

DA8/Chief, Ascent/Entry Flight Techniques

Ascent/Entry Flight Techniques Panel Meeting #7 Minutes

The seventh Ascent/Entry Panel meeting was held on October 4, 1983, at JSC. Rockwell, NASA Headquarters, Draper Laboratory, MSFC, and DFRC participated via teleconference.

Summary

a. The FCS c.g. envelope is expected to expand when the new STS-6 FAD is incorporated. A speedbrake sweep is planned for STS-9 to help us understand the 1/4 Hz phenomenon. A fix for this problem will also help expand the c.g. envelope forward. The c.g.'s for STS-9, 11 and 13 are within the envelope.

b. The heavyweight bending filters will be used on STS-9 to provide better phase and gain margins during rollout prior to derotation, and less ARCS prop usage. Either filter set is acceptable for STS-11 and 13, although heavy filters are required for STS-13 GRTLS.

c. In order to satisfy the current 1/4 Hz forward c.g. limit (1084") and -2 sigma performance criteria on STS-13, OMS/RCS ballast is required and there is a resultant 23 second TAL exposure. However, if STS-9 proves the effectiveness of the 1/4 Hz fix, then the c.g. limit may be moved forward to possibly eliminate TAL exposure for STS-13. Thermal issues still need to be worked.

d. The procedure for the STS-9 NWS DTO is as follows:

- (1) Brakes on at 120 kts with 8 ft/s² deceleration
- (2) NWS on at 100 kts (switch in "GPC" position)
- (3) Steer with gentle turn off centerline and return
- (4) At 20 kts decrease braking to 6 ft/s² until stop

e. On STS-9 the landing target will not be redesignated to NOR in the event of a deorbit underburn or OMS tank failure. The small amount of delta hp required will be obtained instead by increased prebanking. However, the crew will still procedurally redesignate, although the EDW targets will be loaded in the NOR slot.

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f. For emergency deorbit coverage, non-CONUS CLS support will be maintained, but the <ONUS sites (KSC, EDW, NOR) support will be reduced. CONUS sites not on the weather pad for a particular orbit will be released from the 3 hour alert status. Full support will be maintained at KSC and EDW for launch aborts, PLS, and SLS opportunities, but reduced to minimum level for CLS opportunities.

g. If a fuel (OMS, RCS or APU) leak occurs prior to or during entry Šon STS-9, the vent doors will be left in the open position postlanding (all doors are automatically opened at Mach 2.4). If the leak is detected prior to deorbit, selected doors will be opened and the others closed for entry.

h. STS-8 entry performance indicated the body flap was less effective

than anticipated for the up deflections. The STS-9 elevon schedule may cause the bodyflap to saturate in the up direction in the Mach 16-12 region. Rockwell is looking at the thermal concerns. Possible special procedures are to be evaluated.

i. The STS-9 crossrange limits for inhibiting pre-blackout exit PTI's are:

- (1) 750 nmi ascending, site to left of groundtrack (A/L)
- (2) 797 nmi AIR
- (3) 777 nmi D/R
- (4) 751 nmi D/L

1a. Placards and Estimated CG's for STS-9 11 and 13-Rockwell/C. Unger

The STS-9, 11 and 13 c.g. placards and estimated c.g.'s were presented (enclosure 1). The Mach 3.5 yaw trim boundaries shown as a function of elevon deflection are based on the STS-4 FAD, and should improve when the STS-6 FAD aero is incorporated. The 1/4 Hz phenomenon constrains the forward c.g. to 1083 inches. A speed brake sweep is planned for STS-9 to gain data in an attempt to understand the 1/4 Hz problem. This sweep will evaluate one of the potential explanations of the phenomenon. If successful, this may provide some relief to the forward c.g. boundary by the development of a technique which partially opens the speedbrake in the Mach 1 to 2 regime. It should be pointed out that the STS-9 sweep is to gather data, and is not a fix. However, if the theory is wrong, then this DTO may not help. The Mach 3.5 yaw trim boundaries where the bodyflap would become saturated thus throwing the elevons off schedule are also shown in the enclosure. These boundaries could move further aft based on the preliminary STS-8 results which show less up bodyflap effectiveness than anticipated. In-flight c.g. management is planned so that the c.g. at Mach 3.5 is at least 1 inch away from the X c.g. and Y c.g. limits.

