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NASA TECH BRIEF

Advanced Mission Analysis Programs

The problem:

Space mission analysis requires consideration of numerous parameters which affect mission success. In particular, a suitable trajectory must always be found which satisfies imposed mission constraints.

The solution:

A group of computer programs designed to provide preliminary trajectory and guidance information required for feasibility studies in mission analysis.

How it's done:

The Advanced Mission Analysis Computer Programs fall into three categories.

1. Programs for approximate solutions
2. Programs for detailed targeting and output
3. Program for Monte Carlo and linear guidance analysis.

The first category includes all those programs whose solutions are based on single-conic-section approximations for trajectory definition. These solutions may be used as acceptable estimates of the exact solutions for many problems or as "first-cut" iteratives for detailed targeting. The second category includes the programs for detailed targeting and for generating detailed output along the trajectory. These programs "patch" conic sections when the trajectory changes gravitational centers to provide more realistic trajectory simulations than the programs of category 1. The program of category 3 also uses a patched-conic trajectory simulation model in the process of studying the effects of injection errors and midcourse guidance corrections on terminal conditions.

The programs in category 1 are further categorized according to the mission(s) each one treats. The missions which may be treated are:

a. Planet-to-planet transfers (PLANET)
b. Moon-to-Earth transfers (MOON)
c. Earth-to-Moon transfers (MOON, QUIMP)
d. Circumlunar gravity-assist (CIRCUM)
e. Interplanetary gravity-assist (GRASS)
f. Launch-to-orbit rendezvous (RENDEZ)
g. Low-thrust interplanetary rendezvous (LTOPT)

The approximate solution obtained for most of these missions includes the computer values for a set of control variables connecting the transfer orbit to a parking orbit at the launch body. When the transfer trajectory is an escape trajectory from the launch body (a, b, c above) this computation is done in subroutine LAUNCH. When Earth-to-Moon trajectories are being considered, the connection between the parking orbit and the transfer orbit is a fundamental part of the solution for the transfer orbit as computed by MOON or QUIMP.

A capability for parametric variation of launch date and flight time is provided with the programs for approximate solutions. These two parameters comprise the basic input for any single case, so that by asking for their variation, many cases may be automatically generated without additional input. In addition to this feature, the trajectory and parking orbit characteristics associated with each launch dateflight time pair may be systematically stored on tape for later printing or plotting.

The programs in category 2 are intended to provide more detailed answers for the mission analyst than he could obtain from the approximate program. The two general capabilities included here are:

a. Targeting (REFINE)
b. Detailed output (OUTPUT)

(continued overleaf)

Both of these capabilities make use of the patched-conic scheme for trajectory simulation. This scheme, while still only an approximation to an exact simulation treating all known perturbations, has proven acceptably valid and relatively fast for preliminary analysis of most space missions.

Under the patched-conic assumption, the trajectory is considered to be a Keplerian conic section at any given time. When the vehicle reaches the "sphere of influence" of its gravitational center or central body, however, the conic section upon which it is moving is changed to one relative to the primary (Sun or Earth). Or, when the sphere of influence of another massive body (Moon or planet) is reached while the conic is focused on the primary, the conic is changed to be relative to that body. The spheres of influence are considered to be constant in radius.

The guidance analysis program is a tool for studying the effects of injection and midcourse guidance system errors on the achievement of mission objectives for lunar and interplanetary missions. The patched-conic trajectory package previously mentioned is used for all of the trajectory calculations required in the guidance analysis. The program is capable of both linear (propagation and midcourse adjustment of the covariance matrix of state errors) and Monte Carlo (sampling of random errors) treatments.

As many as three midcourse guidance correction maneuvers may be simulated for any mission. Each maneuver is formulated as a velocity impulse to be applied at a specific time. The guidance laws which are available are:

a. Fixed time of arrival, attitude unconstrained
b. Fixed energy at arrival, attitude unconstrained
c. Minimum fuel, attitude unconstrained
d. Miss vector control, ecliptic plane-constrained
e. Minimum fuel, ecliptic plane-constrained
f. Earth-pointing
g. Sun-pointing
h. Target body-pointing
i. Injection velocity-pointing
j. Star-pointing
k. Normal to the ecliptic plane

Each of the three maneuvers for any mission may be based on a different guidance law. Errors in execution of each midcourse maneuver are considered for both the linear and Monte Carlo treatments. The execution error types are:

a. Proportional to the commanded correction
b. Resolution or bias
c. Pointing of the commanded correction

Input of the initial state and the initial state error covariance matrix may be assumed at insertion, immediately prior to the injection thrusting period, or at injection. The program will update the state and the covariance matrix to injection, if necessary, including, linearly, the effects of injection thrust errors.

Notes:

1. These programs are written in FORTRAN IV and MAP for use on the IBM 7094 computer.
2. Inquiries concerning these programs should be directed to:

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No patent action is contemplated by NASA.

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