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SUMMARY OF SPACECRAFT RANGE SAFETY TRAJECTORY ANALYSES FOR APOLLO MISSIONS

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MISSION PLANNING AND ANALYSIS DIVISION

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PROJECT APOLLO

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SUMMARY OF SPACECRAFT RANGE SAFETY TRAJECTORY ANALYSES FOR APOLLO MISSIONS

By Richard E. Kincade

SUMMARY

This document summarizes spacecraft range safety trajectory analyses for Apollo missions and the support provided by the Manned Spacecraft Center (MSC) in order to gain flight plan approval for each mission as required by the Air Force Eastern Test Range (AFETR). The basic spacecraft range safety trajectory analyses for each mission have been completed, and any additional studies which may be required by the AFETR will be provided upon request.

INTRODUCTION

The AFETR provides the facilities, instrumentation, and personnel to support missile and space vehicle testing as required by the Range user. Since there are hazards inherent in the operation of missiles and space vehicles, it is the responsibility of the Range Safety Office of AFETR to insure that all reasonable precautions are taken to minimize the risk to life, health, and property.

The conditions which the Range Safety Office (written as the AFETR during the remainder of the report for brevity) places on a flight test may degrade the probability of mission success. For example, in-flight failure of range safety instrumentations may be the reason for flight termination even though there is no apparent mission failure. For the worst case, the AFETR may not allow a flight to take place if the flight plans and vehicle configuration are not compatible with current policies and regulations. For such cases, the AFETR may agree to waive certain requirements if the launch agency can provide adequate justification.

The effect of range safety constraints on the probability of mission success can be minimized by careful mission planning with range safety considerations in mind. This process basically consists of evaluating the tradeoffs between mission requirements and range safety requirements. To perform this process successfully requires a thorough understanding of current range safety policies, regulations, and practices. It must be done in the earliest mission planning stages to detect and minimize constraints or incompatibilities before hardware configurations are fixed. The cost of this additional planning is insignificant compared to the cost of late hardware changes or to the possible additional risk to mission success.

Approval of the proposed flight plan by the Commander or his designated safety representative is a necessary prerequisite for launch on the AFETR. This approval will be final as long as the mission remains within the specified limits. Approval of the flight plan does not constitute permission to launch. Permission to launch is granted only after all AFETR data requirements have been met.

For NASA to gain flight plan approval and permission to launch Apollo Saturn IB and Saturn V missions, a Range Safety Subpanel was formed by the MSC, Marshall Spaceflight Center (MSFC), and Kennedy Space Center (KSC). This panel, a subpanel of the Flight Mechanics Panel, defines and provides trajectory support necessary to satisfy all AFETR range safety requirements.

AS-201 RANGE SAFETY ANALYSIS

The Range Safety Subpanel determined that for mission AS-201, MSC would prepare the range safety trajectory data package for the spacecraft and MSFC would supply the launch vehicle data. The following agreements between MSC and MSFC were made:

(1) MSFC would have responsibility for the range safety trajectory data for all the launch vehicle stages, interstage, spacecraft LM adapter (SLA), and instrument unit; MSC would be responsible for the service module (SM), command module (CM), and launch escape system (LES).

(2) MSFC would provide the necessary range safety trajectory information for parts of the spacecraft remaining on the launch vehicle after an abort.

(3) MSC would provide the following information to MSFC for inclusion in their range safety studies:

(a) Expected effects of launch vehicle destruct action on the spacecraft components.

(b) Breakup characteristics of the spacecraft due to entry conditions.

(4) The spacecraft trajectory data that MSC would provide the AFETR must include the following information for the various spacecraft components separated from the launch vehicle.

(a) Expected drag coefficients and theoretical nominal impact point for each component of the spacecraft.

(b) Expected theoretical aborted impact points for each component of the spacecraft using the proper time delays when aborting from the launch vehicle nominal, three-sigma maximum performance, three-sigma minimum performance, and three-sigma lateral deviation trajectories.

