BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 11054

SUBJECT: AAP Cluster Mass Properties and CMG Control Capability - Case 620

DATE: November 20, 1969

FROM: W. W. Hough

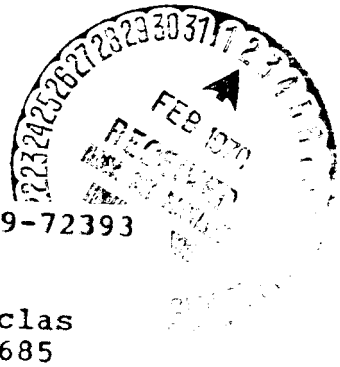
ABSTRACT

NASw 417

Recent weight growth in the SWS has led to concern that two CMG's cannot control the AAP Cluster in the solar inertial attitude mode. This is not the case, and in fact an additional 25% growth in the difference between the maximum and minimum principal moments of inertia is feasible before the peak control requirement reaches 7000 ft lb sec, which is the 8000 ft lb sec maximum capability of two CMG's less a generous 1000 ft lb sec margin.

As a matter of interest, it can be stated that the SWS weight can grow to the Saturn V payload capability if the mass distribution remains as it is currently, and the control capability, including the margin, will not be exceeded. However, if weight is added to the SWS in location far from the center of gravity, such as only on the aft end, then control capability rather than payload capability might well be the factor that limits weight growth.

NASw-417



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MEMORANDUM FOR FILE

Recent changes in the AAP SWS configuration have led to weight increases and attendant growth in vehicle moments of inertia. This growth has again produced concern over the capability of two CMG's to control the Cluster in the solar inertial attitude. The worst-case CMG momentum storage requirement in this attitude is directly proportional to the difference between the maximum and minimum principal moments of inertia,* as illustrated in Figure 1.

Current information on SWS mass properties was obtained from MSFC. These data were up-to-date except for the wardroom/second floor modification in the OWS; the author therefore modified the MSFC data to account for this change by adding 1300 pounds in the proper vehicle location. The corrected data are presented as the first entry of Table I. The second entry in Table I is the similar data for the CSM, which are based on the expected lift-off weight quoted by MSC, but modified to account for the SPS and RCS propellants consumed prior to docking. The grand totals for the Cluster are the remaining entry in Table I. The difference between the maximum and minimum principal moments of inertia, I(3)-I(1), is 3,276,409 slug feet.^{2} When this number is plotted on Figure 1, it is determined that the peak momentum storage requirement is approximately 5600 ft lb sec, or 30% below the maximum capacity of two CMG's. If a generous CMG control margin of 1000 ft lb sec is maintained to account for aerodynamic torque, CMG gimbal lock and bias momentum accumulation, 25% additional growth in the inertia difference is permissible before the 7000 ft lb sec capability of two CMG's is exceeded.

As a matter of interest, it is worthwhile to examine the situation for a case in which the SWS weight grows to the Saturn V payload capability. This payload capability at 50° inclination is 181,000 pounds, but the jettisoned portion of

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*An explanation of this proportionality (including Figure 1) is given in "The Effect of Addition of an Experimental Film Vault on Cluster Inertial Properties and CMG Control Capability," Bellcomm Memorandum for File (B69 09014), W. W. Hough, September 9, 1969.

the payload shroud, 14,400 pounds, must be subtracted to obtain the maximum operational weight of 166,600 pounds. Thus a 35,905 pound growth over the current estimate in the SWS is possible before the payload limit is reached. It is impossible to determine the inertia growth due to such a weight growth without knowing where the weight is added, but it is fairly reasonable to assume a mass distribution identical to the current one. (That is, increase the mass but don't change the location at which the mass is located). An actual growth of 35,905 pounds might produce inertias higher or lower than those produced by this assumption depending on whether the weight is added far-from or close-to the center of gravity. The data for this maximum SWS weight are presented in Table II in a format identical to Table I. The inertia difference - 3,797,173 slug ft^2-is plotted on Figure 1, and it is determined that the peak momentum requirement is approximately 6500 ft lb sec, or within the 7000 ft lb sec capability. As the weight cannot grow past the payload capability, any violation of the two CMG control capability, including the 1000 ft lb sec margin, can result only from locating the added weight far from the vehicle center of gravity.

