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Lyndon B. Johnson Space Center
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TO: Distribution
FROM: DA8/Chairman, Ascent/Entry Flight Techniques Panel
SUBJECT: Ascent/Entry Flight Techniques Panel Meeting #50 Minutes

The 50th Ascent/Entry Flight Techniques Panel (FTP) meeting was held at JSC on October 20, 1988. A continuation meeting was held on October 24 to discuss deferred agenda Items 3 and 4. Rockwell-Downey and Charles Stark Draper Laboratory participated via teleconference. Any questions or comments should be directed to DA8/R. D. Dittmore at 713-483-5417 or FTS 525-5417. The following items were discussed with the decisions made and actions assigned as noted.

Overall Summary

- a. Action Item review. See detailed minutes.
- b. No special headwind or tailwind placards are required for entry with only one APU remaining. Crosswind must be less than or equal to 10 kts with no greater than light turbulence.
- c. Several FDF changes were agreed to in the APU area:
 - (1) Start an APU at deorbit TIG - 9 minutes (versus existing 5 minutes) to allow for an APU that did not start to receive adequate cooling and provide time for subsequent restart attempts prior to the deorbit burn.
 - (2) Do not switch to the APU 8 heater system until the day before entry in order to get a better checkout of the A and 8 heater systems (not checked out on ground).
 - (3) An APU will not be shutdown prior to MECO or post TAEM during entry for increasing lube oil or bearing temperatures. Test experience has shown that an APU will continue to operate, even at elevated lube oil bearing temperatures, without the risk of uncontained APU damage. Flight rules and FDF will be changed for STS-27 to reflect this decision.
- d. Existing FDF FCS channel management is acceptable although BFS engage concerns exist with two FCS channels powered off. No procedural changes are required. A software change to eliminate the BFS engage concern will be pursued for 01-20.
- e. ET separation clearance is acceptable for both the nominal and TAL cases with two FRCS manifolds failed (1 + 3 or 2 + 4 manifold failure combination) even though an Orbiter "roll-off" will occur. The roll is less than 45 degrees for the nominal case and is not a concern. For the TAL case the roll is expected to be greater than 120 degrees. For this case the FTP agreed to stop the roll at 90 degrees and return the Orbiter back to normal attitude (sufficient clearance exists at 90 degrees).
No procedural or software changes are required. However, flightcrews should be aware of the roll-off as a result of the manifold failures and the response required (i.e., do nothing until 90 degrees then stop translation and return to the desired attitude).

Detailed Minutes:

1. Action Item Review

- a. 88/08/26-001: Rockwell-Downey - Confirm the assumption that a single hydraulic system can supply the aerosurface PRL demand.

Rockwell-Downey/FB75/T. H. Payne believes the existing PRL aerosurface rate

restrictions protect single hydraulic system supply capability (best engineering judgment because no actual test data are available). This action is closed.

- b. 88/09/09-001: Rockwell-Downey - Develop procedure for firing FRCS jets while still attached to the ET In order to clear gas potentially trapped in the aft compartment.

Rockwell-Downey/AD56/M. Ramos briefed the FTP on the FRCS tank sensitivities with helium gas Ingested into the lower tank compartment. Gas clearing procedures could result In tank bulkhead structural failure as a result of high gas flow across the bulkhead exceeding delta P limits. As a result, gas clearing procedures utilizing the normal forward RCS configuration (i.e., multiple jets firing) were deemed not feasible. The FTP concurred but asked Rockwell-Downey to determine if ET separation was feasible using only one FRCS jet (versus 4+) considering a 6 minute delay In ET separation and thruster flowrates available with gas ingestion In the lower compartment (i.e., will flowrates support something less than the nominal - 1, 2, or 3 jets firing simultaneously). This action remains open and will be addressed at the next FTP.

- c. 88/09/09-002: Rockwell-Downey - Assess certification status of the "no FRCS ET SEP" procedure. Determine effort required for certification.

Rockwell-Downey/FC94/C. W. LaMont responded to this action with a recommendation to accept a procedural verification process consisting of analysis and testing in manned simulators in order to "certify" or "verify" the "no FRCS ET SEP" procedure. The FTP believes that the procedure was developed for the situation where no other alternatives were available and that verification of the procedure to allow use as a backup to the FRCS jet separation has not been accomplished, nor has the Program or Rockwell officially agreed to the use of the procedure in anything but a "no option" situation. The FTP asked DF6/L. J. Hautzinger to research the FMEA/CIL documentation to determine if this procedure has been referenced in any way as retention rationale for the loss of the forward RCS, lending credibility to Program acceptance as a backup procedure for ET separation. The FTP did not accept the Rockwell-Downey recommendation for verification of this procedure. The action is closed.