(c) Maximum expected lateral deviation from the spacecraft nominal flight path.

(d) Statistical analyses to determine the probabilities of land impact and casualties for cases which involve the flight over inhabited areas.

In addition to this basic data for AS-201, the AFETR required the Range Safety Subpanel to furnish a spacecraft impact dispersion analysis and the LES performance characteristics, sequence of events, and aerodynamics. They also requested that the booster engine shutdown inhibit be extended from 40 seconds to about 60 to 65 seconds of flight time.

Range Safety Trajectory Computations

Reference 1 presents a summary of the input data, methods, and results for the AS-201 preliminary range safety package submitted to the AFETR to inform them of the basic flight plan, nominal trajectory, and nonnominal trajectories for this mission. The package consisted of a magnetic tape and printouts of the spacecraft nominal, three-sigma maximum performance, three-sigma minimum performance, and three-sigma lateral deviation trajectories from S-IVB burnout to the end of spacecraft powered flight. The three-sigma maximum performance trajectory was obtained by perturbing the command and service modules (CSM) weight, service propulsion system (SPS) thrust, and SPS specific impulse. Perturbation values used to generate the three-sigma minimum performance were the negatives of the perturbations used for the above three-sigma maximum performance trajectory. The body attitude perturbation was applied in generating the three-sigma lateral deviation trajectories. From these trajectories and other perturbations (winds, for example), the crossrange and downrange impact dispersions from the CM, SM, and LES nominal impact points were obtained.

The final range safety package (ref. 2) was completed to provide the AFETR with the operational trajectory and dispersion data associated with this trajectory. Magnetic tapes in the AFETR format were generated to include these trajectories. The three-sigma trajectory cases and their impact dispersions were computed using the same methods as those of the preliminary range safety package. The results of these studies indicated that no land areas would be in danger as the result of flying the nominal or three-sigma trajectories.

A summary of launch aborts using the LES on Saturn Apollo missions, as requested by the AFETR, is presented in reference 3. For this study, nominal conditions were taken from a typical AS-201 launch vehicle trajectory, and abort trajectories were computed every 10 seconds from liftoff until nominal tower jettison time. These abort trajectories were divided into two groups due to event sequencing differences as a function of altitude. The two groups were composed of those for aborts at less than 12 000-ft altitude and those at greater than 12 000-ft altitude. Aerodynamic parameters for the launch escape vehicle were provided. For each abort trajectory computed, the relative velocity, relative flight-path angle, and altitude that were imparted to the spacecraft by the launch escape motor and pitch motor were also computed.

Reference 4 was written to inform the AFETR of MSC's opposition to the proposed extension of the booster engine shutdown capacity from 40 to 60 seconds of flight time. MSC was opposed to this extension since it would put the spacecraft in the region of high dynamic pressure. Even if a recontact between the spacecraft and launch vehicle were avoided, the separation distances were below the MSC/NAA specification values if the time were changed to T + 60 seconds. Even with these reasons, the AFETR extended the range safety booster engine shutdown capacity from T + 40 to T + 60 seconds for AS-201.

Other AFETR questions concerning off nominal spacecraft trajectories for AS-201 were answered by abort and alternate mission studies performed by MSC.

Failure Mode Analysis

The AFETR required a probability study assessing the hazards associated with the proposed flight. The first major step specified in undertaking this study was the determination of significant failures which may lead to range safety hazards. Reference 5 determined failure modes pertinent to Apollo spacecraft components on AS-201 and their effect on the impact points of the spacecraft. The emphasis was placed on the effects of the failure or flight conditions on the instantaneous impact point of the spacecraft rather than upon the exact cause of the failure. Hazardous failure modes of the Apollo CSM major subsystems were reviewed to determine the degree of hazard that would exist downrange to land masses in the event that such a failure occurred. The specific types of failure that were considered are as follows:

(1) Hard-over tumble of the SPS thrust chamber.

(2) Failure of the SPS to ignite.

(3) Failure of the SPS to reignite.