For STS-9 the estimated c.g. locations are all within the current placard boundaries, with the AOA c.g. being farthest forward. With a 1 inch c.g. uncertainty, this location is about 1/2 inch off of the 114 Hz boundary. The STS-11 c.g.'s are longitudinally centered in the boundary envelope, but are laterally off by up to 1.3 inches for EOM. Rockwell will determine if FSL evaluations of Y c.g. out to 2.5 inches and their elevon schedules are compatible with the STS-11 elevon schedules and c.g. offsets. STS-13 has a larger range of possible c.g.'s depending on whether or not the SMM or LDEF are returned. The possible X c.g.'s at Mach 3.5 range from 1 104 inches to 1083 inches.

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b. STS-9, 11, and 13 Bending Filters - Rockwell/R. Epple Š
The Rockwell bending filter recommendations for STS-9, and preliminary recommendations for STS-11 and 13 are shown in enclosure 2. Either set of filters was found to be acceptable for STS-9, although the heavy set provides better phase and gain margins, during rollout prior to derotation and reduces ARCS propellant consumption. The PTI schedule was set up using the heavy filters. Moding to the heavy filters requires a manual crew procedure over an S-band station post OPS 3 transition. For STS-11 either set of filters is currently acceptable for all landing cases (deployed and non-deployed EOM's, and all aborts). Auto filter moding can occur, which requires no crew action.

For STS-13 both sets of filters are acceptable with both payloads

deployed, however, for STS-13 GRTLS, moding to the heavy filters is required.

2. STS-13 AOA vs. TAL

a. Ascent Abort Region Covered - MDTSCO/G. Venables

The current STS-13 ascent performance shows the earliest press-to-MECO (PTM) occurs about the same time as negative return, which means there is little or no TAL exposure. This assumes 2200 lb. RCS is available for use, no OMS/RCS ballast is required for X c.g. management, and a pre-MECO ATO OMS dump of about 4700 lb. is required to reduce MECO underspeed. However, without OMS/RCS ballast, the forward c.g. is at 1076.8 inches on a -2 sigma day, which greatly exceeds the allowable forward c.g. limit of 1084 inches. By adding the ballast the cg is moved aft, but the profile then is opened up to a TAL exposure. Enclosure 3 shows that moving along the -2 sigma line to the forward c.g. limit opens up about a 23 second gap between earliest PTM with ARCS and no ballast, and PTM with ballast. This would be the period of TAL exposure. The issue then, was a tradeoff between the forward AOA c.g. limit (1084 inches) and the added TAL exposure. Adding OMS/RCS ballast to protect the 1084 inch AOA c.g. on a -2 sigma day results in 23 seconds of additional TAL exposure. Actually, the ballasting would be accomplished by just not using some of the OMS and RCS propellant already loaded. A pre-MECO ATO OMS dump is not required if 2750 lb. OMS and 2700 lb. ARCS are reserved for ballast. Both the ballasting and TAL exposure could be reduced by expanding the forward c.g. limit, or ballasting to a MPS performance level better than -2 sigma.

b. FCS Assessment - EH2/L. McWhorter

The STS-13 forward c.g. boundary is constrained by Mach 3.5 lateral trim and Mach 1.7 roll control. To move the Mach 3.5 boundary forward requires evaluation of the STS-6 and STS-9 aero data, and development of earlier use of the rudder. For Mach 1.7, evaluation of the STS-9 speedbrake sweep test is required, and the subsequent incorporation of a 1/4 Hz I-load fix (which would be first flown on STS-13). As stated in the previous item, moving the c.g. forward has the advantage of reducing or possibly completely eliminating TAL exposure and the resultant short runway landing at Dakar, but it increases the RCS propellant budget and increases the risk of facing the 1/4 Hz phenomenon. Moving the c.g. boundary forward 1 inch to 1083 inches requires 1550 lbs of ballast. However, this extra prop is already onboard and just would not be dumped. With a more forward c.g. the RCS jet usage increases in the Mach 5-3.5 region. A more forward

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c.g. would require up control surfaces, the thermal impact of which needs to be analyzed. STS-9 data will help since up elevons are scheduled for the first time.