- d. 88/09/09-003: DF6/L. J. Hautzinger - Submit appropriate flight rule and procedural changes to reflect action to delay the nominal ET SEP if the pre-MECO FRCS quantity < 52 percent.

Flight rules have been submitted. The Guidance and Propulsion Systems Branch has decided not to modify the existing procedures because of the difficulty in determining onboard the ability of the leak rate to support delaying ET separation for 6 minutes. The procedure will remain biased to use the FRCS to perform ET separation as long as the propellant quantity > 0 percent (i.e., no comm). The MCC will make a real time call to delay separation if the leak rate will support. This action is closed.

- e. 88/06/17-002: DF6/L. J. Hautzinger - Determine if loss of the OMS crossfeed should be a first day PLS. If the answer is yes, develop an appropriate flight rules CR.

The Guidance and Propulsion Systems Branch has determined that loss of OMS crossfeed capability is not cause for a first day PLS. This action is closed.

- 2. Requirement for Single APU Headwind Placard - Rockwell-Downey/FB75]
T. H. Payne

Rockwell-Downey recommended placarding winds to no greater than 12 kts peak crosswind, 10 kts headwind, 5 kts tailwind, and light turbulence when only a

single APU remains for approach and landing. These relatively mild wind conditions represent Rockwell's desire to minimize the wind conditions present if only a single APU remains, maximizing the ability to control the vehicle through derotation. The FTP agreed with the desire to minimize overall wind conditions but did not agree to placard headwinds or tailwinds to something less than what is presently in the flight rules (headwind < 25, tailwind < 10 kts).

Data presented by Rockwell (Ames data-1988) indicate the slardown rate on the lakebed with a single APU is comparable to earlier lakebed slardown data presented in 1987 that assumed three APU's are available (SES data-1987). The FTP agreed that no special tailwind or headwind placards are required. Crosswind limitations will remain as currently established in the flight rules (less than 10 kts).

3. Pre-Deorbit APU Re start Procedural Concerns - Rockwell-Downey/AE85]
T. Farkas

Rockwell and EP2/W. Scott are concerned about leaving an APU controller powered for long periods of time because of an identified single point failure that can result in APU startup. Currently, the APU controller is powered on at TIG - 45 minutes for APU pre-start activities and remains "on" through APU start and landing.

During the period between APU pre-start and APU start, the tank isolation valves are closed. If an inadvertent start command were to be issued by the controller, the APU would run for only 7-8 pulses before "underspeeding" due to fuel starvation. However, Rockwell and the Systems Branch of the Propulsion and Power Division maintain that 7-8 pulses of operation is sufficient to heat the GG bed to a point where a subsequent start without adequate cooling will result in a hot restart. To complicate matters, the same failure in the controller that resulted in the inadvertent start will not allow APU water injector cooling to take place because taking the APU start switch to "start/override" (i.e., start water injector cooling) will result in an attempt to restart the APU. The only option to cool the APU after the controller failure has occurred is to provide sufficient on-orbit time to allow environment cooling (versus water cooling). Rockwell accepted an action to determine the cool down time period required before a start on the APU could be effected.

Rockwell-Downey/AE85/R. S. Stedman expressed some reservations with attempting to restart an APU that has already been exposed to the controller failure. He accepted an action to review the identified single point failures that can result in an inadvertent APU start to determine if any of these failures present any concern to subsequent APU operation.

The FTP also questioned the need to perform an APU pre-start because it appears that APU startup will still be attempted independent of the pre-start data gathered. Additionally, the information gained during the pre-start is readily available to the MCC personnel without performing the pre-start activities. Consequently, DF4/J. W. Medford was given the action to determine the requirement to perform an APU pre-start. If the pre-start is required, an option exists to perform the activity earlier than TIG - 45 minutes so that if the controller failure were to occur, sufficient time exists between the pre-start activity and normal APU start for APU cool down to be achieved without having to delay the deorbit burn.