(4) Premature cutoff of the SPS during first and second burns.

(5) Failure of the SPS to cut off with a consequent burning until fuel depletion.

(6) Failure of the SM reaction control system (RCS) to orient the spacecraft to the proper attitude.

(7) Failure of the CM RCS to orient the spacecraft to the proper attitude.

(8) Failure of the CM and SM to separate.

(9) Failure of the LES jettison motor.

The probability of occurrence associated with each of these failure modes or flight conditions was determined using information obtained from histories of other space vehicles similar to the CSM.

Impact Probability and Estimated Number of Casualties Analysis

After determining the hazardous failure modes of the CSM, the evaluations of hazards to land masses (probability of impact on land and casualty expectations) associated with the reentry of the LES, SM, and CM were made (ref. 7). In this evaluation the failure mode analysis of reference 5 was revised and updated. It was found that of the nine failure modes considered, only certain attitude errors resulted in impacts of the CM or SM on downrange land masses. The impact probabilities and casualty expectations resulting from these attitude errors were conservative because the assumptions were made that (1) there would be no inhibit or cutoff of the SPS burn, (2) large attitude errors were as likely to occur as small attitude errors, (3) there would be no shelter available for inhabitants of land impact areas, and (4) CM impacts were computed assuming no landing parachutes. The results of this study, using these conservative assumptions, indicated small hazards to life and land.

Effect of Launch Vehicle Destruct Action on the Spacecraft

An analysis was performed in reference 6 which determined the number and characteristics of spacecraft pieces resulting from launch vehicle destruct action. The weight, drag properties, survivability, and lethal areas of these pieces were computed. The breakups of the SM and SLA were considered in three phases. In phase 1 the following actions occurred:

(1) Destruct action was taken on the S-IVB stage.

(2) The LES operated and removed the CM.

(3) The SM and SLA remained on the booster.

Phase 2 consisted of the following:

(1) No booster destruct action occurred.

(2) S-IVB engine cutoff took place.

(3) The SM and SLA remained on the S-IVB.

(4) The LES operated and removed the CM.

The final phase resulted in the following:

(1) No booster destruct action occurred.

(2) S-IVB cutoff took place.

(3) The CSM separated from the S-IVB.

(4) The SM and CM separated before reentry.

(5) The SLA remained on the S-IVB.

The results of this study (weight, drag properties, survivability, and lethal area of the pieces) were provided MSFC for inclusion in their launch vehicle range safety package.

AS-202 RANGE SAFETY ANALYSIS

The Range Safety Subpanel decided that the basic plan for supplying the necessary trajectory data to the AFETR for AS-201 would also be used for AS-202. This subpanel realized that additional trajectory evaluations would have to be made for this mission, as compared to AS-201, since the nominal trajectory was to fly over many different countries and islands before landing in the Pacific Ocean. A presentation of the proposed AS-202 mission plan was given to the AFETR approximately 1 year in advance of the launch date to inform them of the range safety aspects and the range safety trajectory calculations planned for this mission.

The AFETR stated that in addition to the basic range safety trajectory analyses being performed by NASA certain other range safety requirements must be met before flight plan approval could be granted. These requirements were:

(1) The spacecraft trajectory must be reshaped such that the SM three-sigma impact dispersion area was not on a land mass in the event of no second SPS burn.

(2) A procedure acceptable to the AFETR must be established that would prevent gross overspeeds that could result in impact on land masses downrange of the expected target point.

(3) A procedure acceptable to the AFETR must be established that would prevent an SPS burn if it appears land impact will occur as the result of this burn.

Descriptions of the range safety analyses which were performed for AS-202 are found in the following sections. These analyses satisfied the AFETR range safety trajectory requirements.

Range Safety Trajectory Computations

A preliminary range safety package (ref. 8) was submitted to the AFETR to inform them of the proposed mission plan. The package consisted of the following items:

(1) One magnetic tape in the AFETR format containing trajectories from S-IVB burnout to the end of the spacecraft powered flight for the nominal, three-sigma maximum, three-sigma minimum, and three-sigma lateral spacecraft trajectories.