Action: 10/04-001 - Rockwell - Provide thermal analysis of up control surfaces for STS-13.

Based on the information presented during these last two discussions, we decided to keep the current 1084 inch forward c.g. limit and continue training for TAL until the data from STS-9 can be analyzed. STS-9 may provide enough data to prove the a 1/4 Hz fix and determine the effectiveness of up control surfaces so that a 1084 waiver can be obtained, thus eliminating TAL and associated training. This topic will be revisited after STS-9.

3. NWS DTO-ST5-9

a&b. Procedures/Systems Failure Analysis - ETS/C. Campbell

Although post-touchdown steering is normally accomplished using differential braking and rudder control (at higher speeds), nosewheel steering (NWS) would be required in the event of blown MLG tires, and to reduce brake energy on the upwind side in a crosswind. NWS was initiated on STS-3 at 36 kts, and was tested up to 115 kts on ALT with a light vehicle. The purpose of the STS-9 NWS DTO is to evaluate the NWS operation on a heavy vehicle at moderate velocities. The techniques to be used are being developed by the crew in the simulators, and will also be evaluated at FSL. Currently, the procedure is as follows (the values may change):

- (1) brakes on at 120 kts with 8 ft/s² deceleration
- (2) NWS steering on at 100 kts (NWS switch position in "GPC")
- (3) steer Orbiter with a gentle turn off centerline and return
- (4) at 20 kts decrease braking to 6 ft/s² until stop

This DTO is constrained to an EDW lakebed landing with a crosswind no greater than 10 kts.

A schematic and description of the NWS system are given in enclosure 4. The worst consequence of a NWS failure is a hardover command during rollout. The system has failure detection circuitry which will cause the system to automatically shut down and return the nosewheel to free castor if a failure is detected. The SMS does not model this failure detection.

c. Dynamic Failure Effects - EH1/H. Law

The dynamic effects of a hardover NWS failure have been determined analytically, and also using simulators at Ames Research Center (enclosure 5). The response time of the crewmen to react to the failure and switch the NWS off to obtain the free caster mode is critical. One simulator run showed that a 2.75 second reaction time at 75 kts resulted in .4g laterally and a 150 ft excursion from the centerline. It was recommended that the CDR keep his hand next to or on the NWS switch during the DTO, ready to turn it off in case of failure. The CB representative state that this was already standard procedure for the crew, and would be done

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for STS-9. It should be noted that the onboard NWS system will normally go to free castor automatically if hardover failure is detected.

d. Sim Support Requirement Recommendations - LO/R. McKinney

The SMS is being used to train the crew for the NWS DTO, even though its dynamic modeling is not entirely accurate. The response of the real vehicle to lateral rollout commands should be better. The SMS also does not simulate the lateral lurch c.g.'s, and does not have a failure detection and automatic free castoring mode. The NWS must be turned off manually in the SMS when a failure is introduced. Both Mr. McKinney and DG6/T. Brice believe the simulation training for the DTO is acceptable.

4. Deorbit Underburn

a. STS-9 Capability Assessment - FM4/D. Payne

Current entry procedures call for redesignation of the landing runway from EDW to NOR in the event of a deorbit underburn, where an adequate trajectory to EDW cannot be achieved, even after depletion of all available propellant. Redesignation buys about 3 nmi capability in delta perigee altitude (delta hp) for deorbit on tee nominal STS-9 opportunity, and about 5 nmi for a one rev late. The delta hp gained by redesignation for 28.5 deg inclination orbits is typically larger, e.g., for STS-8 with a nominal crossrange of 580 nmi, the delta hp was 10 nmi. The delta hp lost because of underburn can be required by increasing the prebank angle, as shown in enclosure 6, but this regained accepting a slight increase in aeroheating. The nominal and one rev late EDW opportunities use the same prebank schedule. However, these opportunities require different schedules if redesignated to NOR. Based on this, and the small delta hp gained from redesignating, it was the recommendation of MPAD that the redesignation be deleted from STS-9.

