

FROM: DA8/Chairman, Ascent/Entry Flight Techniques

SUBJ:Ascent/Entry Flight Techniques Panel Meeting #8 Minutes

The eighth Ascent/Entry Panel meeting was held on February 22, 1984, at JSC. Rockwell, NASA Headquarters, and DFRC participated via teleconference.

#### Summary

a. The STS 41-C nominal EOM Xcg is 1100.4 inches (Mach 3). The LDEF return Xcg of 1083.2 inches (Mach 3) is too far forward to allow PTI's (flight rules constraint is 1084 inches). FRCS dumps will not be required except for the LDEF return case.

b. The proposed PTI schedule for flights STS 41-C through STS 51-A was reviewed, and results of the PTI's to date were presented. The proposed fix for the 1/4 Hz phenomenon tested on STS-9 did not work, but helped determine the likely cause. On STS 41-C the aileron gain will be increased in the Mach 1-2 region, and this should alleviate the 1/4 Hz problem.

c. The STS-9 and STS 41-8 descent postflight summaries were presented. STS-9 had some equipment failure, and both flights had some OMS pod damage. There is a discrepancy of nearly 3 inches between the predicted and aerocalculated Xcg locations on STS 41-8. STS 41-8 also had a large downtrack navigation error (25 kft) post blackout. There were also some concerns about KSC aimpoint selection.

d. On STS 41-C if the Xcg <1093 Inches (LDEF return case) the alternate path elevon schedule will be selected, while for Xcg >1093 inches (all other cases) the normal path will be used. Either heavy or light bending filter set can be used for this flight.

e. Thermal analysis of STS 41-C shows no safety problems for EOM or AOA. The TAL cases were still being analyzed.

f. The STS 41-C ascent abort regions were examined. With 104 percent throttle there is a 30 second TAL exposure for maximum forward CG (1084 inches), and a 6 second exposure for 109 percent throttles. The abort options priorities were not resolved at this meeting. A free-fall time of 6 minutes (instead of 9 minutes required) was accepted for this flight only to cover an AOA case.

g. The postlanding leak rules were reviewed.

h. The STS-9 PTI's helped move us closer to qualifying the 65 percent CG envelope.

i. The STS 41-6 landing opportunities were reviewed. Nominal EOM is at KSC on rev 72 with 169 nmi crossrange.

1. CG's for STS 41-6 - Rockwell/R. Young

The latest mass properties and CG's for STS 41-6 were presented (enclosure 1). The J719-ADD5 data set is the latest official data available. The only known change to this data set is the OMS pod changeout, but this should not

affect the data significantly. The nominal EOM Xcg is 1100.4 inches at Mach 3. This is assuming no FRCS dump. The SMM return CG listed also assumes no FRCS dump. The nominal Xcg is compatible with the elevon test range of 1089 to 1108 inches.

Action: 2/22-001 - MD2/R. Hirschke: Provide latest SODB CG data to Rockwell.

Action: 2/22-002 - FM5/J. Harpold - Determine the latest CG (mass properties) data set which is being used in the SMS.

[for the LDEF return case, the Xcg shown in the enclosure (1080.3 inches) will shift 3 inches aft with a FRCS dump to Xcg=1083.2 inches at Mach 3. We have a flight rules constraint of 1084 inches for performing PTI's, so for the LDEF return case, we will not do PTI's. However, we will go ahead with the crosswind DTO for the LDEF return case if the Orbiter lands at Edwards, and it stays within the brake constraints.

Action: 2/22-003 - DH3/G. Oliver - Determine rollout margins and recommendations for a KSC landing for LDEF return assuming 8 and 10 fps2 braking.

In summary, CG's and applicable mission rules will not require FRCS dumps for the nominal case, but will require an FRCS dump for LDEF return.

## 2. PTI Schedule through STS 51-A ET3/D. Cooke

Mr. Cooke presented the proposed PTI schedule for STS 41-6 through STS 51-A, and reviewed the results of the PTI's on the flights to date (enclosure 2). The elevon schedules flown so far show that a broad range of elevon settings have been tested, and the data base will be increased with future flights. One phenomenon encountered on the flights to date (including STS 41-8) is a 1/4 Hz oscillation of the roll rate in the Mach 1-2 region. A speedbrake sweep was performed on STS-9 to test one theory on the cause of this phenomenon. The theory was that the double wedge formed by the deployed speedbrake was at a critical angle which caused an oscillatory separation and reattachment of the shock waves on the tail at certain Mach numbers. By manually changing the deflection angle of the speedbrake on STS-9 (see enclosure) it was hoped to alter this critical wedge angle at some point sufficiently to destroy the oscillatory nature of the shock waves. It was found during STS-9 that the speedbrake sweep was ineffective in alleviating the problem, (it was actually more pronounced) but it was noticed that the ailerons are much less effective in the 1/4 Hz region than predicted (see enclosure), and this has a direct effect on the roll characteristics of the vehicle. This was due to the change in trim caused by bringing in the speedbrake, which caused more up travel of the elevons, which in turn reduces aileron effectiveness. Aileron ineffectiveness thus appears to be the 1/4 Hz driver. To fix this problem, on STS 41-C the aileron gain will be kept high into the Mach 1-2 region, instead of being decreased as was done previously. This will give more roll control authority to the vehicle, enabling the aero forces to be damped, and thus hopefully eliminating the 1/4 Hz phenomenon. In conjunction with this, the elevon angle schedule is being changed from +2 deg, back to -2 deg where previous flight data are available. This permits the effects of the fix to be observed.

