STINGER GHAFFARIAN TECHNOLOGIES

International Space Station (ISS) Orbital Debris Collision Avoidance Process

Presented by:

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IMOC II

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Program Description

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- Risk of orbital debris
- History of NASA orbital debris collision avoidance process prior to the ISS
- Current NASA orbital debris collision avoidance process for ISS

Cropped from NASA photo ISS027e036706

Business Problem – Risk of Orbital Debris

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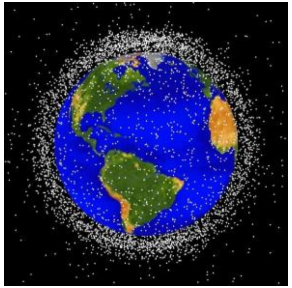

- Orbital debris presents one of the highest risks to the ISS
  - ISS is one of approximately 23,000 objects currently tracked by the Space Surveillance Network (SSN)
    - New objects enter the catalog (launches, debris generating events, deploys)
    - Old objects leave the catalog (directed deorbit, natural decay)
  - Debris has been collecting since the early space age
  - Oldest satellite in the catalog is over 60 years old
  - Collision between one of these objects and the ISS could be catastrophic
  - The joint American and Russian flight control teams have been prepared to maneuver the ISS out of the way should the threat of a collision trigger a certain threshold since the launch of the first ISS module

Technology Solution – Early DAM Process Pre ISS

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- Pre-Challenger - little thought given to orbital debris
- Post-Challenger - refocused attention on flight safety
- A process was created to limit risk to Space Shuttles from orbital debris
- A box, centered on the Shuttle was defined, such that predicted violations by a cataloged object could result in a maneuver
  - Maneuvers not likely
    - low catalog count, Shuttle maneuverability, short duration missions
  - No maneuvers and few notifications prior to ISS related missions

Technology Solution – Early DAM Process Pre ISS

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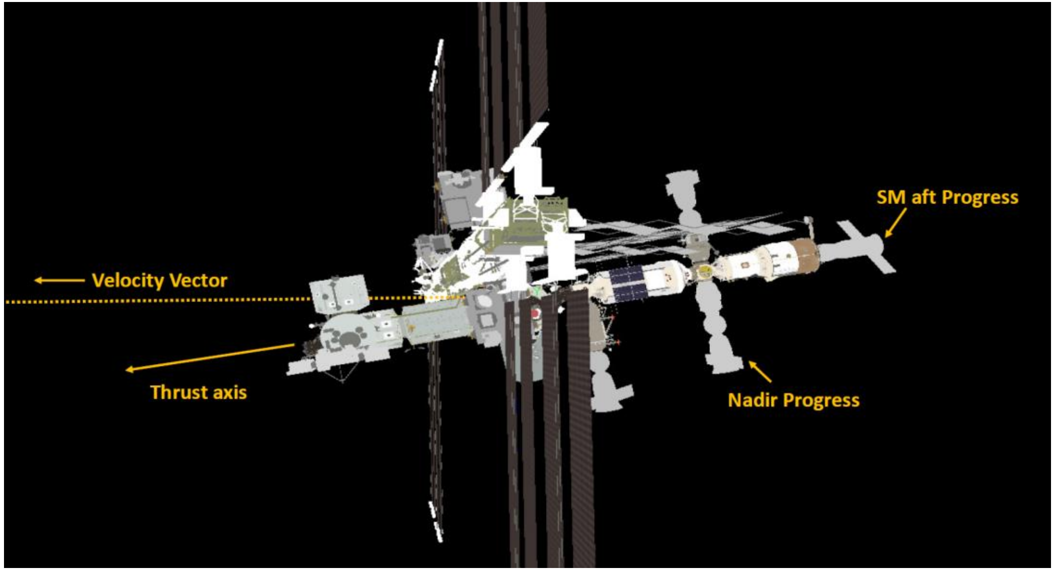
- ISS's long duration, continuous space operations demanded more focus on debris
- The Shuttle "shoebox" method was found to be inappropriate
  - Inconsistent with potential ISS and debris position uncertainties
  - Statistically inefficient: too many false positives and/or negatives
  - Predicted high debris avoidance maneuver rate
  - ISS limited maneuverability
- A strict probability based method was investigated
  - Maneuvers based on risk of collision only
  - Screening volume and maneuver thresholds efficiently chosen to maximize protection while minimizing maneuver rate
  - But … requires trajectory position uncertainties for debris and ISS
  - ISS need for high quality state uncertainty information drove joint NASA/USAF Space Command improvements now used by many US Government missions as well as a host of current commercial and foreign satellite owner/operators