(2) Binary coded decimal (BCD) printouts of this tape.

(3) Printouts for the nominal, three-sigma maximum, three-sigma minimum, and three-sigma lateral spacecraft trajectories from S-IVB burnout to CM entry (400 000 ft).

(4) Nominal LES, CM, and SM trajectories to impact.

(5) Nominal impact points and three-sigma impact dispersion el lipses for the CM, SM, and LES.

Perturbations of the CSM weight, SPS thrust, and SPS specific impulse were used to obtain the three-sigma maximum CSM trajectory. Perturbation values used to generate the three-sigma minimum trajectory were the negative of the perturbations used for the three-sigma maximum CSM trajectory. The three-sigma lateral CSM trajectory was obtained by simulating nominal guidance with the CM target offset a three-sigma distance to the right. These trajectories were used in obtaining the three-sigma impact dispersions for the LES, SM, and CM.

In order to notify the AFETR of the final operational trajectory to be flown, reference 9 was published. The three-sigma maximum and minimum trajectories of this package were computed the same as reference 8 using the appropriate S-IVB three-sigma burnout conditions. The three-sigma lateral booster trajectory was not used for preparation of this report. Guidance analysis indicated that lateral dispersions during CSM flight with guidance error sources were sufficiently small so as not to warrant generating lateral-deviation trajectories. Downrange and crossrange dispersions were then obtained for the LES, SM, and CM impacts.

Expected lateral deviations and tumble-turn envelopes for an alternate mission were also provided. These data were provided since there was the possibility that an alternate mission, using an SCS controlled attitude during the SPS burn, might be flown in the event of guidance and navigation (G&N) failure.

Enclosure 1 of reference 10 presented the action taken by MSC to comply with the AFETR request for first burn retargeting such that the SM would not endanger any land masses if the SPS engine failed to ignite for the second SPS burn. It showed that the trajectory had been reshaped in order that the SM three-sigma impact ellipse would cover water and not land.

Trajectory parameters for real-time monitoring to prevent land impact hazard during spacecraft propulsion system burns were presented in enclosure 2 of reference 10. This enclosure explained how the flight controllers were to control spacecraft overspeed and skipout cases and also their procedure for monitoring the SPS performance during flight over Africa after a nonnominal S-IVB cutoff.

Failure Mode Analysis

Reference 11 presented an analysis of failure modes pertinent to AS-202 spacecraft components and a determination of their effects in relation to range safety. This report gave relevant historical flight test results, the failures considered in evaluating hazardous failure modes, and the associated probabilities of failure for these failure modes. It included a discussion of all failure modes that may endanger land masses together with a listing of the land areas that may be endangered by a particular mode of failure. Since the nominal impact points for the SM and the CM were in a broad ocean area, the determination of whether or not a hazard existed was based on the change to the instantaneous impact point (IIP) as a result of a particular failure. The specific types of failures that were considered were:

(1) Hard-over tumble resulting from hard-over deflection of the SPS chamber.

(2) Failure of the SPS to ignite.

(3) Failure of the SPS to reignite.

(4) Premature cutoff of the SPS.

(5) Failure of the SPS to cut off followed by a burning until fuel depletion.

(6) Failure of the SCS.

(7) Failure of the SM RCS.

(8) Failure of the CM RCS.

(9) Failure of the CM and SM to separate.

(10) Failure of the G&N system.

(11) Failure of the LES jettison motor.

Impact Probability and Estimated Number of Casualties Analysis

Since this mission was to fly over land areas, it was necessary to perform a very comprehensive hazard study for AS-202. The primary objective of reference 13 was to determine the hazards to land masses (both probabilities of impact on land and the associated estimations of human casualties) associated with (1) a successful flight, (2) failures which may occur subsequent to the S-IVB phase of flight, and (3) alternate missions. Updated failure mode analyses were used to predict the in-flight reliability performance of the spacecraft. The modes of failure that were determined to be of primary interest to this study were:

(1) A premature thrust termination of the first SPS burn.

