STS Response to Sightings of Nearby Spacecraft-Generated Debris During Station/STS Mated Operations

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(STS Traj-Related Flight Rules in the Space Station Era)

BACKGROUND

** During a recent 'Space Station' paper simulation, one trajectory-related item involved response to crewmember sighting from cupola of a nearby object (a fist-sized hunk of ice from radiator coolant leak).

** Historically, large space structures have been prolific producers of small debris objects, especially (but not exclusively) during EVA and venting.

** Orbital dynamics effects combined with large differential drag effects show that some departure trajectories will result in subsequent recontact.

** Current STS Flight Rules (e.g., Intelsat STS-49) call for either translational flyover and EVA crew grab, or very rapid avoidance maneuver.

LOOSE OBJECT (PROBABLY A CHUNK OF ICE FROM THE LEAK ON THE RADIATOR LOOP)
After first sunrise with a crewmember in cupola (anytime within 30 min of sunrise)
MET 2/23:19 or 3/00:54 or 3/02:27

Crewmember's Situation: YOU ARE IN THE CUPOLA which is HEAD-TO-EARTH.
The Orbiter is blocking the view directly forward along the plus VBAR.

INTENT of EXERCISE: Require the Control Center to determine the LVLH relative position of the object so as to allow prediction of near-future relative motion, including the possibility of recontact. Since you will at first only specify the Station-relative line-of-sight, they must ask for further information.

ANSWER: The following comments are consistent with an object departing the station backwards along the -X LVLH axis (the minus VBAR), then dropping into a lower orbit which eventually passes below the station, moving ahead in a lower orbit which never returns to the area of the station. BUT make THEM tell you that. Give only the following visual clues, as prompted by time or by MCC questions.

BEGIN:
After time to glance outside, call down: LOG MET of call: _____

"Hey, Houston, there's a small flashing object out the plus X window.
It's flashing as bright as a bright star, maybe about every four or five seconds.
It's too small to see any shape but it seems pretty close."

Respond to question about "What direction is it?" with:

"That's the plus X window in Station coordinates.
It's the window opposite the view of the Orbiter."

If asked again about direction to object.

"It looks pretty straight out the minus V-BAR"

A few minutes later, volunteer this further information:

"It looks about ten degrees above the horizon.
On the space side of the horizon line.
In the last few minutes it seems to have moved slightly closer to the horizon."

Regarding description of object, imagine it is shaped like a crumpled piece of paper about 300 feet away, but do not specify this range (you would not have a direct way of measuring it). You could move from window to window and not notice any perspective shift, which would tell you it was not really close (not within 50-60 ft). You have no idea what its origin might be. You have never seen anything like it.

After about ten minutes from first call (see logged MET time, above), call:

"That flashing object has crossed the horizon
and is now hard to see against the sunlit background."

A2-45 LOST EQUIPMENT DURING EVA

A. ATTEMPT RECOVERY USING PDRS

B. ORBITER TRANSLATIONS

1. ORBITER TRANSLATIONS MAY BE PERFORMED TO RECOVER A FREE FLYING MPESS PROVIDED THE FOLLOWING CONDITIONS CAN BE MET/SATISFIED:

   a. THE STEERING WHEEL MUST BE INSTALLED ON THE MPESS

   b. PROPELLANT IS AVAILABLE - USE MMU RESCUE ESTIMATES

   c. EVA CONSUMABLE MARGINS EXIST

   d. CREW TIMELINE PERMITS

   IT MAY BE NECESSARY TO PREPARE AN EVA STATION FOR RECOVERY (PFR INSTALLATION, TETHER SETUP, etc.). THE ORBITER WILL STATIONKEEP WITH THE MPESS WHILE THESE ACTIVITIES ARE PERFORMED.

CR A11108

The MPESS may be lost during mass handling (when steering wheel is installed) or due to inadvertent EE release. Thus, recovery of the MPESS is not possible. Unless the steering wheel is installed, the EVA crew has no adequate place to grapple the pallet. Unless there is a reasonable chance for recovery (time, consumables permit), no attempt will be made.

2. RECOVERY OF ANY OTHER LOST EQUIPMENT VIA ORBITER TRANSLATIONS WILL NOT BE PERFORMED.

Only the MPESS hardware is important enough to commit the orbiter to a recovery.

THIS RULE IS CONTINUED ON THE NEXT PAGE

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C. IF LOST EQUIPMENT CANNOT BE RECOVERED, A SEPARATION MANEUVER WILL BE NECESSARY TO PRECLUDE RECONTACT BETWEEN THE ORBITER AND THE EQUIPMENT.

THE SEPARATION MANEUVER SHOULD BE PERFORMED AS SOON AS POSSIBLE, BUT NO LATER THAN THE LOSS + 40 MINUTES.

EVERY EFFORT SHOULD BE MADE TO UNLOAD THE PDRS PRIOR TO THE BURN. IF NOT POSSIBLE, THE ARM SHOULD BE PLACED IN POSITION HOLD AT HOVER 6 IF INTELSAT GRAPPLED AND AT EXTENDED PARK IF ASEM HARDWARE ARE GRAPPLED.

