APOLLO SPACECRAFT SOFTWARE CONFIGURATION CONTROL BOARD PROGRAM CHANGE REQUEST

NUMBER (Completed by FSB): 888

1.0 COMPLETED BY ORIGINATOR

1.1 ORIGINATOR	DATE	1.2 ORGANIZATION	APPROVAL	DATE
G. R. Kalan	8/17/69	MIT/IL	George McCherry	8/18/69

1.3 EFFECTIVITY: LUMINARY 1C

1.4 TITLE OF CHANGE: Modification of DAP Control Authority Model to Include Effect of Jet Plume Deflectors

1.5 REASON(S) FOR CHANGE: SEE DATA AMPLIFICATION SHEET

1.6 DESCRIPTION OF CHANGE: Include Effect of Jet Plume Deflectors upon Control Authority in State Estimate and TJETLAW Parameter Calculations

2.0 SOFTWARE CONTROL BOARD OR FLIGHT SOFTWARE BRANCH DECISION FOR VISIBILITY IMPACT ESTIMATE BY MIT

2.1 ☐ APPROVED ☐ DISAPPROVED

2.2 REMARKS:

2.3 SOFTWARE CONTROL BOARD OR FLIGHT SOFTWARE BRANCH SIGN OFF

DATE

3.0 MIT VISIBILITY IMPACT EVALUATION:

3.1 SCHEDULE IMPACT: None

3.2 IMPACT OF PROVIDING DETAILED EVALUATION

3.3 STORAGE IMPACT: 26 Fixed Words, 1 Erasable Word

3.4 REMARKS:

3.5 MIT COORDINATOR

DATE

4.0 SOFTWARE CONTROL BOARD ACTION

4.1 ☐ IMPLEMENT AND PROVIDE DETAILED CHANGE EVAL. ☒ PROVIDE DETAILED CHANGE EVALUATION ☐ DISAPPROVED

4.2 REMARKS: approved for off line assembly

4.3 SOFTWARE CONTROL BOARD SIGN OFF: J F Kilty

DATE: 10-9-69

5.0 MIT DETAILED PROGRAM CHANGE EVALUATION

5.1 MIT COORDINATOR

DATE

5.2 MIT EVALUATION

6.0 SOFTWARE CONTROL BOARD DECISION ON MIT DETAILED PROGRAM CHANGE EVALUATION

6.1 ☐ START OR CONTINUE IMPLEMENTATION ☐ DISAPPROVED OR STOP IMPLEMENTATION

6.2 REMARKS:

6.3 SOFTWARE CONTROL BOARD SIGN OFF

DATE

APOLLO SPACECRAFT SOFTWARE CONFIGURATION CONTROL BOARD

-DATA AMPLIFICATION SHEET -

PAGE 2 OF 2

PROGRAM CHANGE REQUEST NO. 888	PREPARED BY: G. R. Kalan DATE: 8/17/69	ORGANIZATION: MIT/IL

CONTINUATION SECTION (REFER TO BLOCK NUMBER AND TITLE ON PROGRAM CHANGE REQUEST FORM)

1.5 Reasons for Change: Due to the presence of Jet Plume Deflectors, the 2 Jet U and V Axes Control Authorities are currently underestimated by the DAP for the descent configuration and overestimated for the CSM-docked Configuration. This causes an increase in RCS propellant consumption due to rate overshoot during descent maneuvers and extra jet firings due to rate undershoot during CSM-docked Maneuvers.

REMARKS

TP#21812

Massachusetts Institute of Technology
Charles Stark Draper Laboratory
Cambridge, Massachusetts

MEMO

TO: Russ Larson

FROM: J. E. Jones, P. S. Weissman

DATE: 16 July 1970

SUBJECT: Evaluation of PCR 888, "Modification of DAP Control Authority Model to Include Effect of Jet Plume Deflectors"

The autopilot estimates the control authority of the jets when not docked to the CSM by an equation of the form:

$$1JACC = \frac{A}{MASS + C} + B \qquad (1)$$

where 1JACC = the control authority, or "1-jet acceleration"
MASS = the current estimate of LM mass
A, B, C = constants stored in fixed memory

There is a separate set of constants (A, B, C) for each axis and there are different sets for the staged and unstaged spacecraft.

