Conjunction Assessment Space Fence Update

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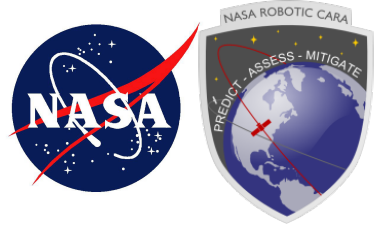
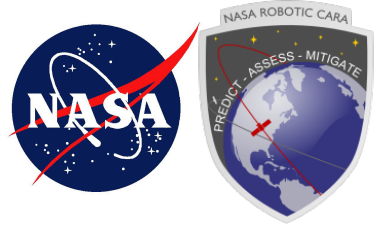
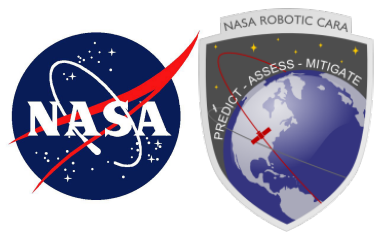


Agenda

- Basic program and schedule information
- Potential catalogue size and quality effects
- Potential large covariances of Space Fence (SF)-only objects: Conjunction Assessment (CA) policy
- Marginal maintenance of SF-only objects: CA policy
- SF data roll-out to CA enterprise



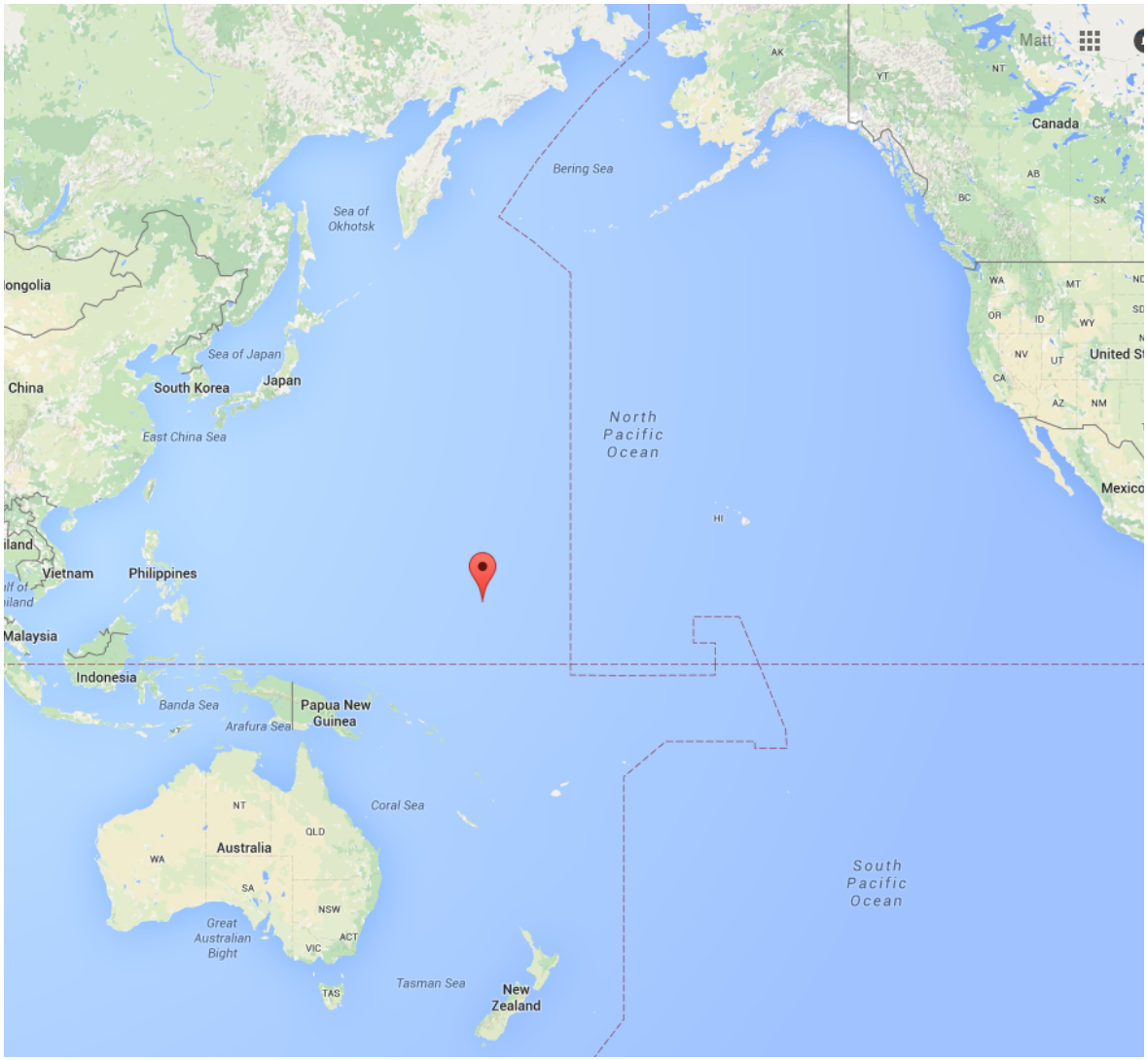
BASIC INFORMATION



S-Band Fence: Description

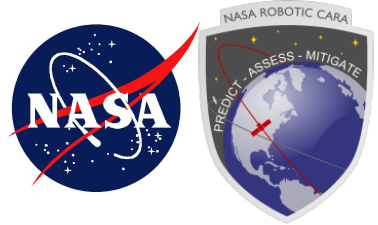
- **Large-aperture S-band radar for small object tracking in Low-Earth Orbit (LEO)**
- **Near-equatorial placement at Kwajelain Atoll, Marshall Islands**
  - Option for second site, probably in Australia
- **Intended for surveillance fence operations**
  - Radar fence will be erected; will track and report on all objects that penetrate it
  - However, beams are electronically steerable to allow for cued/extended tracking
    - Essentially a phased-array radar with “face” pointed up
  - Extended-range mode allows tracking of Deep Space (DS) objects
  - **Will not be considered an explicitly taskable resource for CA**
- **Detectable object size in LEO ~ 5 cm**
- **Two-polarization processing (PP and OP) allows high-precision Radar Cross Section (RCS) determination**
- **Multiple names presently used to refer to program**
  - S-Band Fence, Space Fence, SBF, SF, &c.; these all mean the same thing

S-Band Fence: Location



Space Fence Radar: Near-term Notional Schedule/Events

- ***N.B.: schedule is dynamic and governed by testing progress***
- **Earlier this year: contractor formal compliance testing**
- **October 2019: SF data introduced to test string of 18 Space Control Squadron (SPCS) operational system**
  - Some issues at first; data now being received and to some degree processed
    - Difficulties in executing all needed manual activities on test string; has strongly impaired evaluation of test-side SF data and products
- **Late November 2019: likely to enter formal Trial Period**
  - SF data will flow to live 18 SPCS operational system
  - Intent is to evaluate raw data and derivative data products quality
  - Will be used in live processing in measured way
    - Will be rolled out to certain processes as appropriate
- **Could remain in Trial Period, with all processes enabled, for an extended period before Initial Operational Capability declaration**

