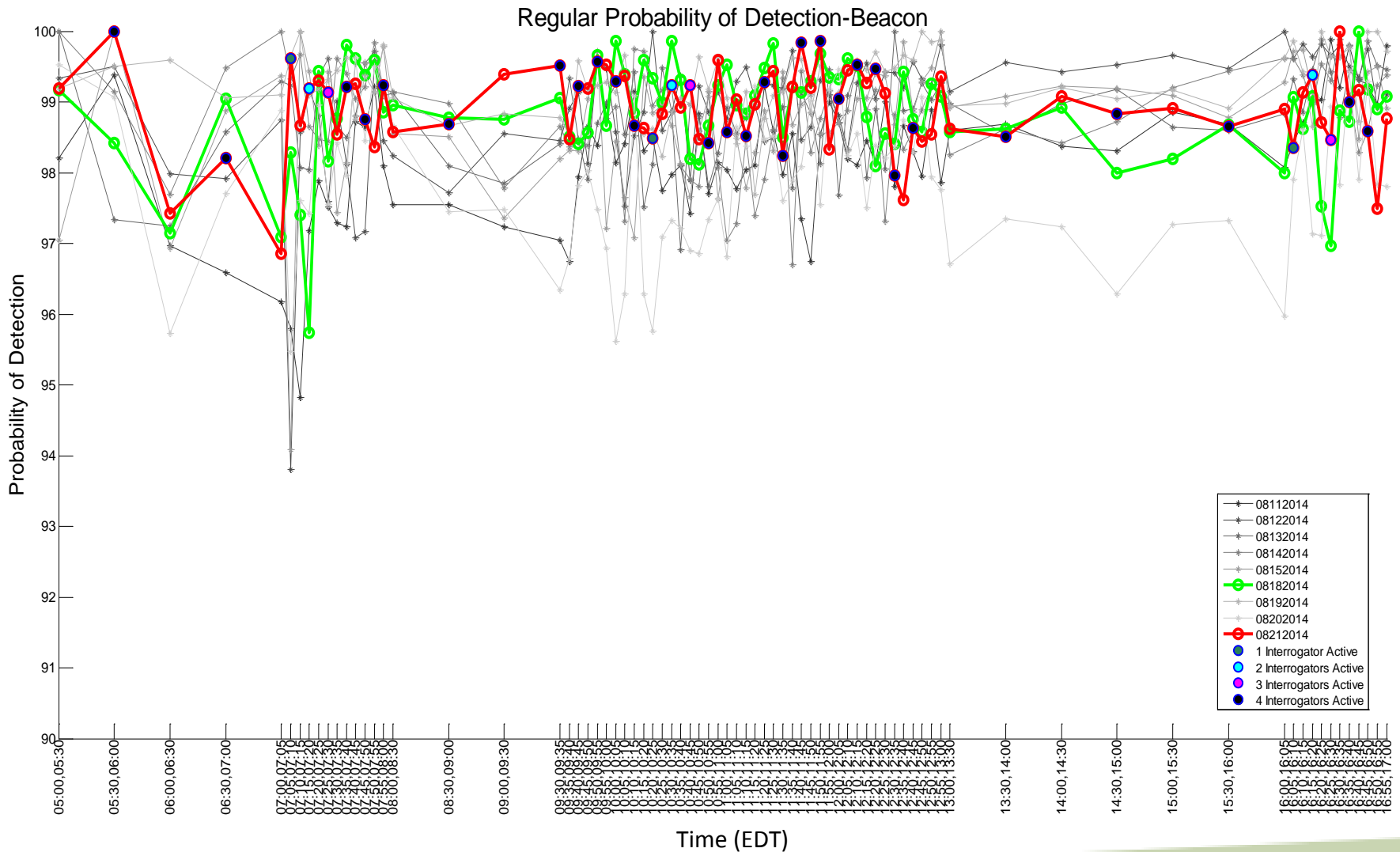
# Probability of Detection – August 20<sup>th</sup>

Regular Probability of Detection-Beacon



Geographic Filter: Hotspot Region  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

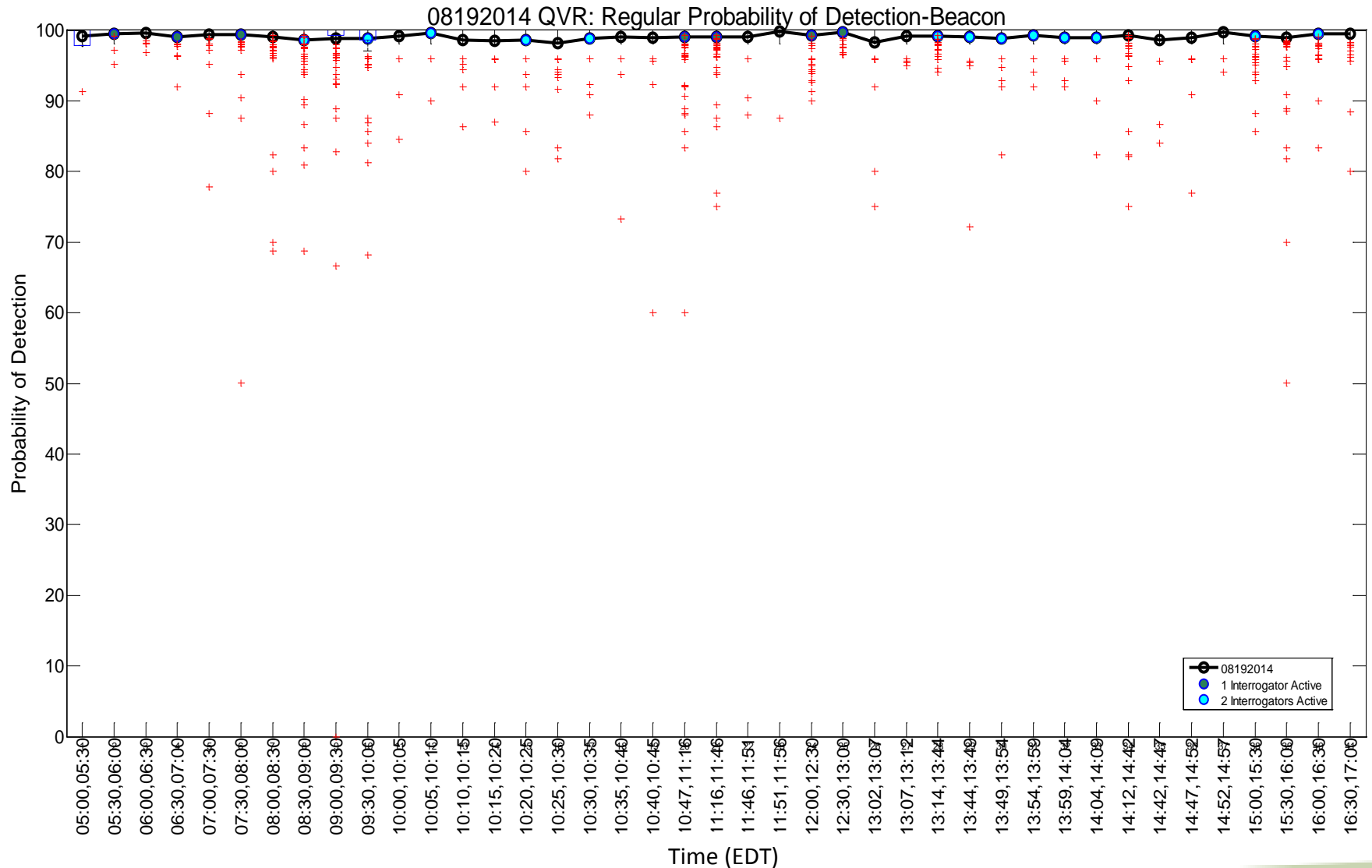


Geographic Filter: Hotspot Region  
 Target Filter: None



# Probability of Detection – August 19<sup>th</sup>

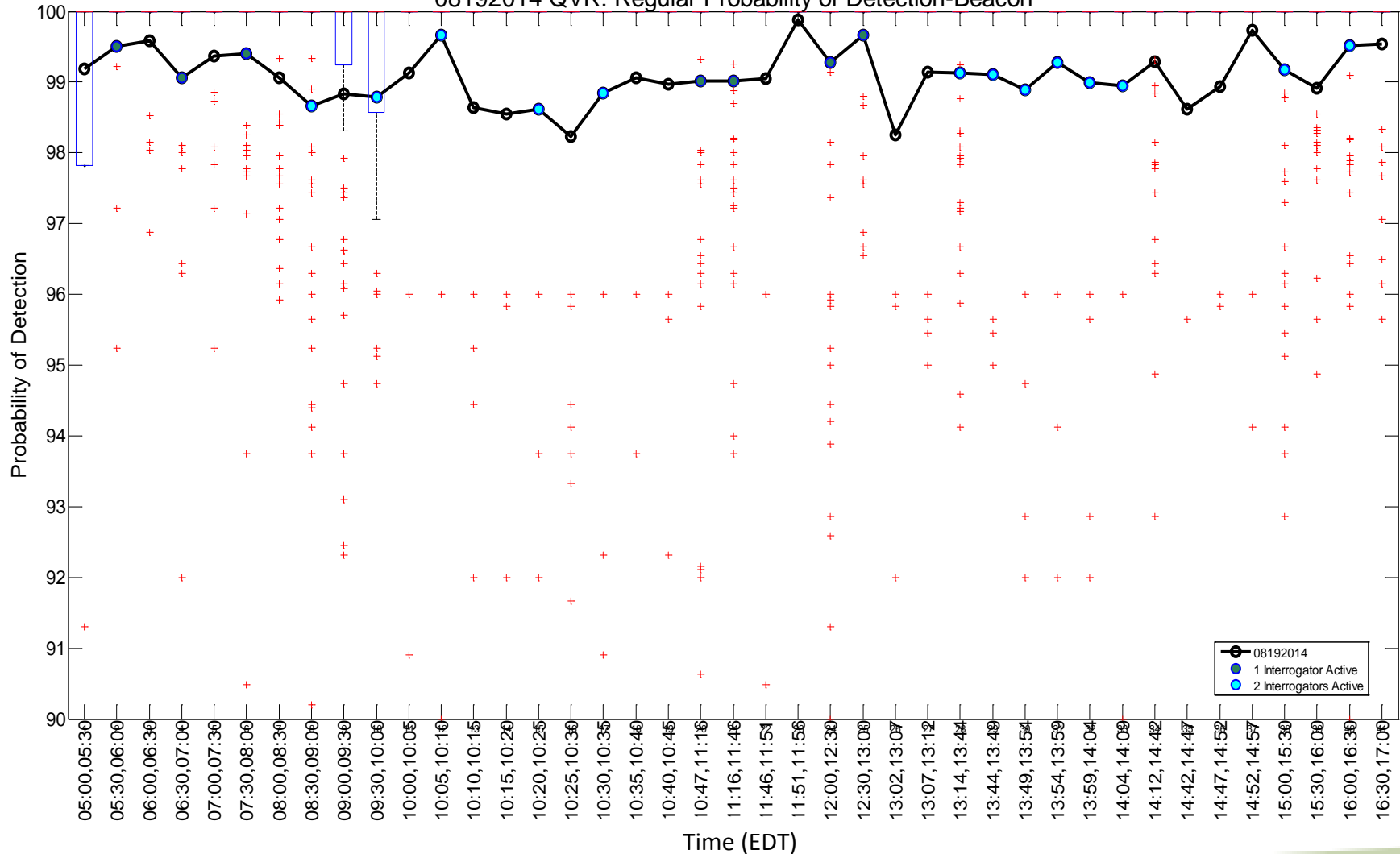
## Individual Aircraft Distribution



# Probability of Detection – August 19<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

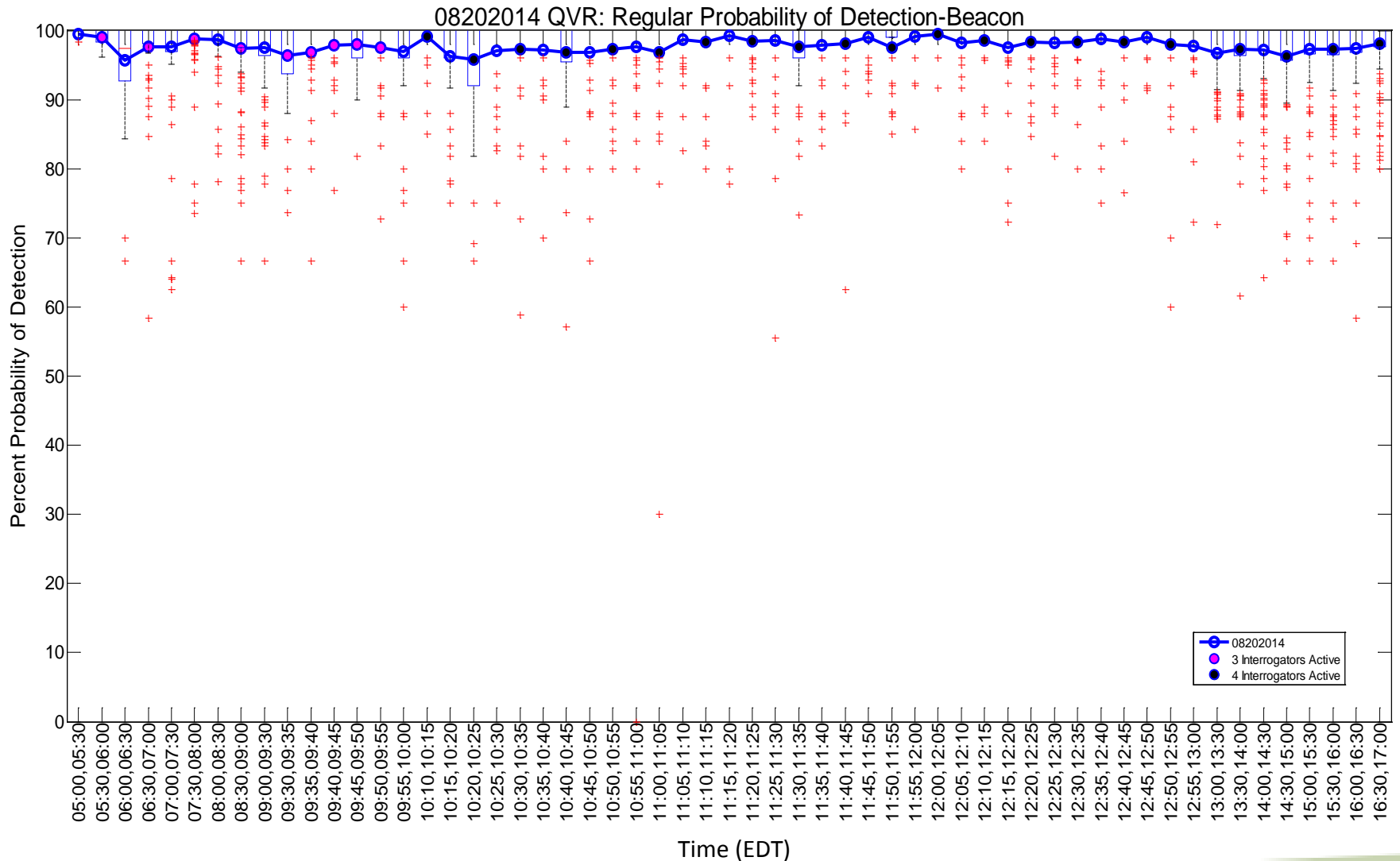
08192014 QVR: Regular Probability of Detection-Beacon