Technology Solution – Current ISS DAM Process

- Propulsion Capability
  - All core propulsive capability is performed by the Russian segment controlled by Mission Control Center – Moscow (MCC-M)
- DAM ΔV
  - Typically ≤1m/s
- DAM propulsion source options
  - Progress resupply vehicle
  - Service Module (SM)
- DAM attitude
  - Dedicated attitude maneuver
  - Torque Equilibrium Attitude (TEA)



Technology Solution – Current ISS DAM Process

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- Identify Risk
  - Personnel at the Joint Space Operations Center (JSpOC), located at Vandenberg Air Force Base, maintains a catalog of objects in orbit based on radar tracking
  - Screens the ISS trajectory against all other objects in the catalog three times per day
  - Notifies the ISS Trajectory Operations and Planning Officer (TOPO) if anything is predicted to pass within a ±2 km (local vertical) x 25 km x 25 km (local horizontal) volume within the next 72 hours
  - TOPO uses data from JSpOC to compute the probability of collision (P_c)
  - Based on a set of criteria, TOPO notifies flight control teams in Houston and Moscow of the potential collision hazard
    - Time of Closest Approach (TCA) ≤ 48 hours
    - Local vertical miss ≤ 0.5 km or $P_c \geq$ 1E-06 (1 in 1,000,000)

Technology Solution – Current ISS DAM Process

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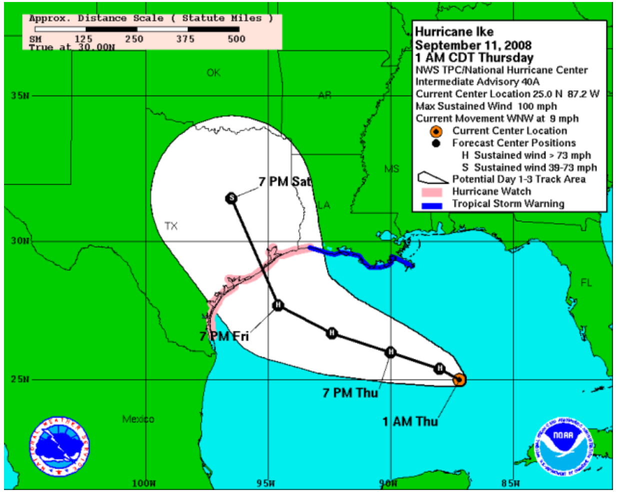
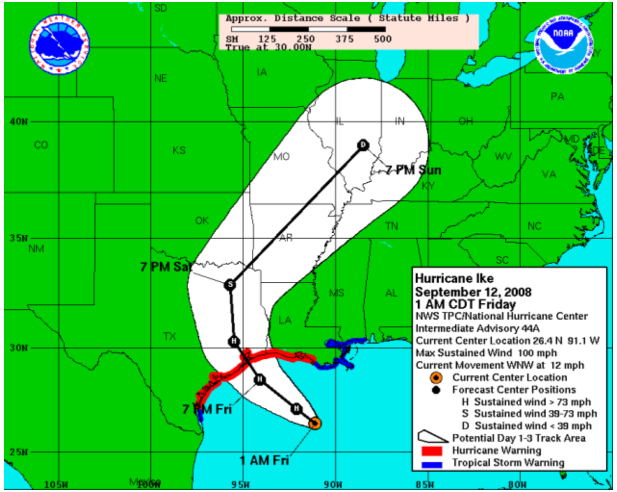
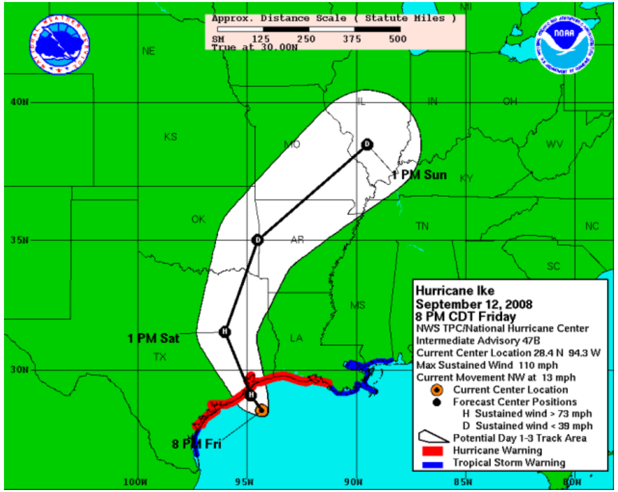
- When do you need to start DAM planning?
- How long can you wait before required to make the Go/No-Go decision?
- Hurricane Ike example below (September 2008)



