

National Aeronautics and
Space Administration
Lyndon B. Johnson Space Center
Houston, Texas
77058

DA8-86-27 (FT)

August 7, 1986

--

TO: Distribution
FROM: DA8/Chairman, Ascent/Entry Flight Techniques

SUBJECT: Ascent/Entry Flight Techniques Panel Meeting #21 Minutes

The 21st Ascent/Entry Flight Techniques Panel meeting was held at JSC on May 29 and June 5, 1986. Rockwell-Downey, KSC, DFRC, and unite Sands participated via teleconference.

Summary

a. The Shuttle barrier system rollout distance, originally thought to be about 650 ft., will probably have to be increased to about 1000 ft. due to loads on the payload bay doors (PLBD) which cause them to be crushed into the payload bay (PLB). TM/Mission Integration Office has the action to determine the minimum rollout distance/loading which will protect the payload envelope.

b. When reviewing the technical criteria for where barriers need to be placed, it was determined that sites with less than 12,820 ft. of runway should have barriers. This number was based on (1) a 240K lb. vehicle, (2) density altitude of 2K ft., (3) no wind, (4) using the short field option with braking at 2K feet remaining (basically Dakar (DKR)), (5) uncertainties totaling 1620 ft., and (6) a deceleration rate of 9 ft/sec². An additional 1K ft. was added in to take care of a 50 percent loss in braking capability. TM believes that barriers should be placed at all transatlantic abort landing (TAL) sites, Edwards Air Force Base (EDW), and KSC. If runway length were the only criteria, barriers would be required at DKR, Moron (MRN), and the Moroccan site (possibly). Zaragoza (ZZA) only exceeds the required length by about 300 ft., so a barrier should also be considered there.

c. The recommended Eastern Test Range (ETR) site priority for the installation of the barriers is DKR, the Moroccan site, and MRN followed by ZZA, EDW, and KSC if more than three barriers are purchased.

d. The rollout margin numbers presently in use were based on some worst on worst uncertainty assessments for wind shears/gusts, density altitude errors, differences in the vehicle trajectory or procedural errors, and a late gear deploy. The total of these uncertainties based on a worst case is 162 ft. This number, vice the present 2K ft. and 3K ft. margins for abort sites and end-of-mission (EOM) respectively will be used for both cases.

e. Tire fires are a definite possibility on TAL aborts or whenever we exceed about 50 million ft-lbs. brake energy. KSC was given the action to generate a plan for handling this situation.

f. The best runway for blown tire cases appears to be a hardsurfaced runway which will not allow the strut to dig in and break. This would mean EDW concrete, KSC, and possibly Northrup Flight Strip (NOR) since it appears to also be a hard surface when compared to the EDW lakebed. It should also be noted that for auxiliary power unit (APU) loss operations, the hard surfaced runway is favored to prevent a hard and possibly catastrophic slapdown.

g. Agreement on landing site priorities will probably not be reached without pursuing this item up the management chain. The primary difference in views between CB/Astronaut Office and the technical community hinges on whether the lakebed or hardsurface runway is the safer place to land. This depends on what you are most concerned about - systems problems, □ like blown tires, which might be of low probability, but are carried as Crit 1 or any crew or piloting problems for which the lakebed may be more forgiving.

h. For other than direct insertion flights, we plan to maintain the orbital maneuvering subsystem (OMS) 1 burn where it is (main engine cutoff (MECO) + 2 minutes) for the time being.

1. Runway Barrier System - TM2/R. D. Tuntland

Mr. Tuntland presented an overview of the Shuttle Orbiter Arresting System requirements and design. The barrier appears typical in design but modified for Orbiter use somewhat. It is supposed to stop a vehicle weighing between 200K and 260K lbs. going a 100 knots with a G load of about 1.5. Orbiter attitude at barrier engagement could be 0-5 degrees from the runway heading, a 4 degree roll, and the nose strut fully extended or compressed. Runout distance was initially specified at 650 ft. for a 150 ft. wide runway. The barrier can be raised or lowered in 5 seconds, should not interfere with egress, and will be flame retardant. Barrier loads would be taken by the main gear, the wings, and the aft portion of the fuselage. The Orbiter will require a nose gear modification to place a cutter on it to make sure any vertical strands caught by the gear will not create an overload and tear it off. It is expected that the nose and main gear doors will be torn off depending on contact speed.

