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ARIA DEPLOYMENT MODEL

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A deployment model has been designed to determine the flight plans for Apollo Range Instrumentation Aircraft (ARIA) in support of the translunar injection phase of Apollo missions. The major objective of developing this model was to envision the operational factors necessary to meet the ARIA support requirements under various conditions. A discussion of the model would be incomplete without a brief description of the ARIA, its mission, and the translunar injection parameters associated with Apollo missions.

There are eight Apollo Range Instrumentation Aircraft in various stages of completion whose mission will be to support NASA/Apollo and advanced Department of Defense missions. The aircraft are converted C-135s with UHF and S-band telemetry and other communication equipment. They will act as relay stations between the spacecraft and ground stations. In Apollo/Saturn V lunar missions, the ARIA will be deployed to obtain data during the translunar injection and the reentry. The term "Injection" will designate the event of changing from an earth parking orbit to a translunar trajectory. In the earth parking orbit, the spacecraft will use the S-IVB stage to transfer it from the parking orbit to the translunar trajectory. The data interval ARIA must support is three minutes prior to S-IVB reignition, the S-IVB burn period which is approximately six minutes, and one minute after S-IVB engine cutoff.

During the development of the computer model, there were several major factors which had to be considered. One factor was the nature of the translunar injection data interval which depends upon a priori information relative to the launch azimuth and the planned revolution of the injection event. A second factor was the location of the Test Support Positions (TSPs) for the ARIA relative to the ground track of the spacecraft. Another factor was the location of the Initial Test Support Positions (ITSPs) or that position the ARIA must be at T-zero or lift-off of the Apollo spacecraft. The final major factor was that of the logic to be considered for the flight plans of ARIA under conditions which vary from the a priori mission parameters.

The translunar injection data interval is considered a prime factor because its location is the basis for ARIA deployment. There are two major variables associated with the data interval, the launch azimuth of the spacecraft and the revolution on which injection is to take place. In the present plan for Apollo-Saturn V missions, the launch azimuth will be between 72° and 108° . On a given launch day the launch window may cover a range of 26° which is a function of the length of a hold. The time duration covering the 26° range of the possible change in launch azimuth is not unique and varies greatly depending on the launch date. The other factor, the revolution on which the injection takes place, is not as complex as the varying launch azimuth, since there are a finite number of possibilities. According to present plans, the translunar injection will occur over the Atlantic or the Pacific but not both on a given launch day. Should the Atlantic be selected as the injection area, the translunar event could occur on either the second or third revolution. Should the Pacific be selected as the injection area, the event could occur on the first, second or third revolution. For the purpose of definition in the computer model, the Atlantic was defined as that area in which the latitude of ground track of the spacecraft was decreasing and the Pacific was defined as that area in which the latitude of ground track was increasing.

The Test Support Positions (TSPs) were defined relative to the ground track of the parking orbit. They were so chosen that two ARIA could continuously cover the mission with an appropriate handover from one to the other in the middle of the ten minute data interval. The choice of TSPs is sensitive to several parameters, such as the antenna pattern of the transmitted signal, the relative positions of the spacecraft and the ARIA, and the elevation angles. In the preliminary analysis, it was determined that the two TSPs for a given data interval are defined as two points, each of which is located in the intersection of a pair of the antenna pattern geometries corresponding to the beginning and end of each ARIA commitment. The TSPs used in the computer model are defined in terms of four input parameters, two downrange distances and two crossrange distances measured from the beginning of the data interval along a given segment of the ground track.

The TSPs are defined for each orbit where the translunar injection may occur. Because of the uncertainty where the translunar injection will actually occur, the deployment of at least three ARIA in the Atlantic (or four ARIA in the Pacific) are considered under the situation where no hold occurs. Some of these ARIA are deployed in support of two revolutions in case a delay of injection occurs. The relative positions of the ground tracks of the initial three revolutions vary depending on the latitude of the initial point of the data interval. Consequently, the relative positions of TSPs also vary. At high latitudes the ground tracks are close together, thus the deployment of the ARIA becomes relatively easier compared to lower latitudes (near the equator) where distance becomes an important factor.

The location at which an ARIA is to be positioned at the initially scheduled time of launch (T-zero) is defined as the Initial Test Support Position (ITSP). In the development of the model, it was assumed that a hold could be any arbitrary length of time. Therefore, the ITSP was chosen to be at a location to the west of a specified TSP at a distance which an ARIA can cover between T-zero and the time the spacecraft reached the beginning of the data interval. This choice for the ITSP gives the maximum flexibility in deployment of the ARIA considering all the variables that can affect the translunar injection mission.