(2) A premature thrust termination of subsequent SPS burns.

(3) A slow turn during the first or subsequent SPS burns.

(4) A hard-over tumble during the first or subsequent SPS burns.

(5) An attitude control failure during a coast phase with a resultant attitude error for the subsequent burn.

(6) A failure to start the SPS engine for the first burn.

(7) A failure to restart the SPS engine for any burn subsequent to the first burn.

(8) A failure to terminate thrust of the SPS engine at the end of the first burn with burning continuing until propellant depletion.

Hazard estimates were then calculated for the nominal mission, premature thrust termination of the first SPS burn, premature thrust termination of the second burn, premature thrust termination of the third burn, premature thrust termination of the fourth burn, a hard-over tumble during the first burn, a hard-over tumble during the second burn, a hard-over tumble during the third burn, a hard-over tumble during the fourth burn, a failure to ignite for any of the four burns, a thrust termination failure for any of the four burns, a gradual turn during any of the four burns, and an attitude mis-orientation during any of the four burns.

Alternate mission hazards were calculated for (1) a successful spacecraft alternate mission resulting from an S-IVB premature thrust termination, (2) a secondary failure of the spacecraft during the alternate mission following an S-IVB premature thrust termination, and (3) an alternate mission of the spacecraft made necessary by a G&N failure after alignment for the second burn.

This study indicated that failures during the nominal or alternate missions would result in small probabilities of killing or injuring people in lands flown over.

Effect of Launch Vehicle Destruct Action on the Spacecraft

Analyses performed for this mission (ref. 12) were essentially the same as those completed for AS-201 (ref. 6). Since only minor variations in weight and propellant loads existed, the spacecraft configuration used in determining breakup characteristics was similar. This breakup study was included in the MSFC launch vehicle range safety package.

AS-204 RANGE SAFETY ANALYSIS

The AFETR requires that trajectory information be furnished from lift-off to a point in flight where effective thrust of the final stage has terminated or to thrust termination of the burn which places the vehicle in orbit. The AFETR required no spacecraft trajectory data other than what was supplied in the MSFC range safety package for the following reasons:

(1) The spacecraft was to be manned for this mission.

(2) The spacecraft was to remain on the launch vehicle up to and during orbit insertion for the nominal mission.

(3) Spacecraft abort and alternate mission studies revealed no hazards to land.

The following sections describe the range safety trajectory analyses completed for this mission.

Range Safety Trajectory Computations

The nominal and three-sigma impact data for the launch escape tower (LET) were calculated and provided to MSFC for inclusion in their range safety package.

Studies were made by MSC which recommended that the time of booster engine cutoff enable be lift-off plus 40 seconds. This setting of lift-off plus 40 seconds would insure no recontacts between the spacecraft and the booster. The AFETR accepted this setting for all manned Apollo/Saturn IB flights.

Effect of Launch Vehicle Destruct Action on the Spacecraft

Reference 14 identified the effect of launch vehicle destruct action on the portions of the Apollo spacecraft remaining on the Saturn booster following an abort of the booster and removal of the CM. The abort and subsequent destruct action was considered in three phases of the ascent flight. These phases are identified below.

Phase 1.- Mission abort near launch pad during first 40 seconds of flight.

Sequence of events:
(1) The abort is commanded.
(2) LES removes the CM (SM and SLA remain on the booster).
(3) Destruct action taken on the booster.

Phase 2.- Mission abort after 40 seconds and before LES nominal jettison.

Sequence of events:
(1) The abort is commanded.
(2) Booster engine thrust cutoff.
(3) LES removes the CM (SM and SLA remain on the booster).
(4) Destruct action taken on booster, if necessary.

Phase 3.- Mission abort after LES jettison.

Sequence of events:
(1) The abort is commanded.
(2) Booster engine thrust cutoff.
(3) SM and SLA separate.
(4) SM engine operates and removes the CSM (SLA panels remain on the booster).
(5) Destruct action taken on the booster, if necessary.