b. Propellant Budget - OMS Tank Failure Coverage - DF6/R. Dittmore

Mr. Dittmore presented the STS-9 propellant margins to cover an OMS tank failure. This coverage is defined as having enough delta V from both OMS and RCS to deorbit to shallow targets assuming an OMS pod has failed. The flight rules do not require this coverage for continuing to nominal EOM, but MCC does track whether or not this coverage exists. If the coverage does not exist, prebanking and redesignation are the available alternatives to make up the dV. The propellant margins and OMS tank failure coverage margins are shown in enclosure 7. If the OMS tank fails during the deorbit burn but after the Orbiter has committed to steep targets, then about 34 fps have to be made up with prebanking. However, redesignation to NOR is not required. If the tank failure occurs prior to the deorbit burn, then shallow targets can be used which results in a 27 fps positive margin. In this case neither prebanking nor redesignation are required.

c. Landing Site Support Recommendations

This is covered in agenda item 5.

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d. Deorbit Underburn Continuance Recommendation - DH3/G. Oliver

Based on the before mentioned considerations, we decided to accept the added thermal impact for larger recovery prebank angles which would eliminate the necessity of having to redesignate from EDW to NOR on STS-9 for deorbit underburn cases. To this effect, it was recommended that the redesignation site data be deleted from the prebank table, and the "B/U HP" references be deleted from the deorbit burn cue cards and del pad. It was decided to accept the recommendations. To avoid training, procedural and FDF impacts for STS-9, the crew's redesignation procedure will not be changed, but the EDW data will be loaded in the NOR slot when the redesignation is implemented. Whether or not redesignation is required on post-STS-9 flights is still being evaluated.

5. Landing Facilities Requirements Redefinition - DH3/P. Chaput

The purpose of this item was to reevaluate the ground support and tracking requirements for STS-9 and subsequent flights in order to reduce manpower requirements and costs. Currently each site is on a 3 hour alert status for all deorbit opportunities to that site. For CONUS sites full support

is required, while non-CONUS sites provide minimum support (see enclosure 8). High speed C-band radars are scheduled for each CONUS site for all opportunities. PLS alert release occurs about 3 hours prior to the prime opportunity landing time, while the SLS and ALS release occurs about 6 hours prior to the first opportunity landing time.

A chart of landing opportunities for a 28-1/20 inclination orbit is shown in the enclosure. Each non-CONUS site provides about one to four daylight landing opportunities each day. Of these sites, Rota generally has one to three opportunities and good weather, but an undesirable up slope on one end of the runway. Honolulu has two to four opportunities and generally good weather. Kadena has two to four opportunities and generally bad weather. Although deleting one of these CLS sites would not have a severe effect on the overall landing opportunities, the cost to keep them as CLS's is small (\$2000/year each, which is for equipment upkeep). If they are deleted as sites, then all references to them must also be deleted. We decided that because of the small cost involved, it was worthwhile to keep the current non-CONUS CLS's to increase our emergency deorbit coverage.

As seen from the table in enclosure 8, NOR provides about three to five opportunities daily, which are concurrent with the EDW and KSC opportunities. The cost for maintaining NOR as a CLS is small (\$5,000-\$10,000 per flight plus runway maintenance and range costs), but could be reduced to as little as \$1,000/flight (plus runway maintenance and range costs) if the support level is reduced to minimum. Based on the low costs involved and that it can be used as a weather alternate for EDW, it was decided to retain NOR as a CLS but with a minimum support level.

Currently all three CONUS sites (EDW, KSC and NOR) are on 3 hour alerts for each landing opportunity, even though one or both of the other sites are also available. A specific site is chosen each orbit on the block weather pad, and there is virtually no chance of a contingency landing at a site not on the pad. It was thus decided to release the CONUS sites from support of opportunities not on the weather pad for STS-9 and subsequent. However, if one site on the pad has marginal weather, an alternate will be kept on alert.

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A full support level is maintained at both KSC and EDW for each opportunity including land aborts. It was decided to maintain this level for the launch abort, PLS and SLS opportunities, but reduce the KSC and EDW support level to minimum for CLS opportunities. The primary costs savings from this support level reduction will be at KSC. A 24 hour notice will be required for full support for landing on a daily primary landing opportunity (i.e., early EOM).

Another issue discussed was whether or not to release AOA weather alternate sites. A late release of an AOA weather alternate site ties up manpower and resources. We accepted the recommendation to make the decision of retaining or releasing the AOA weather alternate site at the L-3:20 crew weather briefing. The alternate site will be released if the forecast weather at the primary AOA site meets the flight rules requirements. It should be noted that this is not an STS-9 issue, but will take effect for STS-11.