The logic in determining the flight plans utilizes the initial conditions as determined by the mission definition with respect to the translunar injection data interval, the corresponding TSPs, ITSPs and a predetermined set of staging and recovery bases. Using these data the ability to support a given mission is determined by testing the sum of the distances from staging base to ITSP, from ITSP to TSP, and from TSP to recovery base against distance capability of the ARIA. Should the sum of the distances be less than the ARIA distance capability, then the flight plan is considered suitable for support of the mission.

The computer model was developed in modular form and consists of two separate programs. The first program gives the ground track of a circular orbit for the first three revolutions. The results of this program are used as input to the second program, the ARIA Deployment Program, in which the generation of flight plans are made. The first program was set up as a separate entity in order to allow for replacement by an actual premission trajectory of an Apollo mission. The output of the first program is presently stored on magnetic tape and is used for the determination

of TSP's which is accomplished in the ARIA Deployment Program.

The ARIA Deployment Program consists of three major subroutines and three utility subroutines. The main program accepts the input parameters, initiates the execution of the program and terminates the computation upon completion. The first major subroutine called from the main program contains a set of instructions which generates the TSPs relative to the calculated set of ground tracks. Since the TSPs are defined only for certain segments of the orbits where the translunar injection should occur, the subroutine utilizes only the trajectory segments which are determined to be of interest. The TSPs for each specified translunar injection opportunity are computed with respect to the ground tracks. A subsequent subroutine determines the staging and recovery bases which can support the previously calculated TSPs. The final major subroutine determines the flight plans necessary to meet the mission requirements under varying condition of hold or injection delay.

The three utility subroutines are used for repeated computations within the above major subroutines. Two of them solve the geodetic coordinate systems for specific combinations of unknowns. The first computes the latitude ϕ_E and longitude λ_E of the end point of a directed great circle path if a given distance S which originates at the beginning point with latitude ϕ_B and longitude λ_B in a given direction α (azimuth relative to true north). The second subroutine calculates the distance S and the azimuth α given the latitudinal and longitudinal pairs of (ϕ_B, λ_B) and (ϕ_E, λ_E) . The third utility program scans the distances from staging and recovery bases to a particular TSP and rearranges the passes in ascending order of distance from the TSP. This enables the program to pick staging and recovery bases in an order of preference defined in terms of determining the minimum distance necessary for mission support.

The ARIA Deployment Program accepts two categories of input parameters, fixed input parameters which do not vary from one problem to another and variable inputs which define a specific operational problem: The fixed input parameters are as follows:

- a. Staging bases; defined in terms of name, geographic location (latitude and longitude) and ranging capability of an ARIA taking off from each base.
- b. Recovery bases; defined in terms of name and geographic location (latitude and longitude).

c. Downrange time; which determines the distance between the beginning of the data interval and the intersection of the ground track and the great circle connecting a pair of TSPs. The distance is represented by the time required for the spacecraft to travel over the designated path.

d. Cross range distance; the distance that TSPs are located from the point determined by the downrange time in directions normal to this given segment of ground track.

The variable inputs parameters are as follows:

a. Theater of operations; called injection opportunity 1 or 2 (or Atlantic or Pacific injection).

b. Injection orbit; the first orbit in which translunar injection is contemplated.

c. Latitude at which data interval begins.

d. Initial launch azimuth for a given date.

e. Hold indicator, number of hold increments, and incremental time steps for hold.

f. Injection delay indicator.

g. A fixed ARIA ground speed.

The output parameters contain the following information concerning the flight plan:

a. Staging base.

b. Recovery base.

c. Take-off time of ARIA related to the originally scheduled launch time T-zero.

d. Distance from staging base to ITSP.

e. Latitude and longitude of ITSP.

f. Distance traversed under hold conditions.

g. Latitude and longitude of the point to which an ARIA should travel under hold conditions.

h. Distance to TSP.

i. Latitude and longitude of TSP.

j. Distance to alternate TSP under injection delay condition.

k. Latitude and longitude of alternate TSP.

l. Distance to recovery base.

m. Remaining capability of the ARIA in terms of time availability for support on station.

This model is an initial attempt to use a computer program to generate flight plans for any specific problem of ARIA deployment. It contains a number of assumptions such as no wind and a fixed ground speed. However, from the point of view of ARIA deployment planning, the model should serve the purpose of isolating a particular geographic area where scarcity of available bases might result in unsatisfactory supporting capability of ARIA in the translunar injection phase of Apollo missions.

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