Geographic Filter: Hotspot Region  
Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution

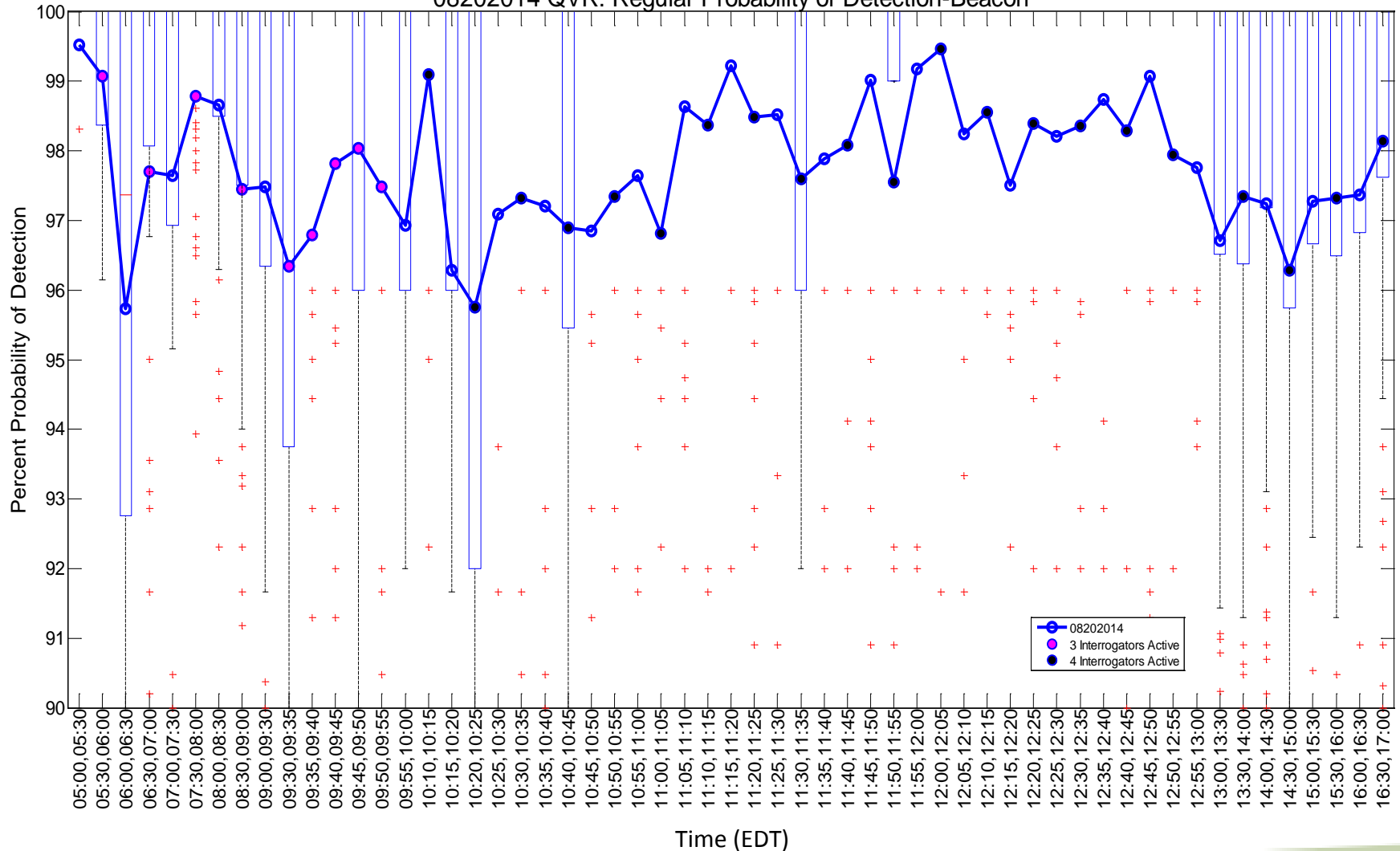


Geographic Filter: Hotspot Region  
 Target Filter: None

# Probability of Detection – August 20<sup>th</sup>

## Individual Aircraft Distribution (zoom-in)

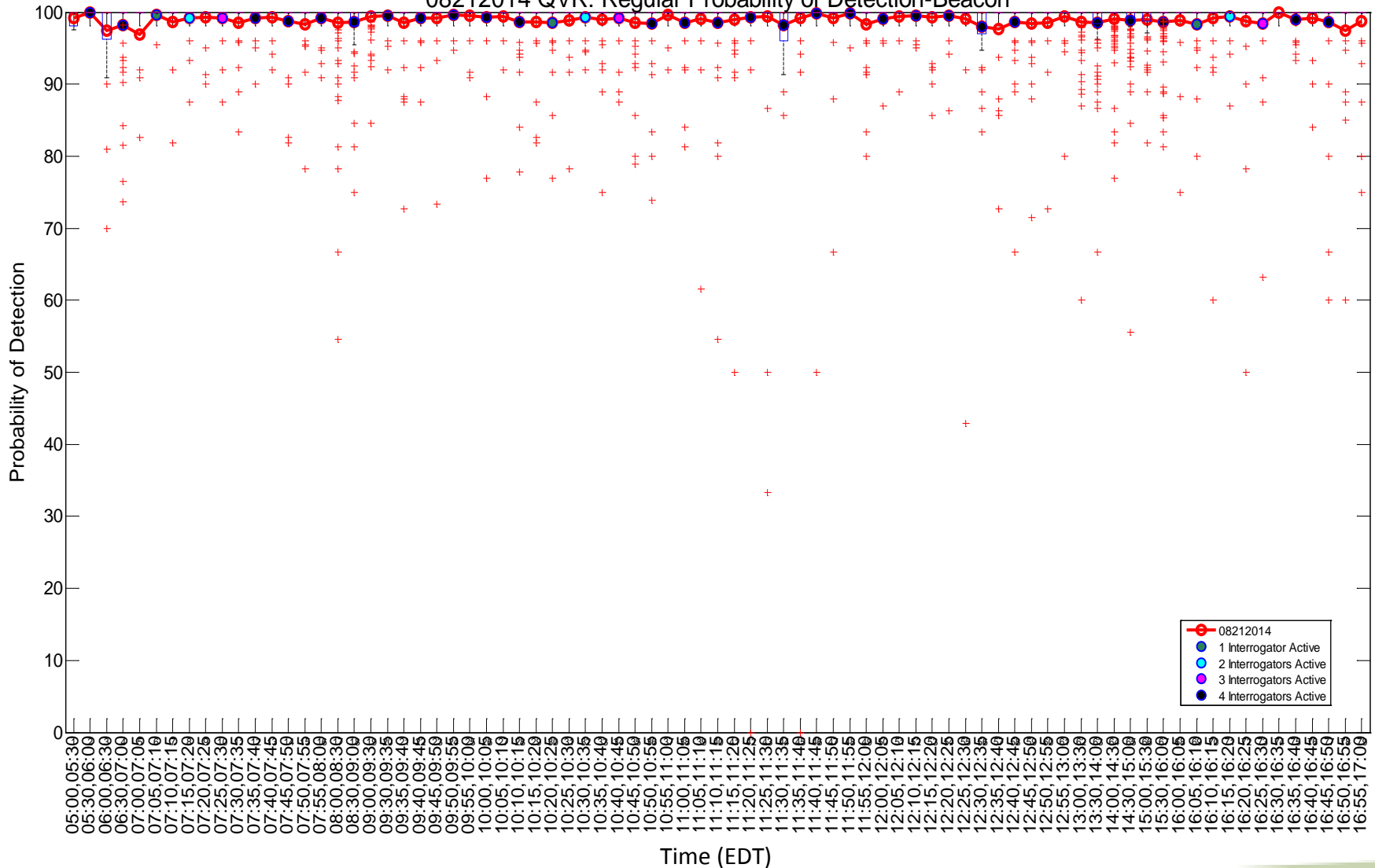
08202014 QVR: Regular Probability of Detection-Beacon



# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution

08212014 QVR: Regular Probability of Detection-Beacon

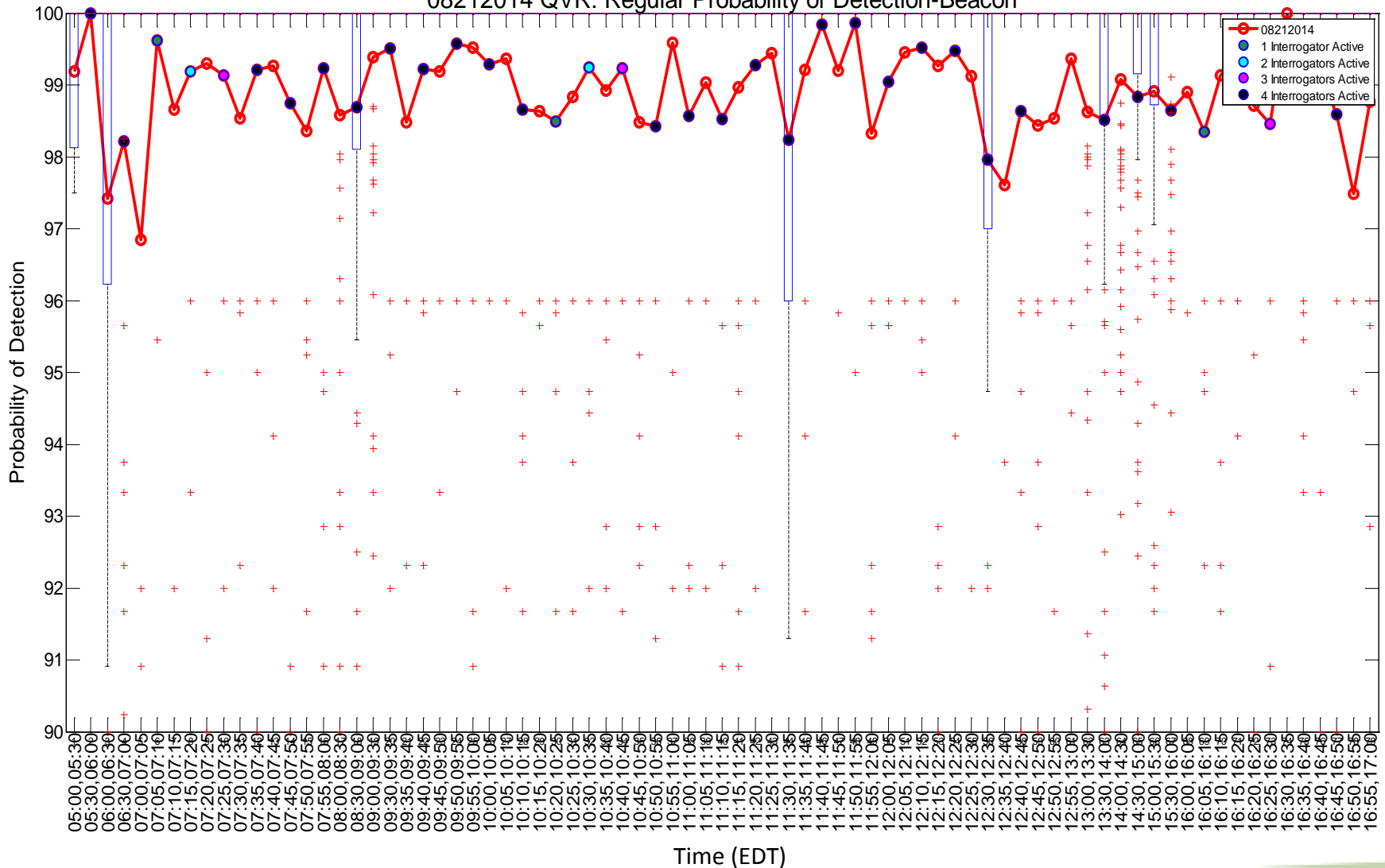


Geographic Filter: Hotspot Region  
Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