Action 88/10/20-001: Rockwell-Downey/AE85/T. Farkas - How much time is required for APU cool down after an inadvertent APU start with the tank isolation valves closed before a restart can be attempted. Provide results to the FTP.

Action 88/10/20-002: Rockwell-Downey/AE85/R. S. Stedman - Determine if a concern exists with restarting an APU that has already been subjected

to an inadvertent" start as a result of one of the Identified single point controller failures. Provide results to the FTP.

Action 88/10/20-003: DF4/J. W. Medford - Determine if the APU pre-start activity is still required. Provide results to the FTP.

The FTP agreed that no FDF changes are required for STS-27. The above actions will be worked and a resolution will be In place for subsequent flights if the planned retrofit of the "new" controller is delayed (currently scheduled to be Implemented on the third flight of 103, second flight of 104, and first flight of 102).

Multiple APU Start Attempts:

Another concern addressed is related to multiple APU start attempts prior to the deorbit burn. Current procedures result in injector cooling after the first start attempt but go directly to "START" with auto shutdown Inhibited if a third attempt is required. Rockwell recommends providing injector cooling for the third attempt to avoid a hot restart condition. The Impact to the FDF is that the APU start activity will have to be moved 4 minutes earlier in order to allow time to perform Injector cooling for two start attempts (TIG - 9 minutes versus TIG - 5 minutes). There is no impact to APU operations or consumables with this change. The FTP agreed to press forward with this change after 575-27.

APU Heater System Checkout:

Because the APU heater system thermostats are not tested between flights, Rockwell and the Engineering Directorate suggested modifying existing heater system management to reselect the A system prior to deorbit (currently the A system is selected at launch with the B system selected midway through the mission through touchdown). Because the thermostats cycle independent of the heater system selected, subsystem engineers desire to verify A system thermostat operation one last time prior to deorbit, especially since the B system has been operating since the midpoint of the mission.

The FTP suggested eliminating the heater system switch at the midpoint of the mission and instead switch to the B system on the day before entry. Rockwell and the Systems Branch of the Propulsion and Power Division agreed with this suggestion. Mr. Medford accepted the action to submit an appropriate block update FDF change.

4. Ascent/Entry APU Management - Rockwell-Downey/AE85/T. Farkas, EP2/W. Scott

Rockwell, Sunstrand, and Mr. Scott all agree that if an APU is operated with high lube oil/bearing temperatures (greater than 400 deg F), the worst thing that can happen is that the APU will experience a contained underspeed shutdown (substantiated through test experience). If the APU is manually shutdown before the under speed occurs, the APU can be safely restarted and has some amount of APU runtime remaining depending upon the magnitude of the lube oil and bearing temperature increase (higher temperatures can result In deformed seals and lube oil leakage during subsequent APU operation that can eventually result in bearing seizure and underspeed shutdown).

For single mission use, Rockwell and the Systems Branch of the Propulsion and Power Division agreed that the lube oil temperature can go as high as 425 deg F and the bearing temperature as high as 450 deg F before subsequent APU operation is significantly impacted. APU operation can still be attempted even if the temperatures Increase greater than the above values but APU runtime is unknown.

Prior to STS-26, an SSME failure mode was experienced In a bypass valve that when combined with the loss of an APU can result in the loss of SSME shutdown

capability (hydraulic and pneumatic). Unfortunately, the bypass valve failure cannot be detected and when combined with an APU failure, prior to MECO, can result in catastrophic consequences.

One way to avoid the consequences associated with the bypass valve failure is to not shutdown an APU prior to MECO. Existing flight rules allow an APU to be manually shutdown prior to MECO when the lube oil or bearing temperatures exceed 355 deg F and 385 deg F respectively in order to save the affected APU for future entry operation. However, based on the desire to avoid hydraulic lockup and Rockwell's information that an APU can be operated at high temperatures and will shutdown "gracefully", the FTP determined to not take any action prior to MECO to manually shutdown an APU that is operating at higher than normal temperatures (i.e., let the APU underspeed shutdown). Action to shutdown the affected APU will be initiated immediately post MECO.

Similar rules exist for entry between TAEM and touchdown where an APU will be shutdown if operating temperatures exceed established limits. Again, because the APU can operate and fail "gracefully" at high temperatures without manual intervention, the FTP determined to allow the APU to continue to operate and take no manual shutdown action.

