5.2 FLYAROUND

A flyaround is a PROX OPS task which involves maneuvering the Orbiter (active vehicle) from one point to another point relative to the TGT (passive vehicle) in the TGT LVLH frame. The term "transition" once meant any operation which resulted in Orbiter movement relative to the TGT (range not necessarily constant), while a "flyaround" specifically required that the Orbiter maintain approximately constant range while moving from one relative position to another. The term "flyaround" has come to refer to any relative movement, with or without constant range.

Level B G&C require that the TGT must be maintained in view from the Orbiter. This visibility requirement is satisfied by pointing the -Z axis toward the TGT, thus allowing the crew to view the TGT through the overhead window (and the COAS); this also gives the best orientation for RR tracking of the TGT (see fig. 5-4A). Since the crew is controlling the vehicle from the aft flight deck and is viewing the target out the overhead window, the aft THC and RHC sense should be -Z.

The requirement to perform a flyaround may result from situations such as the need to perform payload inspection, the requirement to support detached payload experiment operations by appropriate Orbiter relative positioning, or the requirement to move from an initial stationkeeping point (after a RNDZ) to a point from which grappling can be initiated.

The impact of orbital mechanics effects depends on the range and on the duration of the maneuver. For close-in flyarounds (about 35 ft), such effects can be disregarded. For ranges of several hundred feet, orbital mechanics effects can be significant.

The PROX OPS DAP B usually works best due to small translation pulse size. As in all PROX OPS phases, the crew should be aware of the limited insight provided to the MCC by telemetry. They should keep the MCC informed by periodically reporting what they are seeing and doing.

The different transition techniques and their applicability under different conditions are illustrated in fig. 5-4B.

5.2.1 Inertial In-Plane Flyaround

During an inertial in-plane flyaround, a combination of DAP control and pilot THC inputs makes the Orbiter translate and rotate around the TGT. Motion is clockwise when viewed in the traditional LVLH frame with +VBAR to the left (fig. 5-5).

This is the easiest flyaround procedure to perform. However, since this maneuver is always performed with a zero inertial attitude rate (about 4 deg/min or 0.07 deg/sec in the LVLH reference frame), the time to rotate to a desired orientation can be quite long (up to one complete REV).

The maneuver is initiated by placing the Orbiter in inertial attitude hold and then maintaining the TGT in the COAS or RMS EE field of view using the THC. From a position on the TGT +VBAR with Orbiter tail-to-Earth, the initial translation is radial up (-Z in the LVLH frame and +X in Orbiter body axes). This starts a "football" trajectory (section 2.4.2.3) around the target.

Since the flyaround is performed with constant range, THC corrections must be made along the Orbiter-TGT LOS (Orbiter +/- Z axis). Also, since in a pure football the inertial LOS rates to the TGT are not zero, NLOS corrections are needed to keep the TGT in COAS FOV (mainly X body axis).

In some situations, a fast maneuver may be required. Also, since this maneuver is strictly an inplane flyaround, the Orbiter may not be able to be aligned with some TGT orientations (such as if the TGT grapple fixture is on the opposite side of the orbit plane from the RMS). For these cases, more complex flyaround maneuvers are necessary and are described below.

5.2.2 Manual Rotation Flyaround

This technique (fig. 5-6) is good for any TGT relative orientation, including out of plane flyarounds. The pilot receives cues for starting and stopping from out-the-window views of the TGT orientation (it is not necessary to know the desired final attitude in advance). This is the primary technique for aligning the orbiter to the proper grapple attitude w.r.t. the TGT for unknown TGT orientation.

This procedure can be performed for both inertially and LVLH stabilized TGTs. It was originally developed for the inertially stabilized SYNCOM on STS-51I (see appendix A). The procedure was later generalized to include an LVLH flyaround technique for inclusion into the Contingency RNDZ FDF (fig 5-7).

Depending on the TGT's attitude hold mode, the pilot places the DAP in either inertial or LVLH attitude hold. This technique is then performed in each axis (roll, pitch, or yaw), one axis at a time, until the correct alignment is achieved.

For each axis (roll, pitch, or yaw), the pilot places the active axis in free drift (DAP ROT PULSE) and, using the RHC, manually inputs a rotation rate of 0.2 to 0.3 deg/sec (as seen on the UNIV PTG display). It must be emphasized that this is plenty fast enough even it may not look that way out the window (it is 3-4 times faster than inertial).

During this rotation, the pilot must then keep the TGT in the COAS or RMS EE FOV using the THC for NLOS corrections; he also must make LOS corrections as needed to maintain range within limits. Due to cross coupling effects, these THC inputs can change the active axis rotation rate (see section 3.8.1). Therefore, the pilot must carefully monitor and maintain this rate throughout the manuever. When the trim in that axis is finished, that axis is placed back in inertial or LVLH hold (DAP ROT DISC) so the DAP can null out the rotation rates. THC inputs are made as required to keep the TGT in the FOV.

As required, the above sequence is repeated for another axis.

5.2.3 Negative Inertial In-Plane Flyaround

In some cases in which the relative Orbiter/TGT position would require an excessive duration for a clockwise flyaround, a negative inertial flyaround may be performed (fig. 5-7). For example, an inertial flyaround from the +VBAR to the +RBAR would take 3/4 rev, or about 67.5 min, while a negative inertial flyaround would take 1/4 rev, about 22.5 min, to get to the same relative position.

