

National Aeronautics and Space Administration



# CHARACTERIZATION OF THE 2012-044C BRIZ-M UPPER STAGE BREAKUP

**Joe Hamilton - Presenter**

**Mark Matney, Ph.D. – Principle Author**

**Orbital Debris Program Office**

**NASA Johnson Space Center**

**UNCLASSIFIED**



## Breakup Background

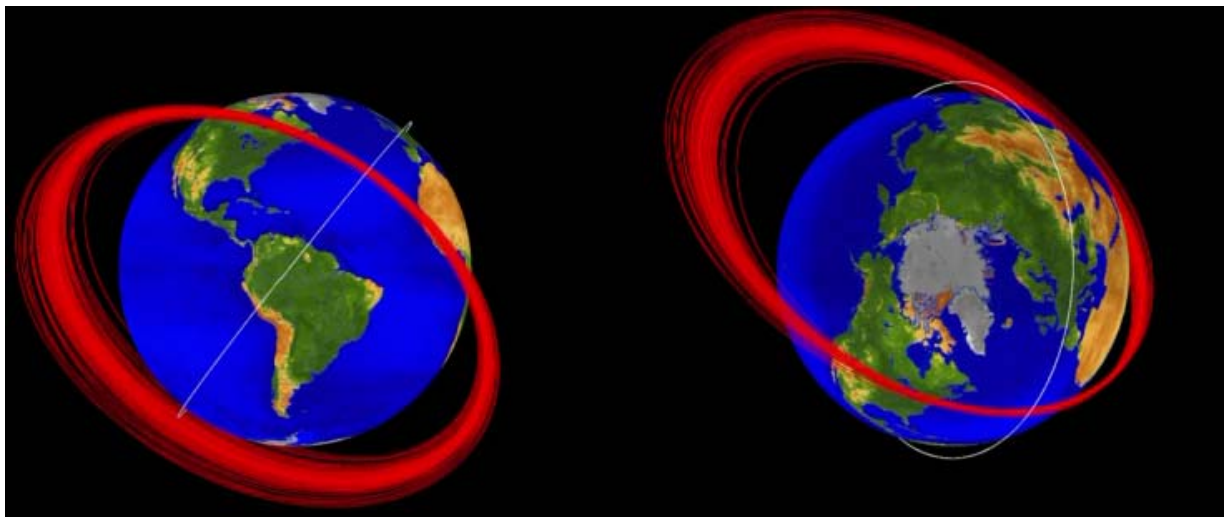
- **On 6 August, 2012, Russia launched two commercial satellites aboard a Proton rocket, and attempted to place them in geosynchronous orbit using a Briz-M upper stage (2012-044C, SSN 38746).**
- **The upper stage failed early in its burn and was left stranded in an elliptical orbit with a perigee in low Earth orbit (LEO).**
- **It broke up 16 October, creating a large cloud of debris with perigees below that of the International Space Station.**
- **The NASA Orbital Debris Program Office requested radar assets to characterize the extent of the debris cloud in sizes smaller than the standard debris tracked by the SSN.**





## Characterizing the Debris Cloud

- **The Space Surveillance Network (SSN) identifies the breakup and tracks the largest debris (> ~10 cm)**
- **NASA uses staring radars to statistically sample the smaller debris population**
  - **Lincoln Laboratory's HAX radar : > ~1 cm**
  - **Lincoln Laboratory's Haystack radar : > ~ 5 mm**
    - Not available due to upgrades
  - **NASA's Goldstone antenna : > ~ 2 mm**
    - Limited availability due to use by Deep Space Network
    - Was unable to get low-altitude passes during available times





# NASA Breakup Model

- **In order to characterize an explosion, a breakup model needs to describe the initial cloud on the basis of:**
  - **Debris size distribution**
  - **Delta-velocity distribution**
  - **Ballistic coefficient distribution**
  - **Also would like to have information on shape and material type distribution, but these are much more difficult to obtain**
- **NASA Breakup Model**
  - **Based primarily upon empirical data**
    - Ground tests
    - Radar observations of on-orbit breakups
  - **Represents “typical” breakup**
    - Individual breakups can vary
    - Always in need of more data to validate/correct models