When questioned about the loads on the PLBD's, it was determined by structures personnel and barrier representatives that the vertical load placed on the PLBD's could deform them into the PLB (as much as down to the sill line). Given this circumstance, and the desire not to put loads on, or deform doors into, a payload which could possibly create a more hazardous situation, Mr. Tuntland was asked to check into this further. It appears that a rollout distance of up to 1K ft. could be required to reduce the PLBD loads and prevent the doors from being deformed into the payload envelope. The length of such a rollout, however, significantly reduces the runway available at sites like DKR, which do not have an overrun. Mr. Tuntland was asked to determine the minimum rollout distance which meets the various criteria previously specified and protects the payload envelope.Š

Action: 05/~-001 - TM2/R. D. Tuntland - Determine the optimum rollout distance to protect the payload envelope.

The placement of the barrier on the runway was discussed and it was decided that for "nominal" abort landings we should not hit the barrier as there is conceivably some risk in this activity, including tile damage, gear door damage, etc. In certain brake failure cases or on days when all the uncertainties were against you, barrier contact could result. When the barrier is down (laying across the runway) the Orbiter should roll over it without any problem. Present plans would be to prepare for barrier set up at the TAL sites and be ready to erect it as early as 3 hours prior to launch. One barrier would be provided at a site and it would be installed on the selected runway in about 6 hours. Given the premise that we do not really want to engage the barrier, any overrun available should be used for rollout thus minimizing the loss of actual runway. This means the barrier should be positioned from the end of the overrun a distance equal to the rollout distance after engagement. The barrier would not be erected until the TAL abort was declared and once erected, it would not be lowered until the Orbiter had stopped. The possibility of lowering the barrier prior to the Orbiter hitting it at slow speed (believing the Orbiter would stop in the rollout) was discussed and discounted as adding more complexity and risk into the situation.

Placement of the barrier will definitely require some rethinking of our margin rules including where the margin is computed from (the barrier, the end of the runway, etc.) and may result in new rules with respect to the barrier and how it relates to a TAL site being go/no go. If the barrier is malfunctioning or has problems, is the site still go? These will have to be addressed during the ascent rules reviews scheduled to start in July.

Action: 05/29-002 - DM6/G. T. Oliver - Determine if barrier rules are required and if so, prepare proposal for rules reviews.

2. Site Selection for Barriers - TM2/R. D. Tuntland, DM5/J. V. West, CB/B. D. O'Connor

In an effort to substantiate the need for barriers at the various augmented landing sites, Mr. West was requested to investigate the runway length which would require their implementation. In general the study centered around using a runway like that at DKR. Mr. West based his studies on (1) a 240K lb. vehicle, (2) density altitude of 2K ft., (3) no wind, (4) using the short field option with braking at 2K ft remaining (essentially a DKR site), (5) uncertainties totaling 1620 ft., and (6) a deceleration rate of 9 ft/sec². Also, when considering the runway length another 1K ft. was added to cover the loss of 50 percent braking. The studies indicate that a site with greater than 12,820 ft. should not need a barrier. The use of 9 ft/sec² as the deceleration rate differs from the 10 ft/sec² used today but is considered more appropriate and conservative.

Action: 05/29-003 - DM6/G. T. Oliver, DM5/J. V. West, DF4/A. L. Schmitt - Submit rules and rationale for changing the deceleration rate from 10 ft/sec² to 9 ft/sec².

Action: 05/29-004 - DM6/G. T. Oliver - Review present margin rules and provide any required updates with respect to barrier use.

Mr. West additionally determined that under the above conditions with the barrier at 10,800 ft. on the DKR runway (allows 650 ft. of rollout) there was no contact with the barrier for a 25 percent loss of braking and with a 50 percent loss the barrier was contacted at about 10 knots. These numbers will have to be adjusted if the barrier has to be moved in on the runway to allow a 1K ft. rollout vice a 650 ft. rollout.

Based on the runway length (including the overrun) which we believe technically justifies the Installation of a barrier, DKR, the Moroccan site (possibly), and MRN in that priority should receive barriers. ZZA with approximately 13,181 ft. is a close fourth and should also be considered.

TN and CB would like to place barriers at all of the augmented TAL and EOM sites regardless of their length using for justification the fact that a given site has the shortest runway, services high and low Inclinations, may see detailed test objective (DTO) braking activity, or may be used as a training site. Mr. O'Conner also discussed the various aspects of hydro-planing on stopping distance on the runway. Flight Techniques does not feel that installing barriers at all the sites is justified based on the possibility of rain greater than .1 inch in the timeframe we are discussing - relatively short for TAL's, about an hour for an abort-once-around (AOA) or EOM to EDW, and using the existing conservative weather rules. If TN believes that barriers in addition to the three specified by Flight Techniques can be justified based on other requirements than runway length then those may also be pursued. At this time there is no technical reason to put barriers at EDW and KSC and putting one at ZZA appears only marginally necessary.