We can conclude that the limit of weight growth has not been reached in the current SWS configuration, and that growth to the Saturn V payload capability is feasible from a control standpoint if close attention is paid to the weight distribution.

1022-WWH-cf W. W. Hough

Attachments

MOMENTUM STORAGE REQUIREMENT VS. INERTIA DIFFERENCE

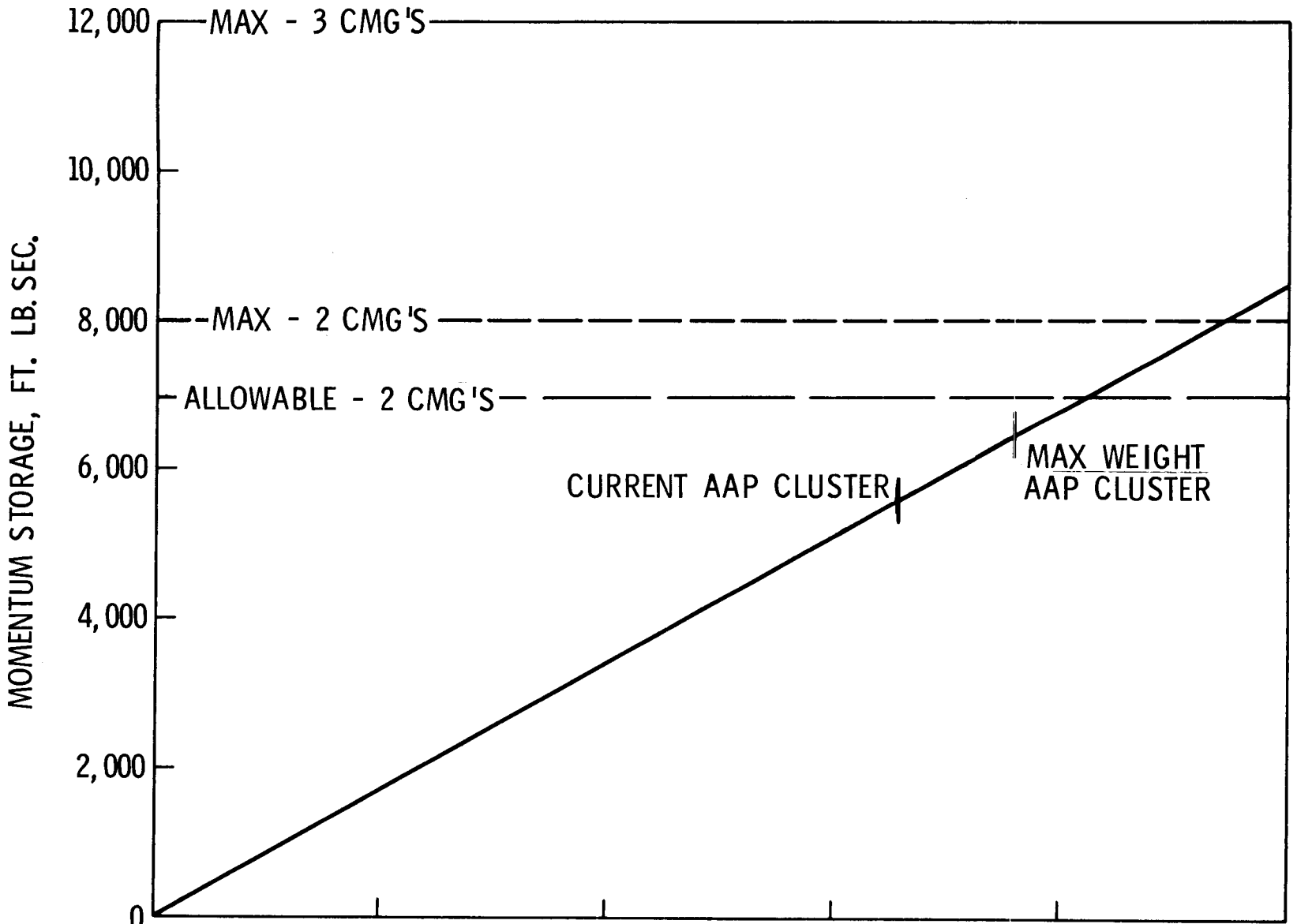

FIGURE 1

TABLE I

CURRENT MASS PROPERTIES SUMMARY

SWS (including 60,000 lb sec TACS and wardroom modifications)