As far as flight rule APU failure criteria is concerned, the FTP determined that 425 deg F and 450 deg F should be used for the lube oil and bearing temperature limits respectively. Instrumentation error should be considered when determining whether or not an APU has exceeded the above temperature limits. This failure criteria will be used when assessing APU status associated with mission duration requirements.

Mr. Medford accepted the action to modify the existing flight rules and FDF procedures for STS-27, reflecting the above decisions.

5. On-Orbit FCS Checkout. Circ Pumps vs APU Start - DF6/M. J. Ferring

Deferred.

6. FRCS Single Engine Roll Control Requirements - Rockwell-Downey/FC94
J. S. Yasuhara

Mr. Yasuhara briefed the FTP on the FRCS propellant tank vector angle for two SSME's failed and the associated amount of FRCS propellant required to protect single engine roll control requirements. This item is being worked in the Flight Design and Dynamics Division Abort Panel and will be brought forward to the FTP at a later date.

7. FCS Channel Configuration for Two GPC's Failed (BFS Engage Concerns) -
DF6/J. M. Webb

A problem was identified during BFS stress testing In SAIL where engaging the BFS with two of the first three FCS channels powered off could result in excessive elevon hinge moment during ascent load relief (6,000,000 Inch-lbs or loss of control during entry below Mach 1.5 as a result of a large pitch) transient at BFS engage. Review of the Incident revealed that the BFS sets the elevon, rudder, and bodyflap position commands equal to the selected feedback on the first PASS through the software (per requirement), Ignoring PASS bypass fail indicators. With the BFS mid-value selecting 1, 2, and 3 channels and two of the three powered off (i.e., null), large pitch transients can occur resulting in the hinge moment concerns In ascent and the loss of control concerns during entry.

Subsequent investigation of the condition in the SMS bounded the concern to ascent-first stage and to entry-post Mach 1.5. There was some concern that the large step command could also result in failure of some hydraulic fittings and subsequent loss of hydraulic fluid. There was an occurrence during early FCHL testing where a step command greater than 2 deg/sec was

commanded on all four elevons resulting in the loss of a fitting on a hydraulic system and subsequent loss of the affected hydraulic system as a result of loss of fluid. It is questionable whether or not this condition would result but even if it did, the BFS can continue to orbit (if ascent failure) or to touchdown (if entry) with only a single hydraulic system remaining. Because of this capability, the FTP directed the attention to only the first stage and entry post Mach 1.5 timeframes.

Mr. Webb presented several short term options including leaving both affected FCS channels In auto, only powering off the first FCS channel and leaving the second channel In auto, leave procedures as currently identified (turn both channels off), uplink a fourth LRU substitution G-MEM, and restring.

The FTP discussed the pro's and con's of each option (enclosure 1) and determined that no short term action is required considering the risk associated with the procedural options, the small range of exposure (ascent first stage; entry post Mach 1.5) and the fact that three failures are required (two failures that would result in the desire to power off two FCS channels plus a subsequent failure to require BFS engage). Additionally, the flightcrew has been advised to attempt recovery of the FCS channels prior to BFS engage should two of the first three channels be powered off.

In the long term, the Systems Division is pursuing a software change to the BFS for 01-20 to eliminate this concern.

8. ET Separation Clearance with Two FRCS Manifolds Failed - Rockwell-Downey/FC94/C. W. LaMont

A problem with ET separation was identified during SMS integrated simulations where an unexpected roll occurred during a TAL ET separation with two FRCS manifolds failed. Subsequent investigation revealed that the autopilot worked correctly and a roll can be expected if certain combinations of manifold failures occur where both down firing jets and yaw jets on the same side are not available (manifolds 1 + 3, manifolds 2 + 4 failure combinations).

Mr. LaMont conducted a separation study to determine if adequate clearance existed between the Orbiter and the ET. He determined that the Initial clearance is satisfactory and that there is no danger of recontact after the initial clearance while still In the auto mode (enclosure 2). However, large roll and sideslip excursions can be expected (nominal SEP: 35-45 deg; TAL SEP: 120-145 deg). Rates remain reasonable and bounded.

The time of translation will be extended from 5 seconds to 23 seconds for the nominal ET separation and from 14 seconds to 62 seconds for TAL. The TAL is more critical because of the desire to be In the desired Orbiter attitude by entry Interface. Data reviewed prior to STS-26 Indicate that approximately 185 seconds is available from the normal TAL ET SEP time to entry interface (qbar 2). Even with the extended separation and additional time requirements to get back into the desired attitude, sufficient time is available from ET separation to El (this assumes TAL MECO targets are achieved).