The number, weight, estimated velocity, reference area, estimated drag coefficient, and lethal area of the pieces resulting from the above destruct action were given to MSFC for inclusion in their range safety package.

AS-206 RANGE SAFETY ANALYSIS

The AFETR has tentatively agreed that the trajectory data furnished for this mission by MSFC will be sufficient for range safety requirements for the following reasons:

(1) The LM is to remain on the booster until orbit insertion for the nominal mission.

(2) There is no LES provided for this mission.

(3) The spacecraft abort and alternate mission studies provide land impact data for nonnominal missions.

No spacecraft trajectory information has been supplied to the AFETR as a result of this tentative agreement. In the event the AFETR does require any special spacecraft range safety studies, they will be performed either by MSC engineers or under an MSC/TRW Task.

Effect of Launch Vehicle Destruct Action on The Spacecraft

Reference 15 presented the analysis of the effect of booster explosion on the LM and the SLA, the structure breakup of the LM and the SLA as the result of this explosion, and the initial velocities and lethal areas of the resulting pieces. The following abort and destruct ground rules were assumed for the analysis of this particular mission and configuration:

(1) Unless the dynamic pressure is below 1.0 psf, the LM will remain on the booster during an abort.

(2) Subsequent to any abort during the powered flight up to the time of orbit insertion, the destruct signal will be sent if the booster (plus the remaining spacecraft components) appears to violate range safety constraints.

Based on these ground rules, it was determined that the effects of destruct action may be experienced during any part of the booster powered flight up to orbit insertion. The results of this analysis were forwarded to MSFC for inclusion in their range safety studies.

AS-501 RANGE SAFETY ANALYSIS

The AFETR has also agreed that trajectory information supplied by MSFC would suffice for this mission. This agreement was made since the spacecraft is to remain on the booster until orbit insertion except for off-nominal cases. The off-nominal cases are to be covered by the abort and alternate mission plans also furnished to AFETR range safety. Any spacecraft studies that may be required by the AFETR will be completed upon request.

Range Safety Trajectory Computations

The LET three-sigma impact dispersions (downrange, uprange, cross-range) for the 500-series missions were computed using the three-sigma maximum, minimum, and lateral booster trajectories, the three-sigma high and low LET jettison motor impulse, the three-sigma high and low LET jettison motor angle, and three-sigma winds on the LET. These three-sigma impact dispersions and the LET nominal impact data were given to MSFC as an addition to their launch vehicle range safety analysis.

The AFETR questioned the choice of a 72° launch azimuth for AS-501 and AS-502 since the S-IVB dwell time across Africa could be significantly decreased by choosing launch azimuths from approximately 90° to 105°. The results of reference 16 showed that the expectation of casualties for a 72° azimuth is less than or nearly equal to those for launch azimuths between 90° and 105°. Other trajectory information proved that the 72° flight azimuth was mandatory to fulfill the tracking requirements for these missions. As a result of this data the AFETR has agreed that a launch azimuth of 72° for this mission is justifiable.

MSC requested that the booster enable cutoff times be set at lift-off plus 30 seconds. This recommended time setting would allow the launch escape vehicle to perform a safe abort well within the separation constraint criteria. The AFETR has accepted this setting for AS-501.

Effect of Launch Vehicle Destruct Action on the Spacecraft

Reference 17 investigated two phases of ascent flight during which an abort and subsequent destruct action might occur. These phases were as follows:

(1) during flight from lift-off to LES jettison when the SM, SLA, and the LM test article (LTA) will remain on the booster,

(2) during the flight from LES jettison to S-IVB first burn cut-off when both the SLA panels and the LTA will remain on the booster.

The number, weight, reference area, lethal area, and approximate incremental velocity of the pieces resulting from destruct action on the S-IVB were computed and forwarded to MSFC for their use.