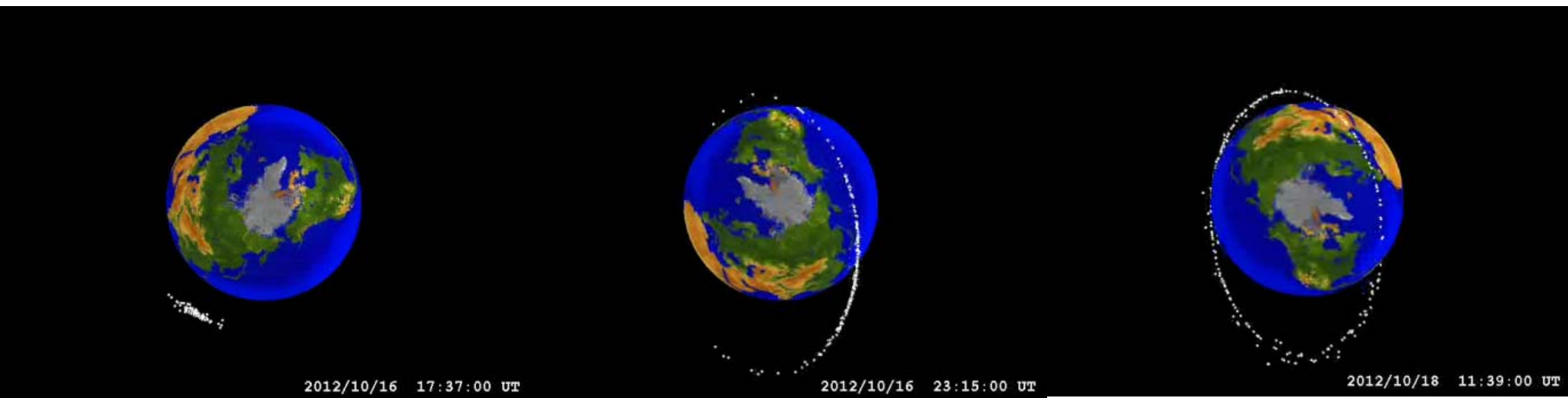
# NASA Breakup Model

- **NASA uses a Monte Carlo approach that generates a set of N “characteristic” fragments**
  - **Individual debris objects are “created” at known breakup time**
    - Delta-velocity added to state vector of parent at time of breakup (provided by SSN)
  - **Each orbit is propagated independently**
  - **If the model is accurate, the ensemble of debris should mimic the actual cloud**
- **Separate models for explosion and collision**
- **Can use the model in a “reference” mode – calculate what the model predicts and compare to actual data**



## Anatomy of a Breakup

- **There are three phases of a breakup cloud:**
  - The initial cloud, that is concentrated in space (Lasts hours to days)
  - The “ring” phase, where the debris mean anomalies are essentially randomized, but the cloud is still in an identifiable orbital plane (Lasts months to years)
  - The “background” phase, when the ascending nodes of the debris orbits become randomized