Starting with STS-9, tracking support will be scheduled for daily prime opportunities to the PLS and SLS only. The weather alternate site will be released 24 hours before the next day's prime opportunity, or as early as the weather forecasts permit. Tracking for the PLS will be released at prime opportunity minus 3 hours, and as much notice will be given as

possible for tracking support of other opportunities. If there is less than 24 hours notice, there is no guarantee of full support; but if there is greater than 4 hour notice, there is the possibility of at least partial support.

6. Postlanding Payload Bay Vent Door Management with Fuel Leaks - DF4/R. Lofton and LN/L. Bell (postmeeting)

The issue here was what vent door configuration (open/close/purge) should be used postlanding if an OMS, RCS, or APU leak occurred on-orbit or during entry. Concerns included payload contamination, having the payload or Spacelab as an ignition source, or the possibility of payload bay overpressure. Mr. Lofton reviewed procedures to open/close all or selected vent doors while in OPS3 or OPS9. However, no final decision was made at the meeting. Subsequently, at a splinter meeting with Mr. Bell, it was decided to leave the doors in their open position postlanding because there is nothing in the payload bay hot enough to react with fuel vapors. The plan is that in the event of a fuel leak prior to deorbit, vent doors 1, 2, 8, and 9 will be opened and the others closed. At Mach 24 (TAEM initiation), the GPC automatically opens all the doors, and these will be left open postlanding.

7. STS-8 Entry Performance - FM5/K. Joosten

The STS-8 entry, TAEM, approach and landing performance was reviewed (enclosure 9). The main discovery was that bodyflap "up" was not as effective as expected. A higher than expected RCS prop usage also occurred at high Mach numbers during maneuvers. This is the first flight that the prop usage was higher than expected in this region. There is currently no explanation for this. It should be pointed out that the RCS usage shown in the enclosure is based on PVT tank measurements. Other aspects of the entry and landing were close to nominal, and all seven PTI's were accomplished.

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8. STS-8 Bodyflap Trim Anomaly (walk-on) - ET3/D. Cooke

It was found during STS-8 that the bodyflap was less effective than expected for up (-) deflections. Enclosure 10 shows the actual (per postflight analysis) and preflight predicted elevon and bodyflap deflection histories. The bodyflap was trimmed more up (-) than expected between Mach 16 and 4, but outside this region was trimmed as expected for the calculated X c.g. The calculated X c.g. thus appears to be correct. Since the bodyflap position was the only difference on this flight, the bodyflap thus appears to be less effective than predicted for up deflections. This causes additional concern for the forward c.g. limit (see agenda item #1).

The STS-9 elevon schedule (+ 4 deg) and c.g. range are such that the bodyflap will probably saturate in the up direction in the Mach 16-12 region. The elevon would then move off schedule to trim the remaining pitching moment. This is not a FCS control problem, but the crew needs to be forewarned preflight and in the FDF. The planned STS-9 and subsequent elevon schedule and predicted bodyflap deflections are also shown in enclosure 10. Although there is no control problem with the saturated up bodyflap, this does pose some thermal concerns. Rockwell is to quantify the thermal concerns.

9. STS-9 Crossrange Capability (walk-on) - FMS/ E. Smith

Mr. Smith presented the latest crossrange limits for STS-9. These crossranges

are with respect to the orbital ground track and not the centerline of the range-crossrange footprint. Thus the crossranges differentiate between ascending or descending pass entries, and whether or not the landing site is to the left or right of the ground track. These differences increase with increased orbital inclination. The PTI inhibit crossrange values are:

- o 750 nmi ascending, site to left of ground track (A/L)
- o 797 nmi A/R
- o 777 nmi D/R
- o 751 nmi D/L

If the deorbit crossrange exceeds the corresponding PTI inhibit value, then the PTI's will be inhibited until exit from blackout. The energy state will then be reassessed via tracking and the PTI's will be reinitiated if the azimuth error is less than 17.5 deg and the drag reference profile has not dropped more than 1.5 ft/s² from nominal. This is similar to what we did on STS-7, when the crossrange was greater than the designated PTI maximum.

Gary E.Coen