IF EQUIPMENT LOST WHILE IN NOMINAL ASEM ATTITUDE, PERFORM 2 FPS POSIGRADE BURN. IF NOT IN ASEM ATTITUDE, FDO WILL PROVIDE SEPARATION MANEUVER.

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A 40-minute limit assumes that hardware is lost out of plane and will return in 45 minutes. If crew can verify that hardware was lost in another direction, this time may be increased and the velocity decreased. Undesirable RMS motion may occur if translational burns take place with a heavy mass on the arm; however, the alternative, free-flying hardware striking the orbiter, is less desirable. Posi-tion hold will actively drive the arm back to its original location; therefore, the total motion should be reduced. Forty minutes should be adequate time to safe the RMS from all configurations except SSF2 with legs attached. The nominal ASEM attitude points bay retrograde, thus lost hardware will notbe traveling posigrade and a posigrade maneuver will be safe. For other attitudes, the FDO mustdetermine the likely direction of the lost hardware and then determine the appropriate separation.

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STATEMENT OF THE PROBLEM

Current STS contingency procedures to avoid recontact with inadvertent spacecraft-generated debris cannot be performed the same way during future Station/Orbiter mated operations.

(Implication: Either the current STS Flight Rules are too overprotective, or the future STS procedures and tools during space station mated ops need to be upgraded to provide the same degree of safety)

QUESTION: IS THE PROBLEM REALLY SIGNIFICANT?

Historically, manned spacecraft have frequently shed unexpected objects

Mercury: Glenn's "fireflies" attracted attention due to their unexpected appearance & relative motion

Gemini: Frequent loss of objects through open hatches, plus loss of equipment from attachment failures; frequent separation of structural and interface material

Apollo: So frequently seen outside windows that crew nicknamed them "moon pigeons"

Skylab: Station-based sun/earth observational instrumentation frequently registered slow-moving nearby small objects crossing field of view.

(more)

QUESTION: IS THE PROBLEM REALLY SIGNIFICANT? (continued)

STS era:

** Repeated patterns of ice (sometimes large) and other loose structural debris from PLB
** STS-11 loss of MFR and subsequent successful flyover and EVA manual recapture
** STS-13 loss of removed parts from SMM spacecraft due to inadequate storage system
** STS 51-A two incidents:
  -- Loss of power tool
  -- Loss of torque wrench (manual recap)
** STS-49 crew observation of object coming loose from area near Ku-band gimbel

WHAT ARE THE CHARACTERISTICS OF SPACECRAFT-GENERATED DEBRIS THAT MAY POSE A THREAT TO STS?

** Generally low sep/recontact rates

** Can be from any LVLH direction

** Usually low mass

** Usually much higher drag effects

** Shape/material can vary widely

** "Prox ops" phase usually very short term

WHAT HARM CAN THE DEBRIS OBJECT DO?

** Impact damage (pressure hull, windows, solar panels, fluid lines, RCS jets, tiles, thermal control)

** Contamination (windows, sensors)

** Mechanical jamming (PLB doors, PDRS, arrays, radiators, antenna masts, instrument platforms)

Sometimes the damage could be immediately apparent but other damage could be cumulative or could be not noticed until later attempts to operate equipment.

FIRST PRIORITY: ASSESS RECONTACT PROBABILITY

Could it come back and hit the Orbiter/Station?

What is its near-future relative motion?

Available information for motion assessment:

- ** Visual only (no RR, ST, etc.)
- ** Line-of-Sight only (brightness cues not reliable due to phase angle variations)
- ** Naked eye parallax range limited to 60-80 ft
- ** Angular size cues unlikely (point object)
- ** Low accuracy of crew visual estimates (rough angles relative to VBar, horizon)
- ** Time history required

WHAT STS TOOLS ARE POTENTIALLY USEFUL?

** CCTV Triangulation could be promising
(current techniques are for in-plane only)

** Handheld laser and Relmot PGSC program
may provide excellent support
(available from STS windows only)

CANDIDATE REACTION PROCEDURES

** Stack avoidance maneuver not feasible

** EVA crewmember usually unavailable

** External manipulators restricted in range and in end effectors

** Special free-flier too expensive

** Deliberate plume "fend-off" may make it worse

** Observe return passage of object

SUGGESTED STRATEGY

1. Immediately upon detection, crew must actively note line of sight, exact time. Repeat and record at short intervals.

2. Assess possibility of triangulation ranging via widely separated observers (crewmembers or CCTV) or use of other STS equipment for ranging

3. Provide Control Center with resulting history of object line-of-sight

4. For objects with predicted recontact possibility, maintain continuous visual surveillance (eyeball and CCTV) during return fly-by to detect location of actual contact (if any)

FOLLOW-UP ACTIVITIES

** Promote awareness in Space Station community of the Space Station's orbital mechanics and the resulting recontact issues implications.

** Maintain alertness to spacecraft-generated debris hazards from station assembly operations and from aging/impact failure modes of Station hardware

** Maintain flexibility to use STS on-board relative motion monitoring tools for this unexpected task

** Maintain FD&D data base of history of manned spacecraft inadvertent generation of debris, and the resulting relative motion and effects on originator