Subsequent to the Flight Techniques meeting Mr. Tuntland presented his request for barriers to the Program Change Review Board (PCRB) and it was decided to initially purchase six barriers. This request only covered ETR launches and more barriers may be required to cover Western Test □

Range

augmented landing sites such as Easter Island, Hao Island, Vandenberg, and Miramar. Flight Techniques again believes that these requirements possibly could be met out of the six barriers for ETR. The cost per site is about \$1 million

3. Rollout Margin Requirements/Adequacy - DM5/J V. West

Mr. West reviewed the composition of the present rollout margin numbers. The numbers presently used as rollout margin requirements are 2000 ft. for abort landings and 3000 ft. for EOM landings. These were initially determined by summing up the various uncertainties considered possible and then adding some additional margin on top of that for the sake of conservatism. The uncertainties considered include (1) wind shears/gust effects, (2) errors in density altitude, (3) a late gear deploy, and (4) trajectory or procedural deviations. the best estimates of cost of additional rollout for these uncertainties was 800 ft. for (1), 120 ft. for (2) which represented a missŠin density altitude of 500 ft., 250 ft. for (3) which represented deploying the gear at an altitude of 200 ft., and 450 ft. for (4). When added in a worst on worst scenario, the total uncertainty is 1620 ft. This number was

then rounded to 2000 ft. for abort sites and an additional 1000 ft. added on top of this for EOM. It should be noted that these uncertainties could have been root sum squared for a value of 959 ft. but it was thought that taking the worst on worst and straight summing was more conservative. It appears that we are presently more conservative than necessary with our rollout margin numbers and that a rollout margin number of 1620 ft. is adequate and still conservative. This number should also be used for both the abort and EOM landing cases. Mr. West pointed out that a 15,000 ft. runway (long runway) is effectively equivalent to a short runway (12,000 ft.) when you consider the differences in nominal guidance vs short field, the differences possibly seen in density altitudes (like between EDW and DKR, and the differences in deceleration rate (7.5 vs 10 ft/sec/sec).

Action: 05/29-005 - DN6/G. T. Oliver - Update the flight rules to reflect the 1620 ft. margin number for abort and EOM landings.

During a discussion of how the brake energy numbers are determined, it was pointed out that the energy numbers used by various groups were not necessarily the same and that the numbers in some cases were total energy absorbed vs brake energy only. It was decided that all users of these numbers should be going with the industry standards which mean that when brake energy numbers are specified, it includes energy going into the brake and tire, not just the brake. Actual brake energy absorbed is roughly about 90 percent of the total energy.

4. Tire Fire Possibilities On Aborts - ES6/C. C. Campbell

Mr. Campbell reviewed the tire fire possibilities for abort landings. Basically, the possibility of a tire fire is very high if the brake energy exceeds 50 million ft-lbs. Generally, the tire fuse plugs would release the N2 tire pressure about 2 to 3 minutes after the vehicle has stopped. The tires would begin to melt and smoke about 5 to 8 minutes after stopping with an actual fire resulting between 8 to 11 minutes after stopping. Rubber flash ignition occurs at 900-1000 degrees F and nylon melts at 350-670 degrees F. The N₂ in the tire prevents auto ignition inside the tire. Preventive techniques include providing air cooling (>30 knots) or repeated application of water or conventional aircraft fire extinguisher chemicals until the brakes/wheels cool down. While this scenario does not seem too bad, if coupled with some kind of hydraulic fluid leak, such a fire could spread quickly. Exactly when the ground team should begin to take the steps necessary to prevent a fire was discussed and it was recommended that the tires should not be approached until the fuse plugs have done their job. It would seem, however, that this could create a variable time for beginning to try to prevent the fire and that possibly some tires could be burning while others might still have intact fuse plugs. KSC was given the action to come up with a plan for preventing/fighting postlanding tire fires.

Action: 05/29-006 - KSC/W. R. Carew - Provide a plan for preventing (If possible) tire fires and for fighting one should it occur. Verify that site equipment and personnel are available and training provided.