In LVLH, the "negative" flyaround is opposite to the inertial flyaround, thus the name. However, in the inertial frame, the flyaround rate is twice LVLH rate. This used to be called "counterclockwise" (CCW).

For a 90 degree angular displacement, this technique costs less than a regular inertial flyaround. Another advantage here is that RCS jet firings generally occur away from the TGT, so TGT plume contamination is much reduced.

This technique was performed during the STS-51DR mission to fly under the SYNCOM TGT. It can be performed as a special case of a manual rotation flyaround (5.2.2, above), or it can make use of the UP ROT option (as such it is generalized in section 5.2.4.1.2, below). It is best to command the +Z axis to center of Earth and then use THC only. This flyaround can also be performed by setting the ROT vector in UNIV PTG to the Orbiter -Y body axis (section 5.2.4.1.1). The latter technique may be twice as fast as the negative inertial technique.

5.2.4 FSW-assisted Flyarounds

The existing capabilities of Orbiter FSW provide several techniques for performing much more flexible flyarounds than can be done with manual inputs alone. Both UP (OPS 201) and ORB TARGET (SPEC 34) can be used.

5.2.4.1 Universal Pointing Function Assisted Flyarounds

In some cases where the TGT attitude is constant and can be determined precisely (is well known pre-flight or can be observed in real-time), the UNIV PTG function provides two methods which can be used to aid the flyaround task. They are:

1) mnvr to an inertial attitude;
2) auto rotation mnvr.

These are inertial maneuvers and as such should only be used if the TGT is inertially stabilized.

These techniques have several advantages. The flyaround can occur at a higher rate than inertial (4 deg/min), and it is not restricted to LVLH in-plane trajectories.

Both these maneuvers require only that the pilot use the THC to keep the TGT in the COAS or RMS EE FOV, because the DAP is controlling the change in Orbiter attitude.

5.2.4.1.1 Maneuver to an Inertial Attitude

If the TGT is in a known inertial attitude, the MNVR option of UNIV PTG may be used to rotate the Orbiter to a specific inertial attitude which, together with manual translations to maintain the TGT LOS, places it in the desired relative position. This inertial attitude is input via the UNIV PTG display, items 5, 6, and 7 (corresponding to roll, pitch, and yaw inertial Euler angles). Item 18 starts the rotation maneuver. The pilot performs NLOS corrections using the THC; if a constant range is needed, LOS corrections will also be required.

One drawback of this maneuver is that the flyaround direction is not immediately obvious in the case where the inertial attitude is called up in real time. As a result, the pilot may not know the direction that the TGT will initially move in the COAS or RMS EE FOV. For RMS ops, this can be tricky because the TGT can move directly toward the EE requiring immediate pilot inputs on the THC to avoid a collision.

5.2.4.1.2 Auto Rotation Maneuver

This technique uses the ROT option on the UNIV PTG display. The pilot inputs a pitch and yaw body pointing vector, via items 15 and 16, about which to rotate. To keep the rotations simple and easy to predict, this ROT vector is usually an Orbiter body axis. Once the rotation is initiated, THC corrections are performed as in section 5.2.4.1 above.

This maneuver was developed for the STS-51DR mission (a simple -Y rotation) and was also used on the STS-51G Spartan mission (contingency rotation in all 3 axes).

5.2.4.2 <u>Targeted Prox Ops Flyarounds</u>

This procedure uses SPEC 34 ORBIT TGT to calculate the translational burns required to move the Orbiter around the TGT; the burns are then performed in ORB MNVR EXEC. The TGT track mode of UNIV PTG is used to keep the -Z axis of the Orbiter pointed at the TGT. These target sets are determined pre-mission to ensure a trajectory of constant range.

The advantage of this procedure is that all aspects of the flyaround (except for trimming the VGO's) are performed automatically by the Orbiter FSW. However, this method is only as good as the sensor data being incorporated into the navigated relative state of the Orbiter.

This technique was developed for the STS-51F Plasma Diagnostics Package (PDP) mission. The Orbiter was repeatedly required to be in an exact position relative to the PDP at a certain time.

Certain orbit targeting I-loads need to be "tuned" for operations at PROX OPS ranges (see discussion in section 3.5.4).

A manual technique to approximate this maneuver was developed which used the MNVR to an inertial attitude (section 5.2.4.1.1) option on UNIV PTG to point the Orbiter in the correct direction with the pilot maintaining the PDP in the COAS FOV and a constant range from the PDP using the THC.

The manual technique had a high crew workload and required constant crew attention to attain the desired points.

-------RESUME TEXT at section 5.2.5 LOS Rate Techniques --------

PTG to the Orbiter -Y body axis (section 5.2.4.1.1). The latter technique may be twice as fast as the negative inertial technique.

~~5.2.4 FSW-assisted Flyarounds~~

~~The existing capabilities of Orbiter FSW provide several techniques for performing much more flexible flyarounds than can be done with manual inputs alone. Both UP (OPS 201) and ORB TARGET (SPEC 34) can be used.~~

replace section 5.2 (through 5.2.4), RPOHB pp. 5-11 to 5-17.
dougherty/oberg/pearson/section may 5, 1989
ADD new illustration 5-4B (TRANSITION TECHNIQUES)
Reverse numbering of figures 5-6 and 5-7