## Individual Aircraft Distribution (zoom-in)

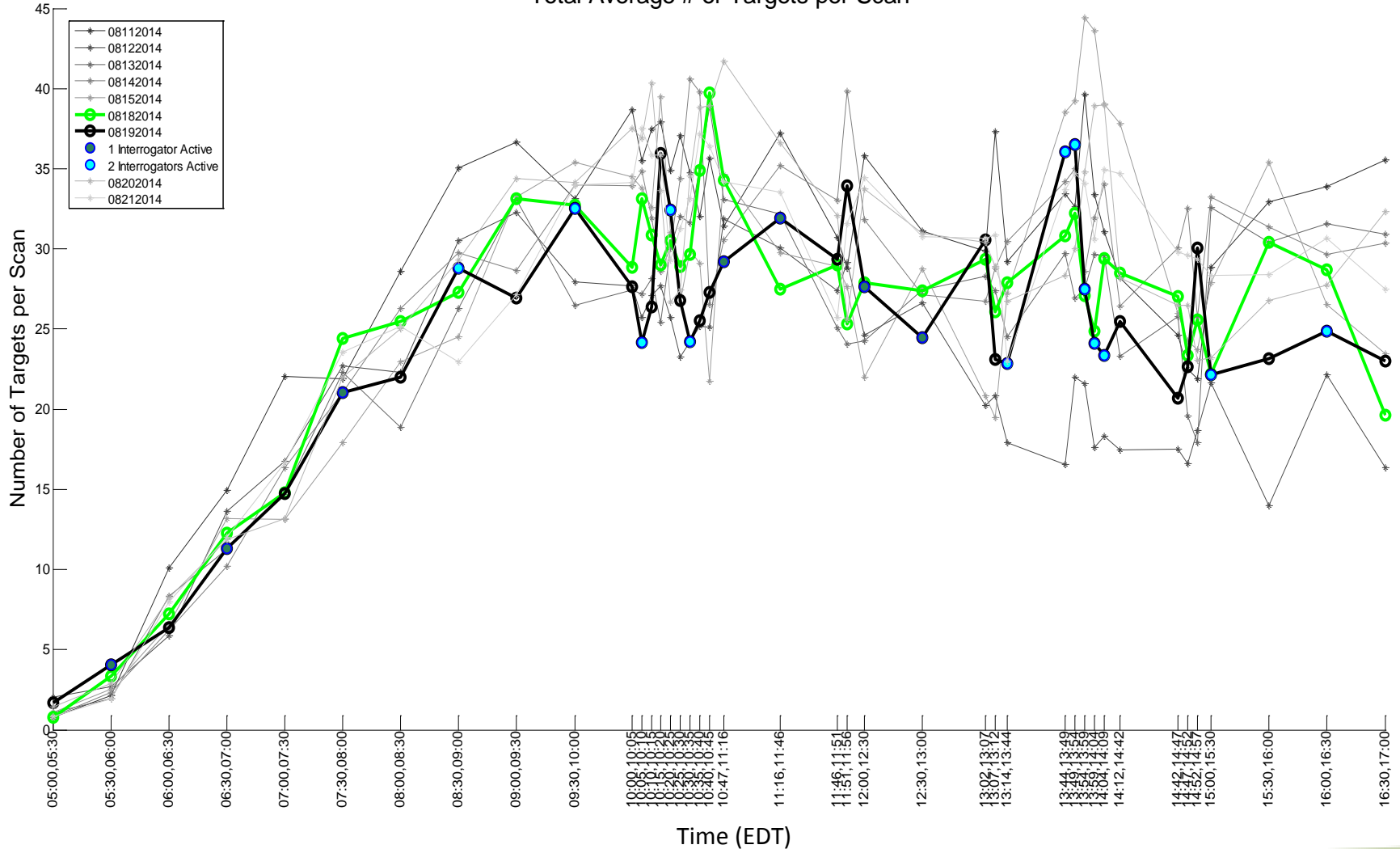
08212014 QVR: Regular Probability of Detection-Beacon



Geographic Filter: Hotspot Region  
Target Filter: None

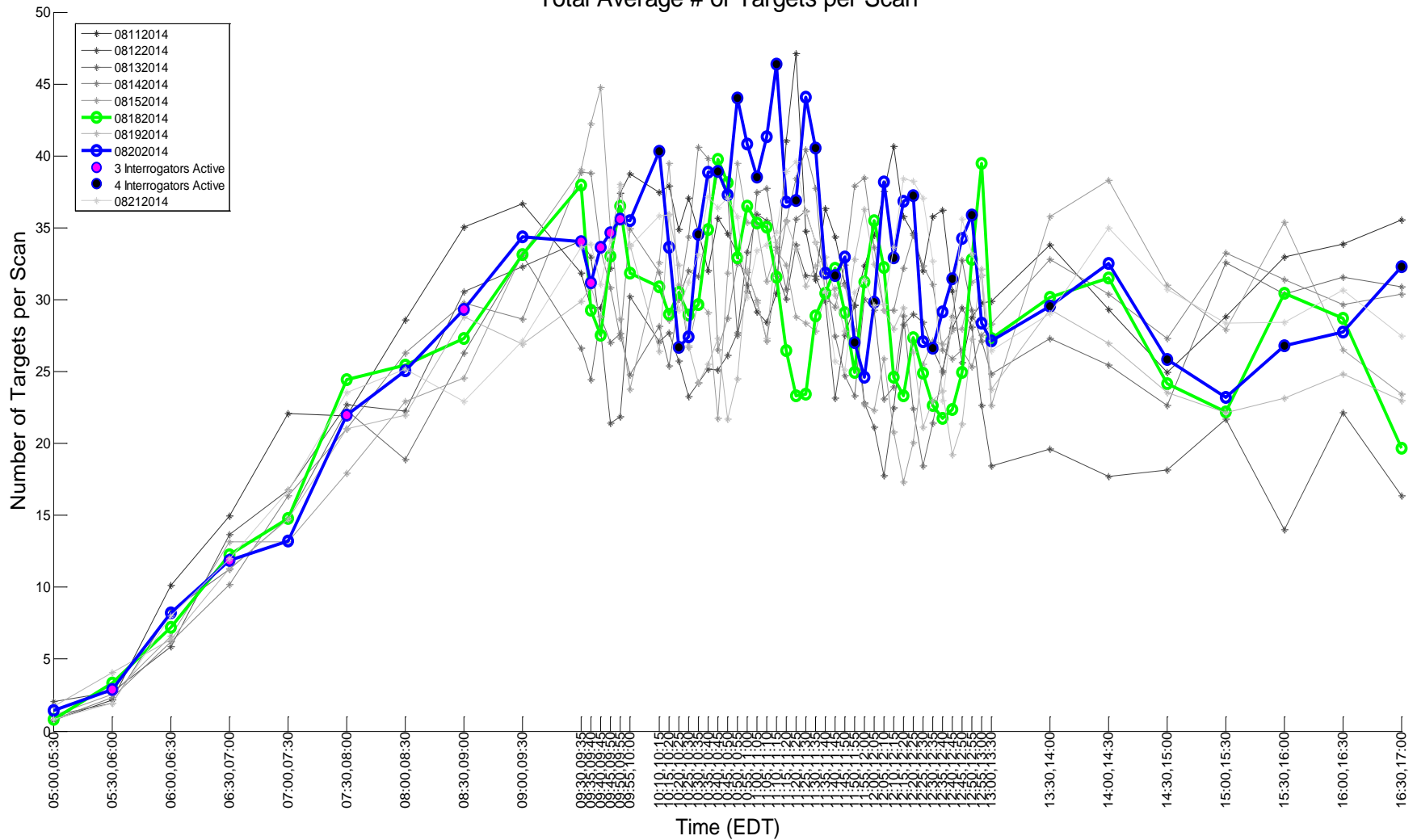
# Targets per Scan – August 19<sup>th</sup>

Total Average # of Targets per Scan



# Targets per Scan – August 20<sup>th</sup>

Total Average # of Targets per Scan

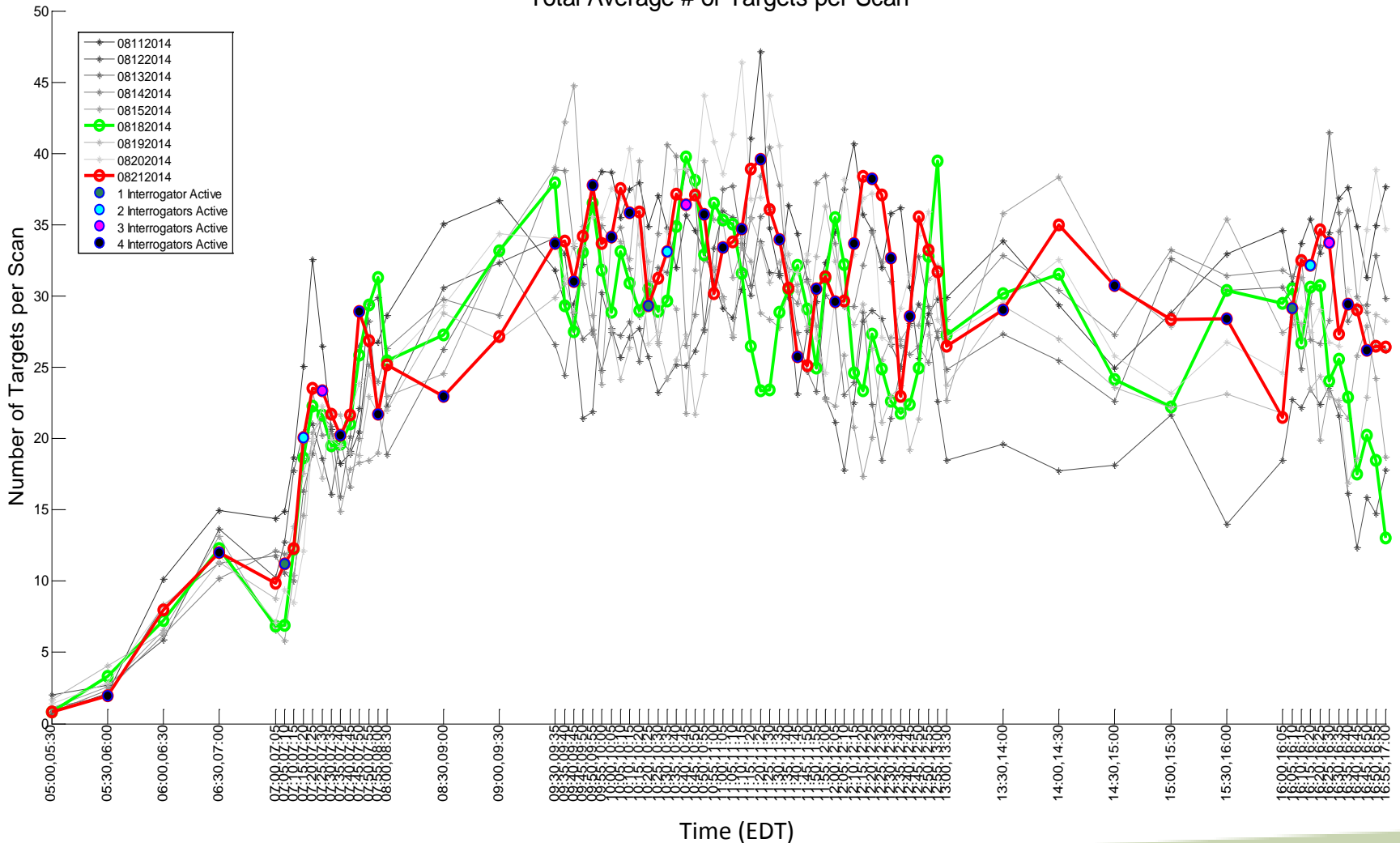


Geographic Filter: Hotspot Region  
Target Filter: None



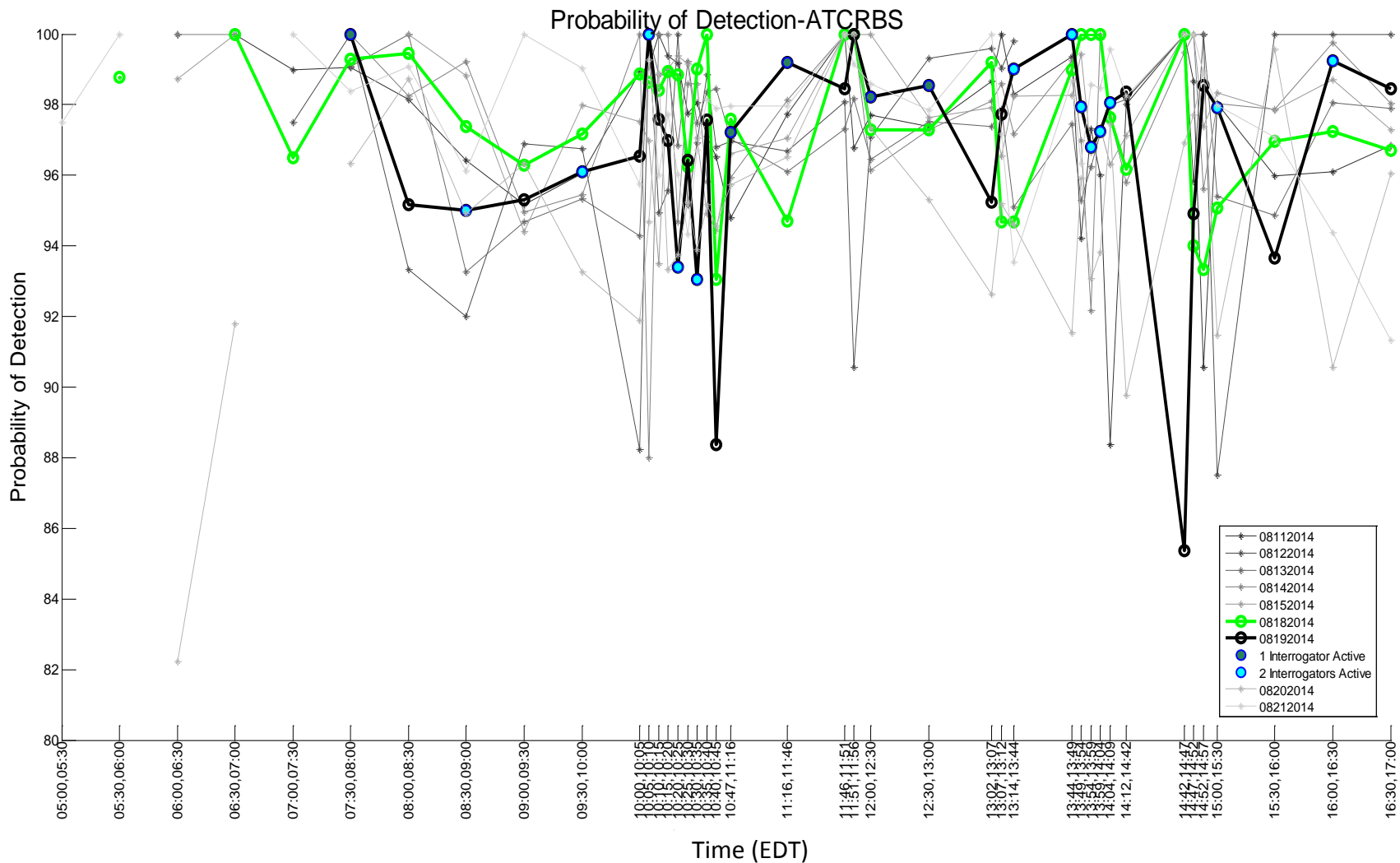
# Targets per Scan – August 21<sup>st</sup>