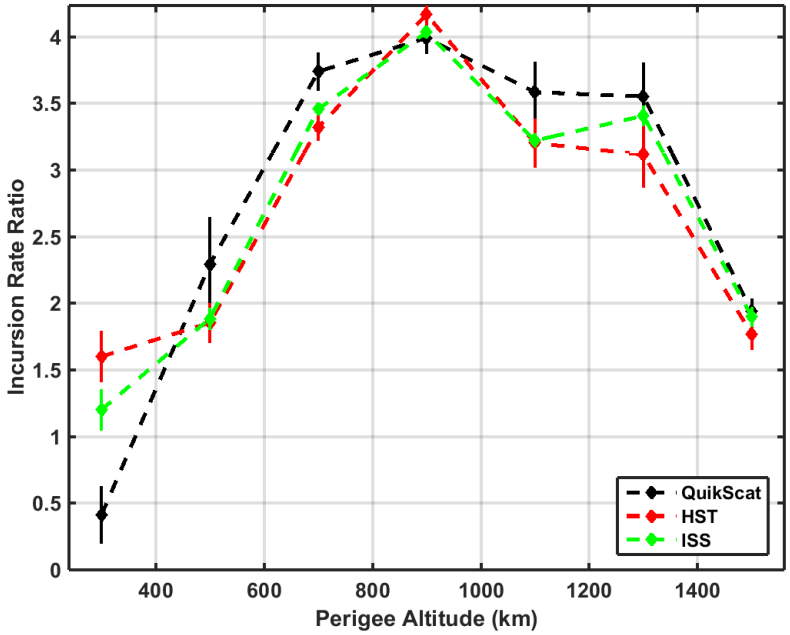


SF Radar

CATALOGUE SIZE AND QUALITY EFFECTS

Expected SF Catalogue Quality Effects: Expected New Objects in LEO

- **Earlier CARA study predicted catalogue growth factor of 3 – 3.5**
  - Function of perigee height, as shown on graph at right
- **Initial SF results below this level**
  - Fewer observations than expected
  - Fewer new objects than expected
- **Certain processing issues under examination; could see further growth**
- **However, probably more likely to see just a doubling of current catalogue size**
  - New objects will be largely to entirely trackable only by SF



Expected SF Catalogue Quality Effects: Additional Tracking on Existing Objects

- **Well-tracked objects will receive additional tracking**
  - Very little change will be observed, as objects are already well maintained
- **Poorly-tracked objects should benefit noticeably**
  - Shemya-only objects should now have their tracking essentially doubled
  - Should result in smaller covariances, which is always welcome
  - Most substantial difference may be decrease in average and upper-tail propagation times
    - Largest source of uncertainty is propagation error, mostly due to atmospheric density forecast error
  - Does not imply fewer serious CA events, however
    - Effect on actual serious event rates difficult to predict

LARGE SF OBJECT COVARIANCES

Large SF Object Covariances: Background

- **SF-only objects may have very large covariances**
  - Maintained by single station; may be time lag between subsequent tracks
- **Large covariances can cause CA difficulties**
  - Large covariance indicates lack of knowledge of object's precise position
  - Even if Probability of Collision (Pc) low, more tracking could potentially produce a high Pc
    - So-called "dilution region" of CA event dynamics
  - Emphasis then moves to trying to obtain more data
    - Often futile because if sufficient data not obtained regularly, then unlikely to be obtained with special tasking (especially for SF-only objects)

Large SF Object Covariances: CARA Perspective

- **CARA CA event mitigation philosophy**
  - When there is good evidence for a serious event, should mitigate
  - When this evidence is lacking, should not mitigate
  - Multiple CARA conference papers on this topic
- **With this philosophy, large covariances not a problem *per se***
  - Typically, large covariances drive the Pc to a value below the mitigation threshold, so it cannot be established that the event is serious
  - If the Pc is high despite a large covariance, then reasonable to conclude that the event is serious and should be mitigated

Large SF Object Covariances: Why Isn't CARA's Approach Reckless?

- **Even with SF, only about one-sixth of the objects large enough to cripple a satellite will be trackable**
  - We know nothing about the positions of the remaining five-sixths
- **An object with a very large covariance is an object about which we know very little**
- **Such objects are thus very similar to the very large number of objects (5/6th of the total) about which we know nothing**
- **It thus does not make sense to exert large amounts of effort to try to improve these large-covariance situations**
  - Efforts to obtain more tracking will probably not be successful
  - Mitigation actions will usually have to be very large and mission-disrupting
  - Reasonable to treat them the same way we treat the untrackable 5/6ths—as part of the risk assumed simply by launching a satellite
- **We should therefore be disciplined about the additional tasking/tracking resources we muster for such situations**