WEIGHT= 130695. LBS XBAR=STA 3227.45 YBAR= -3.76 IN ZBAR= -31.78 IN
IXX= 612290. SLG FT2 IYY= 2221192. SLG FT2 IZZ= 2158910. SLG FT2
IXY= -11608. SLG FT2 IYZ= 18234. SLG FT2 IZX= -355343. SLG FT2

CSM (MSC expected delivery weight less propellants consumed prior to docking)

WEIGHT= 27686. LBS XBAR=STA 3797.43 YBAR= -.64 IN ZBAR= -4.22 IN
IXX= 15332. SLG FT2 IYY= 49852. SLG FT2 IZZ= 50831. SLG FT2
IXY= 1151. SLG FT2 IYZ= -334. SLG FT2 IZX= -213. SLG FT2

Cluster at beginning of AAP 1/AAP 2 mission

WEIGHT= 158381. LBS XBAR=STA 3327.09 YBAR= -3.21 IN ZBAR= -26.96 IN

INERTIA TENSOR FOR CLUSTER, SLUG FEET2 UNITS

631415.	1688.	278094.
1688.	3876814.	-18324.
278094.	-18324.	3811813.

PRINCIPAL MOMENTS OF INERTIA FOR CLUSTER

I(1)= 607278. SLG FT2, I(2)= 3829077. SLG FT2, I(3)= 3883687. SLG FT2

I(3) - I(1) = 3276409 Slg Ft 2, I(3) - I(2) = 54610 Slg Ft 2

DIRECTION COSINE MATRIX

.996254631	-.000998922	-.086462178
.081194241	.354672157	.931458615
-.029735003	.934991246	-.353422125

TABLE II

MASS PROPERTIES SUMMARY WITH MAXIMUM SWS WEIGHT

SWS (at maximum Saturn V payload capability)

WEIGHT= 106000. LBS XBAR=STA 3227.45 YBAR= -3.76 IN ZBAR= -31.78 IN
IXX= 780501. SLG FT2 IYY= 2831406. SLG FT2 IZZ= 2752014. SLG FT2
IXY= -14797. SLG FT2 IYZ= 23243. SLG FT2 IZX= -452964. SLG FT2

CSM (MSC expected delivery weight less propellants consumed prior to docking)

WEIGHT= 27686. LBS XBAR=STA 3797.43 YBAR= -.64 IN ZBAR= -4.22 IN
IXX= 15332. SLG FT2 IYY= 49852. SLG FT2 IZZ= 50831. SLG FT2
IXY= 1151. SLG FT2 IYZ= -334. SLG FT2 IZX= -213. SLG FT2

Cluster at beginning of AAP 1/AAP 2 mission

WEIGHT= 194286. LBS XBAR=STA 3308.67 YBAR= -3.32 IN ZBAR= -27.85 IN

INERTIA TENSOR FOR CLUSTER, SLUG FEET2 UNITS

799775.	4533.	372682.
4533.	4549891.	-23350.
372682.	-23350.	4467636.

PRINCIPAL MOMENTS OF INERTIA FOR CLUSTER

I(1)= 762278. SLG FT2, I(2)= 4495572. SLG FT2, I(3)= 4559451. SLG FT2
I(3) - I(1) = 3797173 Slg Ft 2, I(3) - I(2) = 63879 Slg Ft 2

DIRECTION COSINE MATRIX

.994977198	-.001807795	-.100085508
.092996808	.386654288	.917523868
-.037031738	.922256905	-.384799754

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