Implementation of the PCR would simply involve reevaluation of the six constants that pertain to the pitch and roll axes of the unstaged LM. These constants would be chosen so that equation 1 would yield the average control authority of a couple which consists of a deflected (+ x) jet and an undeflected (- x) jet. No additional fixed or erasable memory would be required.

An alternative scheme would be to treat the deflected and undeflected jets separately in the DAP so as to account more precisely for firings which do not use pairs of jets. However, such a change would constitute a rather

major modification of the DAP. It must also be considered that unbalanced firings only occur:

1. during X-axis translation or ullage,
2. when a jet has failed, or
3. as minimum impules.

Futhermore, it will be shown that the magnitude of the error introduced, even when an unbalanced firing is made, is moderately small. Thus, a major, widespread change is not warranted.

The accompanying figure is a sketch of the "effective inertia" versus mass curves that are now programmed in the LUMINARY program and the corresponding curves for the deflected and undeflected jets. The "effective inertia" is the nominal jet torque, 550 ft-lbs, divided by the angular acceleration created by that jet. The "effective inertia" of an undeflected jet is simply the actual inertia of the LM. The "effective inertia" of a deflected jet differs from the actual inertia by an amount that is a function of the position of the center of gravity relative to the plume deflectors. Ideally, the "programmed" curve would lie midway between the "deflected" and "undeflected" curves.

It can be seen that the autopilot overestimates inertia (underestimates control authority) for masses above about 9500 kg and underestimates inertia for lower masses. Hence, any jet activity with the heavy descent vehicle tends to overshoot the desired rate and use extra RCS fuel; jet activity with the light descent vehicle tends to undershoot the desired rate and use short pulses to close the gap (or possibly use less fuel because the desired rate is not attained).