Total Average # of Targets per Scan



# Probability of Detection – August 19<sup>th</sup>

## ATCRBS Targets - Discrete

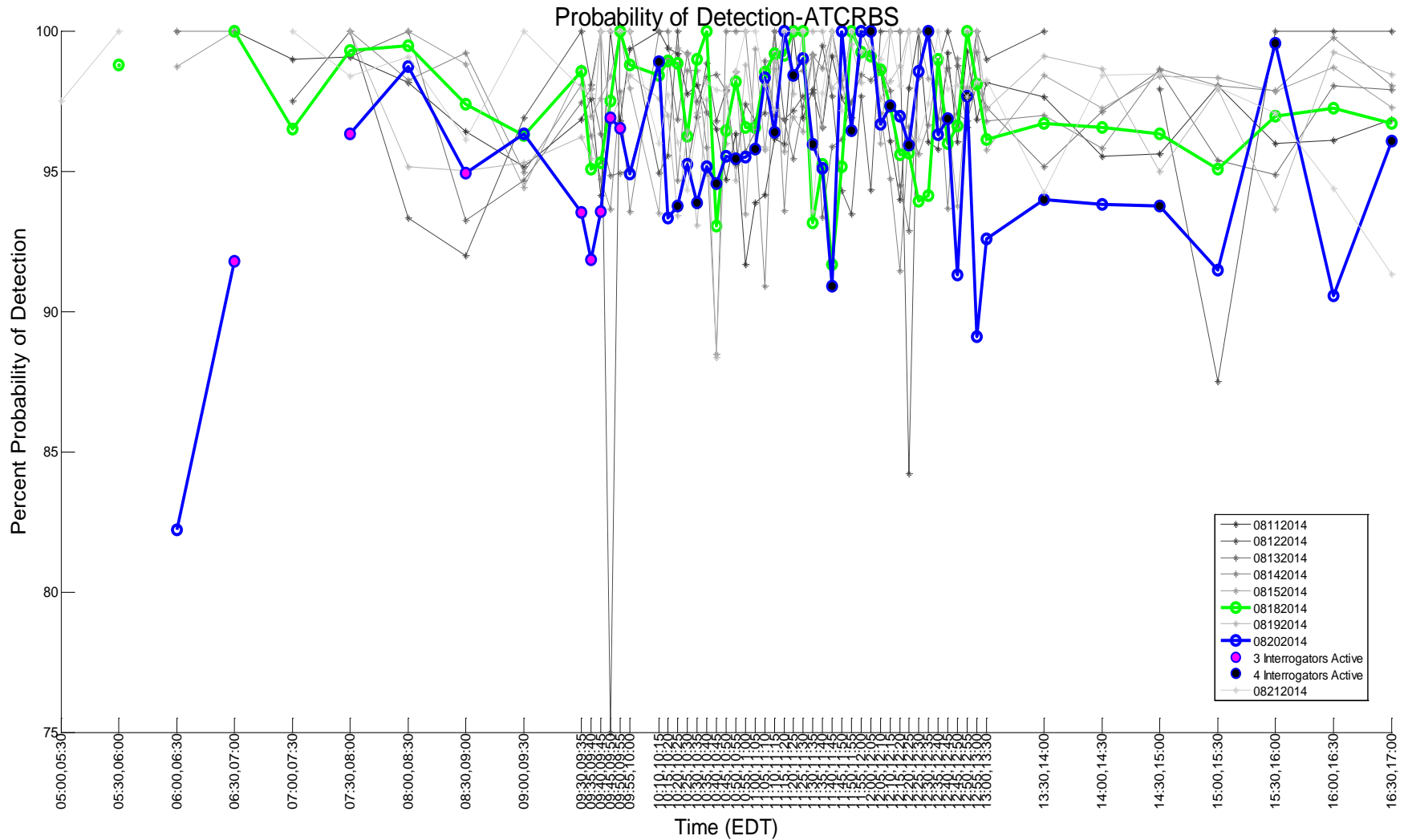


Geographic Filter: Hotspot Region  
 Target Filter: None



# Probability of Detection – August 20<sup>th</sup>

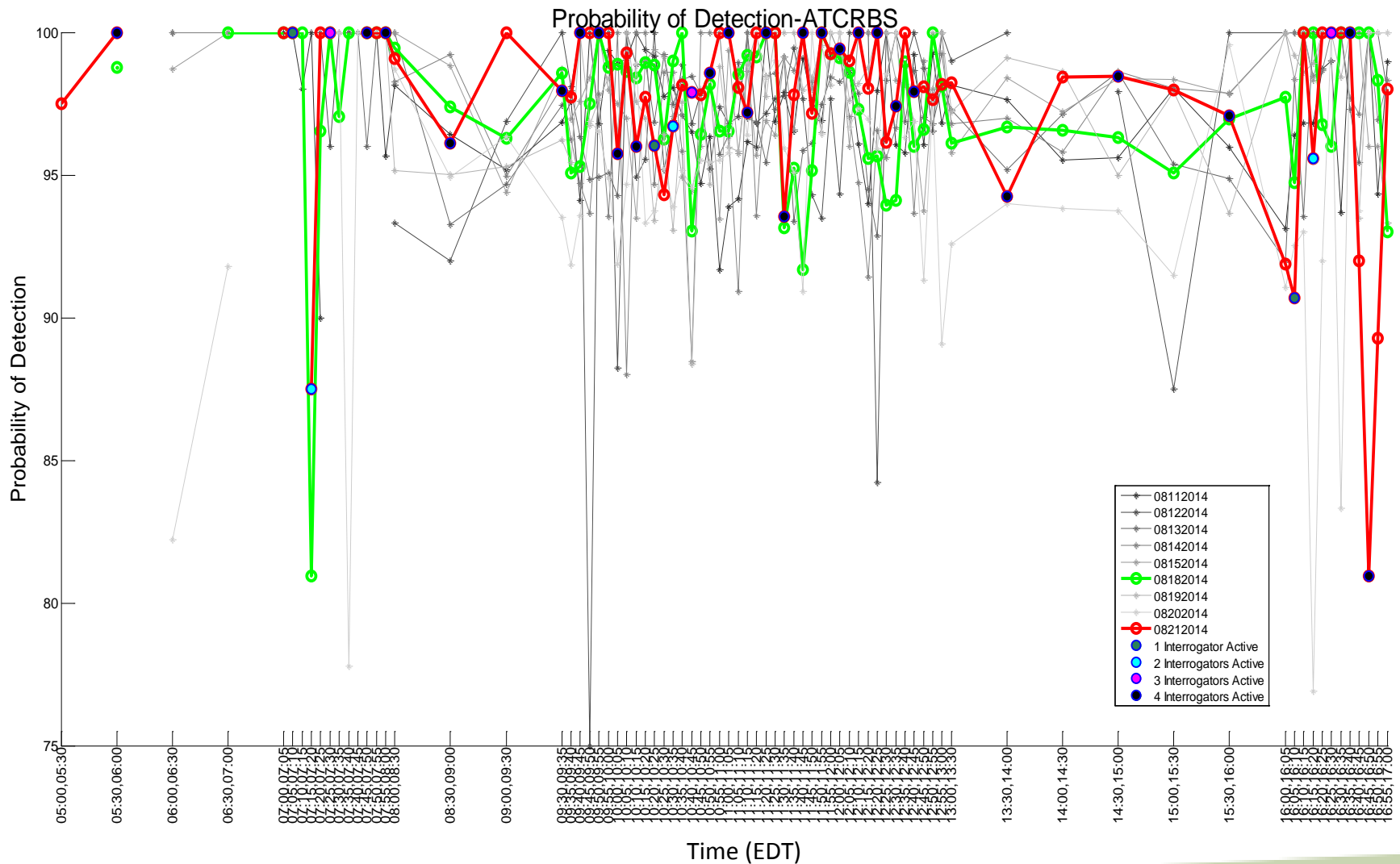
## ATCRBS Targets - Discrete



Geographic Filter: Hotspot Region  
 Target Filter: None

# Probability of Detection – August 21<sup>st</sup>

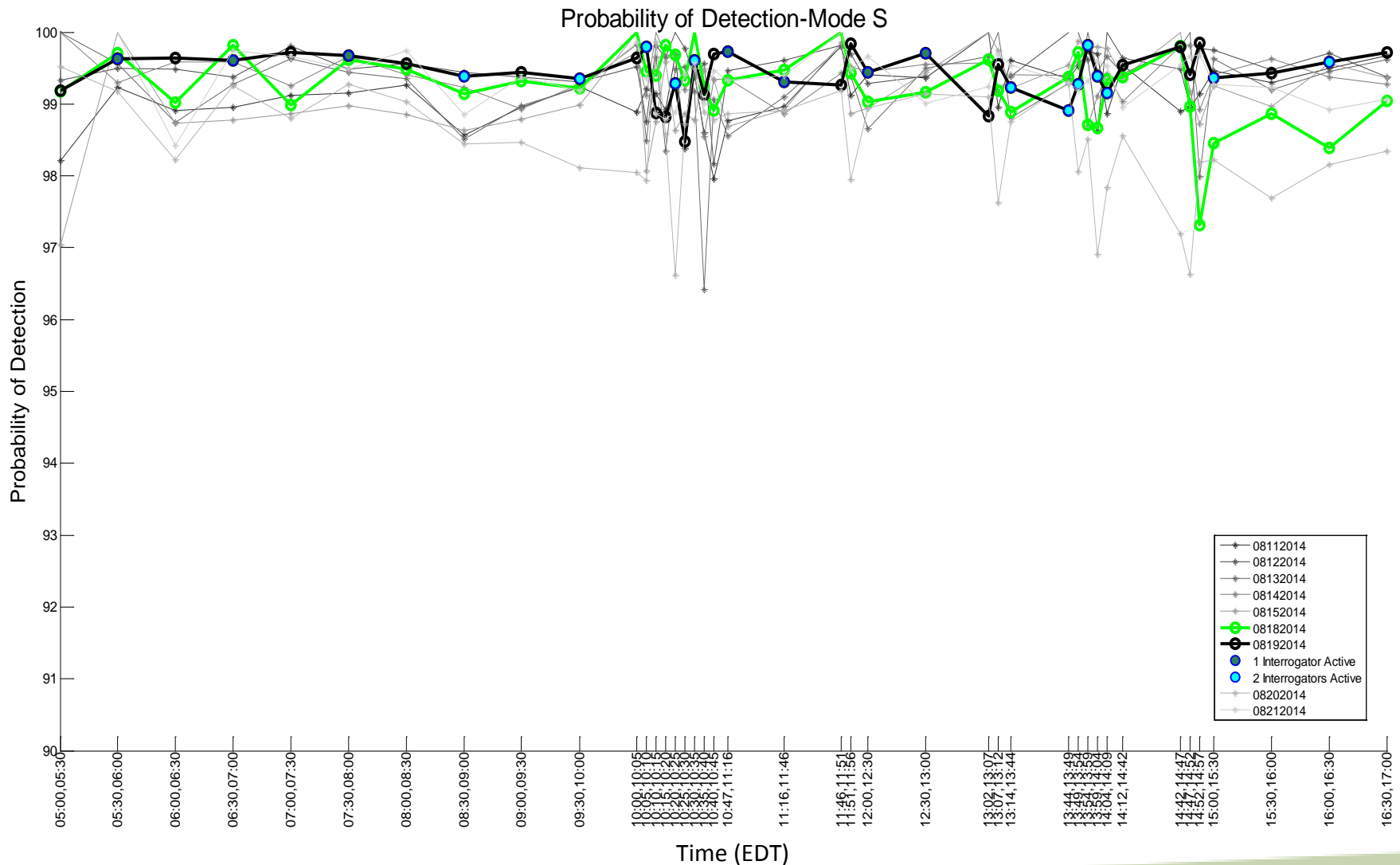
## ATCRBS Targets - Discrete



Geographic Filter: Hotspot Region  