To Improve the post ET separation scheduling problems (attitude maneuver pre-El), the FTP determined that the -2 translation can be terminated when the roll-off reaches 90 degrees (35-40 seconds). Sufficient Orbiter/ET clearance exists to allow termination of the -2 translation, action to maneuver back to "wings level", and then maneuver to the desired El attitude.

The FTP did not feel software changes or FDF changes were necessary considering the failures required to get into this scenario (TAL abort plus the right combination of two forward RCS manifolds failed) but did agree that the flightcrews should be made aware of the potential for off-nominal attitude excursions for these failure combinations and the appropriate action response.

9. STS-26 Brake/Tire Status - EH2/C. C. Campbell

Mr. Campbell reported that the brakes and tires were In very good condition post rollout. No brake damage was observed after the Initial factory Inspection (note that rollout braking was light).

A status report on the tire failure pre-STS-26 was also briefed. Recall that a tire buffed through 5 cords (simulating a crosswind landing at KSC) and heated to 131 deg F failed on the Wright Patterson dynamometer. The failure analysis is still In work but Mr. Campbell reports Rockwell and the Guidance, Navigation & Control Systems Branch of the Avionics Systems Division now believe the 131 deg F test temperature to be too severe for the RTLS environment. After reviewing the RTLS profile, the worst case tire temperature now believed to be experienced is 110 deg F. Mr. Campbell stated that effort is in work to change the abort temperature specification documentation to the 110 deg F value and that future testing will be conducted at the new limit.

10. Banjul Assessment for STS-29 (Walk-on) - DM3/K. D. Walyus

Lt. Walyus conducted a Monte Carlo study for Banjul with STS-29 specific weight and monthly environment data (February-March) (enclosure 3). The results are similar to the data presented at previous FTP meetings using heavy landing weights and yearly variations In winds and density altitude, i.e., Banjul is "no go" based on violation of rollout margin criteria approximately 70-80 percent (no go percentage reflects rollout margin measured from the end of the runway; if measured from the barrier which is located 600 ft from the end of the runway, the "no go" percentage would be In the high 90's).

Lt. Walyus also provided data indicating the headwind placards required to make Banjul "go" as far as rollout margin is concerned (enclosure 4). For a mean day (density altitude), the headwind required to protect 2000 ft rollout margin measured from the end of the runway is 5 kts (9 kts if measured from the barrier).

Barrier engagement speed was also discussed even though the Monte Carlo analysis shows all cases stopping prior to engaging the barrier (enclosure 5). It is Important to note that the Monte Carlo analysis does not take into account any dispersions associated with wind change, shear, density altitude, trajectory deviations, and crew procedures. If these dispersions are considered In the worst case scenario, the Orbiter will stop 2000 ft further down the runway and in the majority of the cases result In barrier engagement with no landing deceleration failures (remember the 2000 ft rollout margin is an RSS'd value of several uncertainties).

if the rollout margin is measured from the end of the runway and the runway is considered to be "go", the worst case barrier engagement speed is 62 kts considering all the dispersions present (remember the likelihood of being "go" for this scenario is only 20-30 percent). If the philosophy were to allow the barrier to account for any and all dispersions Instead of protecting the 2000 ft, the worst case barrier engagement speed assuming 100 percent braking capability would be approximately 90 kts. In this latter case the runway "go" percentage based on rollout would Increase to 100 percent (i.e., no cases would result In a runway "no go" based on rollout distance).

The barrier has been designed to withstand a 260,000 Orbiter Impact at 100 kts. Note that the above barrier engagement speeds represent cases with 100 percent braking capability. For failures In the nosewheel steering or braking systems, engagement speeds at greater than 100 kts are possible if rollout margin criteria is not required.

The probability of Banjul being "go" is low because of the weather and rollout considerations. However, when the weather is satisfactory, the option exists to use Banjul as a full-up TAL site if the Program elements are

willing to risk engagement of the barrier with no landing deceleration failures. Barrier engagement is not a concern at the other TAL sites because the barrier is located in the overrun area of the runway and is protected by the rollout margin being measured from the end of the runway (In front of the barrier).

Ronald D. Dittemore

5 Enclosures