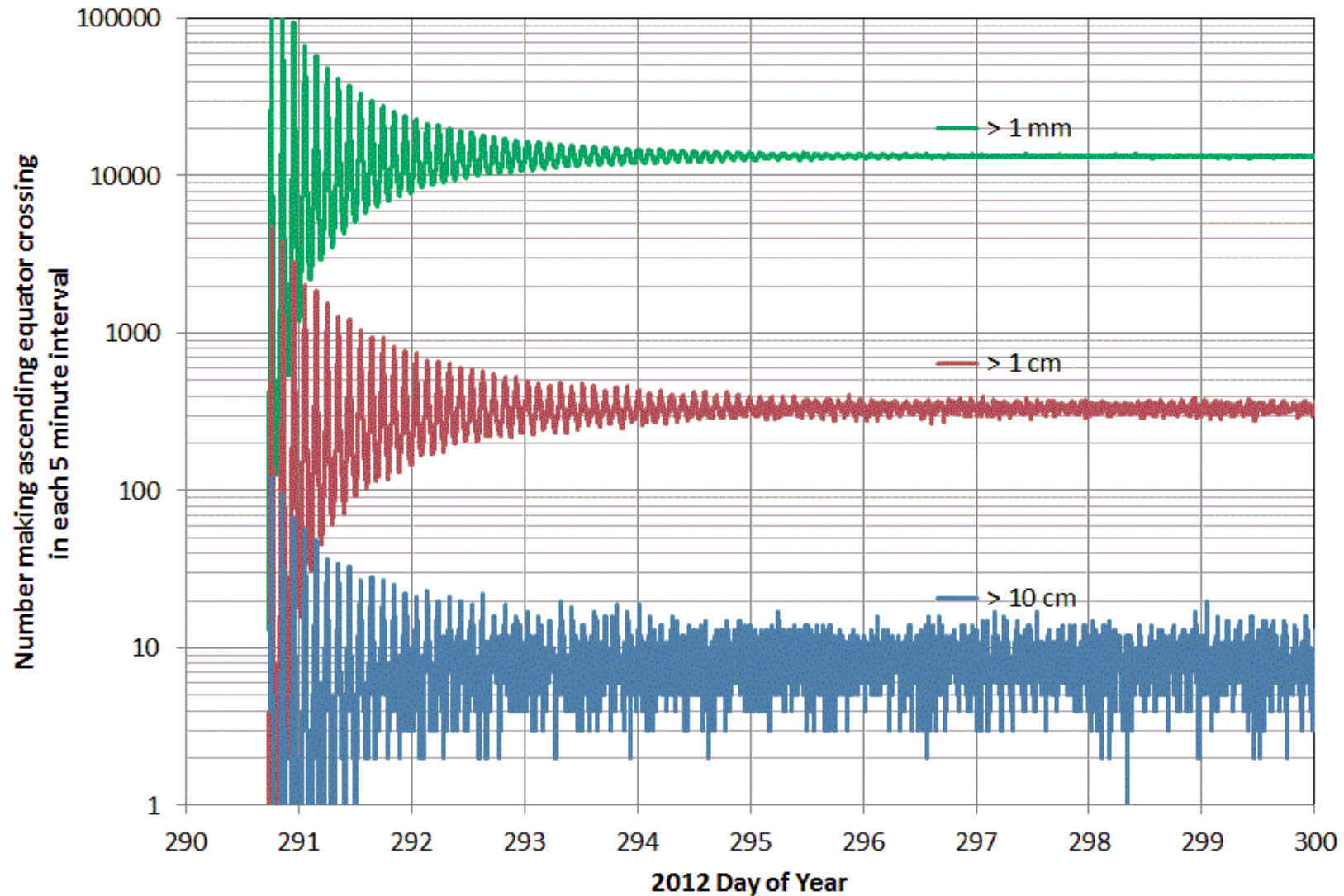


- **The time span of each phase is highly dependent on the parent orbit and where in the orbit that breakup occurred**



National Aeronautics and Space Administration

# Evolution of BRIZ-M Breakup Cloud Based Upon Breakup Model Evolution



- BRIZ-M mean anomaly is mostly randomized after a few days

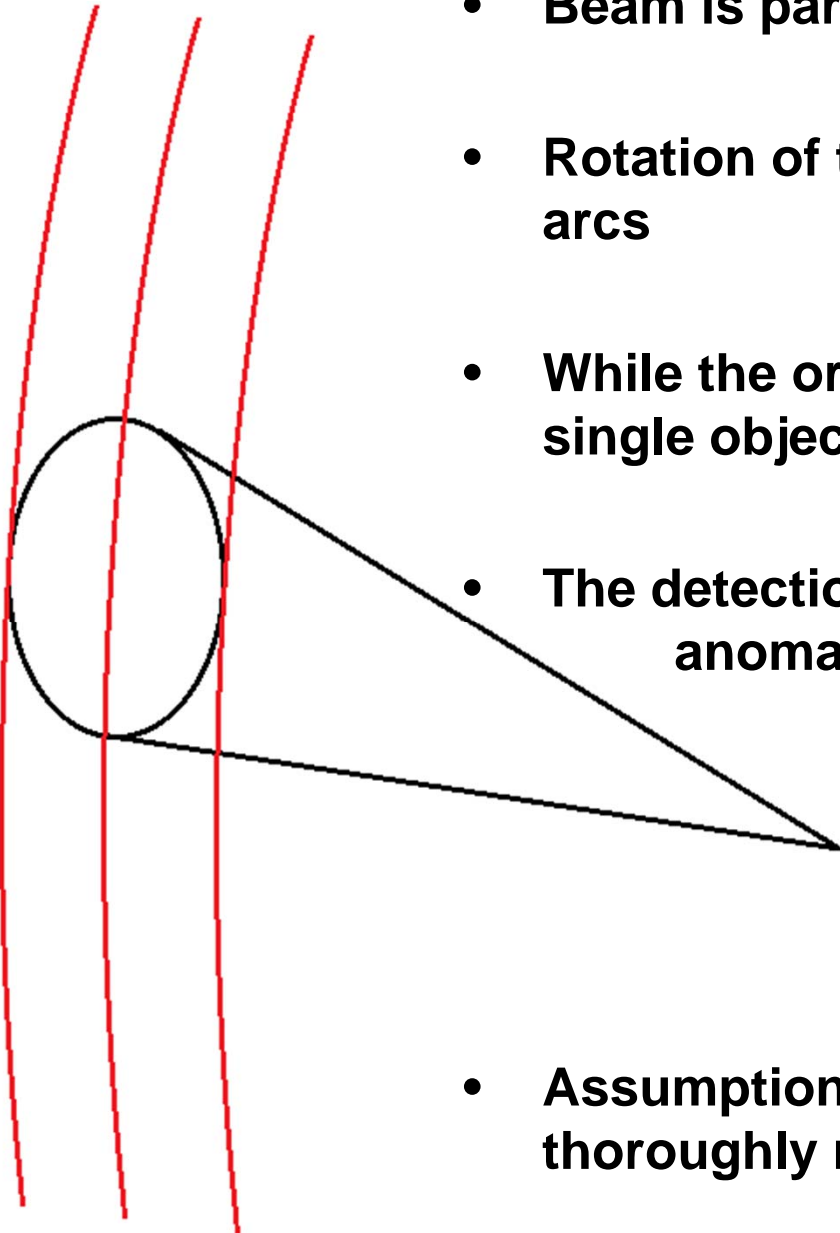


## Beam Stare Strategy

- Beam is parked at a particular elevation and azimuth
- Rotation of the Earth causes beam to sweep across orbit arcs
- While the orbit arc is in the beam, the rate of detection of a single object in that beam is once per orbit period
- The detection probability for an object with a random mean anomaly in the given orbit will be:

$$\frac{\textit{Amount of time orbit arc is in beam}}{\textit{Period of orbit}}$$