 Target Filter: None

# Probability of Detection – August 19<sup>th</sup>

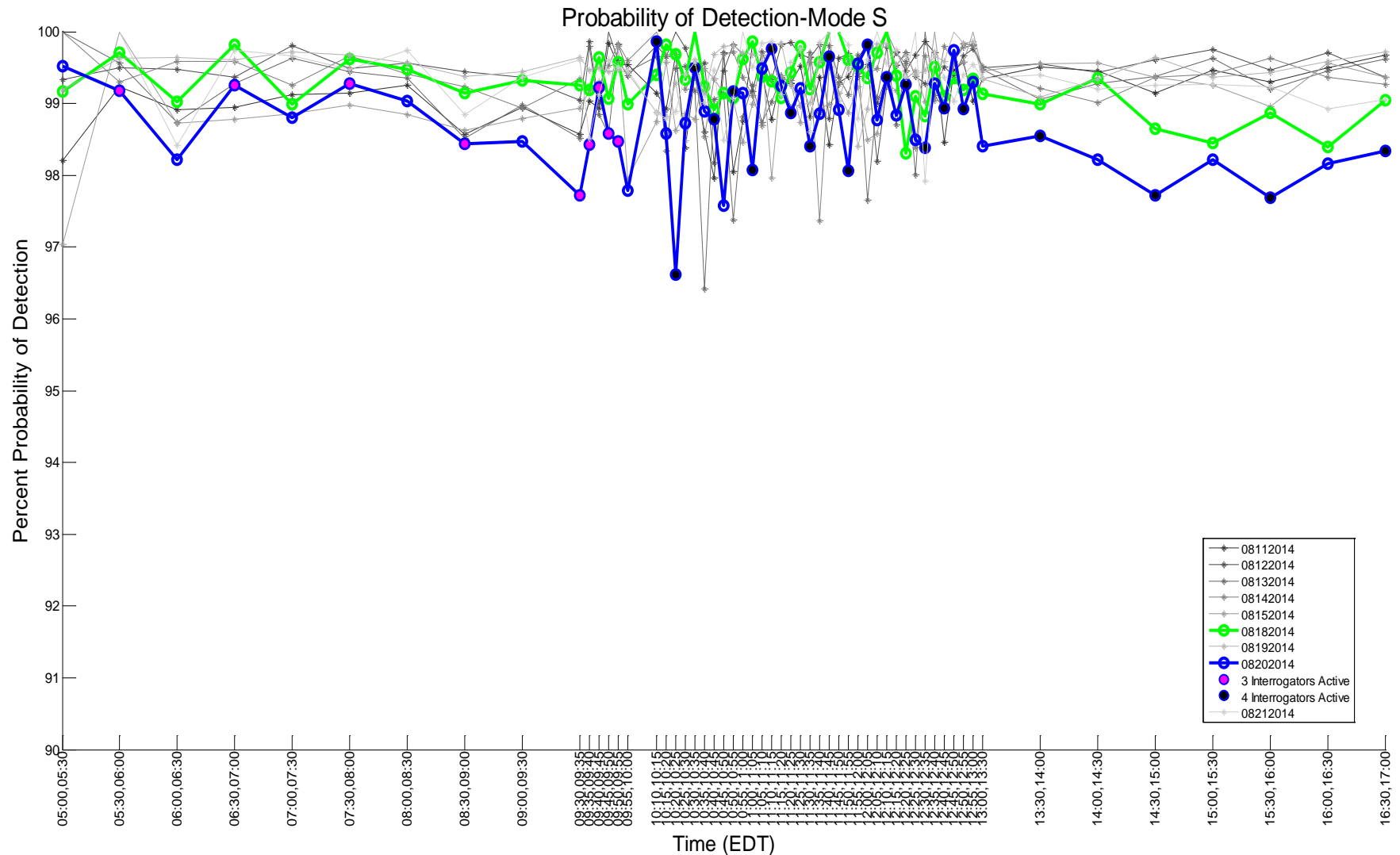
## Mode S Targets



Geographic Filter: Hotspot Region  
 Target Filter: None

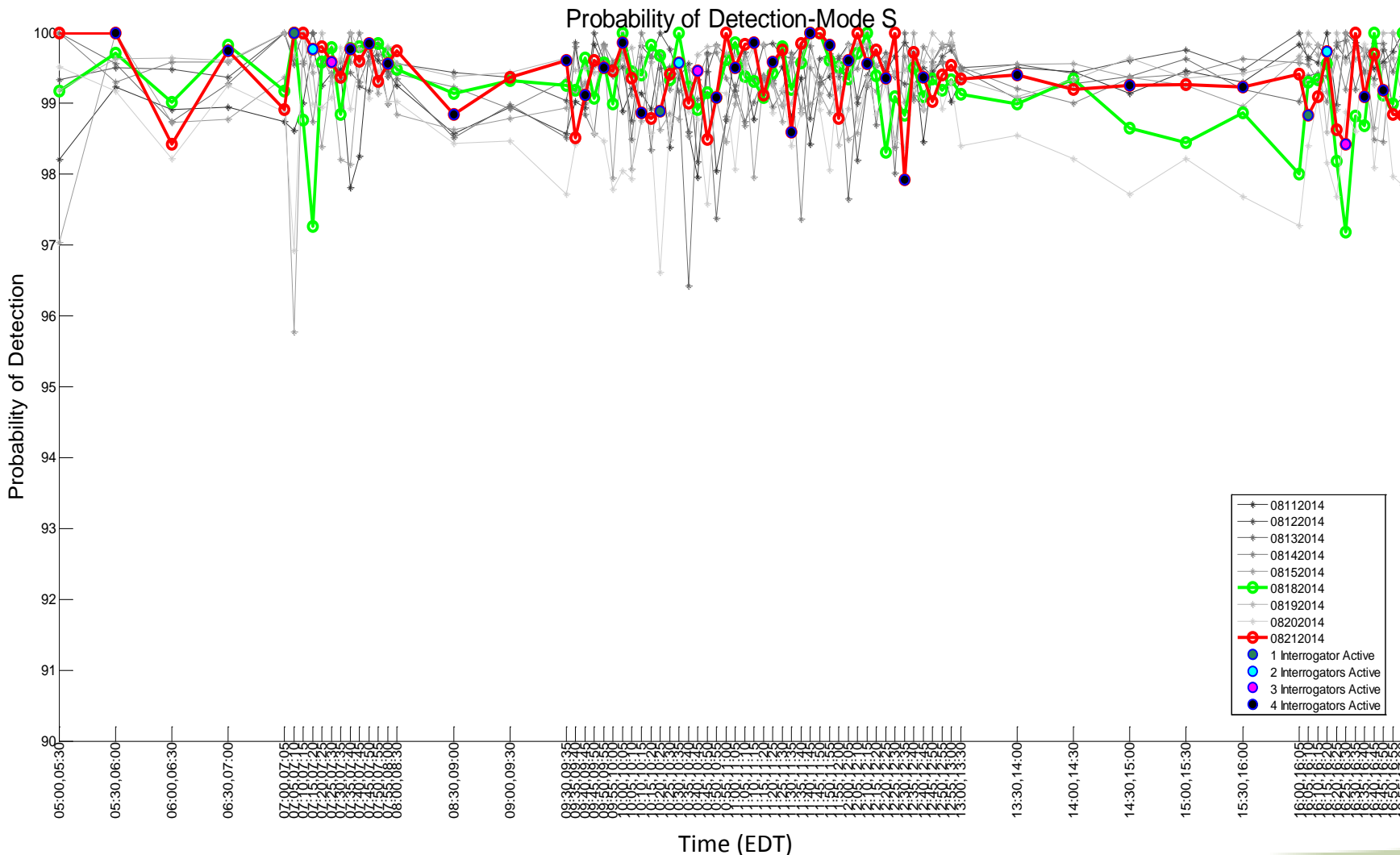
# Probability of Detection – August 20<sup>th</sup>

## Mode S Targets



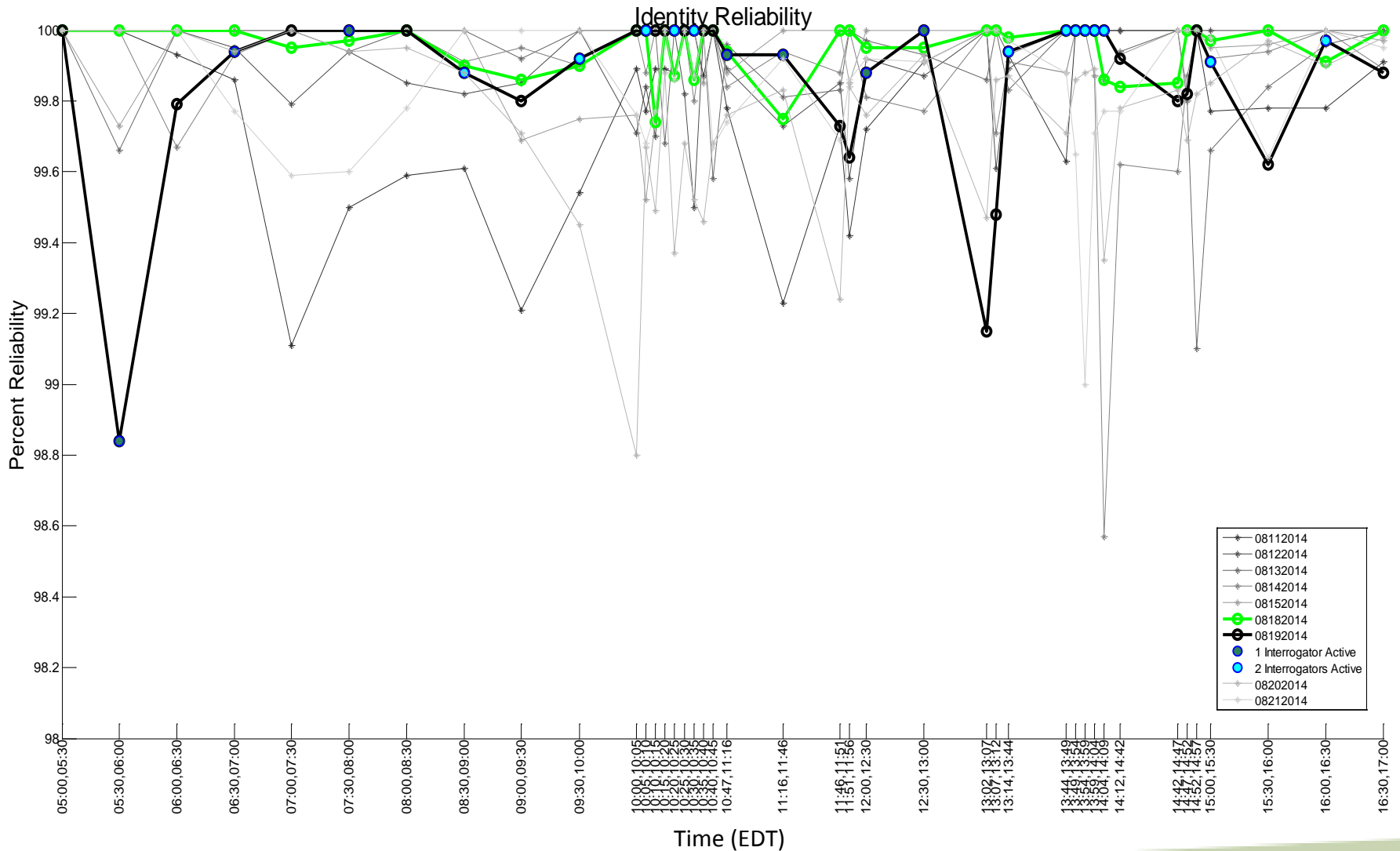
# Probability of Detection – August 21<sup>st</sup>

## Mode S Targets



Geographic Filter: Hotspot Region  
Target Filter: None

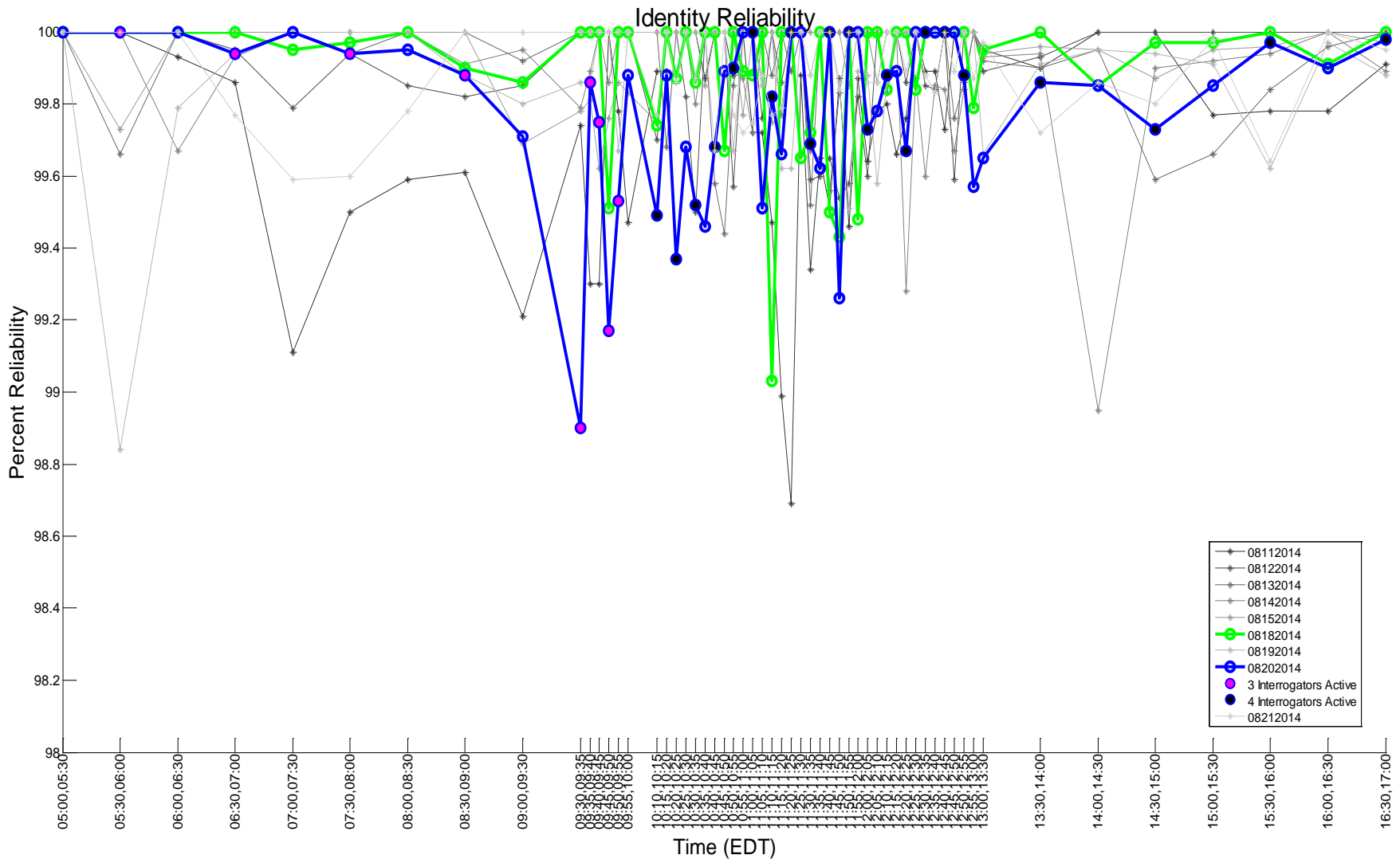
# Identity (3/A) Reliability – August 19<sup>th</sup>