Landfall – 48 hours



Landfall – 24 hours



Landfall – 5 hours

Technology Solution – Current ISS DAM Process

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- Maneuver Decision
  - TOPO continues to refine P_c as new tracking information arrives on both ISS and threat object
  - TOPO monitors trends in orbit determination, covariance behavior, miss distance, and P_c
  - Flight Rules govern when a DAM should be performed to minimize risk of collision
    - P_c threshold to maneuver depends on ISS activities underway or planned in near future
    - Flight Rules dictate the exceptions to perform a DAM
      - Example – inbound crewed Soyuz has launched requires higher P_c to warrant a DAM
    - Action thresholds:
      - **Black** $Pc \geq 1.0$ E-2 (1 in 100)
      - **Red** $Pc \geq 1.0$ E-4 (1 in 10,000)
      - **Yellow** $Pc \geq 1.0$ E-5 (1 in 100,000)
      - **Green** $Pc < 1.0$ E-5 (no action taken)

Technology Solution – Current ISS DAM Process

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- Maneuver Execution –Legacy Debris Avoidance Maneuver (DAM)
  - Dedicated command script (cyclogram) built by Moscow flight controllers uplinked to ISS
  - Pros:
    - Custom ΔV within vehicle capability – useful if eliminating near-term planned reboost
    - ISS can maneuver from any attitude to the DAM attitude LVLH YPR 0,0,0 or 180,0,0 deg
  - Cons:
    - Requires approximately 24-hours notice due to requirements to run on dedicated test stand
      - Late-notice conjunctions with high risk
        - Crew must shelter-in-place inside Soyuz
      - Risk of debris not always known well at 24-hour decision point
        - Unused work - DAM planning which is ultimately canceled once risk decreased below action thresholds

Technology Solution – Current ISS DAM Process

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- Maneuver Execution – Pre-determined Debris Avoidance Maneuver (PDAM)
  - New operation late 2012 and primary method for ISS DAM
  - Pre-canned cyclogram executed by MCC-M or the crew 1 hour before the PDAM ignition
  - Normally, ignition occurs ~2 hr 20 min prior to closest approach
  - ΔV options (expanded from original 0.5 m/s only option)
    - 0.3, 0.5, 0.7, 1.0 m/s using aft engines (Progress, Service Module)
    - 0.3, 0.5 m/s using Progress docked to DC1-nadir port
  - PDAM can be performed from either LVLH YPR 0,0,0 or 180,0,0 deg attitude
  - Pros
    - Decision point to perform maneuver as late as 5 hr 20 min prior to closest approach
      - Long pole is getting ISS US systems configured for reboost (appendages in position and power down, if required)
      - Reduced unused work
      - Reduced chance of ISS crew needing to shelter-in-place for high-risk conjunctions
  - Cons
    - ΔV limited to discrete options
    - ISS must be near LVLH YPR 0,0,0 or 180,0,0 attitude for PDAM cyclogram to initiate

Future Roadmap

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- PDAM Enhancements in work
  - Later PDAM options
    - Houston and Moscow flight control team personnel working together to allow PDAM to occur NLT 30 minutes prior to closest approach
    - Allows planning process to start NLT 3hr 30 min prior to closest approach
  - ISS maneuvers from any attitude to preferred PDAM attitude
    - Currently, ISS must be near either the LVLH YPR 0,0,0 deg or 180,0,0 deg attitude to initiate PDAM
    - ISS may not be near either option for PDAM initiation
    - Best PDAM attitude may the option opposite of current operations
      - Example - retrograde PDAM may be preferable in some circumstances

Contact Information

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