- Assumptions only apply once debris mean anomalies are thoroughly randomized





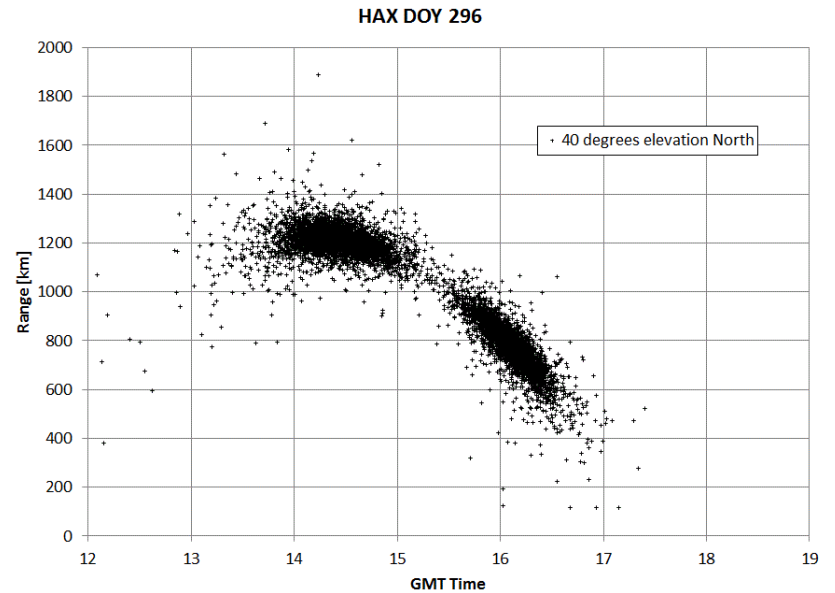
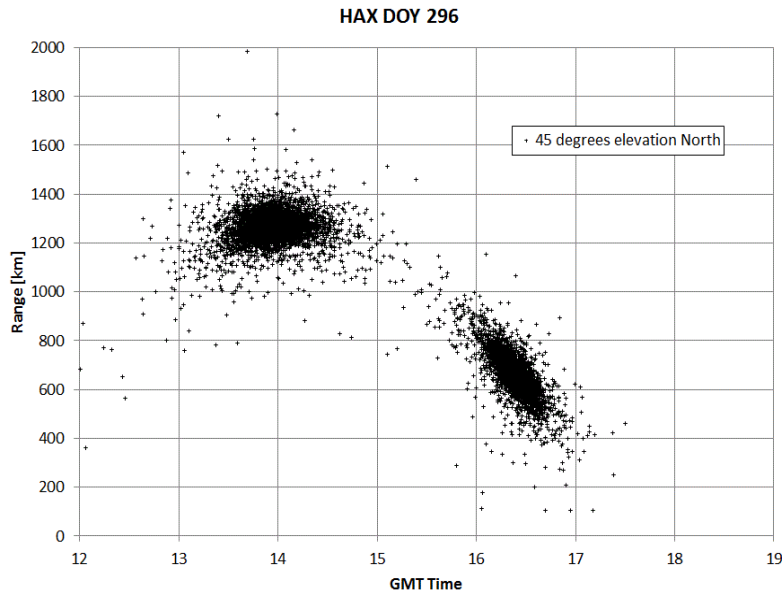
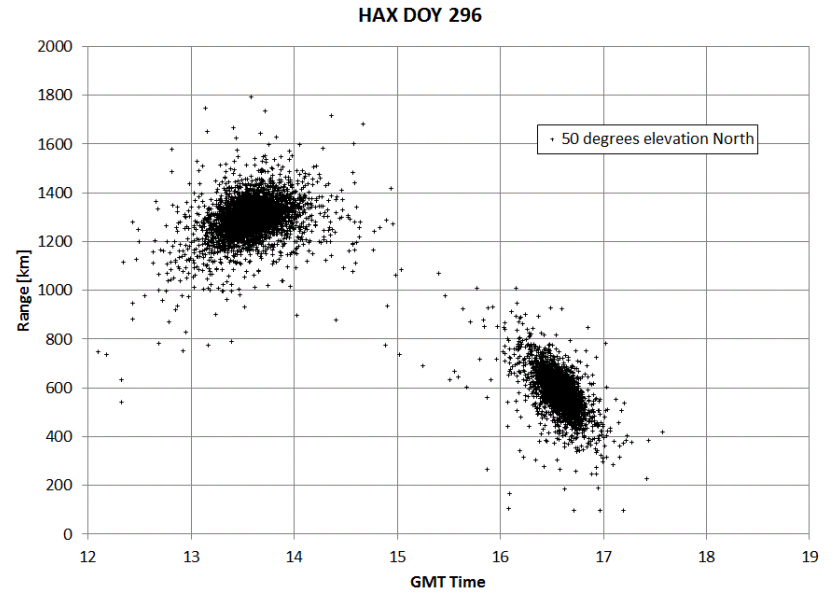
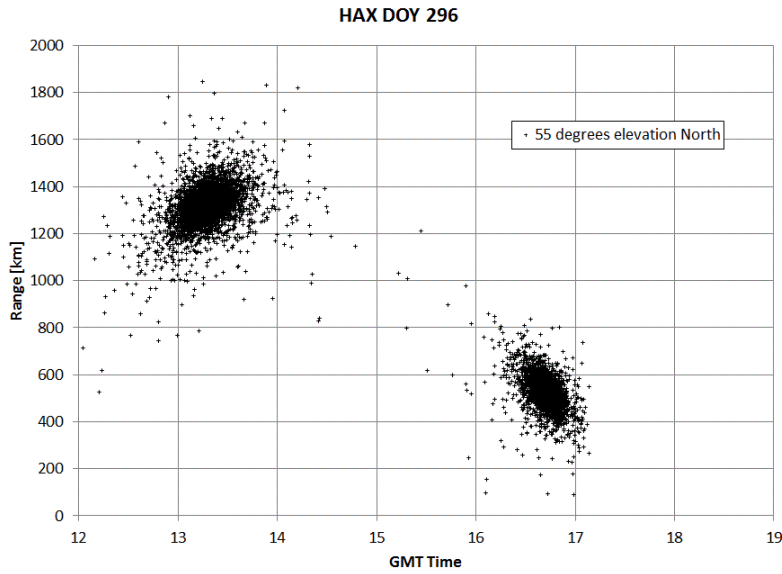