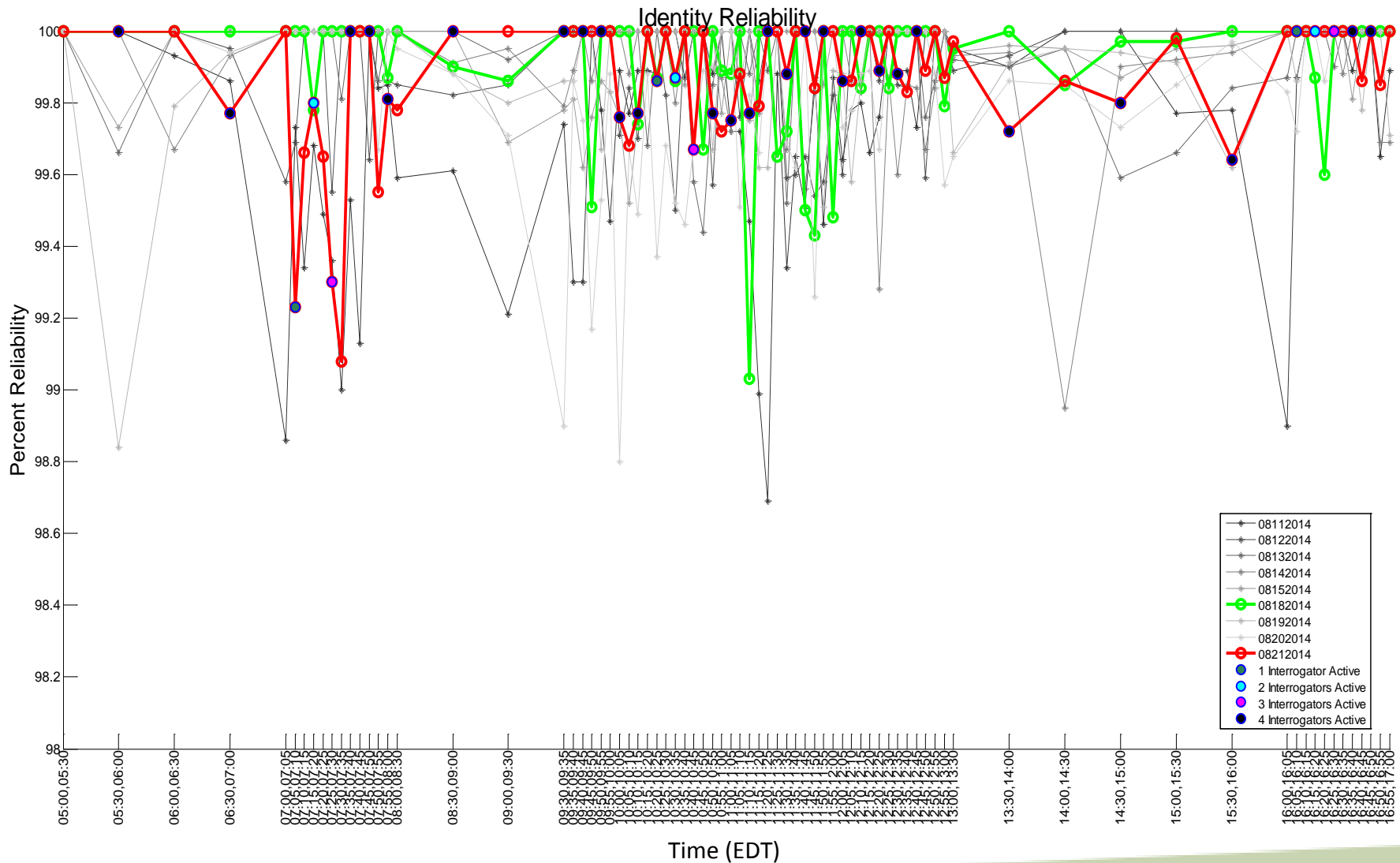
Geographic Filter: Hotspot Region  
Target Filter: None