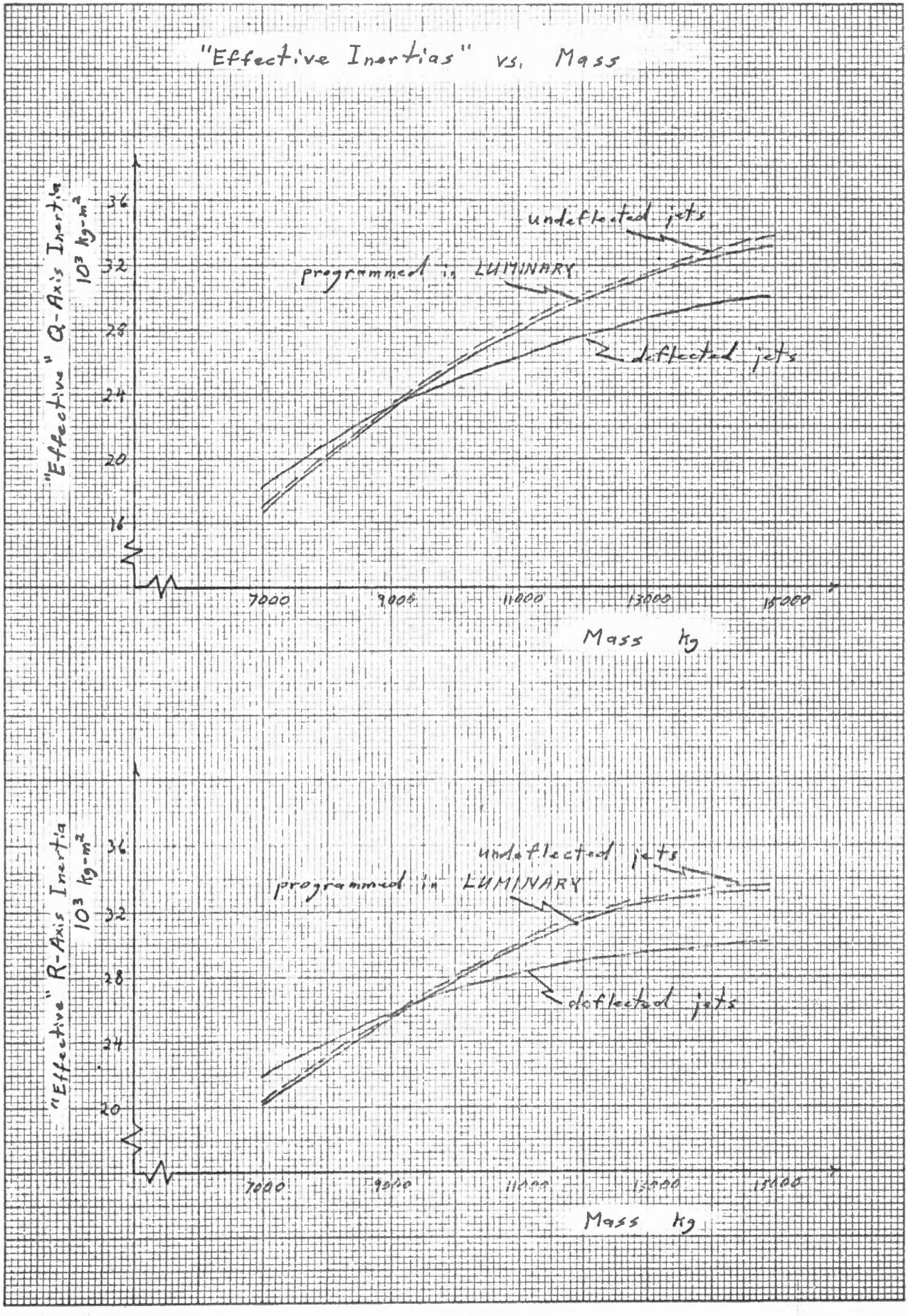
The magnitude of the discrepancy is shown more clearly in the following table, which compares programmed lJACCs with calculated average control authorities at the nominal extremes of the mass range. The calculations are based upon the latest SODB mass properties for LM8 (Apollo 14).

		LUMINARY	CALCULATED AVERAGE	ERROR
PDI ignition	Q, R axes	1.24	1.30	-4.6%
Lunar T.D.	Q axis	2.26	2.08	+8.7%
	R axis	1.91	1.79	+6.7%

1-Jet Control Authorities (Deg/sec/sec)

On the basis of our experience with such mismatches, including a special landing simulation that was run for this purpose, it can be said that these errors are quite small. This is true in part because the control is closed-loop, so that rate estimation errors are quickly corrected. However, there is no point in purposely allowing degraded nominal performance. It is therefore our recommendation to implement PCR 888. It will cost one or two man-days. No special testing is required because the change is so slight, even in the off-nominal cases when unbalanced jets are fired. As mentioned earlier, there is no storage impact (The PCR should be corrected; the original impact evaluation envisioned the more elaborate alternate scheme).

However, it should be emphasized that this recommendation is a rather mild one. Policy or politics may suggest that even such a simple, limited change not be made to the program since the improvement in fuel consumption and in vehicle response would be rather small.


"Effective Inertias" vs. Mass
"Effective" Q-Axis Inertia
10^3 kg-m²
36
32
28
24
20
16
undeflected jets
programmed in LUMINARY
deflected jets
7000
9000
11000
13000
15000
Mass kg
"Effective" R-Axis Inertia
10^3 kg-m²
36
32
28
24
20
undeflected jets
programmed in LUMINARY
deflected jets
7000
9000
11000
13000
15000
Mass kg

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