MARGINALLY MAINTAINED SF-ONLY OBJECTS

Cataloguing of Marginally-Maintained Objects: Background

- **Marginally-maintained object definition**
  - An object that cannot be reacquired at will and thus does not obtain regular tracking
- **Effect of cataloguing such objects**
  - Cycle on and off of attention/lost lists
  - Unlikely that a fresh state estimate/covariance exists at any given moment
  - When such objects are CA event secondaries, often cause problems
    - Scrambling for additional tracking data to try to resolve situation
    - Hesitancy in making mitigation decisions and difficulty in scheduling associated decision meetings
- **Should such objects be placed in the catalogue?**
  - "Catalogue" defined here as the state vector / covariance repository used for CA screenings
  - General agreement that there should be some minimum tracking/ acquisition standard to enable cataloguing
- **Planned approach draws on "dynamic LUPI" concept**

LUPI: Length of Update Interval

Cataloguing of Marginally-Maintained Objects: Dynamic LUPI Explained

- **Batch Orbit Determination (OD) updates require a method to determine how far back from current time to retrieve data**
  - This period of time is called the "length of update interval," or LUPI
  - If too long, then increased prediction error
  - If too short, then a poor drag solution (and perhaps not enough data)
  - Optimal period based on orbit type and data density
- **Dynamic LUPI (DLA) is this algorithm**
  - Begins with a "maximum LUPI value"
  - Tries to shrink interval while retaining adequate data density
  - If this is not possible and not enough data at maximum LUPI value, will extend LUPI to try to get an adequate data sample
    - This feature ("extended LUPI") not part of original DLA; was added to try to ensure a Special Perturbations (SP) update for every catalogued object
    - Extending LUPI beyond maximum value creates state estimate distortions and covariance realism problems
- **Objects that cannot be regularly maintained without "extended LUPI" are not good CA candidates**

Cataloguing of Marginally-Maintained Objects: Dynamic LUPI as Basis for CA Relevance

- **SF-only objects will be examined with regard to their empirical LUPI history**
- **If DLA typically expanding LUPI past maximum value, such objects will be segregated to special section of the 8-series catalogue**
- **These objects will be excluded from CA runs**
  - They do not represent objects of a sufficient maintenance quality to enable CA mitigation decisions

CA SF-ONLY OBJECT ROLLOUT

SF CA Data Phase I: Catalogue Stabilization

- **After start of Trial Period on live system, need period of time for catalogue stabilization**
  - Formation of candidate satellites
  - Catalogue ramp-up
  - Data quality analyses
  - Sensor calibration runs with sufficient live data to achieve stable results
  - Trial runs of all major processes
- **Present thinking is a period of probably two weeks' to one month's duration**
  - Highly dependent on resolution of observation quality and tagging issues
- **SF tracking data on objects in current catalogue will be included in catalogue maintenance and will thus contribute to CA**
  - Probably for only LEO objects at first
- **SF-only objects will not be included in CA screenings**

SF CA Data Phase II: SF "Trial Size" to Exercise External Systems

- **Smallish number of SF-only objects added to CA screenings**
- **Intent is to exercise external systems**
  - Nine-digit satellite IDs
  - No accompanying Two-Line Elements (TLEs)
  - Potentially large covariances
- **Present thinking is a period of one week's duration, but may last longer if issues discovered and mitigating actions required**

SF CA Data Phase III: Initial Chunk of SF Catalogue

- **First transfer of significant number of SF-only objects to CA enterprise**
  - Exact number TBA, but probably several thousand
- **Diligent monitoring of situation**
  - Increases in event counts, by orbit regime
  - Data quality, especially of covariance
  - Regular actionabililty criteria/protocols will inhere
- **Mission feedback will be extremely helpful to assess situation**
- **Present thinking is a period of two weeks' duration, but may last longer if issues discovered and mitigating actions required**

SF CA Data Phase IV: Subsequent/Final Chunk of SF Catalogue

- **At this point, additional chunks can be added**
  - Same protocol as for Stage III, although timelines may be different
- **Depending on size of augmented catalogue, could decide to jump to full catalogue if this seems more prudent**
- **Situation analysis will continue for months after movement to full catalogue**
  - Covariance realism (durable evaluation not possible until months of data collected)
  - Other data quality indices
  - CA serious event rates