# Identity (3/A) Reliability – August 20<sup>th</sup>

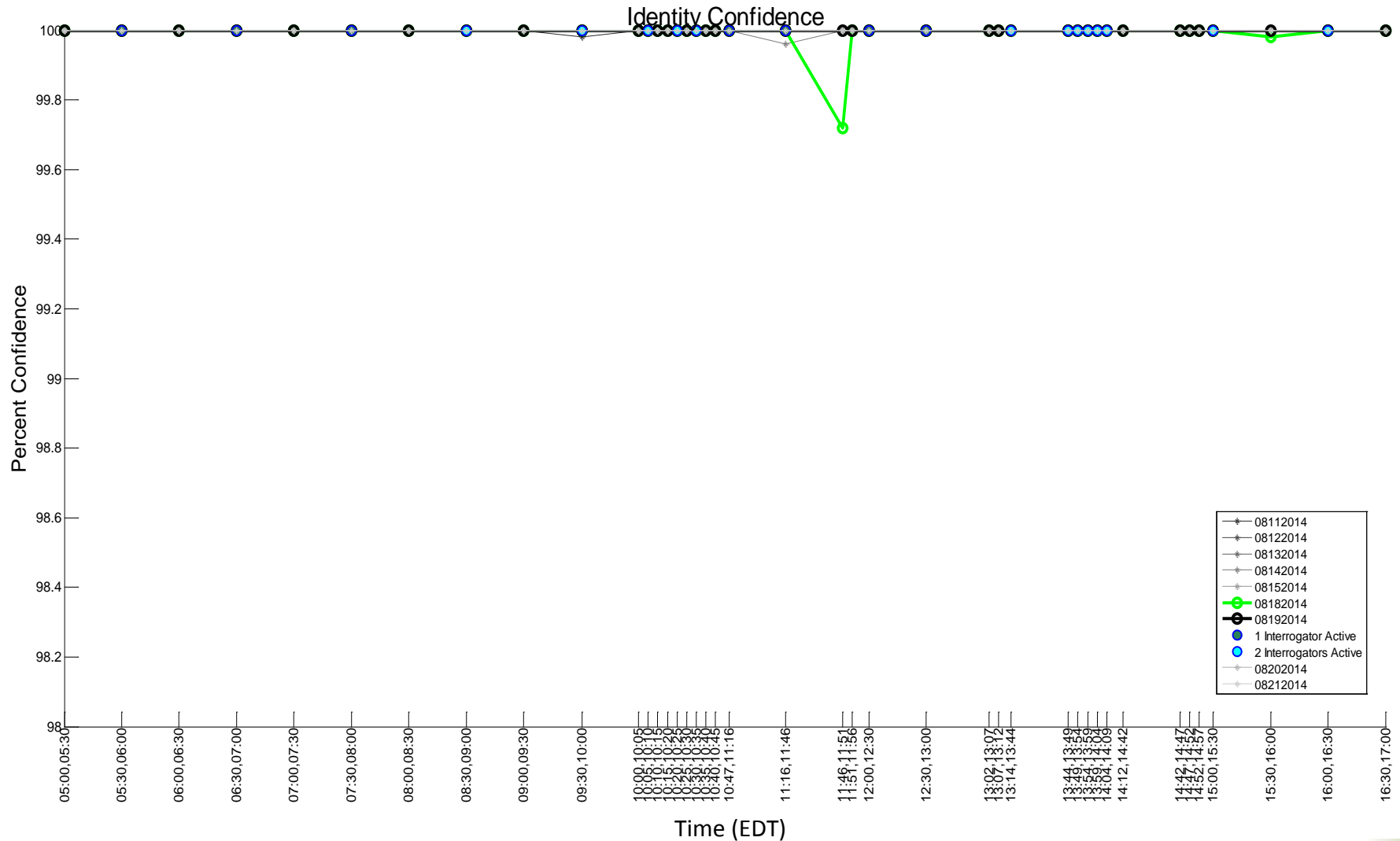


# Identity (3/A) Reliability – August 21<sup>st</sup>

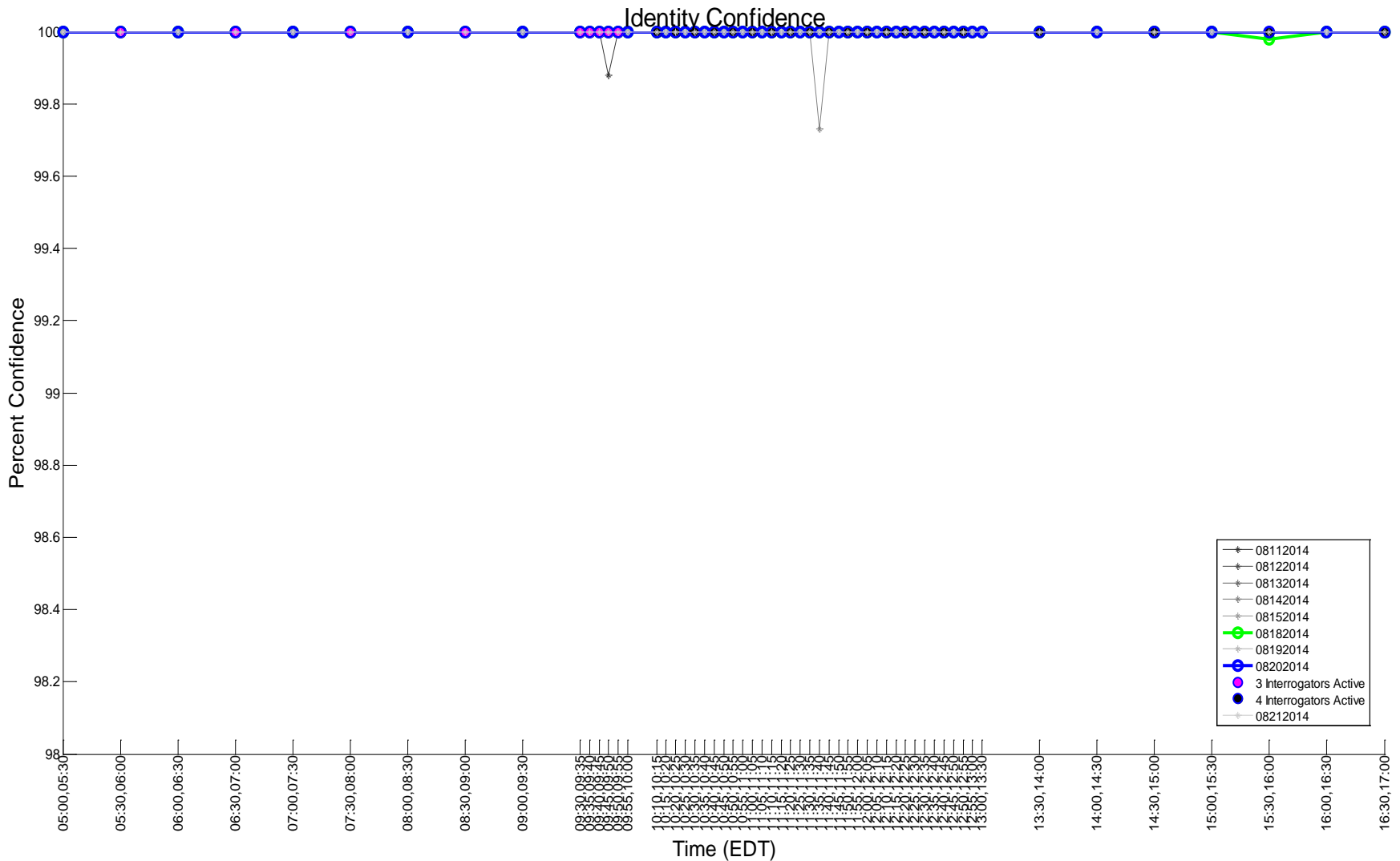


Geographic Filter: Hotspot Region  
Target Filter: None

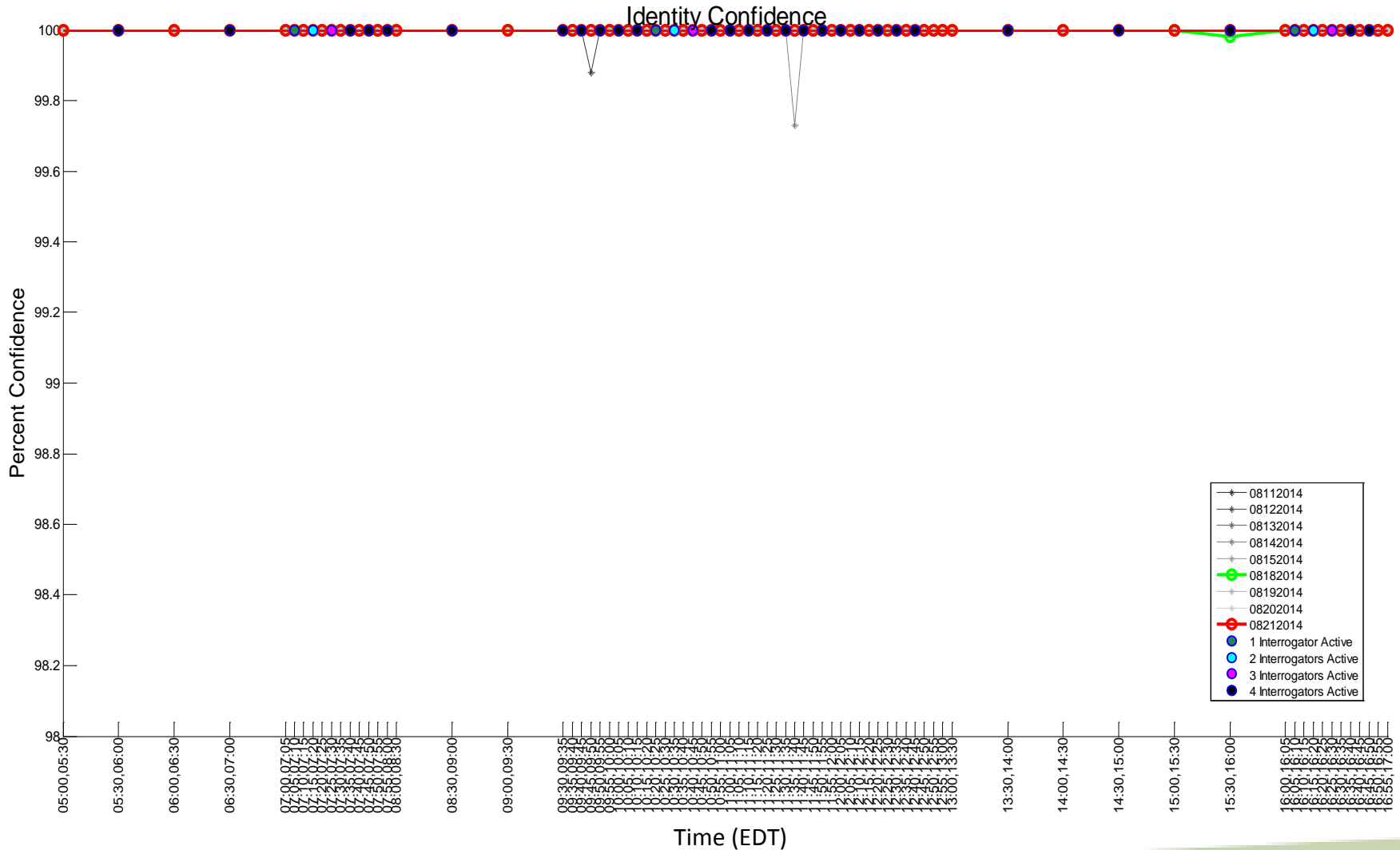
# Identity (3/A) Confidence – August 19<sup>th</sup>



# Identity (3/A) Confidence – August 20<sup>th</sup>

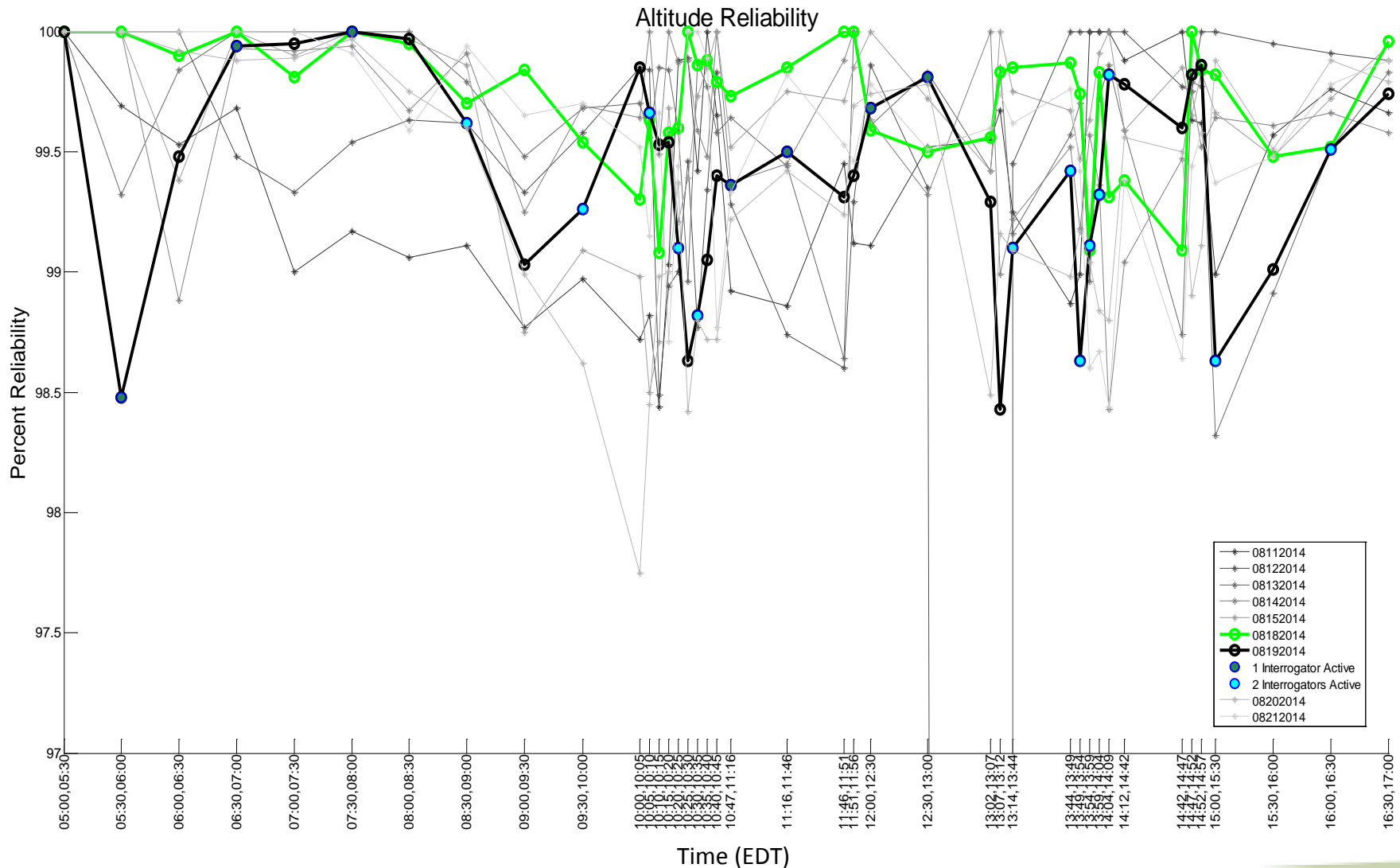


# Identity (3/A) Confidence – August 21<sup>st</sup>



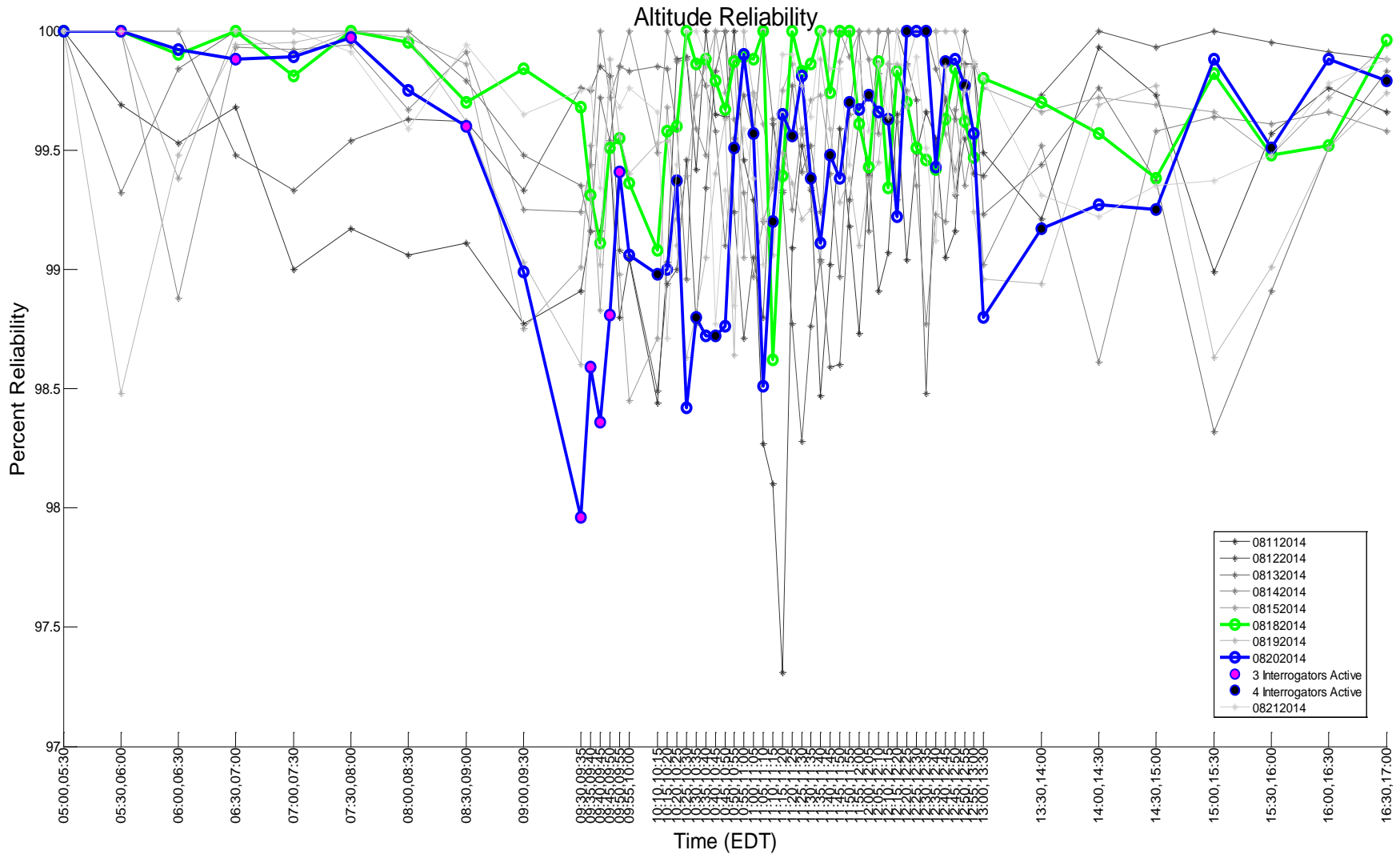
Geographic Filter: Hotspot Region  
Target Filter: None

# Altitude (C) Reliability – August 19<sup>th</sup>



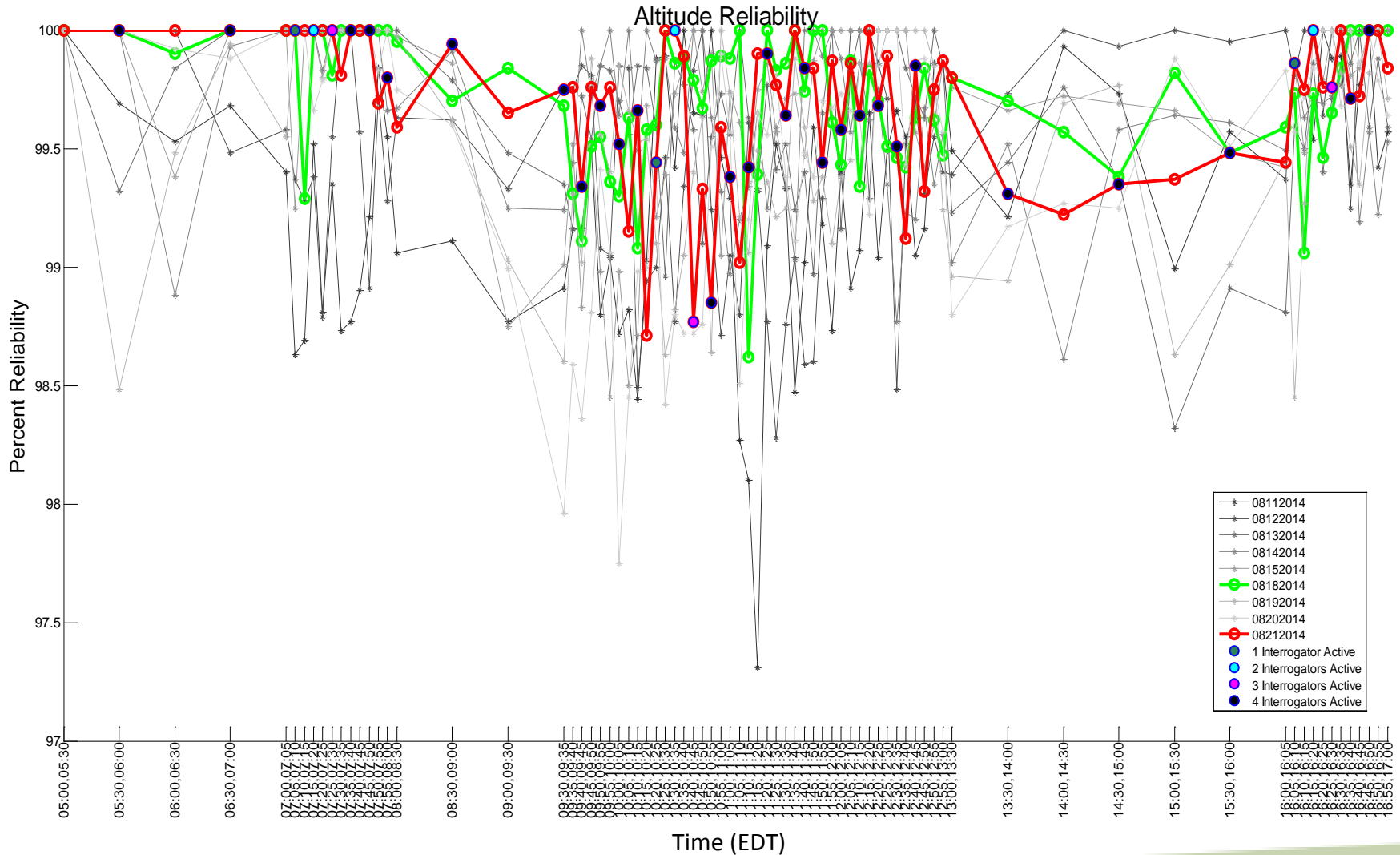
Geographic Filter: Hotspot Region  
 Target Filter: None