AS-502 RANGE SAFETY ANALYSIS

No spacecraft range safety trajectory information, other than what is supplied by MSFC, has been requested by the AFETR for the same reasons as those given for AS-501. As in the case of the preceding missions, special data requirements will be fulfilled upon request.

Range Safety Trajectory Computations

It was determined that the LET impact dispersion ellipse computed for AS-501 was also applicable to the AS-502 LET. The nominal LET impact for AS-502 was computed and was forwarded along with this impact dispersion ellipse to MSFC for inclusion in their range safety analysis.

Effect of Launch Vehicle Destruct Action on The Spacecraft

Since the spacecraft configuration (i.e., SM, LTA, and SLA) is essentially identical to the AS-501 configuration, and the ascent trajectory and increased dynamic pressure resulting from destruct action are very similar to those for AS-501 (ref. 17), it was determined that the structural breakup resulting from destruct action on the booster is expected to be the same as for mission AS-501. MSFC was notified by reference 18 to use the AS-501 results in their AS-502 range safety analyses.

AS-258 RANGE SAFETY ANALYSIS

Since both the AS-205 and AS-208 missions are placed into orbit, no spacecraft range safety trajectory work (other than what is covered in the MSFC range safety analyses) has been requested by the AFETR. The LET impact data will be computed as soon as the nominal trajectory is finalized. Any other range safety studies will be performed as requested.

Effect of Launch Vehicle Destruct Action on The Spacecraft

The investigation made in reference 19 considered the ascent phase of AS-205 (manned) to LET jettison and the AS-208 (unmanned) ascent-to-orbit-injection phase. During these ascent trajectories, an abort of the mission was assumed to occur if the booster malfunctioned or an impending failure was indicated. The objective of this investigation was to analyze the effect of a destruct and any impending explosion on the SM and SLA for the AS-205 launch and on the LM and SLA for the AS-208 launch. Estimates of the size, weight, expulsion velocity, and lethal areas of the pieces were determined for each launch and provided to MSFC.

AS-503 RANGE SAFETY ANALYSIS

The AFETR has indicated that no spacecraft range safety trajectory computations (other than those contained in the MSFC range safety package) will be necessary for this mission.

Effect of Launch Vehicle Destruct Action on The Spacecraft

An analysis was performed to determine the effect of launch vehicle destruct action on the SM, LM, and SLA for this mission. Reference 20 presents the destruct induced environment realized by the spacecraft, the mode of spacecraft structural breakup, and the initial velocities and lethal areas of the resulting pieces. This information was forwarded to MSFC for inclusion in their launch vehicle range safety analyses.

AS-504 RANGE SAFETY ANALYSIS

The AFETR spacecraft trajectory requirements for this mission should be the same as those for the preceding orbital missions. Any special studies for the spacecraft will be performed by MSC.

Effect of Launch Vehicle Destruct Action on The Spacecraft

Reference 21 evaluated the effect of launch vehicle destruction and explosion on the SM, LM, and SLA. The number, weight, reference area, lethal area, and approximate incremental velocity of the pieces resulting from launch vehicle destruction were given. This data will be included in the launch vehicle range safety plan.

CONCLUSIONS

The spacecraft range safety studies performed by MSC and TRW were invaluable in the early phases of the Apollo program. Since the AFETR was especially concerned about a new spacecraft which had never been launched on the AFETR, it was very important that MSC furnish them with all information required for a new type program. MSC furnished all this required spacecraft information for AS-201 and AS-202 and aided in gaining flight plan approval for these missions.

Since the majority of range safety analyses for orbital flights is concerned with the launch vehicle, it would appear that the spacecraft range safety studies are of minor importance. This is not true since it is very important to supply MSFC with the results of the launch vehicle destruct action on the spacecraft. Without this information a true picture of the total hazards resulting from a launch vehicle destruction could not be made. In addition, the AFETR is always requesting range safety information and data concerning the abort and alternate mission planning for each flight and the rationale for selecting the various flight plans. This information and data must be supplied by MSC before flight plan approval can be granted.

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