5. Best Runway for Blown Tire Cases - EH2/H. G. Law, ES6/C. C. Campbell

Mr. Campbell reviewed the estimated sliding coefficients of friction for a metal strut in contact with the runway surface for our possible landing runways. These numbers are estimates but are 0.8 for EDW lakebed, 0.25-0.55 for EDW concrete, and 0.45 to 0.65 for KSC concrete. A H for NOR was not available. The value currently used in simulations is 0.4. It is desirable to have a N that is comparable to that achieved by the brakes and tires. It is believed by Mr. Campbell that the EDW hard surface runway (22 or 04) is the best option since the y of the strut is approximately the N of the brakes/tires and it is sufficiently wide and long with stabilized shoulders. Mr. A. Paczynski, White Sands, provided data on NOR and believes that NOR should rank high among the contenders for the best runway for blown tires. The runway (17/35) is covered by gypsum dust anywhere from 0.5 to 6 inches thick, but under this, there lies a hard mantle which is not affected to any extent by rainfall. If a strut were to drag here he felt that it would penetrate the covering layer but not the mantle. The runway is also sufficiently long and wide to handle blown tire cases. Mr. Paczynski also provided pictures of NOR runway surface conditions and landing effects on the surface. One could see that the Orbiter left rubber skid marks on the hard surface mantle which appeared to have almost no covering at all. Mr. Law presented data on what happens when tire failures occur during landing with respect to slapdown, steering resistance, loss of braking energy, etc. He reviewed the EDW lakebed and concrete runways along with KSC with respect to possible lateral dispersions, slapdown, and stopping distance. He determined that the best runway for overall rollout control was also EDW 04/22.

There are a number of factors which need to be considered when trying to select the best runway for blown tire cases or cases where you know that there is a high probability of losing the tire(s) on landing. There is not even an agreement in the general community and military on whether the lakebed or hard surface is the better place to land. You need to consider the vehicle weight, gear strength, roll on rim capability and controllability. With respect to the runway and support facilities, you need to consider runway hardness, consistency, length, width, weather acceptability, and H aspects. It seems that all data being considered, the technical answer appears to be land on EDW 04/22 if one is concerned about blowing tires. This same position is also taken by those concerned about landing with one or two APU's failed. In this case, a hard surface runway is desired to aid in reducing slapdown loads and the EDW concrete runway is again recommended. There are questions concerning whether we really have roll on rim capability on the Orbiter. At present, we are not sure that the rims will hold up on either the lakebed or the runway and to what extent that even if they do hold up, they will dig into the surface. Digging in has got to be worse on a lakebed, either EDW or NOR. There may be some blown tire/roll on rim testing done later this year after all other testing has been completed to get needed data. Additionally, the possibility of modifying the rims to strengthen them is being pursued. This does not solve the dig in problem however. The skid design envisioned to help take the load and protect the second tire should one tire be low or blown was initially designed for a hard surface runway.

Designing it for either the lakebed or hardsurface could create even greater design problems than if you just considered a hardsurface runway. By the way, the initial skid design did not work. Based on all the above data, it would seem that we ought to be going to EDW 22 for blown tires and other reasons.

6. First Flight EOM Landing Priorities - DM6/G. T. Oliver, CB/F. D. Gregory

Mr. Oliver presented a summary of the pro's and cons of the proposed EOM landing sites for next flight. Based on all of those considerations (enclosure 1), the flight dynamics officer's (FDO) proposed EOM priorities of EDW concrete, EDW lakebed, KSC, and NOR. You would delay a day to go to EDW if conditions were predicted to improve. Mr. Gregory presented the CB position with respect to landing priorities (enclosure 2). These initial priorities were EDW lakebed, EDW concrete and NOR lakebed without using KSC. They would delay a day before going to NOR to try to get into EDW. Both of these positions, FDO's and CB's had been generated prior to the discussion on which runways were better for blown tires or single auxiliary power unit (APU) operations and so those aspects had not really been fully factored into their priority thoughts. The CB position relates to being conservative, reducing the crew intensive landing task, and demonstrating the "new" (thick stator) brakes. Additionally there still exists controversy over tire models, friction coefficients, nosewheel steering capability, etc. After the first landing we would then revisit these priorities to see if any changes could be made. The FDO's position, based on the items presented in enclosure 1, would not change but would remain in place after the first flight. The flight director position, at least going into this meeting, agreed with the FDO position with respect to landing site priorities, but consideration had also been given to the blown tire and APU loss cases. After having heard the blown tire/APU loss discussions, it would appear that the priorities should be EDW concrete, KSC, NOR, and EDW lakebed given that blown tires or the loss of a second APU are the only considerations. After a great deal of discussion CB requested that further information (to allow a better decision later) be provided with respect to runways, friction coefficients, roll on rim capability, anti-skid handling of rolling rims, skid friction coefficients, etc. Some of this data will be available later in the year, but even if it is provided, on any given launch day, there will be concerns that frictional coefficients have changed since they were last measured, that the lakebed (EDW or NOR) consistency is questionable or that our rims will hold together. Weather should not be a factor in the priority process since on the given landing day if conditions are not per the flight rule requirements, a given site priority would be passed over for the next priority. One consideration that is hard to quantify but deserves full consideration is the landing task/stress associated with landing on the various runways. According to the technical data we have, it appears the landing procedures are really the same for both lakebed and hardsurface runways. Guidance and energy problems should not be considered as related to making it to a given runway, i.e., we should be able to rely on these systems to get us to the appropriate runway. Systems failures generally require the use of hardsurface runways. So how do we trade crew landing task/stress related concerns against possible systems failures which are probably low in probability but critical in their nature. Pilot errors induced under the landing tasks/stress situation can also be critical in nature and a lakebed runway could