# Altitude (C) Reliability – August 20<sup>th</sup>



Geographic Filter: Hotspot Region  
 Target Filter: None

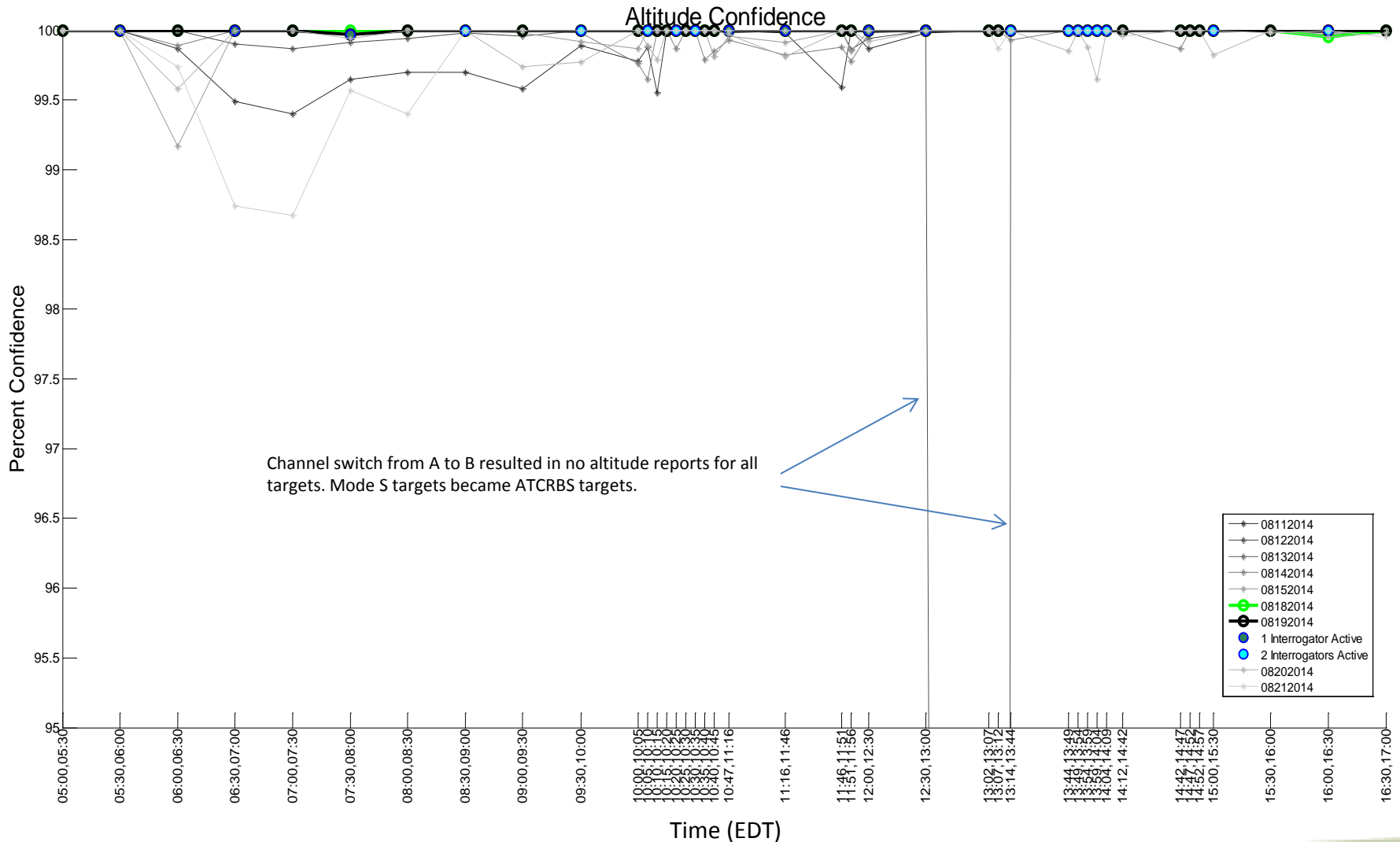
# Altitude (C) Reliability – August 21<sup>st</sup>



Geographic Filter: Hotspot Region  
Target Filter: None

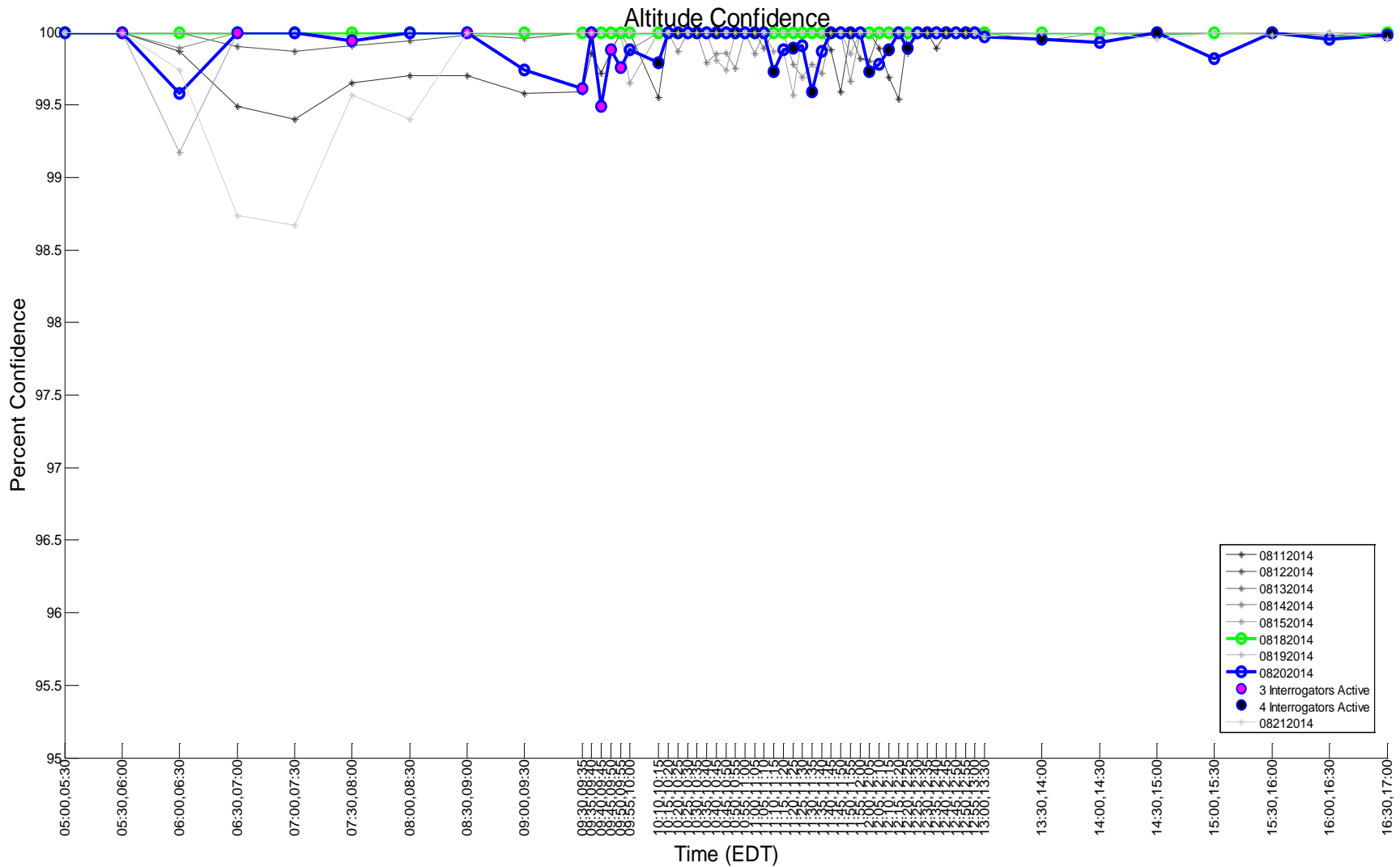


# Altitude (C) Confidence – August 19<sup>th</sup>

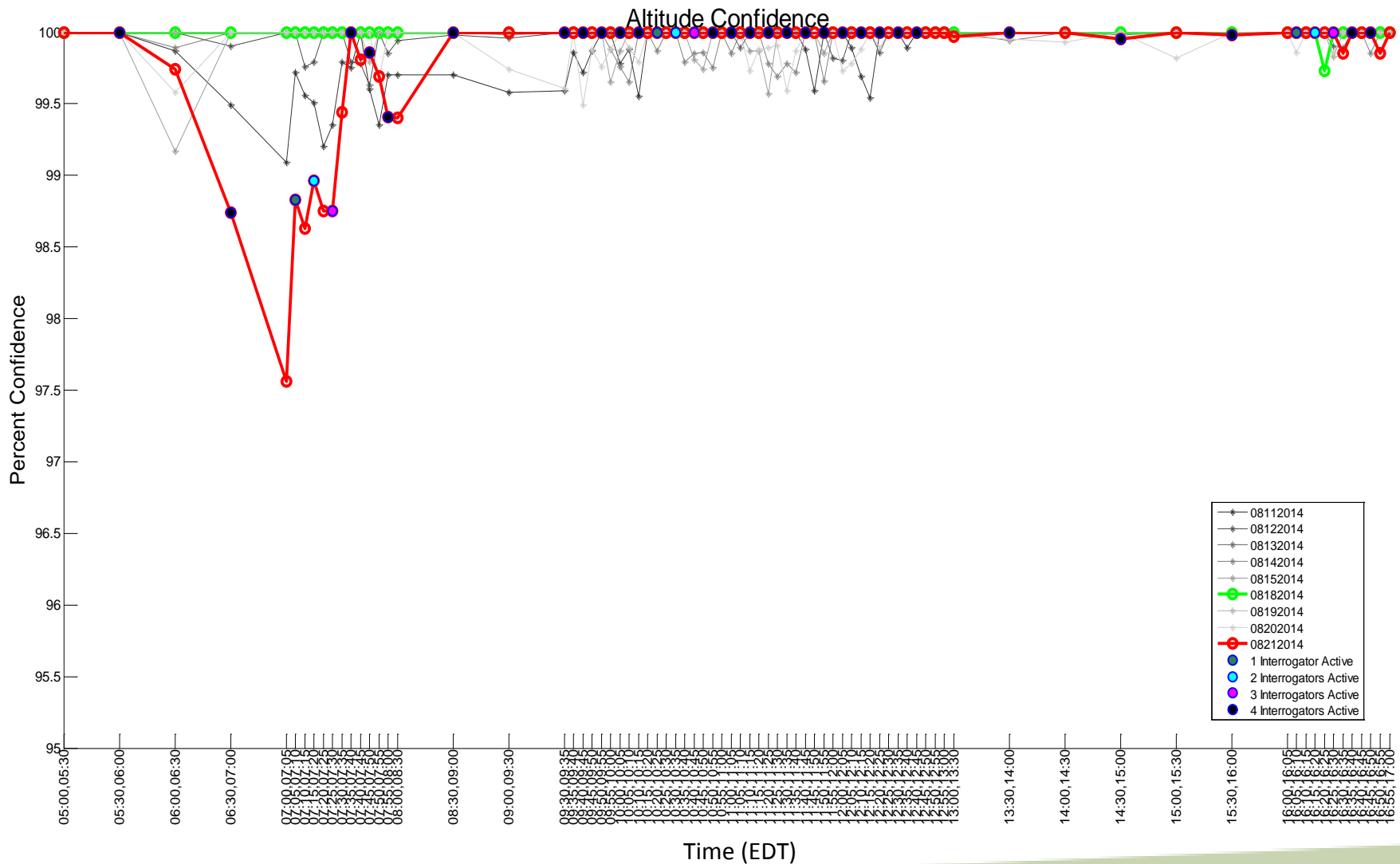


Geographic Filter: Hotspot Region  
Target Filter: None

# Altitude (C) Confidence – August 20<sup>th</sup>



# Altitude (C) Confidence – August 21<sup>st</sup>



Geographic Filter: Hotspot Region  
Target Filter: None