## Stare Modes

- **Normally, NASA uses the Haystack and HAX radars in a 75° East mode (75° elevation, 90° azimuth)**
  - Operating off-vertical provides indication of orbit inclination by using Doppler
- **However, because of the very low perigee of this breakup, much of cloud would pass too close to the HAX radar (closer than the nearest range bin) for some 75° elevation observations and times**
  - Also, short-range observations can see smaller debris, but the count rate is lower because the beam is narrower at short ranges
- **NASA developed several optimal viewing modes based on the model predictions for this breakup cloud and asked for HAX to observe these modes**
  - A variety of observation modes were run from day 293-301



# Probability Distribution



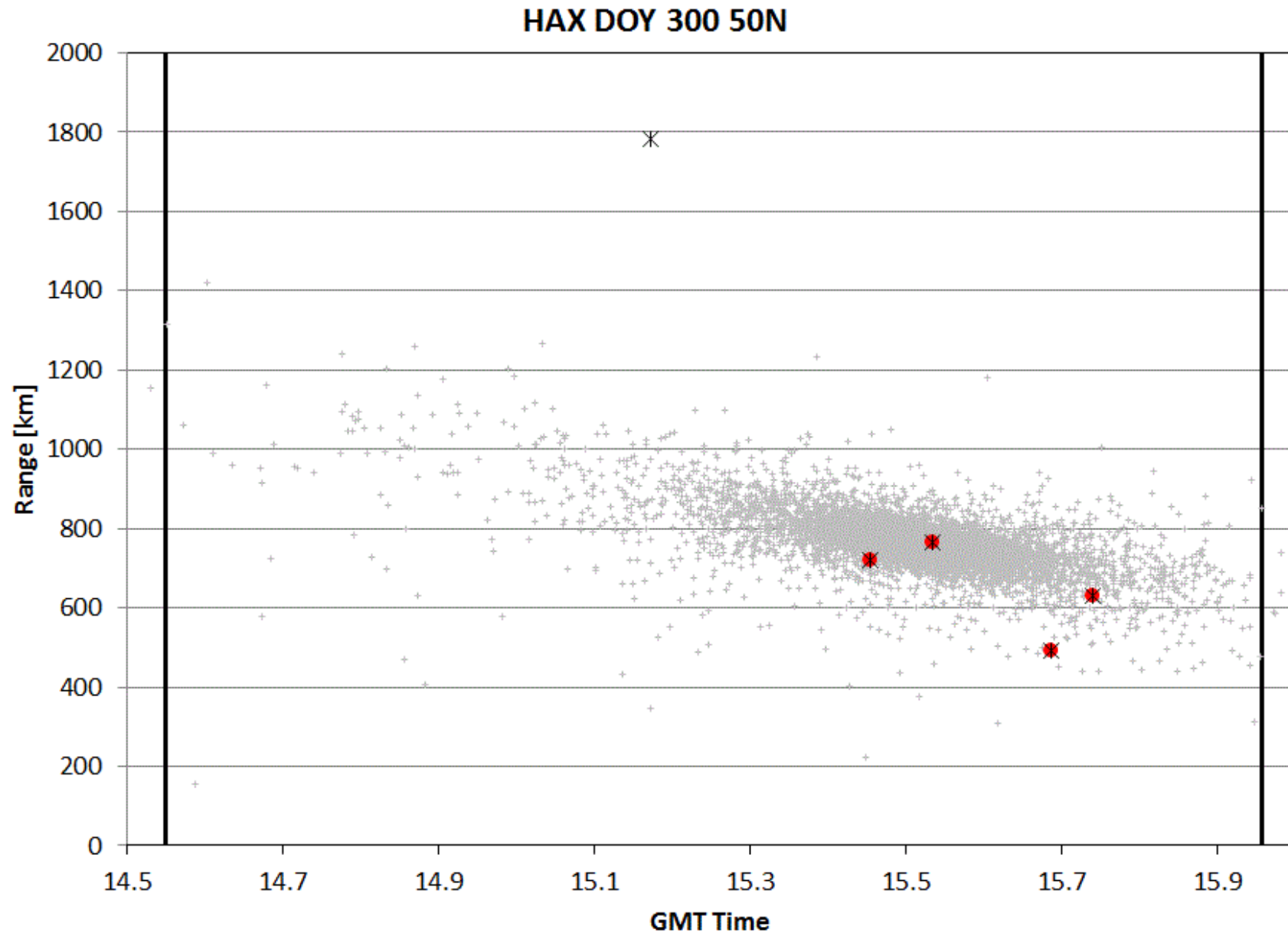


## Candidate Identification

- **Potential cloud candidates identified by comparing both model and data patterns in three dimensions**
  - Time
  - Range
  - Doppler Range-Rate
- **In following graphs:**
  - Grey points indicate the model predictions for all Monte Carlo cloud objects
  - Black stars represent HAX detections
  - Red dots represent detections assigned to the BRIZ-M cloud based on time/range/range-rate correlation