The elevon schedules for STS 41-F and STS 41-G were swapped ( $M > 10$ ) because the CG position on STS 41-F would have caused the bodyflap to be at or beyond the 15 deg limit. This would not be so on STS 41-G because of a move favorable CG location. STS 41-F will have the elevon schedule loaded in the alternate path for nominal EOM (like STS-9), while the other flights through STS 51-A use the normal path.

We took the action to review and identify all procedure malfunctions at a splinter session.

### 3a. STS-9 Descent Postflight Summary - FM5/J. Hansen

The descent of STS-9 was near-nominal from a trajectory, energy and ground-track standpoint, and nine of 10 PTI's were accomplished (PTI 10 was deleted because of high HAC turn angle caused by the off-nominal 167 landing rev). Touchdown at EAFB runway 17 on rev 167 was at 1649 feet and 185 knots, with a rollout distance of 8456 feet (10,105 feet point on runway). The touchdown speed was a little lower than nominal, and this combined with a late start on derotation caused the Orbiter to fall through derotation until nosewheel touchdown (8.50/second at touchdown). The panel concluded that it is important to emphasize to the crews that derotation be cued to start on velocity rather than the time past main gear touchdown.

While on-orbit the Orbiter lost GPC 1 and 2 (because of loose solder in ICD element), and although GPC 2 was regained prior to entry, it was lost again at nosewheel touchdown. IMU 1 also failed prior to entry (capacitor failure in 5V power supply). APU 1 and 2 failed postlanding (because of cracks in hydrazine flow stem), and there was damage to the right outboard brake. The payload bay door suffered some scorching, and the OMS pods has some debris damage with one resultant burn through. The elevons and bodyflap also suffered some damage to the thermal protection system (TPS).

The trajectory and control descent profiles are shown in enclosure 3. As can be seen in these charts, an atmospheric density shear (peak) was encountered around 230,000 feet altitude ( $V$  approx. 23,800 fps). The substantial inertial side-slip angle ( $\beta$ ) shown is due to crosswind and not vehicle side-slip because of the negligible  $N_y$  side force component. This crosswind helped lower the angle-of-attack ( $\alpha$ ) profile, which coupled with the heavy vehicle weight and 8-9 percent higher atmospheric density encountered in the shear may have resulted in the over heating of the OMS pods. It is believed that the difference in heating between the right and left pods was a local phenomenon since there was no significant relative side-slip.

The RCS propellant usage was higher than expected during descent (difference between planned and actual was 242 pounds). The touchdown energy budget is also shown in enclosure 3. Braking was started at 122 knots and averaged 7.5  $\text{fps}^2$ . A nosewheel steering test was done between 81 and 65 knots ground speed. Aero surface feedbacks were lost at about 89 knots.

### b. STS 41-B Descent Postflight Summary - FM5/K. Joosten

STS 41-B had a nominal vehicle state at  $E_1$ , nominal energy and groundtrack, no significant trajectory problems, and all 10 PTI's were accomplished. The landing was at KSC runway 15 on rev 128 with MLG touchdown at 1930 feet and 196 knots, and a rollout distance of 10,807 feet (vehicle stop at 12,737 feet

point on runway).

Only minor damage occurred to the TPS, except for the OMS pods. Both pods suffered debris damage, but the left pod had major damage due to ice impact from an on-orbit water dump. The SSME insulation was also more damaged than on previous flights.

Two atmospheric density shears were encountered on this flight, one at 250,000 feet (24,000 fps), which was a "hole" instead of a "peak", and another at 148,000 feet (7,500 fps). Preliminary charts showing the performance of some of the aero, trajectory and control parameters are given in enclosure 4. Two major anomalies occurred during descent, explanations for which are still being developed.

The first anomaly is in the Xcg location. Based on the aero and control surfaces data, the CG appears to be about 3 inches forward of prediction (1085 vice 1088 inches). This would explain the bodyflap being saturated up at Mach 12. However, initial postlanding determination put the Xcg fairly close to predicted (within an inch). This discrepancy is still to be resolved. The weight and balance determination of the Xcg will be reviewed at the next Ascent/Entry Flight Techniques Panel meeting.

Action: 2/22-004 - MD2/R. Hischke - Present the STS 41-B Xcg determination history for review at the next flight techniques meeting.

The second anomaly that occurred during STS 41-B was a large downrange discrepancy between onboard and ground navigation post-blackout. The navigation required a 24,000 foot downrange correction when updated at TACAN acquisition (Mach 6). The navigation did converge with the TACAN data and had no subsequent effect on the landing, but the discrepancy still needs explaining.

Action: 2/22-005 - FM8/R. Savely - Present a detailed review of the STS 41-8 navigation performance at the next flight techniques meeting.