§ -7-

definitely be more forgiving in some of these instances, but not all. - Flight Techniques will pursue getting more hardness data to support our required landing priority decision but it is expected that this item will require a management decision.

Action 05/29-007 - TM2/R. D. Tuntland - Determine if the hardness and consistency of the EDW lakebed and NOR lakebed can be accurately determined. Coordinate with ES6/C. C. Campbell to see if frictional coefficients can be determined for the roll on rim and dragging strut cases for EDW, KSC, and NOR.

7. Weather Predictor Capabilities at Abort Sites - Deferred

8. Nominal OMS 1 Delay - DM6/B. D. Perry, CB/F. D. Gregory

This item was brought to techniques due to the fact that more and more flights are becoming direct insertions and the Centaur flights had moved OMS 1 to the delayed OMS 1 time (MECO + 12 minutes) since this provided critical time needed to access abort requirements and perform Centaur dumps. It was thought that some standardization could be achieved while also providing the crew with a more relaxed post MECO timeline. Mr. Perry reviewed the delaying of OMS 1 with respect to the philosophical and historical aspects as well as delta V implications. The nominal OMS 1 on time targets (MECO + 2) are designed for nominal MECO conditions and provide protection for small underspeeds. They also allowed time for onboard and Mission Control Center (MCC) evaluation of the MECO conditions and time to maneuver to attitude. Additionally, some time of ignition (TIG) slip capability up to about MECO + 4 minutes is available. The delayed targets (MECO + 12) were designed for nominal MECO conditions and were provided to accommodate systems failure cases. While different geometry from on time targets is involved there is generally no delta V impact over nominal on time burn execution. A TIG slip for the delayed case does incur an AOA delta V penalty, however, and impacts the AOA profile and post insertion timeline. Enclosure 3 provides an on-time vs delayed OMS 1/2 comparison. As can be seen, the nominal vs delayed total delta V is not in any way significant, but there is an increase in delta V required for an AOA to EDW or NOR. Also to be considered somewhat is the fact that by delaying the OMS burns we probably delay the software OPS 2 transition by about 15-20 minutes, but this does not seem like any real driver. Mr. Perry recommended that for near term operations we keep the MECO + 2 standard TIG, but investigate the possible use of a later on time TIG for nominal targets (MECO + 6 or later) while retaining MECO + 2 for underspeed support. Mr. Gregory presented the crew views on delaying OMS 1 for standard insertions while also pointing out that the desire is to use direct insertion profiles whenever possible. Originally, to simplify training, a single OMS 1 time was desired that accommodated nominal and underspeed cases. This assured that both the crew and ground were prepared to deal quickly with underspeed situations and systems problems which could impact the burn. The time that best met those requirements was MECO + 2 minutes. Mr. Gregory pointed out that the MECO + 2 timeline is tight and that only continuous and intense training allows crews to "comfortably" work this timeline while experiencing the micro G environment for the first time. Delaying OMS 1 would allow more crew adaptation time and a more relaxed timeline allowing more time for discussion of any problems. The impact on AOA

delta V and OMS 2 transition time is recognized but the real probability of an AOA may be questioned and there would appear not to be a big impact in delaying the OPS 2 transition. It was the recommendation of the crew to move OMS 1 to MECO + 12 but Insure that training includes adequate underspeed cases that force MECO + 2. In addition, they also asked that some other OMS 1 time that allowed unrushed activity (>MECO +6) be Investigated. It was decided that for the near term we should keep the OMS 1 burn at MECO + 2 for the standard insertion cases but not totally rule out moving it at a later date. Keeping the burn at MECO + 2 keeps the same time for the nominal and underspeed TIG and keeps the flight control team and crew prepared to perform the burn and train on quick recognition of problems. If the ascent is nominal and for some reason more time is required to work specific crew or systems problems, the delayed target set/OMS 1 time can be used to provide the additional time needed.

9. RTLS ET Separation Study Status - Deferred

Alan L. Briscoe