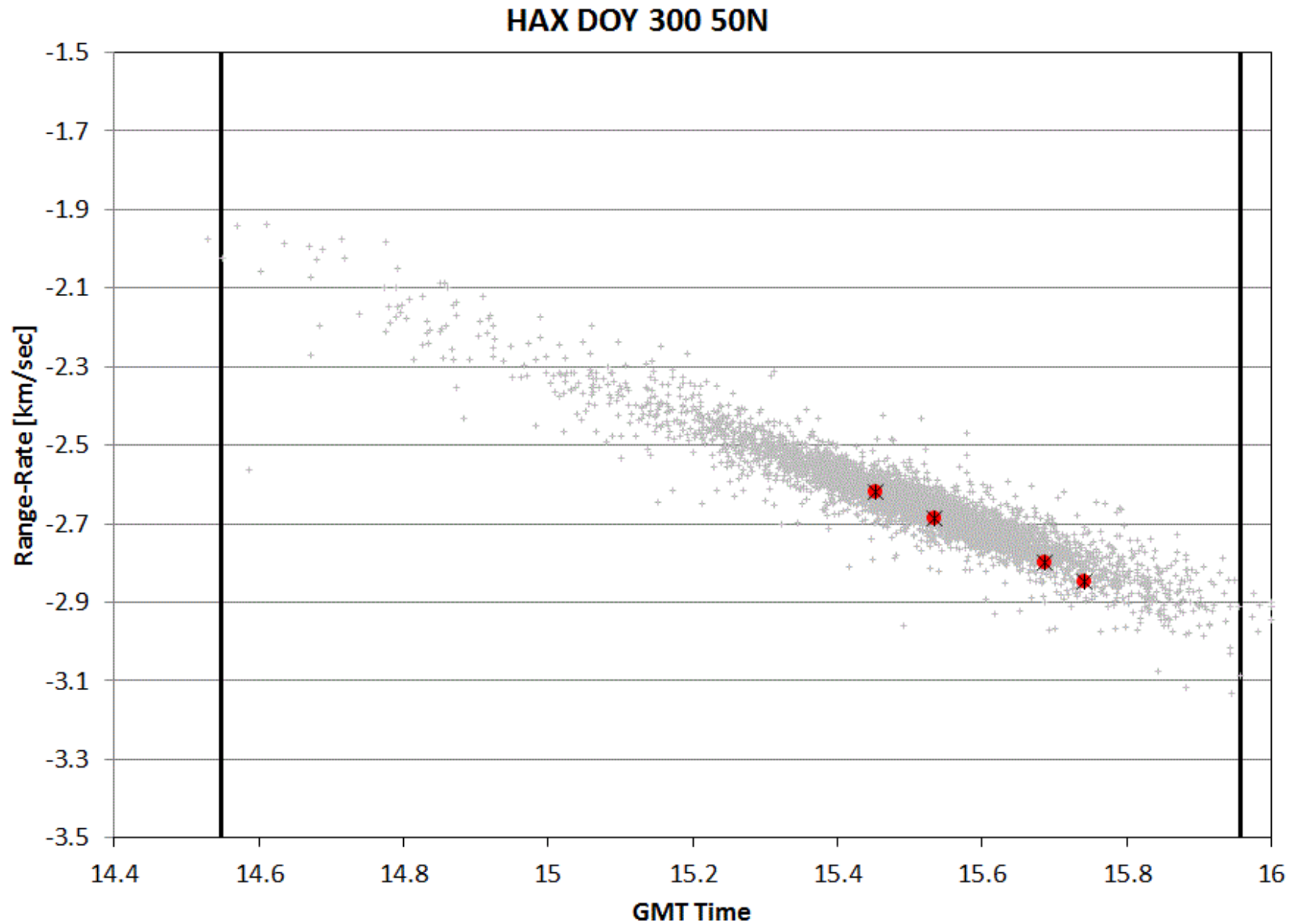


# Candidate Identification



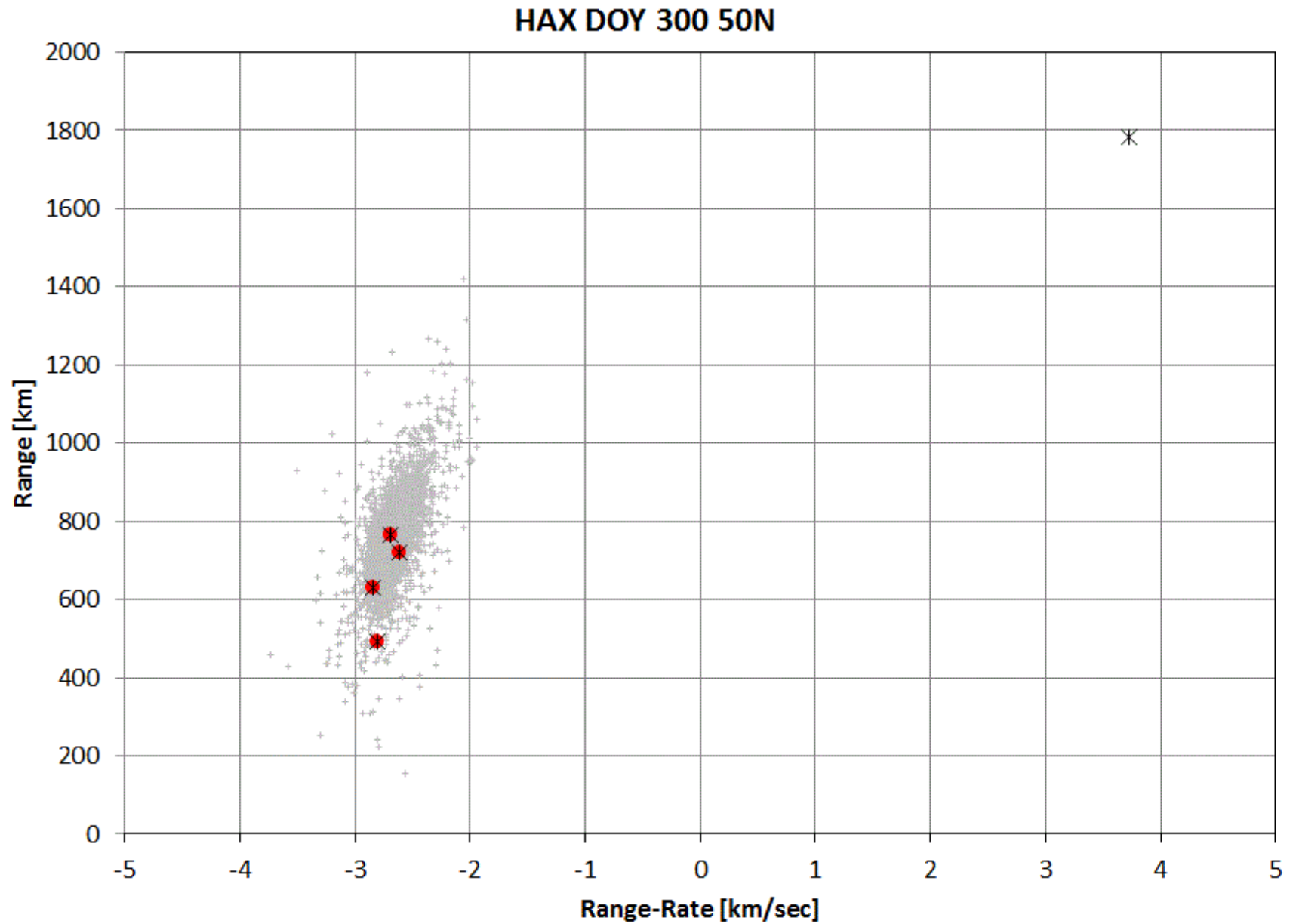


# Candidate Identification





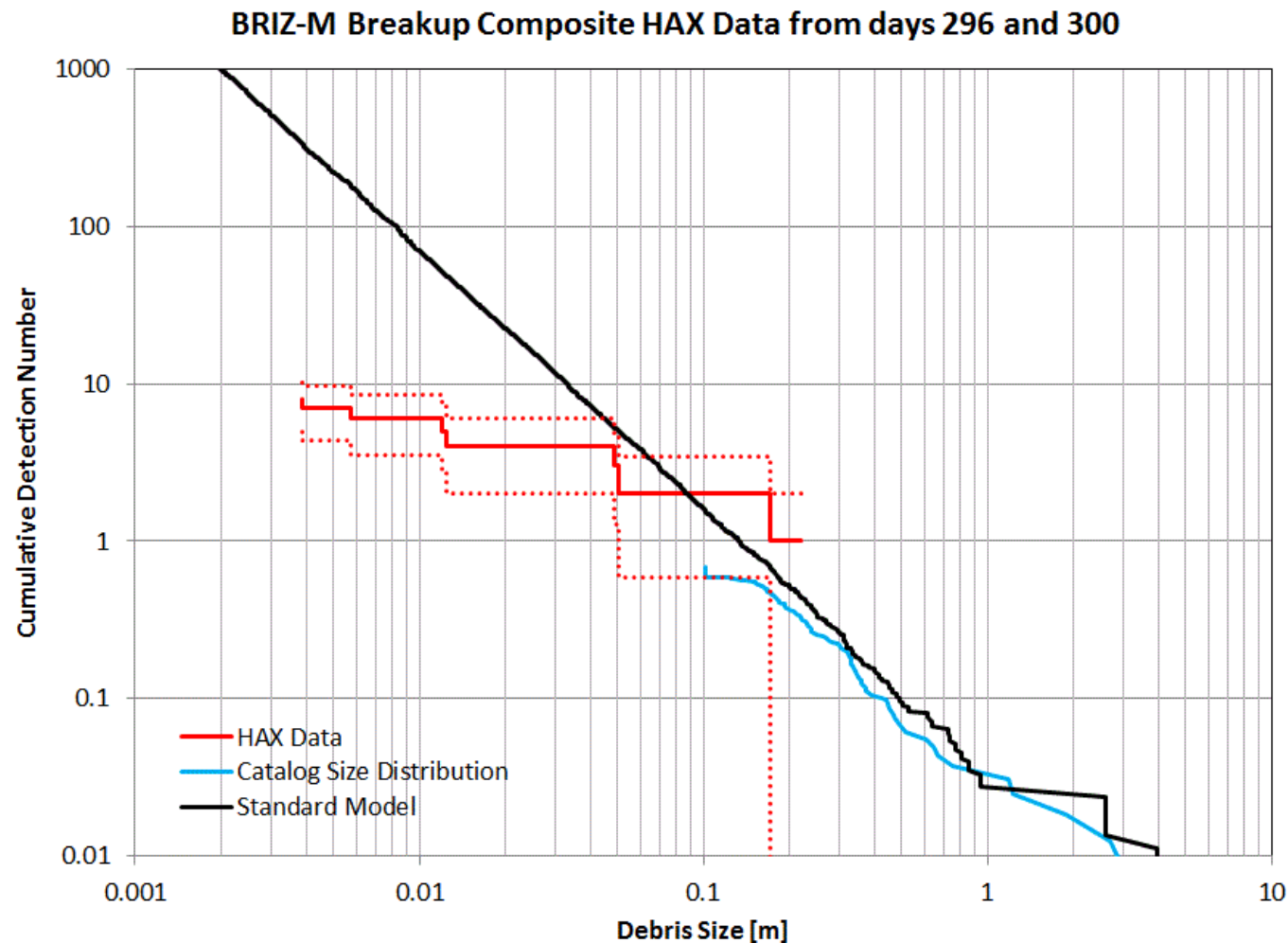
# Candidate Identification





# Size Distribution

- Rate of detection of a particular size (RCS) is then compared to the model predicted population





## Conclusions

- **The NASA breakup model prediction was close to the observed population for catalog objects.**
- **The NASA breakup model predicted a larger population than was observed for objects under 10 cm.**
- **The stare technique produces low observation counts, but is readily comparable to model predictions.**
- **Customized stare parameters (Az, El, Range) were effective to increase the opportunities for HAX to observe the debris cloud.**
- **Other techniques to increase observation count will be considered for future breakup events.**