The RCS propellant usage was also somewhat higher than predicted. TAEM had nominal energy, altitude and dynamic pressure profiles. The speedbrake did vary from the full open to full closed positions due to winds. The high wind aim point was used for landing. There were discrepancies between the STA and balloon analysis data, which will be examined in detail at the next flight techniques panel meeting.

#### 4. Elevon Schedule and Bending Filter Recommendations for STS 41-C - Rockwell/Honeywell/R. Epple

If the LDEF is returned (Xcg <1093 inches) then the alternate path elevon schedule will be used. For all other cases (Xcg >1093 inches) the normal path will be used. Either the heavy or light bending filter set can be used for any STS 41-C entry case (with or without deployed payload).

#### 5. Thermal Results for STS 41-C - Rockwell/J. Harvey

Thermal analysis for STS 41-C shows that there are no safety issues with either EOM or AOA. The TAL cases are still being analyzed. There was a question about the thermal effects of a 45 deg prebank entry from the high altitude of this flight. This will be reviewed at the next meeting.

6. STS 41-C Ascent Abort Regions - MDTSCO/G. Venables

The STS 41-C abort boundaries are shown in enclosure S. It should be noted on the first chart that Morone, Spain has been dropped as a TAL site, and subsequent to this meeting Rota, Spain was approved as the weather alternate TAL site (with Dakar still as the prime TAL site). With 104 percent throttle there is a 30 second TAL exposure for maximum forward Xcg (1084 inches), and with 109 percent throttle this reduces to a 6 second exposure. Dumping OMS pre-MECO violates the Xcg, and if sufficient propellant is maintained as ballast (2750 pounds OMS, 2200 pounds ARCS) to prevent CG violation, then an additional 20 seconds of TAL exposure is added on a -2 sigma day. This TAL exposure can be reduced either by expanding the forward Xcg limit, or ballasting to a NPS performance level greater than -2 sigma. It was decided that we need to develop the abort options priority (CG vs TAL vs maximum throttle, etc.). Another ascent abort issue for STS 41-C is the free-fall time available for a single OMS engine AOA steep abort off a 200 nmi ATO post-OMS-1 orbit (see enclosure). The curves shown are based on wasting the OMS prop down to the tank landing constraint levels. The current free-fall time constraint requires a minimum of 9 minutes free-fall. The delayed ATO 200/AOA steep case with about 100-150 fps underspeed allows only 6 minutes of free-fall time.

Subsequent to this meeting we decided to accept the possible 6 minutes free-fall minimum for this mission only.

7. Postlanding "Leak Rules"

a. RCS/OMS - DF6/R. Jackson

Mr. Jackson presented the current flight rules pertaining to RCS/OMS leaks postlanding. It was agreed that no changes are required.

b. APU - DF4/R. Lofton

Mr. Lofton presented the current flight rules pertaining to APU leaks post-landing. The only proposed change to the existing rules was to add a paragraph D to rule 16-17 (enclosure 6) which states that a mode V egress will not be performed if the leak is detected only by temperature indications and the fuel tanks are isolatable. The panel recommended that the last sentence be modified to read "FOR APU FUEL LEAK CASES" instead of "FOR THESE CASES" because that is what is really meant and avoids any possible confusion.

8. STS-9 PTI Results - ET3/O. Cooke

M. Cooke presented the results of the STS-9 PTI's (enclosure 7). STS-8 data in the Mach 16 to 4 region indicated lower bodyflap effectiveness when deflected above 0 deg. The STS-9 CG and elevon schedules were planned to obtain up-bodyflap data throughout entry to aid in determining this loss in effectiveness. The actual STS-9 data showed more up-bodyflap than predicted. The contributions to pitching moment differences are currently being defined. These include the basic pitching moment, bodyflap effectiveness and aeroelastic effects, elevon effectiveness, and flow transition effects. Although this anomaly affects elevon trim-range requirements, Mr. Cooke recommended that the 65 percent to 67.5 percent Xcg should still be cleared. The success

of the proposed fix to the 1/4 Hz problem is also required for certifying 65 percent (note: the 1/4 Hz phenomenon was discussed in detail in item 2 of these minutes and will not be repeated here).

An updated set of stability and control derivatives and uncertainties was released after STS-6, and the flight data since then generally agrees, with just a few minor updates. STS-9 was the first flight with 0 deg elevon from Mach 10 to Mach 3, and the aileron data appear nominal (this approaches 65 percent CG requirements with nominal Cm). Between Mach 1.8 and 1.4 the elevon was trimmed at -9 deg (this also approaches 65 percent CG requirement).

A summary of the problems and accomplishments of the PTI and entry data analysis to date is also given in the enclosure, as well as the predicted change in Xcg envelope as the Shuttle Program matures.

#### 9. STS 41-C Landing Opportunities - FM5/J. Hansen

The landing opportunities for STS 41-C are shown in enclosure 8. Nominal landing is at KSC on rev 92 with a descending left pass and 169 nmi cross-range. Plenty of backup daylight opportunities exist up to nominal plus 3 days.